Using Ecological Indicators to Evaluate Ecosystem Integrity and Assess Restoration Success on the Middle Sacramento River

FINAL REPORT

to California State University, Chico and the California Bay-Delta Program's Ecosystem Restoration Program

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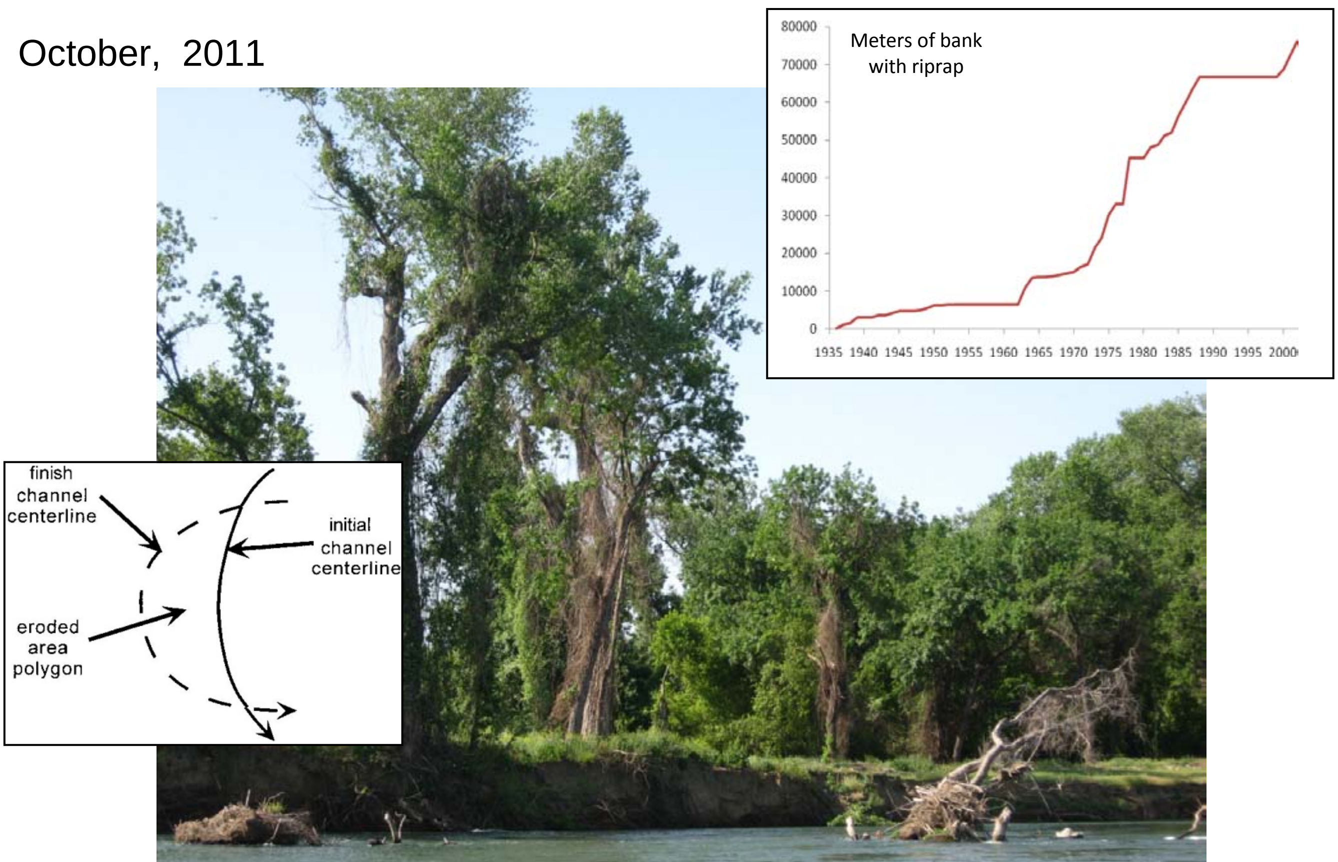

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EXECUTIVE SUMMARY

Over the past several decades, significant resources have been invested in conservation and restoration of aquatic and terrestrial resources along the middle Sacramento River. Yet to date, there has not been any comprehensive evaluation of the effectiveness of implemented actions, nor has there been an appraisal of the overall status of biodiversity health. To help fill these gaps, this report introduces and applies an ecological scorecard framework.

The framework is based on quantitative evaluation of a suite of 68 indicators which are representative of a more limited number of key ecological attributes selected to represent the status of the conservation targets. In addition to assessing the status of conservation targets, these indicators are used to assess the progress that have been made in achieving the specific goals and visions that were laid out in the CALFED Ecosystem Restoration Program (ERP) Plan. Conservation Targets, and ERP goals and visions that this project focuses on are limited to terrestrial and floodplain resources (including vegetation and biota) and channel dynamics (including planform and flow regime parameters), but not aquatic biota, such as fish.

Scorecard indicators are also used in this report to evaluate the success of restoration efforts, both by tracking changes in indicators over time at restoration sites, and by comparing restoration sites with remnant (reference) habitats. In addition, they are used to characterize the contribution that restoration efforts have made to both the current and projected future conditions of the landscape. These applications are informative not only for what it what they reveal about the changing status of Sacramento River resources and the effectiveness of implemented restoration actions, but also for what they show about the varying ways in which scorecard indicators can be applied.

Progress toward achieving **ERP Vision for Habitats** was assessed for *Riparian and Riverine Aquatic Habitats* by synthesizing information on 12 indicators. Overall, progress has been “Fair”. Mild increases were observed over the past 20 years in the percent of historical riparian zone currently in conservation ownership, and the percent of historical riparian zone currently in natural habitat. Landscape metrics such as the forest patch proximity, forest patch core size have shown positive changes with implemented restoration. Additional indicators such as length of river frontage in conservation ownership on both sides of the river, and percent of riparian shoreline bordered by >500 meters of natural habitat have also increased. Importantly, analyses have shown that many of these indicators have the potential to increase quite dramatically if strategic acquisitions and subsequent restoration takes place. Indicators that prevented progress toward this vision being rated as “Good” include total river length and whole river sinuosity. Both have declined since the early 1900s, and have not changed significantly in recent decades.

Progress toward achieving **ERP Visions for Species and Communities** was assessed for *Plant Species and Communities, Neotropical Migratory Birds* (including the Yellow-billed cuckoo and bank swallow), the *Valley Elderberry Longhorn Beetle,* and a suite of other species (bees, beetles, bats, and colonial waterbirds) that were not specifically identified in ERP goal statements.

Progress toward achieving the vision for *Plant Species and Communities* was assessed by synthesizing information on 19 indicators. Overall, progress has been “Good”. There have been significant increases in the acreage of native vegetation, largely as a result of all the planting that has been done at restoration sites. At restoration sites there have been positive responses in terms of habitat development. Basal area of woody species has increased, as has diameter at breast height. Changes in importance values of different species suggest that the sites are proceeding along a successional pathway with certain species (e.g., coyote brush, box elder and valley oak) increasing, while others (e.g., elderberry and sycamore) are decreasing. Less encouraging is the status of understory vegetation. At restoration sites native understory species have been slow to colonize, and frequency of occurrence has been low. These findings have led to the implementation of an understory component to the more recent (post-1999) restoration plantings. Survival of understory plantings has generally been good.

To measure progress toward achieving the vision for *Neotropical Migratory Birds* (including the Yellow-billed cuckoo, bank swallow,) information was synthesized on 13 indicators. Overall, progress has been “Fair”. Nest survival does not appear to have increased and is low at least for the Lazuli Bunting. Apparent adult survival is variable, with Black-headed Grosbeaks faring better than Spotted Towhees. PRBO cautions, however, that more data are needed to accurately report trends in these parameters. In contrast, bird species richness has increased, quite dramatically, at restoration sites as has abundance for certain species (e.g., Black-headed Grosbeak, Common Yellowthroat), although not others (e.g., Yellow Warbler and Yellow-breasted Chat). The Sacramento River corridor is the major population center for both Yellow-billed Cuckoo and Bank Swallow. For both species there is cause for concern. For cuckoos, there is a very low number of occupied territories, and for Bank Swallows, there has been a dramatic decline in the number of burrows at active colonies.

To measure progress toward achieving the vision for *Valley Elderberry Longhorn Beetle* information was synthesized on 2 indicators. Overall, progress has been “Good”. At restoration sites there has been a dramatic increase in the percent of elderberry shrubs that are occupied by the VELB. However the Importance value for the VELB’s host plant has declined as the sites have matured, raising the question as to what the long-term habitat suitability will be at these sites.

Progress toward restoring healthy populations of other native terrestrial fauna (not specifically called out in the ERP Program Plan) was assessed by synthesizing information on 4 indicators. Overall, progress has been “Good”. Similar to what was found with landbirds, species richness of bees, beetles and bats was found to be higher at older restoration sites than at younger sites, and overall, the aerial extent of waterbird colonies was found to be fairly extensive.

Progress toward achieving **ERP Visions for Ecological Processes** was assessed for *Central Valley Streamflows*, *Stream Meander*, and *Natural Floodplain and Flood Processes*.

To measure progress toward achieving the vision for *Central Valley Streamflows* information was synthesized on 3 indicators. In the case of the streamflows for the Sacramento River, ‘progress’ can perhaps best to understood in the context of preserving the dynamic range of the existing flow regime, and in the future, restoring some of the lost dynamics.

The first indicator is bed mobility, expressed as days exceeding the flow needed to fully mobilize the bed, for which 55,000 cfs is used, based on empirical studies. The second indicator is floodplain inundation (to reestablish lateral connectivity between channel and floodplain), for which we use 70,000 cfs based on prior work along the middle reach of the river, and based on the flow at which Fremont weir overflows and the Yolo Bypass is watered. The third indicator is periodic connection of secondary channels with the mainstem, which drives hydrodynamics and ecological processes in the secondary channels.

For these indicators, the status is measured by number of days above a threshold value, determined based on empirical observations by various researchers over the past three decades. The type of water year (wet, normal, dry) needs to be accounted for, because the river experienced large natural variability in these variables prior to human alterations. The goal with all these indicators is to achieve flow regimes that more closely resemble the natural flow regime for the river. The indicators are not such that ever-increasing values are necessarily good.

Overall, progress for achieving the vision has been “Poor”. The current status for bed mobility is “Poor”. During the ten years prior to, and including, water year 2010, an average of only 4.6 days per year were greater than 55,000 cfs, and six of those prior ten years had no flows above the bed mobility threshold.

The current indicator value for side channel reconnection, reflecting a 10-year average of inundation of three different elevational classes of side channels, is “Fair”. This is a combined result of two “Poor” and one “Good” rating for the number of days with flows exceeding 50,000cfs, 6,000cfs, and 22,000cfs, respectively. Thus flows were sufficient over the past decade to connect only the mid-elevation side channels at the recommended frequency.

As of the end of WY 2010 there had been an average of 0.7 days per year above 70,000 cfs and 8 of the previous ten years had zero days above 70,000 cfs. This places the current condition of the floodplain inundation indicator in the “Poor” category. The extent of floodplain inundation is even worse when actual flood extent is considered, due to effect of levees along the channel.

To measure progress toward achieving the vision for *Stream Meander* information was synthesized on 10 indicators. Overall, progress has been “Poor”. Although there has been considerable variability in indicator values among time periods (in part due to variations in flows), and most of the indicators that were studied to assess progress toward this vision are only meaningful over long time frames, the collective weight of evidence presents a clear picture. Channel dynamics and channel complexity have shown reductions over the period of record (1906 to 2007), and there has been no appreciable improvement in recent years. Far from it, some of the most important indicators of stream meander (e.g., meters of bank with riprap) have continued to decline, despite goals being set to achieve the opposite. On a brighter note, the length of river with conservation ownership on both banks has increased, suggesting an increase in opportunities for restoration of natural channel processes.

To measure progress toward achieving the vision for *Natural Floodplain and Flood Processes* information was synthesized on 4 indicators (see Goals and Visions section). Overall, progress has been “Poor”. The frequency of floodplain inundation and side-channel connection is reduced relative to what is recommended based upon the historical record, actual floodplain extent has decreased, and riprap has increased steadily. A positive outcome is the fairly rapid increase in soil organic carbon observed at restoration sites.

Progress toward achieving **ERP Visions for Reducing or Eliminating Stressors** was assessed for *Levees, bridges and bank protection*, and *Invasive riparian and marsh plants*.

To measure progress toward achieving the vision for *Levees, bridges and bank protection* information was synthesized on 2 indicators (see Goals and Visions section). Overall, progress has been *“Poor”.* Riprap has increased, and although the Length of river with conservation ownership on both banks has increased, little on-the-ground work has been done. Infrastructure that currently limits natural river processes has yet to be removed, although there have been a few improvements (e.g., small levee breaches at restoration sites). Several projects (e.g., Hamilton City and Kopta Slough), currently at the planning stage, may help lead to progress toward achieving this vision in years to come.

To measure progress toward achieving the vision for *Invasive riparian and marsh plants* information was synthesized on 6 indicators (see Goals and Visions section). Overall, progress has been *"Poor".* Reductions have not been observed in the area of non-native riparian and marsh plants. Quite the contrary, *Arundo,* black walnut, Himalayan blackberry, and *Ludwigia* have all increased in aerial extent from 1999 to 2007. Relative native understory cover, an indicator of restoration site success has remained virtually unchanged from one survey period to the next. Thus competition that native flora face from non-native species is likely increasing.

The overall status of biodiversity, as determined by the application of the ecological scorecard framework to the Sacramento Project area is "Fair". When considering the conservation targets individually, two of them (terrestrial riparian habitats and birds) ranked as "Fair", and one (aquatic riverine habitats) ranked as "Poor". Examining the status of the individual indicators that were rolled up to produce these conservation target ratings can help explain why the conservation targets received the overall ratings.

In short, the riparian habitats and the terrestrial species that inhabit them (including birds) are in "Fair" condition due to all of the efforts that have been put towards reestablishing native vegetation throughout the Sacramento River Project area. Many positive outcomes have been observed as a result of these efforts. This report details such outcomes by reporting changes in ecological indicators that have been observed through time at restoration sites, and in comparison to remnant habitats.

In contrast, the status of the third conservation target, aquatic riverine habitats was determined to be "Poor". This is the direct result of the hydrologic and geomorphic processes being constrained by anthropogenic alterations to the river. Of particular concern is the steady increase in riprap that has been observed since the 1930s, and the alteration of the natural flow regime since the mid 1900s. As more and more riprap has been installed, and the hydrology has been increasingly modified, the river has lost much of its natural dynamism, and with that, a reduction in its ability to create and maintain the habitats that are essential to native species and communities. Planting of native vegetation has been an important "stop gap" measure, and has kept the status of the two other conservation targets from dropping to "Poor", however, their continued persistence, even at this level, is uncertain.

Clearly the future of Sacramento River terrestrial resources is dependent upon the degree to which the elemental natural riverine processes of erosion, sediment deposition, and flooding can be restored. Future conservation efforts should focus on restoring these processes where it is possible to do so without adversely impacting important functions that rivers provide to people. Fortunately, opportunities exist to implement projects that provide benefits to both the ecosystem and society at large.

A FRAMEWORK FOR THE ASSESSMENT OF ECOLOGICAL INTEGRITY

Introduction

The conservation of biological diversity is recognized as an essential, albeit daunting, task for the future of life on earth (e.g., Wilson 1988, World Resources Institute 2000). In recognition of this, governments, corporations and non-profit organizations are directing substantial resources toward myriad projects designed to conserve biodiversity. However it is often not known specifically which approaches to conservation will be most effective in particular circumstances. Also resources available for such efforts are typically in short supply relative to the magnitude of the problems. For these reasons, it is imperative that there be accurate, quantifiable frameworks in place for measuring the project success (Salafsky and Margoluis 1999). Without rigorous evaluations of prior conservation actions, missteps will be repeated, with additional and/or continued ecosystem degradations being a likely consequence.

Any attempt to determine the extent to which natural resources have been conserved (or restored, in the case of restoration projects) will require some type of ecological status assessment, and, ideally, knowledge gained from such status assessments will inform subsequent conservation actions via the adaptive management process (Holling 1978, Walters 1986). To assess the status of populations at the species level, conservationists often rely on well-developed methodologies of population viability analysis (PVA, Shaffer 1987, Beissinger and McCullough 2002). Insights gained through PVA have, in certain instances, advanced conservation in dramatic ways (e.g, Crouse et al. 1987, Wooton and Bell 1992, Morris et al. 1999). However, there is no agreed upon theory, or even general scientific consensus, for how to assess the status of higher levels of biological organization, such as natural communities and ecosystems, although the importance of their conservation is well recognized (e.g., Scott et al. 1995, Maddox et al. 2001).

In the absence of a well-developed theoretical foundation, it is commonly accepted that given adequate knowledge of natural community and ecosystem structure, function and process, important and necessary initial steps may be taken to begin to solve conservation problems in need of immediate attention. Such is the case with conservation activities on the Sacramento River, where considerable emphasis has been placed on the moving conservation projects forward on the ground, even in the absence of a fully-developed framework for assessing ecological integrity and tracking ecosystem responses to management actions.

This document introduces a framework that TNC has developed to promote a quantitatively rigorous method of Ecological Integrity Assessment. This framework is designed to provide information needed to evaluate the effects of conservation actions in large landscape-scale projects such as that which TNC and its partners are engaged in on the Sacramento River. When properly applied the framework generates standardized methodologies and testable hypotheses and promotes the advancement and transfer of knowledge among scientists and natural resource managers. Moreover, when appropriately implemented, this methodology should translate to more effective and efficient allocation of scarce conservation resources.

Components of the Ecological Integrity Framework

The Ecological Integrity Framework is based on analyses of biodiversity health through a limited selection of attributes that strive to (1) capture the complexity and processes required to sustain the biological diversity in question, (2) facilitate the establishment of quantitative and specific long-term conservation goals, and (3) establish a scientifically rigorous protocol that can be consistently applied across space and over time – three issues recognized as necessary in developing effective ecological indicators (Dale and Beyeler 2001).

The framework describes a process for setting conservation goals and measures of success, and assessing the viability, or ecological integrity, of focal biodiversity at multiple scales. It consists of the following four components:

1. Identification of key ecological attributes that determine the composition, structure, and function of focal biodiversity.

2. Identification of measurable indicators to describe key attribute status.

3. Determination of acceptable ranges of variation for key attributes based on reference conditions, and establishment of minimum integrity threshold criteria for conservation.

4. The rating of key attribute status and assessment and monitoring of overall integrity status based on status of all key attributes.

Woven through each of these components are two principal objectives: (1) the maintenance or improvement of biodiversity health and (2) the abatement of critical threats to biodiversity. Achieving these objectives requires the integration of the best available ecological knowledge into the measures employed.

In this framework, the concept of “key ecological attributes” is presented as the currency for identifying and measuring the composition, structure, and function of focal biodiversity. For each of these key attributes ecological indicators are described and ratings thresholds are set which form a consistent, scientific basis for evaluating the status of individual key attributes. To the extent possible these thresholds are based on reference conditions that reflect the acceptable ranges of variation. The result is a categorical measurement system that is detailed in its scientific justification, yet simple, informative and compelling to any type of audience regardless of their scientific or conservation training.

Key Ecological Attributes

The framework rests on the premise that for any species, community or system there are a number of identifiable key ecological attributes that sustain the conservation target and maintain its composition, structure and function. Examples of key ecological attributes include natural hydrologic regimes, species composition/dominance, population size, successional dynamics, connectivity among communities, depredation and parasitism. The Ecological Integrity Assessment framework is based on the assumption that a significant disruption in the function of any of these key ecological attributes will degrade the integrity of that conservation target.

The identification of key ecological attributes relies on an understanding of how conservation targets function (Box 1). There are likely no conservation targets whose ecology is fully understood. Yet, for almost every conservation target there are experts who are familiar with the general composition, structure, and function of the biodiversity focal point in question, or who are familiar with a similar system from which comparisons may be drawn. The understanding of key ecological attributes always involves developing hypothetical descriptions about what biological composition, biotic interactions, abiotic conditions, and ecological processes characterize a conservation target in its "healthiest" or most "natural" state. Even when reliable knowledge of a conservation target is limited, it is important to formulate these hypotheses with the best available information, while documenting assumptions and information gaps.

Box 1: How to Identify Key Ecological Attributes

The *Key Ecological Attributes* are those components that *most clearly define or characterize the conservation target, limit its distribution, or determine its variation over space and time, on a time scale of 100+ years.* The best way to identify such Attributes is by reviewing or developing conceptual models for the biodiversity in question. They may include:

- Major characteristics of ***biological composition*** and the ***spatial structure*** of this composition, such as:
  - characteristic and keystone species, functional groups or guilds
  - population and/or community structure, including size of a minimum viable population for species targets
  - presence and distribution of characteristic species, ecological communities, or successional (seral) stages and gradients, seed banks
  - characteristic horizontal or vertical spatial relationships among size/age cohorts, species, ecological communities, or seral stages and gradients
  - species or groups of species that have significant impacts on the distribution of biomass at different trophic levels or on the physical or chemical structure of habitat.
  - primary production / respiration balance
- ***Biotic interactions*** that significantly shape or control this variation in biological composition and its spatial structure over space and time, such as:
  - food-web dynamics: levels of predation or large-scale herbivory
  - inter-specific competition and succession
  - migration, aggregation, and dispersion
  - pathogens, infestations, invasions, and other natural biological disturbances
  - pollination, aging, and reproduction
- ***Environmental regimes and constraints*** (or abiotic interactions) that significantly shape physical and chemical habitat conditions, and hence shape variation in biological composition and structure over space and time in relation to these conditions. Both extreme environmental disturbances and "normal" variation should be considered. Examples include:
- atmospheric temperature and precipitation (solar radiation influx)
- disturbance regimes
  - minimum dynamic area of disturbance should inform size
  - fire
  - wind, precipitation, and flooding extremes
  - soil erosion and accretion
  - temperature extremes
  - geologic events (geothermal energy)
  - spatial extent of disturbance
- surface and ground water hydrologic regimes
  - soil moisture
  - groundwater elevation and surface – sub-surface exchange
  - snow / ice cover / ice transport
  - freeze / thaw
  - water mixing and circulation
  - lake level variance
  - inflow variation (local runoff, groundwater, riverine)
  - water flow
  - storm event
- water and soil chemistry
  - chemistry (nutrients, hydrocarbons, gases, salinity)
  - temperature and pH
  - particulate and dissolved organic matter
  - water turbidity / clarity
- geology, topography/bathymetry, and geomorphology
  - soil structure and drainage, porosity and texture
  - macro / micro bathymetrics and outlet morphology
  - coarse organic debris
  - reef topography
  - shoreline complexity
- ***Environmental and ecological connectivity*** that affects the ability of species and groups of species or their propagules to move or be carried (e.g., by wind or water or other biota) among suitable locations on the land- and water-scape, to maintain diversity at genetic, species, and ecological community levels. Connectivity also affects the ability of natural environmental processes to transport habitat-forming matter across the land- and water-scape, such as dissolved nutrients, soils, stream sediments, woody debris, and other organic matter. Types of connectivity to consider include:
  - connectivity with adjacent systems (e.g., terrestrial / aquatic)
  - intra- and inter-patch connectivity (e.g., within and between patched in a riparian corridor)

Ecological Indicators

Identifying the key ecological attributes for the focal biodiversity provides only one of the building blocks for a rigorous framework for measuring success. It is also necessary to identify the field-based indicators that can be used to measure the status of each key ecological attribute.

An indicator for a key ecological attribute consists of some characteristic of that factor, or some collection of characteristics combined into an overall index, that strongly correlates with the status of that factor. Such indicators are a measurable means for obtaining information that substitutes for or summarizes what you most need to know about the key ecological attribute, when you can not directly measure the attribute itself.

Ideally, there would be a single indicator inextricably linked to the status of each key ecological attribute that directly informs practitioners of the key ecological attribute's true state. At times, however, more than one indicator is needed to characterize the key ecological attribute's status. Box 2 provides some guidelines that may be followed to aid in indicator selection, and Figure 2 provides an example of how indicators may be evaluated to provide rankings of attribute health at different levels of biological organization. Figure 1 also illustrates the basis for indicator rating. Further details on the development and application of rating criteria are presented in the next section.

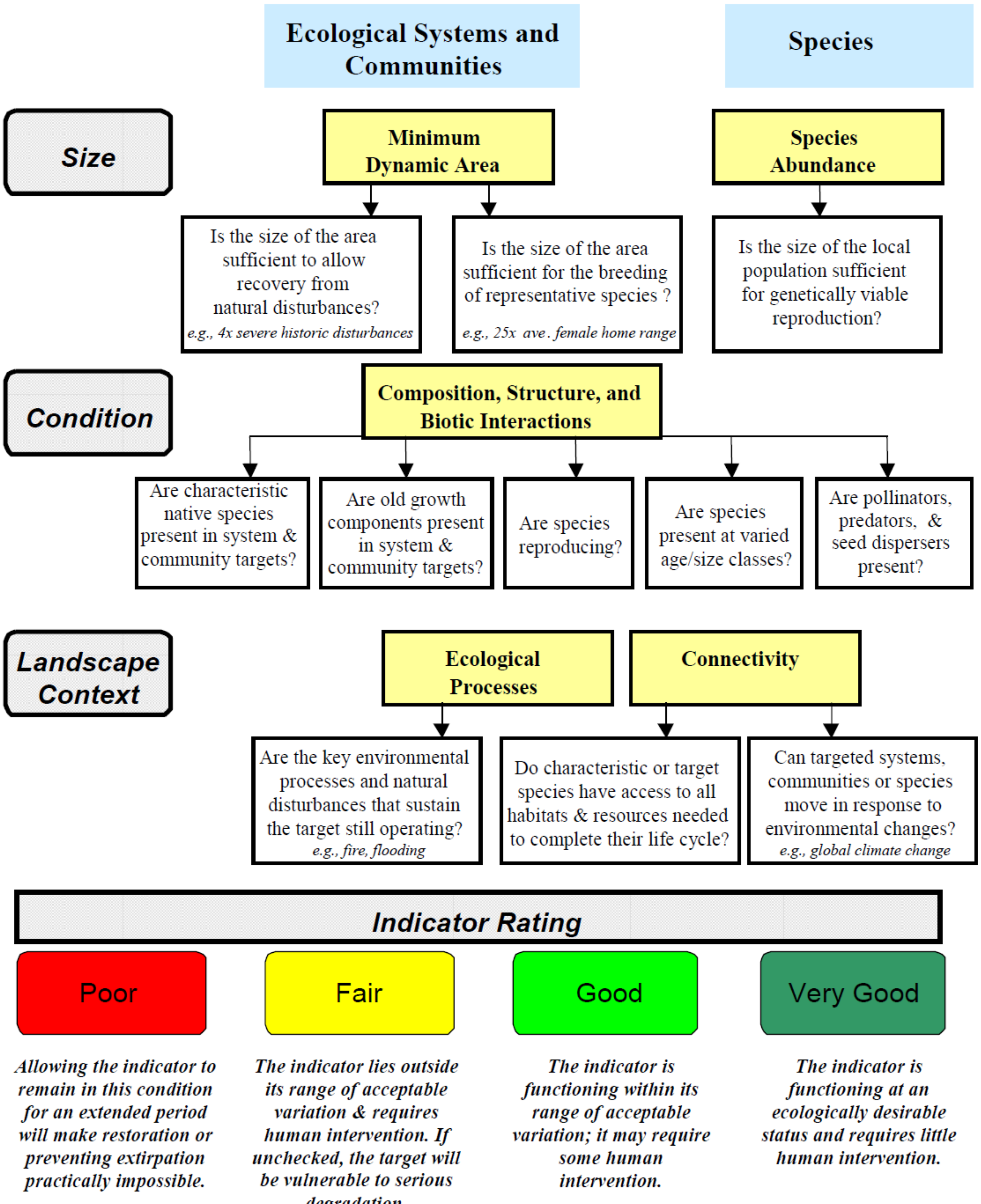
Box 2. Characteristics of Efficient and Effective Integrity Indicators

All indicators should be measurable, precise, consistent, and sensitive. To ensure that indicators are also meaningful and effective for TNC's conservation work, they need to be:

1. *Biologically relevant* (i.e., represent an accurate assessment of biodiversity health)
2. *Socially relevant* (i.e., value is recognized by stakeholders)
3. *Sensitive to anthropogenic stress* and reflective of changes in stress without extreme variability
4. *Anticipatory*, providing early warning (i.e., indicate degradation before serious harm has occurred)
5. *Measurable* (i.e., capable of being operationally defined and measured using a standard procedure with documented performance and low error)
6. *Cost-effective* (i.e., inexpensive to measure, providing the maximum amount of information per unit effort)

Indicators are monitored to track the status of a conservation target, and ultimately to measure the success of our conservation strategies. While the indicators identified may not meet all of these criteria, select those that satisfy the largest possible number (or a complimentary set) and proceed with a strategy for monitoring. Under the premise of Adaptive Management, we can refine the list of indicators as more is learned about the ecological system.

Figure 1. Example Indicators of key ecological attributes[1]. Indicators will vary by attribute and target. Sample types of questions below are illustrative only: they do not represent an exhaustive list.



[1]Modified from Low, G. 2002. Landscape-scale, Community-based Conservation. TNC.

Assessing Status of Key Attributes: Acceptable Ranges of Variation and Reference Conditions

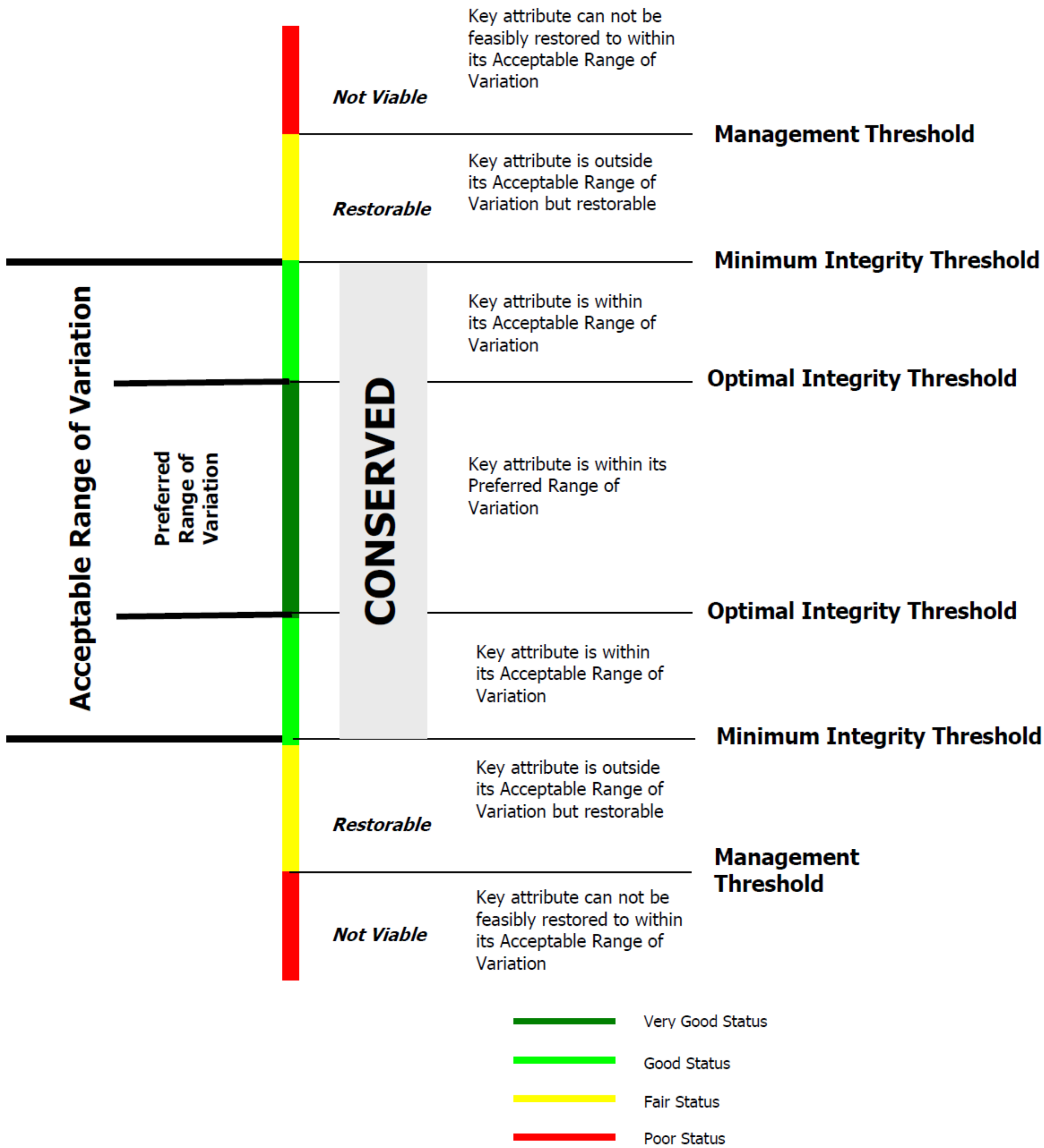
The recommended approach for assessing the ecological integrity of focal biodiversity rests on the widely accepted premise that the composition, structure, and function of all conservation targets - species, communities, and ecological systems - are naturally variable. This dynamism is limited to a particular range of variation that is recognized as natural and consistent with the long-term persistence of each conservation target. More precisely, each key ecological attribute exhibits some “natural range of variation” over space and time. For example, there will be some natural variation in the age and species composition of a forest canopy, the frequency and intensity of fires, or the frequency and magnitude of hurricanes, floods or droughts.

For most biodiversity, what is “natural” is difficult to define, given limited knowledge of many species and systems, and the extent to which human disturbance has either directly or indirectly impacted influenced natural systems around the globe (Hunter 1996). However, through careful scientific reference, reflections on historical data, and comparisons with the best preserved reference examples of a conservation target, at least an outer range of variation for each key ecological attribute can be defined that will maintain the composition, structure and function of the conservation target at acceptable levels over the long-term (Swetman et al. 1999, Stephenson 1999, Moore et al. 1999). For any focal biodiversity to be considered “conserved,” all key ecological attributes should remain intact and functioning within their acceptable ranges of variation, as measured by their specific indicators.

As with the identification of key ecological attributes, descriptions of acceptable ranges of variation constitute hypotheses, crucial to carrying conservation work forward while remaining open to refinement over time. It is important to describe the limits of this variation because these limits set the ecological thresholds beyond biodiversity integrity is expected to degrade. For species, such degradation might involve a collapse of population or range; for communities and ecological systems, such degradation might involve change from one community or system type to another.

The most important threshold to consider for each key ecological attribute is its “minimum integrity threshold” (Fig. 2). The minimum integrity threshold for a key ecological attribute is the outer limit of its acceptable range of variation. Once this threshold has been crossed, the overall integrity of the conservation target cannot be restored so long as the altered attribute is outside of its range of acceptable variation. The composition, structure, and function of a conservation target may not begin to degrade immediately when one of its key attributes moves outside of its acceptable range of variation. However, this shift can be expected to set in motion chains of events, that will (if unchecked) result in additional alterations to other key attributes and leave them vulnerable to significant disruptions from additional disturbances, that in turn may push the associated attributes still further outside of their acceptable ranges of variation. Defining the minimum integrity threshold for individual key attributes is the mechanism by which ecological science can influence the ecological integrity rating of the focal biodiversity in question. In the Ecological Integrity Assessment framework, the focal biodiversity can only be considered as conserved when all of its key attributes are within their minimum integrity thresholds. Conservation strategies therefore need to focus on keeping or moving the key attribute status to levels that are within acceptable ranges of variation. Such strategies should either abate threats that alter key attributes, or guide ecological management and restoration for key attributes that need intervention to return to acceptable ranges.

Figure 2. Key Attribute Thresholds and Status Assessment. Thresholds for some key attributes can be points (such as a fixed pH beyond which the system loses integrity), for others the threshold may be a range.



The Nature Conservancy's Measures of Success Framework

The Nature Conservancy has developed a framework of "measures of conservation success" that describes the change in biodiversity health and threat status of all focal biodiversity over time within a conservation planning geography through qualitative ratings (The Nature Conservancy, 2000). This system rates the status of focal biodiversity's "size", "condition", and "landscape context" as *Very Good*, *Good*, *Fair*, or *Poor*, based on scientific inquiry, in order to convey a snapshot of biodiversity health and conservation progress over time in a clear and compelling manner. The Ecological Integrity Framework seeks to provide increased rigor and consistency to that inquiry by determining the key attributes within the categories of *size*, *condition*, and *landscape context* (Fig. 2), and by rating their status based on the minimum integrity thresholds as stated above.

> ***Size*** is a measure of area of occurrence of an ecosystem or community, or the population size of a species.
>
> ***Condition*** measures biotic interactions and physical or age structure of communities and populations.
>
> ***Landscape Context*** refers to the important ecological processes that maintain the focal biodiversity and issues of biological and spatial connectivity.

This categorical framework has proven to be helpful in assisting conservation practitioners think broadly and comprehensively about important elements of the focal biodiversity's ecology that must be managed and conserved, and in allowing practitioners to speak a somewhat common language about these elements.

The status indicator ratings are defined as:

> ***Very Good:*** The indicator is functioning within an ecologically desirable status, requiring little human intervention for maintenance within the natural range of variation (i.e., is as close to "natural" as possible and has little chance of being degraded by some random event).
>
> ***Good:*** The indicator is functioning within its range of acceptable variation, although it may require some human intervention for maintenance.
>
> ***Fair:*** The indicator lies outside of its range of acceptable variation and requires human intervention for maintenance. If unchecked, the target will be vulnerable to serious degradation.
>
> ***Poor****:* Allowing the indicator to remain in this condition for an extended period will make restoration or prevention of extirpation of the target practically impossible (e.g., it will be too complicated, costly, and/or uncertain to reverse the alteration).

Tools for the Assessment of Ecological Integrity

The Nature Conservancy has developed an automated Excel-based tool to assist in the assessment of ecological integrity and house the documentation and scientific references for the assignment of ecological integrity status for focal biodiversity. This automated tool guides planners and practitioners measuring conservation impact through a series of questions related to the Ecological Integrity Framework. This tool is designed for landscape-based conservation projects, such as the Sacramento River, although it can be applied at both lesser and higher geographic scales. The program is available at www.conserveonline.org

APPLICATION OF THE ASSESSMENT OF ECOLOGICAL INTEGRITY FRAMEWORK TO THE SACRAMENTO RIVER

Study Area and Anthropogenic Alterations

The Sacramento River (Fig. 3) supplies 80% of freshwater flowing into the Bay-Delta (CA State Lands Commission 1993). The 24,000 square mile watershed provides a critical source of water and habitat for a wide variety of species. Historically, the river was lined by approximately 800,000 acres of riparian forest (Katibah 1984). However, over 95% of this habitat has been lost to logging, agriculture, urban development, flood control, and power generation projects. Levees and riprap confine two-thirds of the linear extent of the river's banks. Channelization, bank protection and the construction of the Shasta Dam degraded many habitats by restricting the dynamic forces that promote natural habitat succession and regeneration along the river. Cumulatively, these changes have greatly stressed the Sacramento River ecosystem. The loss and degradation of riparian habitat has diminished the river's ability to support viable wildlife populations and encouraged the invasion and proliferation of non-native invasive species (NIS).

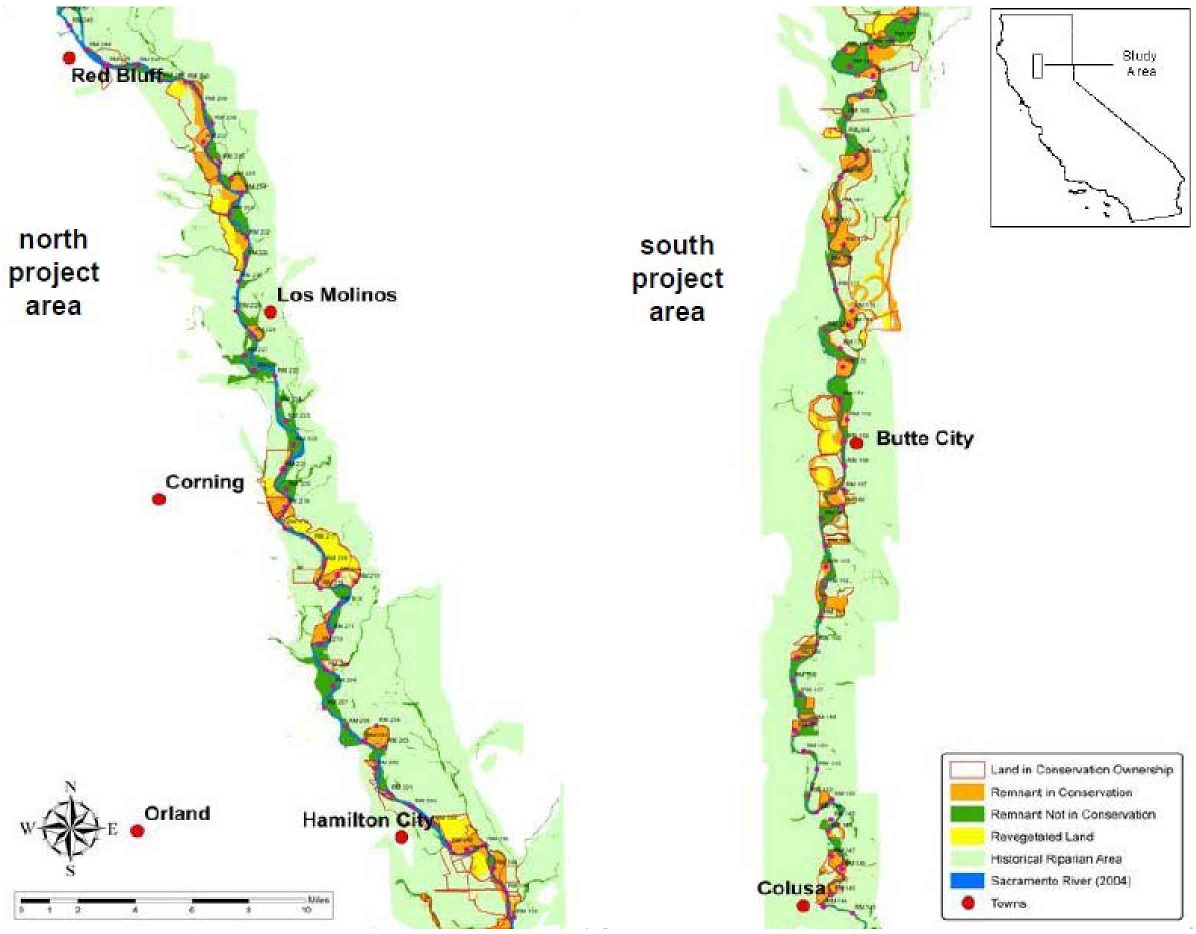


Figure 3. Map of conservation lands in the 100 river mile Sacramento River Project area, located between the towns of Red Bluff and Colusa. Also shown are remnant and restored habitats, and the historical riparian zone as drawn from the Holmes 1913 soil map. Figure from TNC.

At-risk species

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. 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*). Bird species that no longer reproduce along the river include least Bell's vireo [*Vireo bellii pusillus*] and willow flycatcher [*Empidonax trailii*]) (Gaines 1977, Shuford and Gardali 2008, Howell et al. 2010).

Restoration Programs and Focus

Although severely degraded, the Sacramento River is still 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 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), a non-profit organization, formed, and set as its primary goal the preservation of remaining riparian habitat and the reestablishment of a continuous riparian corridor from Red Bluff to Colusa. CALFED has specified collaboration with the SRCAF as a priority for the Sacramento River region.

Over the past 18 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 2000). TNC and RP have planted a suite of native woody species (trees and shrubs, Alpert et al. 1999), and more recently, forbs and grasses on > 6,000 acres of Sacramento River floodplain habitat (Fig. 4). 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).

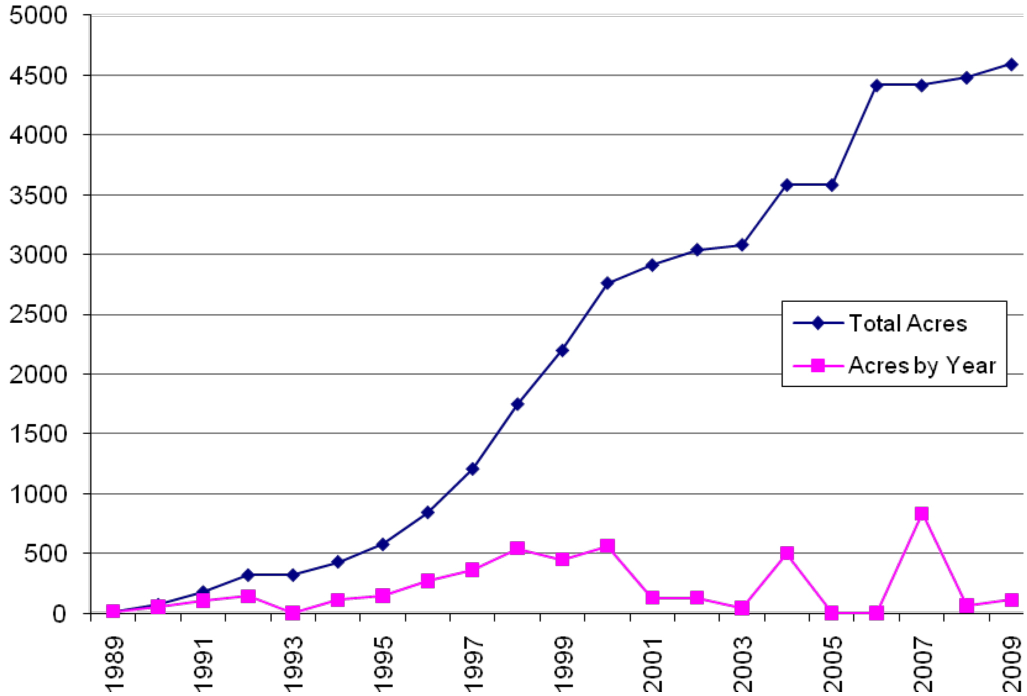


Figure 4. Cumulative and per-year acres of riparian habitat restored by TNC through horticultural restoration on the Sacramento River between Red Bluff and Colusa. Additional acreage has been planted by other entities. Data from TNC (unpublished).

Monitoring Ecosystem Response

Although localized monitoring confirms the success of restoring habitats for wildlife (Alpert et al. 1999, Brown and Wood 2002, Griggs and Golet 2002, Golet et al. 2003, Hunt 2004, Stillwater Sciences 2003, Wood 2003, River Partners 2004, Gardali et al. 2006, Borders et al. 2006, Williams 2007, Golet et at. 2008), there is a need for a more comprehensive assessment of previously implemented projects. In particular, we need to determine how successful horticultural restoration projects have been at achieving CALFED's recovery goals for habitat (ERP goal 4, CALFED 2000b), and native at-risk species including songbirds, the VELB, and salmonids (ERP goal 1, CALFED 2000b) on a wider geographic basis. To do this requires examining the ecosystem as a whole, including both restored and non-restored areas and the major ecological processes that can spell the fate 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 future restoration strategies—especially as additional restoration is required to meet ERP goals.

To comprehensively address these information gaps we need to use integrated remote sensing and field-based monitoring techniques to better characterize existing habitats and species abundance, distributions, fecundity, growth and survival (at both restoration sites and in remnant riparian areas) at the landscape scale. This information can then to be integrated into an overall assessment of ecosystem health.

This report presents the results of an initial effort to provide such an assessment. It utilizes the Nature Conservancy's Ecological Integrity Framework to evaluate the status of terrestrial riparian resources and habitats on the Sacramento River. It incorporates results of past field studies that have generated a wealth of valuable information. For example, PRBO Conservation Science has conducted songbird research and monitoring on the Sacramento River since 1993, and University of California researchers have studied the VELB on five north state rivers (including the Sacramento) for over five years. Here we use this existing knowledge base and other recently derived information (e.g., results of vegetation mapping and channel planform analyses) in a landscape-scale analysis to assess recovery of species and habitats over the entire Sacramento River Project area (Red Bluff to Colusa). We used the iterative process of mapping and characterizing riparian habitats and conducting field-based ground-truthing of mapped areas to evaluate the recovery of riparian habitats, songbirds and the VELB over a large geographic area.

Information on the status of key ecological attributes of a suite of restoration targets is presented in an ecological scorecard. The scorecard has a broad ecological basis, and focuses on monitoring the physical and biological components of successful Sacramento River restoration. It tabulates quantitative data assembled by project partners, teams of partner institutions and experts to track important ecological characteristics and synthesize their status into a set of simple categorical ratings of biodiversity status in an area. Through repeated measurement, managers can use the scorecard to determine whether the status of biodiversity is responding to conservation investments and strategies over time. The scorecard has the added advantages of providing a rigorous basis for setting conservation objectives, assessing threats to biodiversity, identifying research needs, and communicating management information to non-specialists.

The project has produced important outcomes including: comprehensive estimates of the amount and type of habitat that has been created on the river (through natural processes and through horticultural means); estimates of the response of songbirds and the VELB to previously implemented projects; and characterizations of the success of restoration projects in promoting the recovery of riparian habitats and associated species.

The main premises of our key attribute and indicator selection are that: 1) successful riparian habitat restoration requires dynamic interactions between the river and floodplain, and 2) success is indicated by the productive use of natural riparian habitats and aquatic areas by native riparian species.

Our indicators characterize the structural condition of two primary foci—1) channel and floodplain geomorphology and 2) riparian vegetation structure and composition. We assessed the structural condition with data derived from a series of coordinated and complementary field investigations and remote sensing studies. Two responding biological components that are central to CALFED restoration planning (the VELB and songbirds) are used as indicators of river and floodplain condition. Each biological component is dependent upon different structural features of restoration sites, and thus offers a unique and complementary perspective on environmental condition. The VELB requires plant communities containing mature elderberry shrubs and may be influenced by flooding and other plant species. Songbirds require riparian vegetation for foraging and breeding, and their abundance and reproductive success is influenced by restoration site age and structural habitat elements that are shaped by river and floodplain processes.

The scorecard houses a vast amount of information derived from knowledgeable scientists with expertise in different facets of the natural history of the Sacramento River ecosystem. It combines advanced mapping techniques, field investigations, and dynamic modeling to provide scientists, managers and stakeholders with the information that allows insights to be drawn on the status of the Sacramento River ecosystem. At the broadest level, the scorecard evaluates restoration success and ecosystem integrity. At the finest scale, our studies resolve critical uncertainties to advance understanding of the life history needs of a set of organisms that are central targets of CALFED's ERP. By evaluating past restoration actions, it supports adaptive management of a primary CALFED ERP Stage 1 Action (*Action 1: Protect, enhance and restore the meander belt between Red Bluff and Chico Landing,* CALFED 2000b), and thus aid the Bay Delta Authority and other agencies in identifying and prioritizing future conservation and restoration investments in the region.

GOALS AND VISIONS FOR THE SACRAMENTO RIVER ECOLOGICAL MANAGEMENT ZONE

Scorecard metrics were selected to characterize the status of important Sacramento River terrestrial resources and to assess progress toward attaining the Vision for the Sacramento River Ecological Management Zone expressed in the CALFED Restoration Program Plan. This vision is:

> *"to improve, restore, and maintain the health and integrity of the Sacramento River riverine-riparian and tributary ecosystems to provide healthy conditions for sustainable fish and wildlife populations and the plant communities on which they depend"* (CALFED 2000b).

As described in the Restoration Program Plan (CALFED 2000b), the pathway to this vision is through preservation and restoration of erosional and depositional channel and floodplain forming processes, riparian and wetland habitats, spawning gravel recruitment, and reducing the extent and influence of stressors. It also includes managing streamflow and flow regime in ways that benefit ecosystem health.

In addition to the overall vision for the ecological management zone, the Restoration Program developed specific vision statements for the two ecological management units that comprise the Sacramento River Project area.

Vision for the Red Bluff Diversion Dam to Chico Landing Ecological Management Unit

The ERP-stated vision for the Red Bluff Diversion Dam to Chico Landing Ecological Management Unit is:

> *"to protect and expand the quantity and quality of the stream meander corridor; protect the associated riparian forest and allow it to reach maturity; to maintain flows that emulate the natural hydrology to the extent possible; and recover or contribute to the recovery of threatened, endangered, and special concern species. The existing meander belt should be protected and improved to sustain the riparian and riverine aquatic habitat*

> *component that is important habitat for riparian forest dependent species, such as yellow-billed cuckoo, other neotropical migrant bird species, and the valley elderberry longhorn beetle."*

The ERP vision statement goes on to state that restoring endangered species and species of special concern requires that water management activities be consistent with maintaining ecological processes. These include flows that emulate the natural hydrologic regime to the extent possible and are compatible with the high level of development of water in the upper section. Important considerations include flows needed to maintain natural stream meander processes, gravel recruitment, transport, deposition, and establishment and growth of riparian vegetation. The broad riparian corridors throughout the unit should be connected and should not be fragmented. These corridors connect larger blocks of riparian habitat, typically greater than 50 acres. The riparian corridors should generally be greater than 100 yards wide and would support increased populations of neotropical migrants, such as the yellow-billed cuckoo, and unique furbearers, such as the ring-tail and river otter. Species such as the bank swallow will benefit from the restoration of processes that create and maintain habitat within this unit.

Vision for the Chico Landing to Colusa Ecological Management Unit

The ERP-stated vision for the Chico Landing to Colusa Diversion Dam to Ecological Management Unit is:

> *"to improve habitat and increase survival of many important fish and wildlife resources by preserving, managing and restoring a functioning ecosystem that provides a mosaic of varying riparian forest age classes and canopy structure; maintaining a diversity of habitat types, including forest and willow scrub, cut banks and clean gravel bars, oxbow lakes and backwater swales with marshes, and floodplain valley oak/sycamore woodlands with grassland understory; maintaining uninterrupted gravel transport and deposition; supporting a complexity of shaded and nearshore aquatic substrate and habitats with well-distributed instream woody cover and organic debris; setting back levees. Closing gaps in the shoreline riparian vegetation and nearshore aquatic habitat will be accomplished by several means. These include natural colonization or active restoration of expanded floodplain along channels. The continuance of the natural river migration within its meander zone is essential to create and maintain most of these habitats."*

The ERP calls for a mix of solutions to be employed to reduce the need for future additional bank protection or separation of the channel from its floodplain. Measures listed as likely to be employed include strategic levee setbacks. In this unit, broad riparian corridors should be interconnected with narrower corridors that are not subject to fragmentation. These corridors should connect larger blocks of riparian habitat, typically larger than 50 acres. These blocks should be large enough to support the natural cooling of the river by convection currents of air flowing from the cool, humid forests and across the river water. The wider riparian corridors should generally be greater than 100 yards wide to support neotropical migrants better, such as the yellow-billed cuckoo. Cavity nesting species, such as the wood duck, and special status species, such as the bank swallow, will benefit from restoring the processes that create and maintain habitat within this unit.

MORE SPECIFIC ERP VISION STATEMENTS, ECOLOGICAL TARGETS AND ASSOCIATED SCORECARD INDICATORS

Below are the more specific vision statements of the CALFED ERP that correspond to ecological processes, habitats, species and communities, and stressors. For each the scorecard indicators are listed that were used for assessing progress in achieving these visions.

Detailed information on all 68 individual scorecard indicators is provided in Appendix 2. More specifically, Appendix 2 characterizes the following information on each indicator.

- How specifically the indicator is defined
- Rationale is for it being a meaningful indicator and references that support its use as an indicator of river health.
- Scale at which the indicator is most useful (e.g., site, reach, parcel, patch, whole river)
- Selected rating cutoffs for poor, fair, good and very good condition, and how they were selected
- Methods for calculating the indicator or citations to published documents
- Current indicator value (and rating status), and the date and location that this corresponds to.
- Desired rating (and rationale) and when it should be achieved by
- History of data collection, and any additional values
- Source of the current indicator data, including contact information.
- Additional comments (considerations for interpreting data, related or alternative indicators, etc.)

ERP Visions for Habitats

RIPARIAN AND RIVERINE AQUATIC HABITATS: The vision is to maintain and restore extensive areas of riparian and riverine aquatic habitats. The primary area for this is along the Sacramento River above Colusa.

TARGET 1: Provide conditions for riparian vegetation growth along channelized portions of the Sacramento River.

TARGET 2: Increase the ecological value of low-to moderate-quality SRA habitat by changing land use and land management practices.

TARGET 3: Maintain existing streamside riparian vegetation.

<u>SCORECARD INDICATORS:</u> Forest edge contrast, Forest patch proximity, Forest patch core size, Patch morphology, Percent of historical riparian zone currently in conservation ownership, Percent of historical riparian zone currently in natural habitat, Length of river frontage in conservation ownership on both sides of the river, Length of riparian shoreline, Percent of riparian shoreline bordered by >500 meters of natural habitat, Number of in-channel large woody debris aggregations, Total river length, Whole river sinuosity.

ERP Visions for Species and Communities

PLANT SPECIES AND COMMUNITIES: The vision for plant species and communities is to protect and restore these resources in conjunction with efforts to protect and restore wetland and riparian and riverine aquatic habitats.

<u>SCORECARD INDICATORS:</u> Basal area of woody species, Importance value of Arroyo willow, Importance value of Box elder, Importance value of Coyote brush, Importance value of Fremont cottonwood, Importance value of Goodding's black willow, Importance value of Valley oak, Importance value of Western sycamore, Native understory species frequency of occurrence, Native understory species richness, Frequency of Box elder with a DBH > 10 cm, Frequency of Fremont cottonwood with a DBH > 40 cm, Frequency of Gooding's black willow with a DBH > 20 cm, Frequency of Valley oak with a DBH > 20 cm, Area of annual and perennial grasses and forbs, Area of fremont cottonwood forest, Area of mixed riparian forest, Area of riparian scrub, Area of valley oak woodland.

NEOTROPICAL MIGRATORY BIRDS: The vision for neotropical migratory birds is to maintain their diversity and abundance by restoring habitat upon which they depend. Protecting and restoring riparian and riverine aquatic habitats will be critical to maintaining population abundance and distribution. The creation of wide riparian corridors or patches will help reduce brown-headed cowbird predation. Specific visions for Yellow-billed Cuckoo and Bank Swallow are listed separately (see below).

<u>SCORECARD INDICATORS:</u> Nest survival for Black-headed Grosbeak, Nest survival for Lazuli Bunting, Nest survival for Spotted Towhee, Adult survival for Black-headed Grosbeak, Adult survival for Spotted Towhee, Bird species richness, Abundance for Black-headed Grosbeak, Abundance for Common Yellowthroat, Abundance for Spotted Towhee, Abundance for Yellow Warbler, Abundance for Yellow-breasted Chat.

WESTERN YELLOW-BILLED CUCKOO: The vision for the Yellow-billed Cuckoo is to contribute to the recovery of this State-listed endangered species. Potential habitat for the cuckoo will be expanded by improvements in riparian habitat areas. These improvements will result from efforts to protect, maintain, and restore riparian and riverine aquatic habitats throughout the Sacramento River Ecological Management Zone. Rebuilding the Yellow-billed Cuckoo population to a healthy state will require restoring ecosystem processes and functions, restoring habitat, and reducing or eliminating stressors. Restoration of riparian woodlands along the Sacramento River will focus on natural stream meander, flow, and natural revegetational/successional process. These will be extremely important to providing shaded riverine aquatic habitat, woody debris, and other habitat values that contribute to the health of Yellow-billed Cuckoo populations.

<u>SCORECARD INDICATORS:</u> Number of occupied Yellow-billed Cuckoo territories, Importance value of Fremont cottonwood, Frequency of Fremont cottonwood with a DBH > 40 cm.

BANK SWALLOW: The vision for the Bank Swallow is to contribute to the recovery of this State-listed threatened species. Potential habitat for bank swallows will be improved by sustaining the river meander belt and increasing the coarse sediment supply to support meander and natural sediment erosion and deposition processes.

<u>SCORECARD INDICATORS:</u> Number of Bank Swallow burrows, Number of Bank Swallow colonies.

VALLEY ELDERBERRY LONGHORN BEETLE: The vision for the valley elderberry longhorn beetle is to recover this federally listed threatened species by increasing its populations and abundance through restoration of riparian systems.

SCORECARD INDICATORS: Importance value of Blue elderberry, Average number of VELB exit holes per shrub.

ADDITIONAL SPECIES SCORECARD INDICATORS: Bee species richness, Beetle species richness, Bat species richness, Aerial extent of colonial waterbird colonies.

ERP Visions for Ecological Processes

CENTRAL VALLEY STREAMFLOWS: The vision for these flow patterns can be attained by supplemental short-term releases from the major storage reservoirs to provide flows that emulate natural peak flow events.

TARGET: More closely emulate the seasonal streamflow patterns in dry and normal year- types by allowing a late-winter or early-spring flow event of approximately 8,000 to 10,000 cfs in dry years and 15,000 to 20,000 cfs in below normal water-years to occur below Keswick Dam.

SCORECARD INDICATORS: Frequency of bed mobility, Frequency of Floodplain inundation Frequency of side channel connection.

STREAM MEANDER: The vision is to maintain and preserve existing areas of meander and to reactivate meander in other areas that are impaired by bank protection activities.

TARGET: Preserve and improve the existing stream meander belt in the Sacramento River between Red Bluff and Colusa by purchase in fee or through easements of 16,000 to 24,000 acres of riparian lands in the meander zone.

SCORECARD INDICATORS: Area of floodplain reworked, Duration of bed material (and spawning gravel) mobilization, Channel bend meander migration rate, Meters of bank with riprap, Whole river sinuosity, Number of bends with sinuosity greater than 2.0, Total river length, Average half-wavelength, Average bend entrance angle, Length of river with conservation ownership on both banks.

NATURAL FLOODPLAIN AND FLOOD PROCESSES: The vision is to maintain existing areas where the Sacramento River seasonally inundates its floodplain and to reestablish this seasonal inundation in smaller areas.

TARGET: Increase and maintain floodplains in conjunction with stream meander corridor restoration.

SCORECARD INDICATORS: Frequency of Floodplain inundation, Frequency of side channel connection, Meters of bank with riprap, Soil organic carbon.

ERP Visions for Reducing or Eliminating Stressors

LE VEES, BRIDGES, AND BANK PROTECTION: The vision is to modify or remove structures in a manner that greatly lessens adverse affects on ecological processes, habitats and aquatic organisms.

TARGET 1: Construct setback levees along leveed reaches of the river as part of the stream meander corridor.

<u>SCORECARD INDICATORS:</u> Meters of bank with riprap, Length of river with conservation ownership on both banks.

INVASIVE RIPARIAN AND MARSH PLANTS: The vision is to reduce the spread or eliminate invasive non-native riparian species such as giant reed (i.e., *Arundo* or false bamboo) and salt cedar (Tamarisk) that compete with native riparian vegetation

TARGET 1: Reduce the area of invasive non-native species.

<u>SCORECARD INDICATORS:</u> Area of *Arundo* (giant reed), Area of Black walnut, Area of Himalayan blackberry, Importance value of Black walnut, Relative native understory cover, Area of *Ludwigia* (water primrose).

Following the TNC Ecological Integrity Framework we defined a set of Ecological Targets and associated nested targets (Table 1). The target list for TNC's Sacramento River Project also includes anadromous fishes, however, including this element was beyond the scope of the current project, and thus it is not listed here.

Table 1. Set of Conservation Targets and associated nested targets for the Sacramento River project area, Red Bluff to Colusa. Additional definition of targets is provided in the Microsoft Excel workbook that this table was extracted from.

Targets
Sacramento River

Conservation Targets	terrestrial riparian habitat	aquatic riverine habitats	birds (resident and migratory)
	1	2	3
Type of Target	Ecological System	Ecological System	Species Assemblage: Animals: Birds
Habitat Associations	Riparian Areas	Rivers, Streams, Creeks	
Focal Target Description	ecological community that includes all spp that inhabit all successional stages of habitats on terrestrial floodplain areas	Ecological community that includes all spp that inhabit the waters and sediments within the main channel, associated off-channel areas.	All resident and migratory birds that use riparian and associated wetland aquatic habitats
Nested Target # 1	native vegetation communities of trees shrubs, forbs, grasses, and associated decomposers (fungi, bacteria)	native resident deep-bodied fishes (Sac perch, tule perch), cyprinids (hitch, blackfish, splittail), suckers and pikeminnow	Riparian birds
Nested Target # 2	bats and other native mammals (ringtail, fox, etc)	native mammals (beaver, river otter, etc)	waterfowl
Nested Target # 3	valley elderberry long-horned beetle and other important insect pollinators (native bees, etc.) and predators	native phytoplankton, zooplankton, algea and macrophytes	shorebirds
Nested Target # 4	native reptiles (snakes and lizards)		waterbirds
Nested Target # 5			raptors

The Ecological Scorecard summary for the Sacramento River is presented in Appendix 1. Not contained in this appendix is the wealth of information that is contained within the excel workbook that provides supporting information and rationale for the summary scorecard display. The workbook is available upon request. Appendix 2 presents much of this additional information in narrative form.

APPLICATIONS OF SCORECARD INDICATORS

In addition to being useful for assessing the current status of ecological targets, scorecard indicators can provide a wealth of additional information. If repeated measurements are taken with the same methods at particular locations, then they may be used to track changes in the status of resources over time. They may also be used to characterize the contribution that restoration efforts have made to both the current and projected future conditions of the landscape. Also, and importantly, they can be used to evaluate the success of restoration efforts, either by tracking changes in indicators over time at restoration sites, or by comparing restoration sites with remnant (reference) habitats. Each of these applications is introduced below. The discussion is informative not only for what it shows about the varying ways in which scorecard indicators can be applied, but also for what it reveals about the changing status of Sacramento River resources and the effectiveness of implemented restoration actions.

Measuring Change in the Status of Sacramento River Natural Resources over Time

a) Current Status Relative to Some Past Condition

Larsen (2010) mapped channel centerlines on a 160 km meandering alluvial reach of the central Sacramento River, California (from Red Bluff to Colusa) from historic topographic maps (1904) and aerial photographs (in 7 time periods between 1937 and 2007). He tracked temporal changes in these channel centerlines and bend geometry over a 103-year time interval and calculated the following seven scorecard indicators.

TOTAL RIVER LENGTH:

The river channel length, beginning and ending in the same valley location, tended to decrease from 1904 to 2007 (Fig. 5).

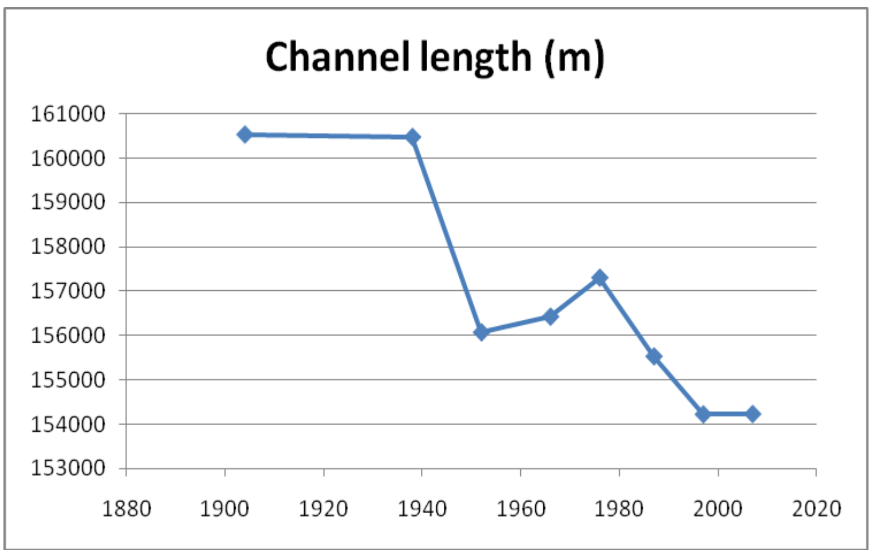


Figure 5. Change in total river length of the Sacramento between River Red Bluff and Colusa from 1906 to 2007. Data and figure from E. Larsen, UCD (unpublished).

Interpretation: This suggests that river length lost due to cut-off has not been replaced by channel migration over the study period. It further suggests that the complexity of the river and its associated habitats has decreased over the last century.

WHOLE RIVER SINUOSITY:

Whole river sinuosity, assessed from the early 1900s to the present, has decreased (Fig. 6).

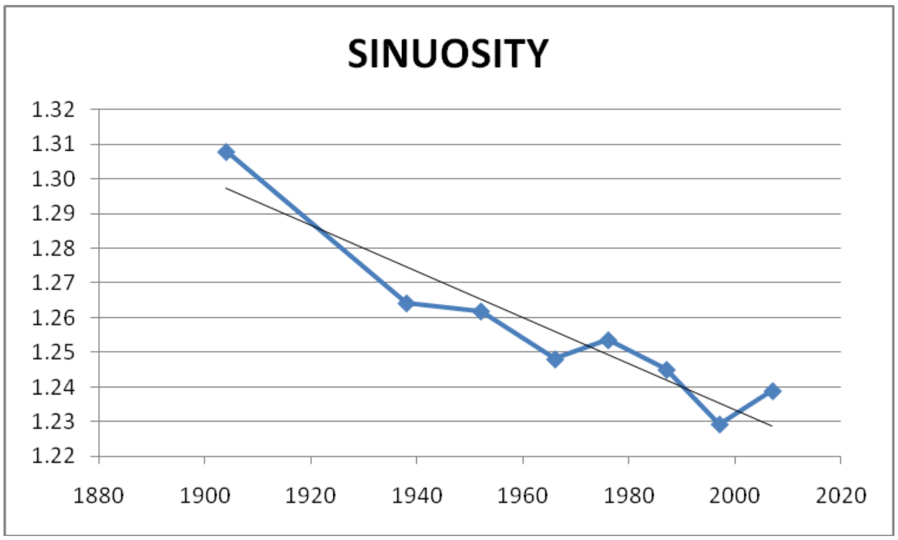


Figure 6. Change in whole river sinuosity of the Sacramento between River Red Bluff to Colusa from 1906 and 2007. Data and figure from E. Larsen, UCD (unpublished).

Interpretation: The formation of high sinuosity bends susceptible to future cut-off has declined. This suggests that the complexity of the river has decreased over the last century, and has implications for the health of the riparian ecosystem.

CHANNEL MEANDER MIGRATION RATE:

Although channel meander migration rate has been highly variable over the period of record, it has tended to decrease over time (Fig. 7).

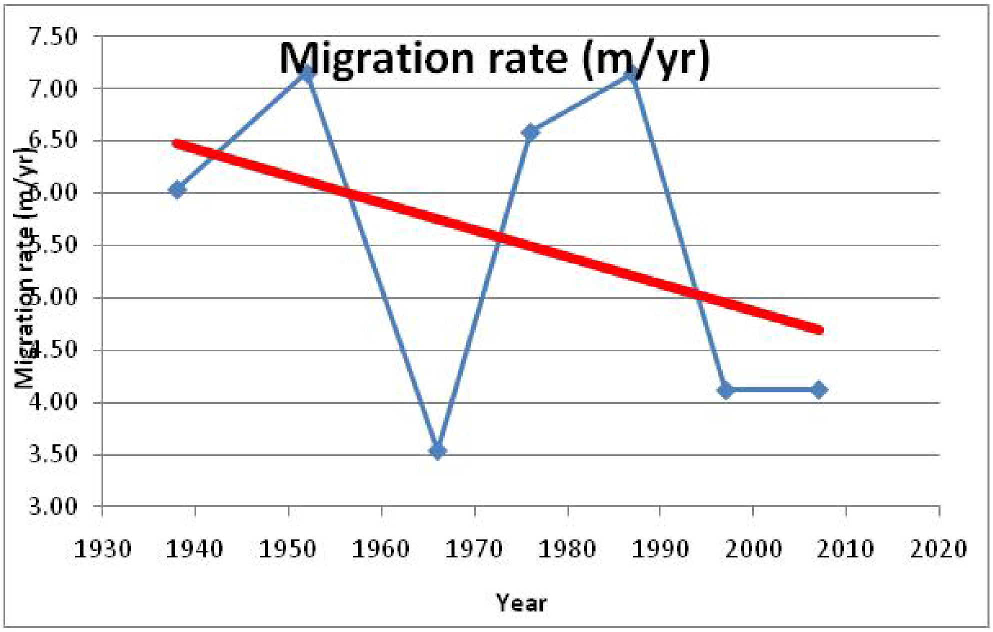


Figure 7. Change in channel meander migration rate on the Sacramento between River Red Bluff and Colusa from 1906 to 2007. Data and figure from E. Larsen, UCD (unpublished).

Interpretation: Channel migration is a function of flow, but is also influenced by the degree to which the channel is constrained with riprap (which has increased dramatically over time (see Fig. 7). A reduction in the rate of meander has implications for habitat forming processes of erosion and sediment deposition with adverse consequences for riparian species and communities.

NUMBER OF BENDS WITH SINUOSITY > 2.0:

The number of bends with a sinuosity of > 2.0 (or 2.4) has been variable, but overall has decreased over the past century (Fig. 8)

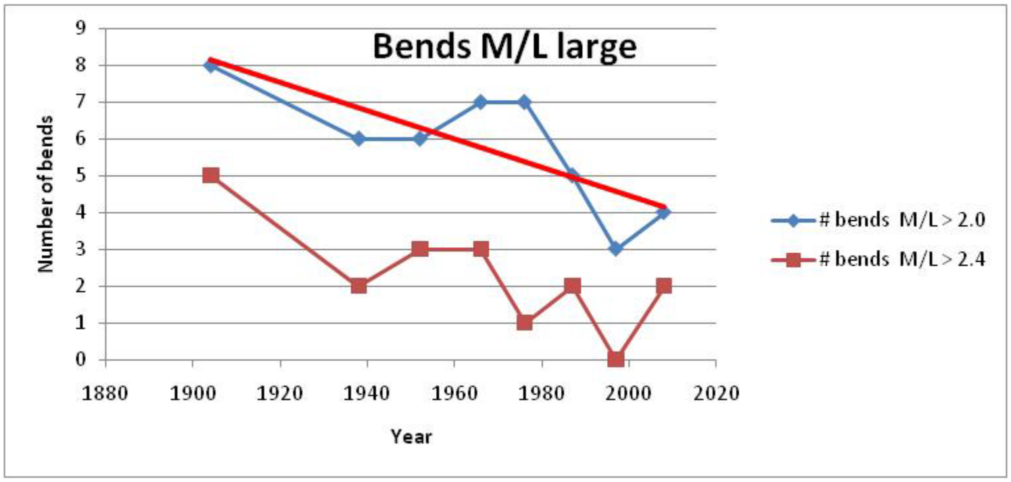


Figure 8. Change in number of bends on the Sacramento with a sinuosity >2.0 between River Red Bluff and Colusa from 1906 to 2007. For comparison, also shown is the change in number of bends on the Sacramento with a sinuosity >2.4. Data and figure from E. Larsen, UCD (unpublished).

Interpretation: These data suggest that the susceptibility of the river to future cut-off has declined. This suggests that episodic, habitat forming processes are less likely to occur now compared to in the past. This has implications for the health of the riparian ecosystem, because many species and communities are adapted to habitats that are formed or maintained when cut-offs occur.

AVERAGE ENTRANCE ANGLE (Θ):

Similar to other channel planform indicators presented here, average entrance angle has been variable over the past century, but overall has decreased (Fig. 9).

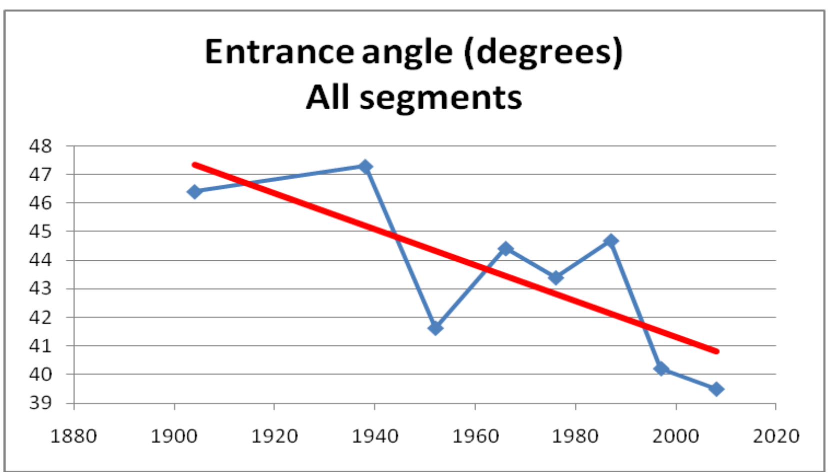


Figure 9. Change in average entrance angle on the Sacramento between River Red Bluff and Colusa from 1906 to 2007. Data and figure from E. Larsen, UCD (unpublished).

Interpretation: The entrance angle represents the upstream curvature of a bend and can be correlated with the tendency of a river bend to cut-off (Constantine and Dunne 2008; Micheli and Larsen 2010). Cutoffs can produce sloughs and oxbow lakes on the Sacramento River, which are important habitats for a variety of species (RHJV 2004, Morken and Kondolf 2003).

AREA OF FLOODPLAIN REWORKED:

Comparisons of this geomorphic scorecard indicator over time reveal a high degree of variability, but an overall decline (Fig. 10).

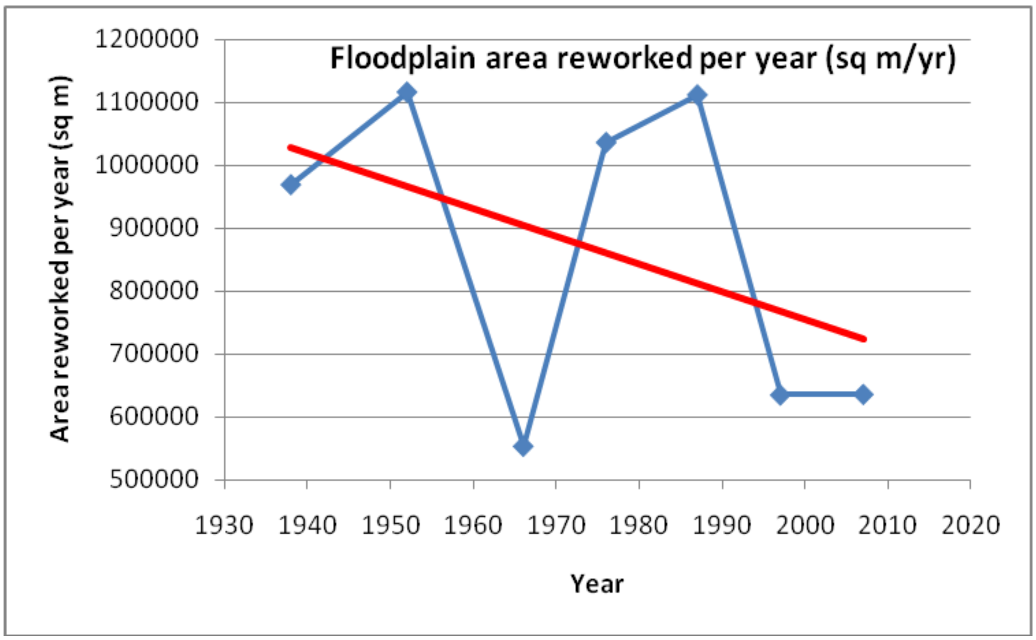


Figure 10. Change in area of floodplain reworked per year on the Sacramento between River Red Bluff and Colusa from 1906 to 2007. Data and figure from E. Larsen, UCD (unpublished).

Interpretation: Area of floodplain reworked is a function of flow, but is also influenced by the degree to which the channel is constrained with riprap (which has increased dramatically over time (see Fig. 10). These data suggest that the river is becoming less dynamic over time. The degree to which a bend is dynamic provides a characterization of the river's ability to create new floodplains. Dynamic river processes (e.g., erosion, sediment deposition) revitalize riverine habitats and are beneficial to native flora and fauna. Cottonwood and willow forests naturally regenerate on freshly deposited floodplain surfaces, and salmon and other aquatic species benefit from fresh gravel inputs.

AVERAGE HALF-WAVELENGTH:

The half-wavelength, or distance between inflection points for individual bends, has shown considerable variability, but has increased overall in the past century (Fig. 11).

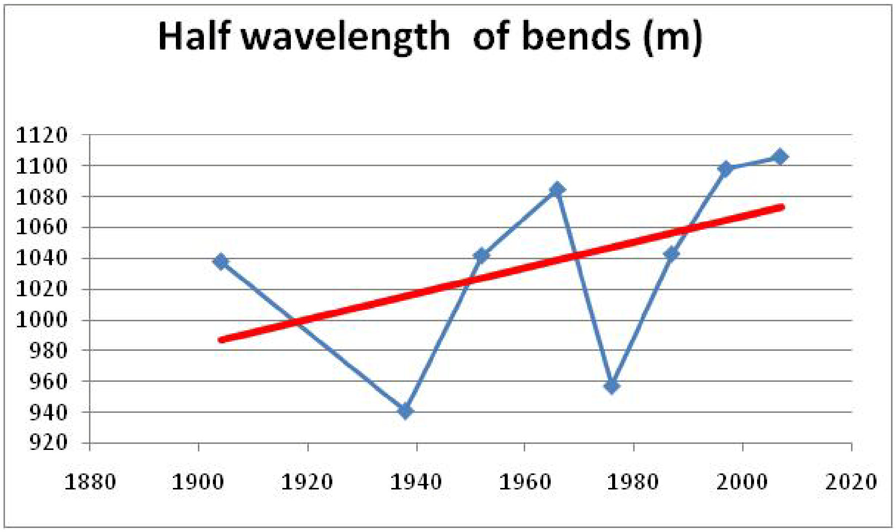


Figure 11. Change in average half wavelength on the Sacramento between River Red Bluff and Colusa from 1906 to 2007. Data and figure from E. Larsen, UCD (unpublished).

Interpretation: These data suggest provide some information about the hydraulic characteristics of the meander bends. The half-wavelength is correlated with flow. Leopold et al. (1964) showed that the dominant (or "effective") discharge and the meander wavelength are positively correlated. In other words, if channel forming flows of the system increases, the average half-wavelength will also increase. The implications of the change in this indicator are less clear than those of others. It may be the case that an increased in river baseflow during the summer has led to an increase in half wavelength. However, it may also be the case that other anthropomorphic changes to the system (installation of levees and riprap) have caused the observed changes.

Frequency of Bed Mobility:

The mobility of the bed was reduced from pre-dam conditions, even though the pre-dam period included the dust-bowl drought, the longest dry period on record (Fig. 12).

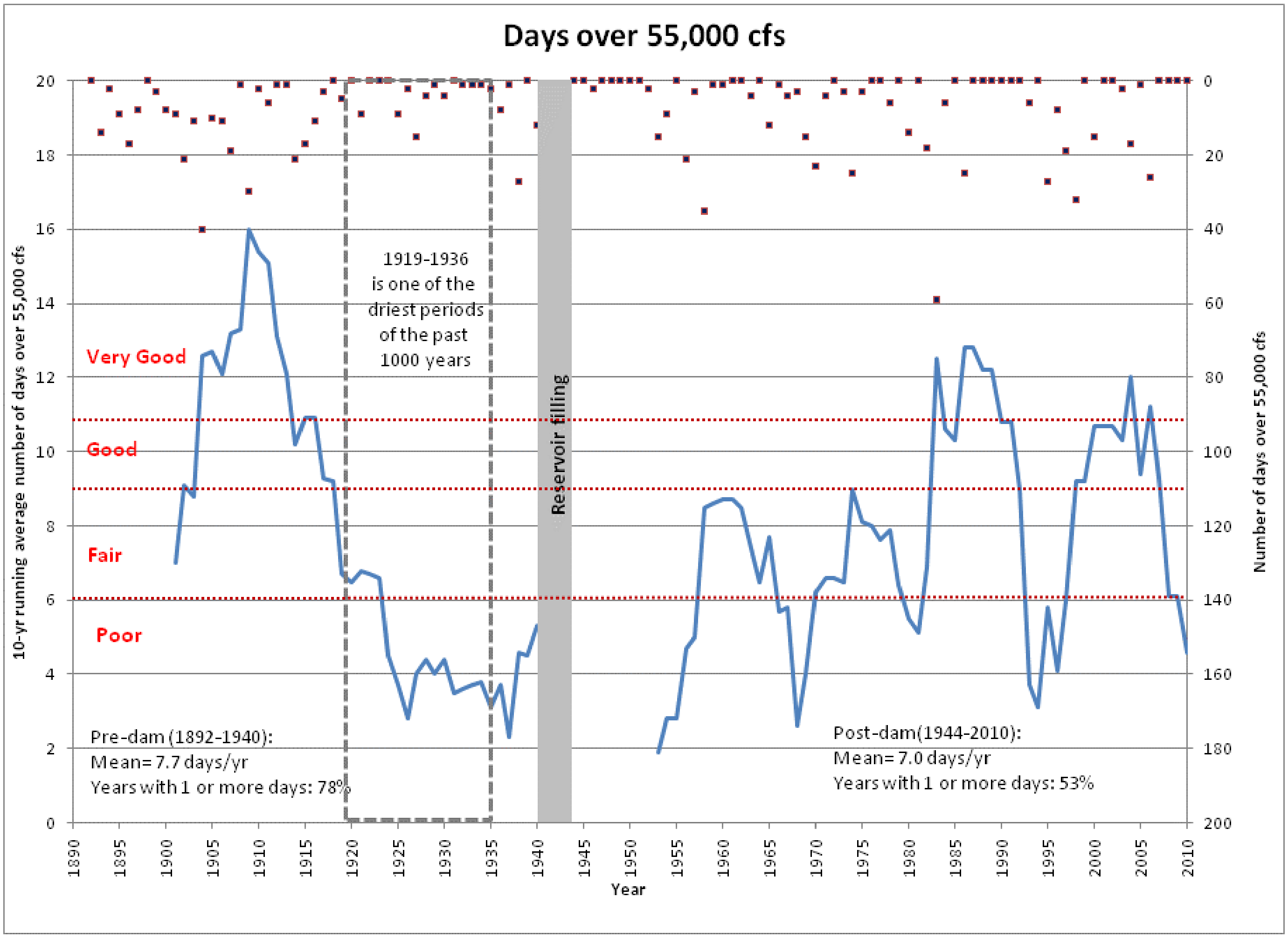


Figure 12. Red points represent the number of days that exceed 55,000 cfs in each individual year. The blue line shows the number of days exceeding 55,000 cfs averaged over the preceding ten years. Cutoffs ("very good", "good", "fair", and "poor") are indicated by dashed red lines.

Interpretation: While the bed is still frequently mobile, it is less mobile that under pre-dam conditions for comparable precipitation regimes. This results from storage of high flows and release of higher base flows by Shasta Dam. Of particular relevance is likely the larger number of years that pass without any bed-mobilizing flows.

FREQUENCY OF FLOODPLAIN INUNDATION: The frequency and duration of floodplain inundation was decreased post-dam more severely than the bed mobility. The floodplain inundation flow indicator decreased from very good to fair pre-dam in all but dust-bowl years, to fair to poor under post-dam conditions (Fig. 13).

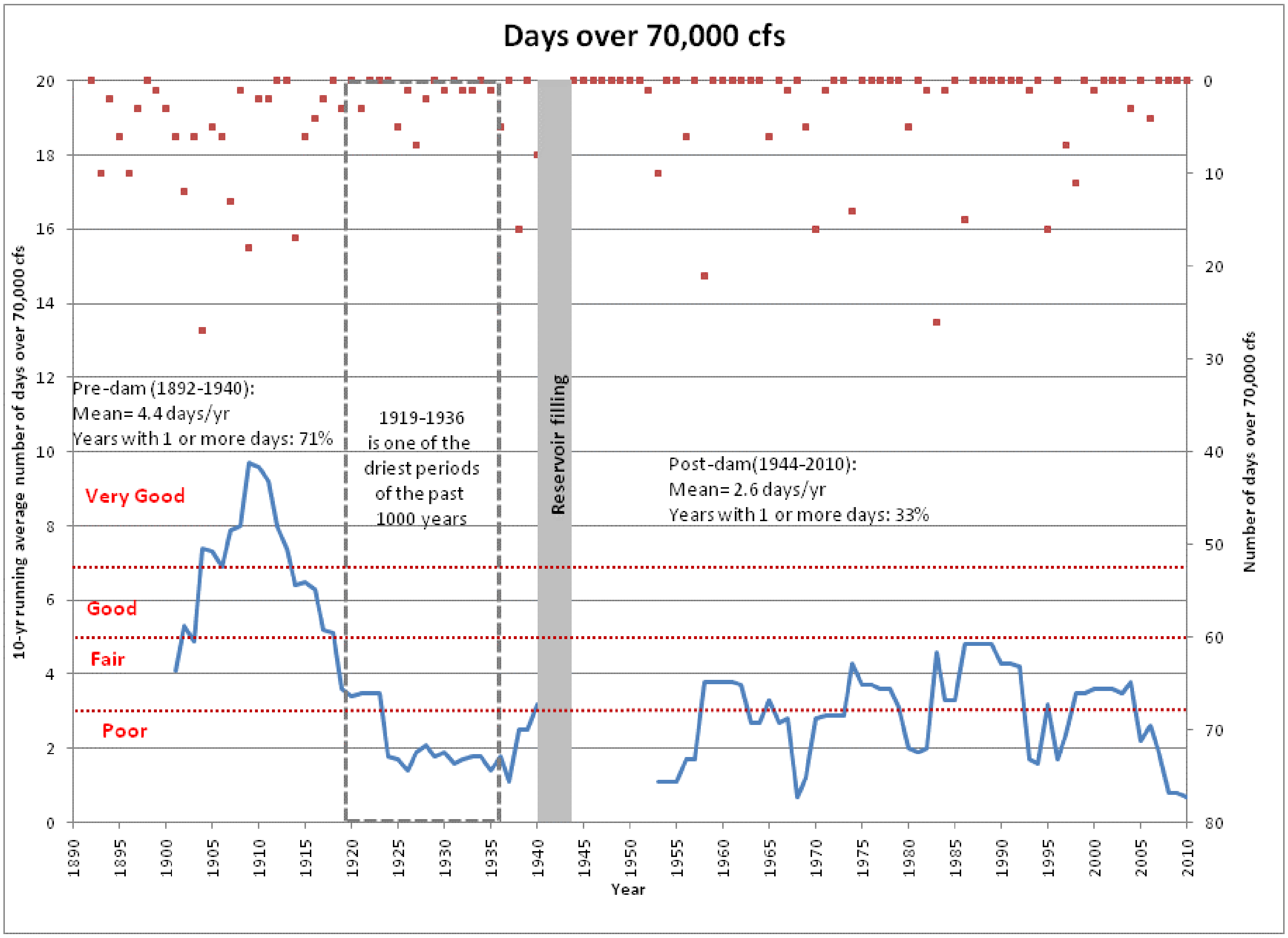


Figure 13. Ten-year running average of number of days with flows over 70,000 cfs recorded at the USGS gauge Sacramento River at Red Bluff (blue line, left labels y-axis), along with number of days with flows over 70,000cfs for each year (red data points, right labels y-axis).

Interpretation: The less-frequent flows capable of overbank flow result from storage of high flows by Shasta Dam, which affected the 70,000 cfs overbank flow threshold more severely than the 55,000 cfs bed mobility threshold. Floodplain disconnection from the channel is even greater than implied by the flow indicator, because extensive reaches of the Sacramento River are flanked by levees that prevent overbank flow, even if flows were sufficient to produce overbank flooding.

FREQUENCY OF SIDE CHANNEL CONNECTION: Side channels along the Sacramento River range widely in age, size, and topographic elevation at which they become connected. Gomez et al (in preparation) studied a broad cross-section of side channels, and through field observation, surveys, and hydrologic modeling, estimated the flow thresholds at which a representative sample population of 17 side channels became hydrologically connected to the mainstem. When ranked by flow at connection, three distinct populations of side channels are evident: a set of side channels that are connected at flows exceeding 50,000 cfs, another set connected at flows exceeding 15,000 cfs, and a set connected by flows greater than 5,000 cfs. Since regulation by Shasta Dam (and since interbasin water transfers from Trinity River), the first group of side channels has experienced a small decrease in frequency and duration of connection, the second has experienced a larger decrease, when the third group (those connected at flows of over 5,000 cfs) has experienced a substantial prolongation of connection because of augmented base flows (Fig. 14).

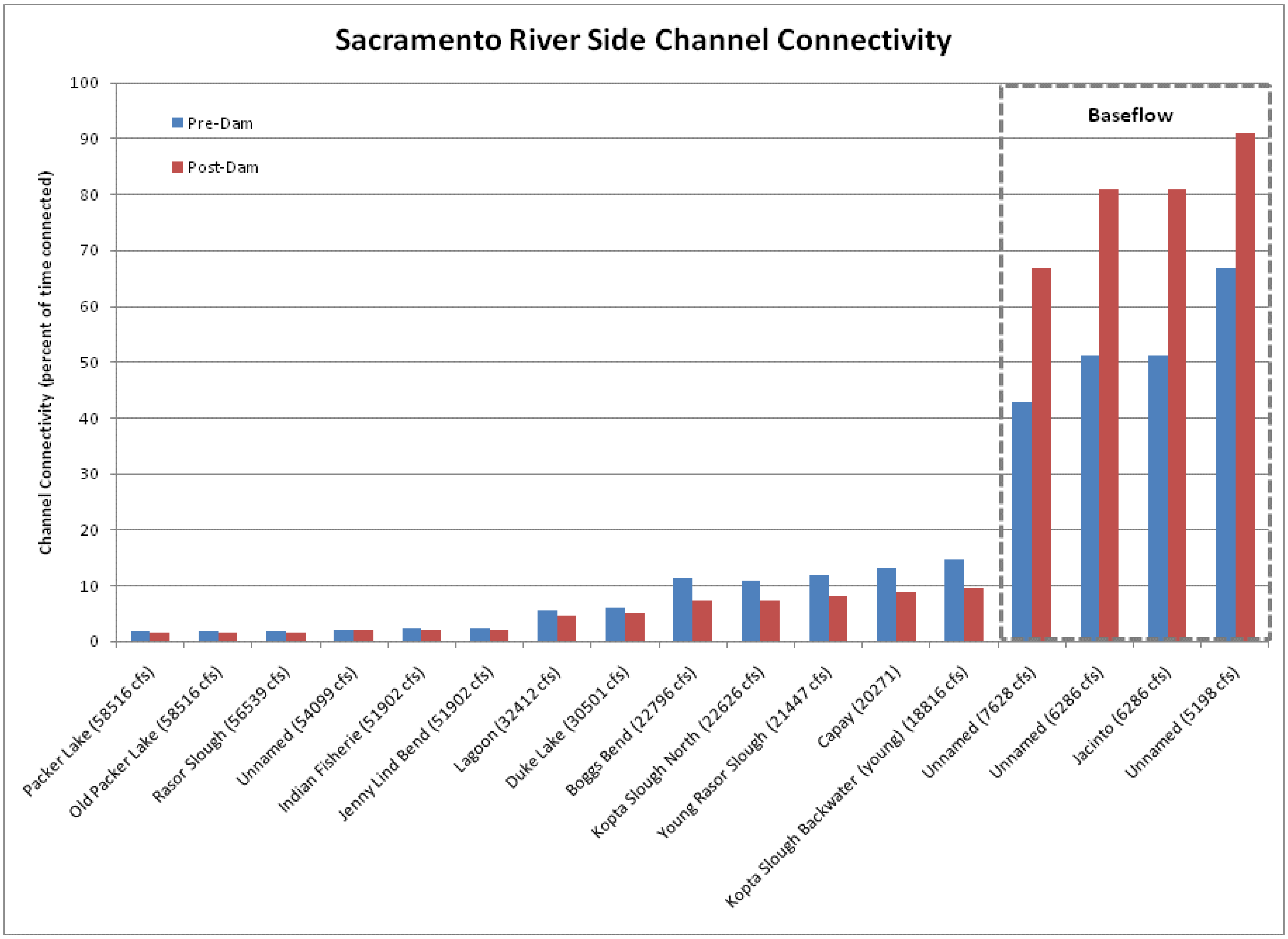


Figure 14. Percentage of time that side channels studied by Gomez et al (in prep) would be connected to the mainstem under pre-Shasta-Dam and post-Shasta-Dam conditions. Note that side channels with very low plugs and thus low thresholds for connection (under 8,000 cfs) actually stayed connected for longer than would be the case naturally because of artificially increased base flows, which would result in decreased diversity of habitat. All other side channels experienced less frequent connection than under natural conditions.

Interpretation: Reduced frequency and duration of high flows caused by storage in Shasta Reservoir has reduced the frequency of most side channels' connection to the main channel, resulting in loss of natural hydrologic conditions that supported native species. Release of stored winter flood waters from Shasta Reservoir during summer irrigation months, augmented by inter-basin transfer of water from the Trinity River, has resulted in elevated summer base flows. These artificially raised summer water levels now keep some side channels as nearly permanent backwaters to the river, with static, artificially raised water levels in summer. While still providing habitat, these flooded side channels no longer dry out seasonally, and thus are less likely to support native species over exotic.

PERCENT OF HISTORICAL RIPARIAN ZONE CURRENTLY IN CONSERVATION OWNERSHIP:

In 2007, 16.20% of the historical riparian zone (within the mapped area) was in conservation ownership.

The corresponding value in 1999 is a range (9.3% - 10.5%). This is reported as a range rather than an absolute number because some conservation ownership properties were purchased before 1999 but had more land added to them after 1999. Since the piece-by-piece breakdown of when each bit was added is unavailable, this metric was calculated both with and without those properties that were added to after 1999. Data and analyses from TNC (unpublished).

Interpretation: Conservation ownership increased by at least 35 (and up to 43) percent from 1999 to 2007. The increase in conservation ownership is a result of ongoing acquisitions by conservation entities and state and federal agencies. Having more land in conservation ownership should result in improved habitat management for wildlife.

PERCENT OF HISTORICAL RIPARIAN ZONE CURRENTLY IN NATURAL HABITAT:

In 2007, 17.7% of the historical riparian zone (within the mapped area) was in natural habitat. In 1999 the comparable values were 16.0% (including restoration sites). Data from M. Nelson et al. (2008). Analyses by TNC (unpublished).

Interpretation: This represents an 11% increase in habitat over 8 years. This is smaller than expected, given the substantial increase in land in conservation ownership over this same time period. There are several plausible explanations for the decrease being smaller than expected. One is that some of the sites that were acquired by conservation entities are still in agriculture and have not yet been restored with native species. Another is that the mapping done in 1999 may have be more comprehensive of small "stringers" of habitat that are small in and of themselves, but that collectively add up to a significant amount of habitat. Also it is conceivable that what was mapped as habitat differed between the two time periods. Finally, it is possible that the increase was in fact small, and that there has been some clearing of habitat in areas not in conservation ownership (e.g., around existing farms). Further examination of the data to understand the observed pattern is warranted.

PERCENT OF RIPARIAN SHORELINE BORDERED BY >500 METERS OF NATURAL HABITAT:

As of June 2007, 22.3% of the riparian shoreline was bordered by natural habitat of 500 meters or greater. In 1999 the comparable value was 15.6%. Data from Nelson et al. (2008), CSUC GIC. Analyses by TNC (unpublished).

Interpretation: This represents a 43% increase over 8 years. This indicator increased considerably more than one discussed above (percentage of historical riparian zone in natural habitat). The relatively greater increase may be the result of restoration activities being focused on properties that have river frontage, as opposed to those that are not adjacent to the river. It is appropriate that restoration focus most intensively on the riverbank, as this benefits both riparian and aquatic species and communities.

LENGTH OF RIVER WITH CONSERVATION OWNERSHIP ON BOTH BANKS:

As of June, 2007, 69,777 meters of the river had conservation ownership on both banks. This compares to between 33,626 and 40,806 meters in June 1999. The value of river frontage in conservation ownership is reported as a range in 1999 because some conservation properties were purchased before 1999 but had more land added after 1999. Because the piece-by-piece breakdown of when each bit was added is unavailable, this metric was calculated both with and without those properties that were added to after 1999. Data and analyses from TNC (unpublished).

Interpretation: This represents a significant increase (between 71 and 108 percent) in the length of river on which there is conservation ownership on both sides. Owning both sides increases the likelihood that natural riverine processes such as bank erosion, sediment deposition and flooding can take place. It also reduces the probability that new riprap or levees will be installed, although it does not guarantee this, as recent events (e.g., at river mile 182) have shown. Ideally owning both sides of the river can allow riprap removal or at least the deterioration of existing bank revetment over time. It also reduces pressure for new rip-rap that may come from adjoining agricultural owners.

PATCH CORE SIZE:

Patch core size was calculated for a suite of landcover types in both 1997 and 2007 (Table 2).

Table 2. Comparison in mean patch size (core area) for 8 landcover types in the Sacramento River riparian zone (Red Bluff to Colusa) between two time periods. Data from Nelson et al. (2008). Analyses by Schott and Shilling, UCD (unpublished).

1997

TYPE	Core Area Weighted Mean CORE_AM	Core Area Standard Deviation CORE_SD
Herbaceous	31.1	7.9
Forest	12.4	4.1
Developed	85.2	16.4
Orchard	220.7	86.1
Row Crop	60.3	12.1
Scrub	139.6	58.0
Gravel Bar	2234.4	136.5
Wetland	6.5	2.5

2007

TYPE	Core Area Weighted Mean CORE_AM	Core Area Standard Deviation CORE_SD
Herbaceous	19.4	3.8
Forest	88.1	15.3
Developed	72.5	6.5
Orchard	201.7	71.5
Row Crop	101.1	37.0
Scrub	1.2	0.6
Gravel Bar	8.5	2.8
Wetland	3.9	1.2

Interpretation: Mean core area for forested patches has increased dramatically; whether because of the creation of large patches of forest, or because of the augmentation of existing patches. Herbaceous, scrub, and wetland have all decreased in mean patch core area. Differences between 1997 and 2007 in gravel bar and wetland may be related to differences in height of inundation, as opposed to real changes in actual extent.

EDGE CONTRAST:

Edge contrast was calculated for a suite of landcover types in both 1997 and 2007 (Table 3).

Table 3. Comparison in edge contrast for 8 landcover types in the Sacramento River riparian zone (Red Bluff to Colusa) between two time periods. Data from Nelson et al. (2008). Analyses by Schott and Shilling, UCD (unpublished).

1997

TYPE	Edge Contrast Index Area Weighted Mean ECON_AM	Edge Contrast Index Standard Deviation ECON_SD
Herbaceous	78.5	10.7
Forest	48.8	23.1
Developed	93.2	7.7
Orchard	69.0	16.4
Row Crop	64.9	14.2
Scrub	61.8	16.4
Gravel Bar	59.6	26.9
Wetland	73.6	24.4

2007

TYPE	Edge Contrast Index Area Weighted Mean ECON_AM	Edge Contrast Index Standard Deviation ECON_SD
Herbaceous	63.4	13.8
Forest	72.0	13.0
Developed	94.5	7.0
Orchard	66.3	15.9
Row Crop	55.7	17.7
Scrub	50.7	11.9
Gravel Bar	44.3	20.7
Wetland	59.7	21.6

Interpretation: In general, between 1997 and 2007, edge contrast has increased dramatically for forested patches and decreased for herbaceous, scrub, and wetland patches. Given that the total forest core area has increased 5 fold in extent in that time, it is likely that the increase in edge contrast is due to new forest establishment in areas that adjoin agriculture. For core-forest dependent species, an increase in edge contrast is expected to extend edge effects into the forest patch interior, however this impact is likely offset by increases in overall patch size.

PATCH PROXIMITY:

Patch proximity was calculated for a suite of landcover types in both 1997 and 2007 (Table 4).

Table 4. Comparison in patch proximity for 8 landcover types in the Sacramento River riparian zone (Red Bluff to Colusa) between two time periods. Data from Nelson et al. (2008). Analyses by Schott and Shilling, UCD (unpublished).

1997

TYPE	Area-Weighted Mean Proximity Index PROX_AM	Proximity Standard Deviation PROX_SD
Herbaceous	146.77	226.74
Forest	15.58	31.11
Developed	103.51	173.01
Orchard	813.07	746.23
Row Crop	43.73	117.13
Scrub	368.98	477.78
Gravel Bar	440.74	4339.13
Wetland	2.73	6.13

2007

TYPE	Area-Weighted Mean Proximity Index PROX_AM	Proximity Standard Deviation PROX_SD
Herbaceous	30.98	53.53
Forest	204.87	588.86
Developed	46.89	73.45
Orchard	584.98	825.96
Row Crop	271.12	327.89
Scrub	17.13	19.96
Gravel Bar	6.89	20.01
Wetland	6.17	8.37

Interpretation: Forested patches were dramatically improved in their proximity to other forested patches (indicated by increase in the proximity index from 1997 to 2007). This is likely to improve habitat condition for area sensitive species (e.g., yellow-billed cuckoo). Herbaceous and scrub vegetation patches dramatically worsened in terms of their proximity. It is unclear why these changes resulted, although it is possibly an artifact of how the mapping was done. Wetlands had very low proximity and did not change much from 1997 to 2007.

PATCH MORPHOLOGY:

Patch morphology was calculated for a suite of landcover types in both 1997 and 2007 (Table 5).

Table 5. Comparison in patch morphology for 8 landcover types in the Sacramento River riparian zone (Red Bluff to Colusa) between two time periods. Data from Nelson et al. (2008). Analyses by Schott and Shilling, UCD (unpublished).

1997

TYPE	Area-Weighted Mean Shape Index SHAPE_AM	Shape Standard Deviation SHAPE_SD
Herbaceous	4.75	1.08
Forest	2.92	0.72
Developed	4.39	1.38
Orchard	2.50	0.60
Row Crop	2.85	0.61
Scrub	1.91	0.43
Gravel Bar	26.46	1.77
Wetland	3.37	0.92

2007

TYPE	Area-Weighted Mean Shape Index SHAPE_AM	Shape Standard Deviation SHAPE_SD
Herbaceous	3.26	0.76
Forest	6.14	1.19
Developed	2.66	0.51
Orchard	2.62	0.63
Row Crop	2.16	0.53
Scrub	2.93	0.74
Gravel Bar	2.82	0.71
Wetland	2.69	0.63

Interpretation: Forested patches have become more convoluted, on average, between 1997 and 2007. This means that they have increased in the amount of edge length that they have relative to their core areas. Herbaceous and wetland areas became less convoluted in shape between 1997 and 2007, on average, and scrub became more convoluted. Not surprisingly, row crops and orchards stayed unchanged, primarily because they tend to be square fields.

AREA TOTALS FOR MAPPED VEGETATION CATEGORIES:

In both 1999 and 2007 vegetation was mapped from aerial photographs (see Nelson et al. 2008 for methods). The 1999 vegetation coverages were established from analysis of aerial photos taken from May 18-21, and the 2007 coverages were from flights on June 26. Although the mapped categories were not identical, a crosswalking of categories was developed and some meaningful comparisons (Table 6) can nonetheless be drawn between the two time periods.

Table 6. Comparisons in area for vegetation indicators between two time periods from aerial mapping. All values are acres. Data from Nelson et al. (2008). Analyses by TNC (unpublished).

Scorecard Indicators	**Years**	
	1999	**2007**
Natives		
Annual and perennial grasses and forbs	3,425 (called herbland)	4,396
Fremont cottonwood *(Populus fremontii)* forest	4,147	7,692
Mixed riparian forest	5,476	1,126
Valley oak *(Quercus lobata)* woodland	1,638	3,938
Riparian scrub	2,206	2,401
Total	16,892	19,553
Non-native Invasives		
Giant reed *(Arundo donax)*	122	136
Black walnut *(Juglans hindsii)*	226	2,538
Water primrose (*Ludwigia peploides)*	338	387
Himalayan Blackberry *(Rubus discolor)*	226	310
Total	912	3,371

Interpretation: Between 1999 and 2007 the total area comprised of the native vegetation listed in the above table increased. It likely increased more than is shown because in 1999 black walnut was not separated out to the same degree that it was in 2007. Because of this some of the differences listed may not be real, but rather a result of how the classifications were done in the mapping. More specifically, some of the areas that were called out as cottonwood forest, valley oak woodland, and black walnut in 2007 were coded as mixed riparian in 1999. This would explain the apparent decline in mixed riparian forest as well as some of the pronounced increase in acreage of the other vegetation categories between the two time periods.

METERS OF RIPARIAN SHORELINE:

GIS analysis of aerial photos taken in June 2007 revealed 598,625 meters of riparian shoreline. Analyses conducted by the same technician of the June 1999 aerials documented 739,437 meters. Data from Nelson et al. (2008). Analyses by TNC (unpublished).

Interpretation: These data suggest that the amount of riparian shoreline decreased by 19% over this 8 year period. It is unknown why there is this difference, or whether or not it is real or an artifact of how the analysis was done. One possible explanation for the difference is that it was a function of the river being mapped at somewhat different discharge levels. Discharge affects stage, and stage dictates where the shoreline is located. During the period of May 18-21, 1999, the river stage was at ~12,500 cfs at the Hamilton City gauge, whereas on June 26, 2007, the flow was ~8,900 cfs at this same gauge.

NUMBER OF IN-CHANNEL LARGE WOODY DEBRIS AGGREGATIONS:

GIS analysis of aerial photos taken in June 2007 revealed 387 aggregations of large woody debris in the river between Red Bluff and Colusa. Analyses conducted by the same technician of the June 1999 aerials documented 738 aggregations. Analyses by TNC (unpublished).

Interpretation: There were approximately twice as many aggregations of woody debris in the river in 1999 as there were in 2007. It may be the case that more wood was in the river in 1999 due to the very high flow events that took place in 1997. Regardless of the cause, it is interesting to note the difference, given the great importance of wood in rivers to aquatic biota.

METERS OF RIPRAPPED BANK:

The extent and location of riprap has been mapped on the Sacramento River between Red Bluff and Colusa since the mid-1930s. The most recent survey took place in 2002, and documented approximately 77,000 meters of riprap.

Interpretation: Riprap has been steadily increasing over time (Fig. 12). Although comprehensive mapping has not been done since 2002, local knowledge suggests that between 500 and 1000 meters of additional riprap has been installed since 2002. This steady increase in riprap is suggestive of a continued deterioration of riparian and aquatic habitats on the Middle Sacramento River. Riprap brings an abrupt halt to some of the most important ecological processes in river systems. This is an alarming trend that is almost certainly causing adverse consequences for a wide range of species (e.g., bank swallows, salmon) and communities (e.g., riparian forest). The continued installation of riprap on the river is reducing the functionality of the riparian ecosystem and making all of the gains that have resulted from two decades of conservation restoration efforts much less significant than they would otherwise be. Of all the indicators that point to problems with the Sacramento River system, this is among the most troubling.

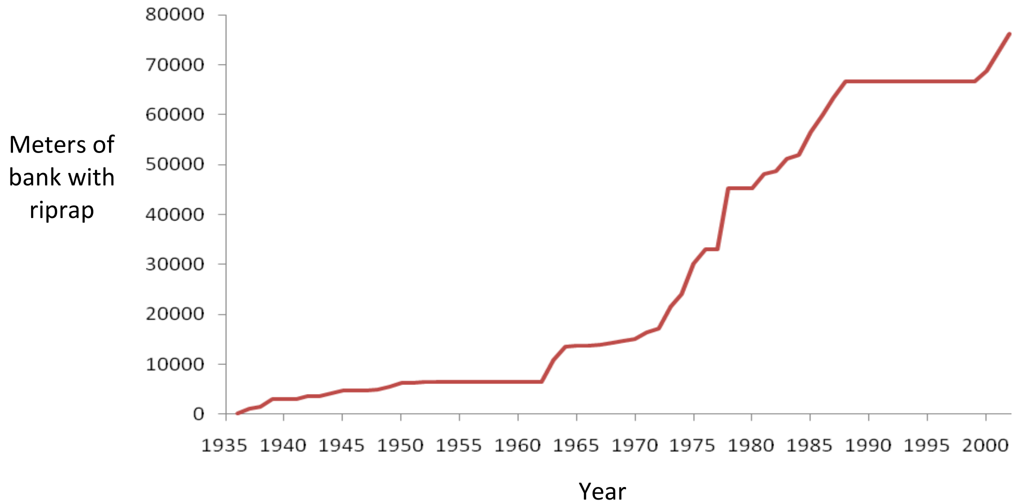


Figure 15. Change in the amount of riprapped banks on the Sacramento River between Red Bluff and Colusa from 1937 to 2002. Data from A. Henderson, DWR (unpublished).

NUMBER OF BANK SWALLOW BURROWS:

Colony and burrow counts have been conducted nearly every year from 1986 to the present. Three years were missed. Data from 1999 onwards have been error checked. This remains to be done for earlier years.

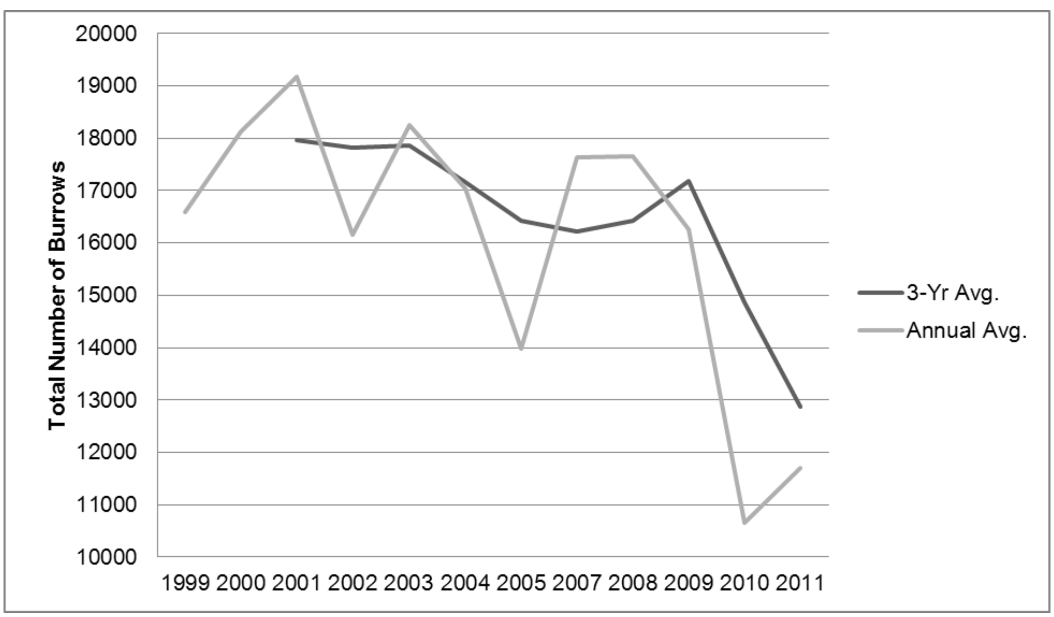


Figure 16. Bank Swallow burrow counts, Red Bluff to Colusa, Sacramento River. Data from J. Silveira, USFWS (unpublished).

Interpretation: The Bank Swallow population on the Sacramento River appears to have undergone a pronounced decline, most dramatically in 2010, and remaining at a low level through 2011. The burrow counts for 2010 represent a 34% decrease from 2009, or a 14 % decrease from the 3-year running average. In 2011 the 3-year running average decreased by an additional 13%. Girvetz (2010) found that the spatial structure of the habitat patches was not important to the viability of this population. Rather the total area seemed to be driving the population. Importantly restoration of riverbank habitat (removal of riprap) reduced extinction probability to less than 10%. This is a 57% reduction in the probability of the population dropping below the quasi-extinction threshold compared to the current condition.

NUMBER OF BANK SWALLOW COLONIES:

Colony (and burrow) counts have been conducted nearly every year from 1986 to the present. Three years were missed. In July 2010 there were 38 colonies counted between Red Bluff and Colusa. This corresponds to a “Poor” rating, and represents a 21% decrease in the number of colonies from 2009.

Interpretation: The number of colonies is an important component of bank swallow population health. Having more colonies may help buffer the population from impacts (e.g., predation, disturbance, etc) that are location specific. It is beneficial to spread the risk among numerous geographic areas. The downward trend in the number of colonies suggests that the Sacramento River Bank Swallow population is facing an increased risk of extirpation.

NUMBER OF OCCUPIED YELLOW-BILLED CUCKOO TERRITORIES:

Data from the 2010 field season are still being analyzed to provide the exact number of occupied territories, but it has determined been determined to be less than 25. Data from C. Howell, PRBO Conservation Science (unpublished).

Girvetz and Greco (2009) reported that of the 102 sub-patches identified as suitable, 13-18 were occupied per year in 1987-1990, 23 were occupied in 1999, and 28 were occupied in 2000. Although this appears to indicate an increase, survey effort, survey methods, and survey interpretation varied considerably among years so it is not possible to compare data across years.

Interpretation: Although differences in survey methods over time make cross-year comparisons challenging, the low number of occupied cuckoo territories is of great conservation concern, especially since the Sacramento Valley is thought to be a major population center for this state endangered species.

b) *Assessing the Contribution of Restoration Sites (Comparisons with and without Implemented Restoration)*

AREA TOTALS FOR MAPPED VEGETATION CATEGORIES:

Restoration sites have contributed a considerable amount of habitat along the Sacramento River. Table 8 lists the amount of vegetation in various classes at Sacramento River restoration sites in June 2007, as determined by mapping of aerial photos by the CSUC Geographic Information Center (Nelson et al. 2008).

Table 7. Amount of vegetation in various classes found at Sacramento River restoration sites in June, 2007. Also shown is the total amount of each vegetation class mapped across the entire study area (which approximates the historical riparian zone), and the percentage of this that is contributed by restoration. Data from Nelson et al. 2008; analyses by TNC.

VEGETATION CLASS	acres (hectares) in restoration	acres (hectares) in total	Percent in restoration
Box elder	45 (18)	861 (349)	5.2
Blackberry scrub	4 (2)	286 (116)	1.5
California annual grasses	564 (228)	3,832 (1,551)	14.7
California sycamore	0.1 (0.1)	176 (71)	0.1
Fremont cottonwood	2,706(1,095)	7,686 (3,111)	35.2
Mixed willow	57 (23)	1,842 (745)	3.1
Perennial grassland	156 (63)	465 (188)	33.5
Riparian scrub	189 (77)	2,411 (976)	7.8
Valley oak	1,623 (657)	3,950 (1,599)	41.1
Total	5,344 (2,162)	21,508.2 (8,704)	24.8

Of note is the amount of planted valley oak (41%) and Fremont cottonwood (35%) that is being contributed to the total habitat in the area. It is also interesting to consider that ~25% of the entire area that was mapped in the riparian habitat classes listed above is found on restoration sites.

PERCENT OF HISTORICAL RIPARIAN ZONE CURRENTLY IN NATURAL HABITAT:

In June 2007, 17.7% of the historical riparian zone (within the mapped area) was in natural habitat. The above value includes restored areas. If restored areas are excluded then the value is 14.9%. Data from Nelson et al. (2008). Analyses by TNC (unpublished).

Interpretation: This comparison demonstrates that restoration has increased the amount of riparian habitat in the historical riparian zone by ~19%. Note that this does not imply that riparian habitat has increased by this amount over the time period that restoration has been implemented (post 1989). That amount is calculated by another indicator comparison.

PERCENT OF RIPARIAN SHORELINE BORDERED BY >500 METERS OF NATURAL HABITAT:

In June 2007, 22.25% of the riparian shoreline was buffered by natural habitat > 500 meters wide. If restoration areas are removed, the value drops to 14.25%. Data from Nelson et al. (2008). Analyses by TNC (unpublished).

Interpretation: This comparison demonstrates that restoration has increased the amount of riparian habitat in the historical riparian zone that has a buffer of natural habitat by ~56%. Note that this does not imply that riparian habitat has increased by this amount over the time period that restoration has been implemented (post 1989). That amount is calculated by another indicator comparison.

c) Comparisons between Current Condition and with Potential Future Build Out of Riparian Habitat.

Scorecard indicators are also useful for analyzing the potential gains that could come from expanding the amount of habitat along the river. This was done by identifying a suite of potential property acquisitions. These potential acquisitions were selected based on their proximity both the river and to existing protected lands. Approximately 12,000 acres were selected for this exercise. This is approximately double the amount of conservation land that has been acquired in the past 20 years.

LENGTH OF RIVER WITH CONSERVATION OWNERSHIP ON BOTH SIDES:

If these properties are acquired, then this will add 59,739 meters of additional bank with conservation ownership on both sides. Data and analyses by TNC (unpublished).

Interpretation: Currently 34,889 meters of the river have conservation ownership on both sides. Adding this set of properties would bring the total up to 94,628 meters, amounting to a 171% increase. Owning both sides increases the likelihood that natural riverine processes such as bank erosion, sediment deposition and flooding can take place. It also reduces the probability that new riprap or levees will be installed, although it does not guarantee this, as recent events (e.g., at river mile 182) have shown. Ideally owning both sides of the river can allow riprap removal or at least the deterioration of existing bank revetment over time. It also reduces pressure for new rip-rap that may come from adjoining agricultural owners.

PERCENT OF HISTORICAL RIPARIAN ZONE CURRENTLY IN CONSERVATION OWNERSHIP:

If all of these properties are acquired then this will bring the total of lands in conservation ownership up to approximately 41,000 acres. Currently there are 29,398 acres in conservation ownership. This represents 16.2% of the historical riparian zone (181,468 acres). Adding these additional properties would bring the total up to 22.6%. Data and analyses by TNC (unpublished).

Interpretation: Although the increase only adds 6.4%, this represents a ~40% increase compared to the current condition. Increasing the land in conservation ownership has obvious benefits for managing lands to maximize habitat values for wildlife.

PERCENT OF RIPARIAN SHORELINE BORDERED BY >500 METERS OF NATURAL HABITAT:

If all of these properties are acquired then this will add an additional 11.8% of the total river bank with a border of riparian vegetation that is more than 500 meters. This would bring the total up to ~34%.

Interpretation: This comparison reveals that with less than 12,000 acres of strategic land acquisition and restoration, more than one third of the river will have a significant buffer of riparian habitat. This is a ~55% increase over the current condition.

Assessing the Performance of Restoration Sites

a) *Comparisons of restoration sites with remnant habitat*

SOIL ORGANIC CARBON

Soil carbon accumulates as a result of the decomposition process of organic material, the main input being from vegetation. Soil organic carbon was selected as an indicator for its importance in ecosystem function, and because it is reliably quantified through instrumental analysis. Soil carbon and nutrient cycling are of fundamental importance to biological systems and play a central role in water retention, which directly affects site productivity.

Soil carbon was sampled at 2, 10, and 24-cm depths at three sites. One of these sites (the WCB site) is remnant forest, and the other two are restoration sites. Site II was planted earlier than site VII. Each seasonal carbon concentration represents a mean of the nine samples collected for each location.

Soil carbon concentration results from the three sites, measure at a depth of 10 cm, are presented below (Fig. 17). Results of percent carbon measured at the other two depths are presented in Brown and Wood (2002). All figures show a similar pattern. The natural riparian forest site (WCB) had the highest soil carbon content, and the youngest restoration site (Site VII) had the lowest. The older restoration unit (Site II) had an intermediate level.

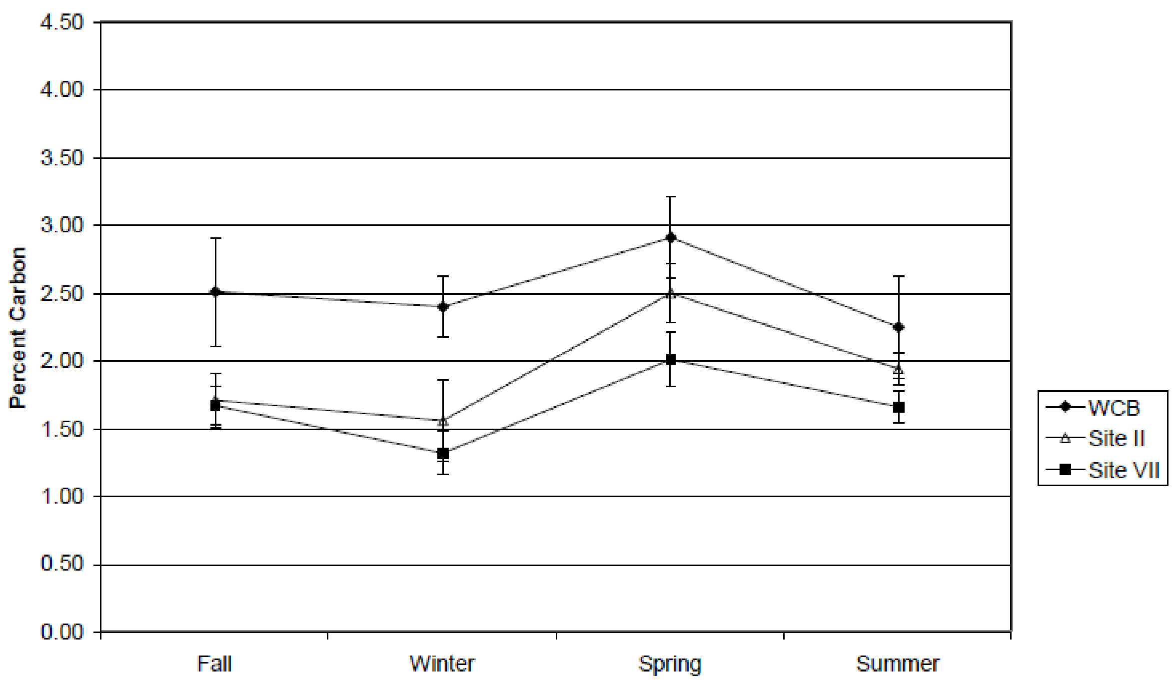


Figure 17. Soil carbon at 10-cm depth. Values are means +/- 95% confidence intervals. Figure reprinted from Brown and Wood (2002).

Interpretation: Given the greater amount of standing biomass and subsequent leaf litterfall in the WCB site, it is not surprising that this site should contain a greater amount of soil carbon than the restoration sites. Still, the restoration sites are not deficient in soil carbon.

NATIVE UNDERSTORY SPECIES FREQUENCY OF OCCURRENCE:

Table 9 reports values for native understory frequency in restored sites in 2001, the same restored sites measured again in 2007, and reference sites. These sites did not have understory species planted at them.

Interpretation: Restoration sites are well below remnant habitats in native understory frequency. There was a modest 8 percentage point increase at restoration sites over 6 years between surveys, however, the value is still far below remnant sites, and the colonization and spread of native understory species has been slower than was hoped for. Also there is a wide range of values among restoration sites with some being very low. Relative to restoration sites, remnant sites had consistently high values. The current practice of planting native understory species should help improve this parameter.

Table 8. Native understory indicator values at Sacramento River riparian restoration sites and remnant habitats. Values reported are mean, median, and range (in parentheses). The 2001 results are from Holl and Crone (2004). 2007 results from McClain and Holl (unpublished).

	Surveyed in 2007	Surveyed in 2001	Remnant Riparian
Native understory species frequency of occurrence (percent)	56.0, 55.3, (19.0-100)	48.1, 47.1, (21.4-94.9)	87.2, 88.9, (82.5-97.5)
Native understory species richness (species)	6.7, 6.0, (3-10)	4.7, 5.0, (2-6)	10.1, 10.5, (8-13)
Relative native understory cover (percent)	32.3, 24.5, (4.3-79.8)	20.7, 22.0, (2.5-61.3)	65.1, 61.9, (45.1-87.9)

RELATIVE NATIVE UNDERSTORY COVER:

Table 8 reports values for relative native understory cover in restored sites in 2001, the same restored sites measured again in 2007, and in reference sites. These sites did not have understory species planted at them.

Interpretation: Restoration sites are well below remnant habitats in relative native understory cover. There was a 12 percentage point increase at restoration sites over 6 years between surveys, however, the value is still far below remnant sites, and the colonization and spread of native understory species has been slower than was hoped for. Also there is a wide range of values among restoration sites with some being very low. Relative to restoration sites, remnant sites had high values, although there was considerable variability among sites. The current practice of planting native understory species should help improve this parameter.

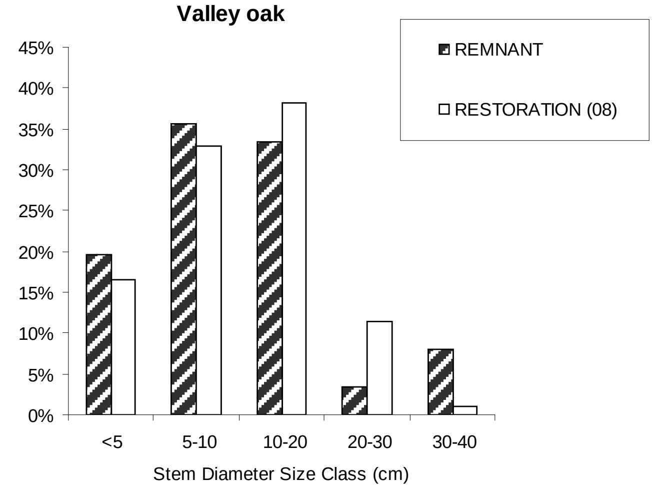
NATIVE UNDERSTORY SPECIES RICHNESS:

Table 8 reports for native species richness in restored sites in 2001, the same restored sites measured again in 2007, and in reference sites. These sites did not have understory species planted at them.

Interpretation: Restoration sites are well below remnant habitats in native understory species richness. Mean richness increased by 2 over 6 years between surveys, however, the value is still far below what was observed at remnant sites, and the colonization and spread of native understory species has been slower than was hoped for. Also there is a wide range of values among restoration sites with some being very low. In contrast, remnant sites had relatively high values. The current practice of planting native understory species should help improve this parameter.

STEM SIZE DISTRIBUTION:

The figures below compare stem size distribution data collected in 2008 from restoration sites (River Unit, Rio Vista, Princeton Ferry, Sam Slough) and remnant forest habitats (Figs. 18A-18D).



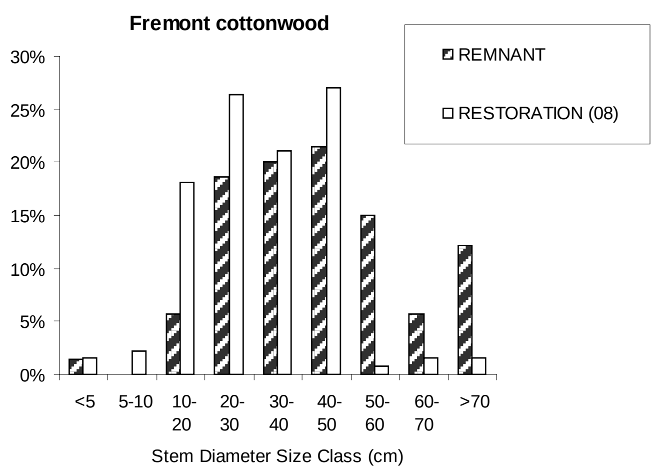


Figure 18A and 18B. Stem size distribution for Valley Oak, and Fremont Cottonwood, at Sacramento River Restoration sites. Data and figures from D. Wood (unpublished).

Figure 18C and 18D. Stem size distribution for Gooddings Black Willow, and Box Elder at Sacramento River Restoration sites. Data and figures from D. Wood (unpublished).

Interpretation: Valley oak and box elder are rated as "Very Good" because the distribution of restoration sites closely approximates that of remnant forest. Fremont cottonwood and Goodding's black willow are rated as "Fair" because their tree size distribution is shifted to the left (i.e. smaller trees) from that of remnant forest. However, given more time the size distribution of these species should come to match that of remnant forest. In a related study, the average stem size of valley oaks is reported (in dbh) from measurements taken at six restoration sites ranging from seven to eleven years after planting (Griggs and Golet 2002).

BEETLE SPECIES RICHNESS:

Comparisons of ground-dwelling, surface-active beetle assemblages (Order: Coleoptera) among restoration sites of different ages, and remnant riparian habitats, revealed that remnant riparian habitats had significantly higher species diversity than either young (1-3 years post planting) or older restoration sites (6-10 years post planting, Fig. 19, Hunt 2004, Golet et al. 2008).

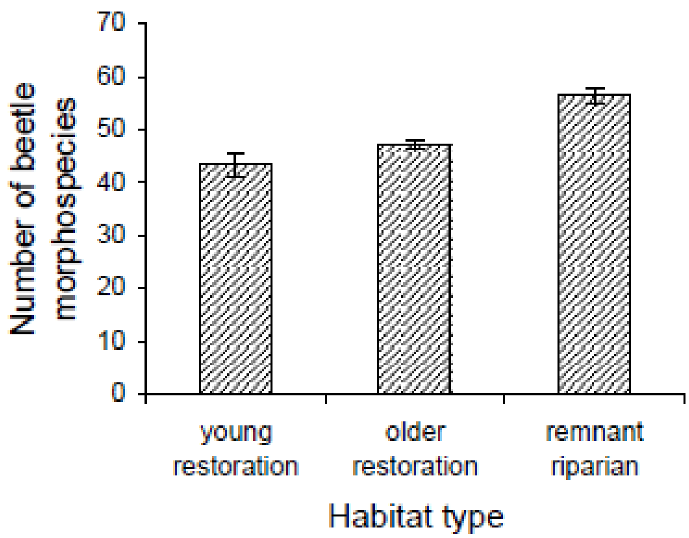


Figure 19. Ground-dwelling beetle species richness (mean ± SE) at young restoration sites, older restoration sites, and remnant habitats within the Sacramento River Project area, California. Data from J. Hunt. Figure reprinted from Golet et al. (2008) with permission.

Interpretation: As restoration sites matured they gained species becoming more similar to remnant habitats in morphospecies richness. In addition Hunt (2004) compared community compositions and found that Coleoptera species assemblages appear to transition predictably as a function of forest age such that older restoration sites were more similar to remnant riparian sites than were young restoration sites. This suggests that restoration is successful in establishing beetle fauna.

LANDBIRD ABUNDANCE:

The abundance of many species, with diverse life-history requirements, is approaching values observed at remnant habitats (Fig. 20, Gardali et al. 2006).

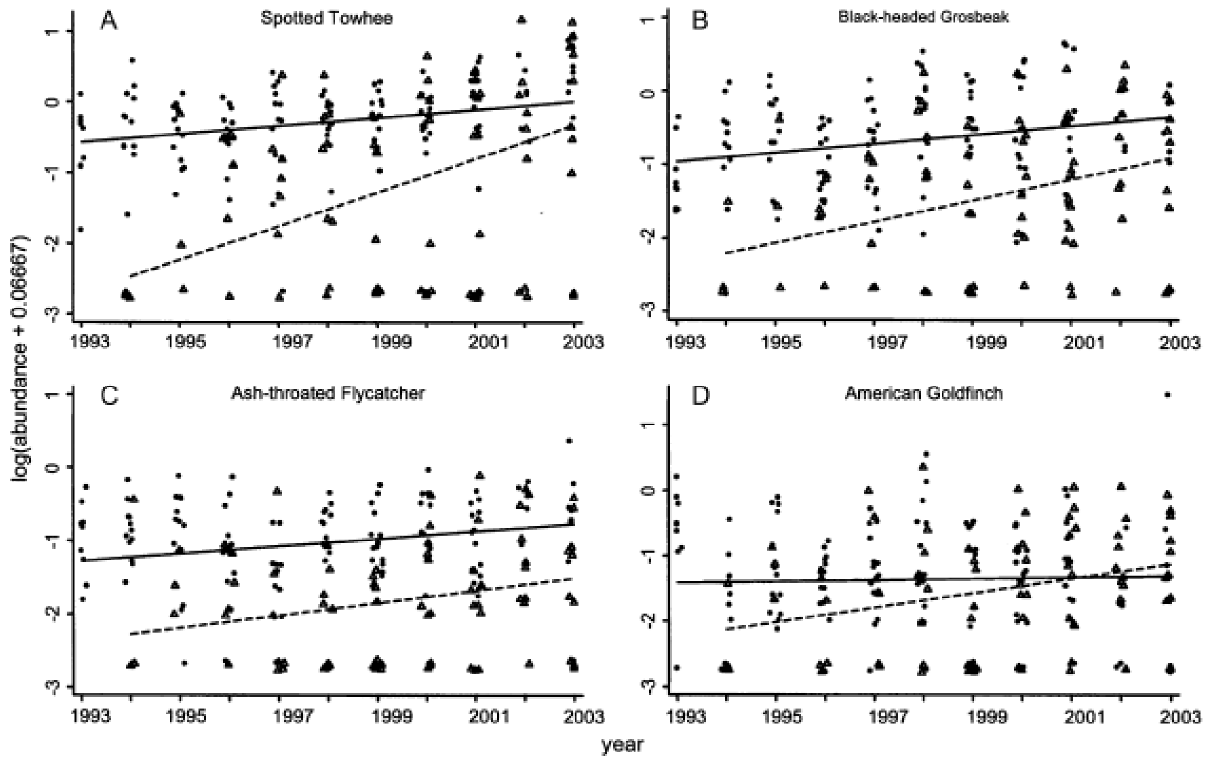


Figure 20. Point count detections of Spotted Towhees (A), Black-headed Grosbeaks (B), Ash-throated Flycatchers (C), and American Goldfinches (D) in remnant (solid line, circles) and revegetated (dashed line, triangles) riparian forests in the Sacramento Valley, California from 1993 to 2003. Line shows values predicted from log-linear regression. Each circle and triangle represents datum from 1 year for each site (points are jittered to better show data). Data from PRBO Conservation Science. Figure reprinted from Gardali et al. (2006) with permission.

Interpretation: Comparisons between restored and remnant forests showed that the abundances of many bird species in older restoration sites approached values observed in remnant habitats. Interestingly, abundances of many species studied were also increasing at remnant forest sites—although usually at a slower rate perhaps due to an increase in riparian habitat in the landscape (Gardali et al. 2006). These results suggest that restoration efforts may be producing positive spillover effects for bird populations in the larger Sacramento Valley, although other factors (e.g., climate, conditions in wintering areas, etc.) may also be responsible (Golet et al. 2008).

LANDBIRD ADULT SURVIVAL:

The Black-headed Grosbeak had survival rates at a restoration site that were slightly lower than what was observed at two remnant sites and considerably higher than a third grazed remnant site (Fig. 21, Gardali and Nur 2006). For Spotted Towhee, adult annual survival was lower at the restoration site than at two remnant sites and nearly identical to the grazed remnant site (Fig. 21).

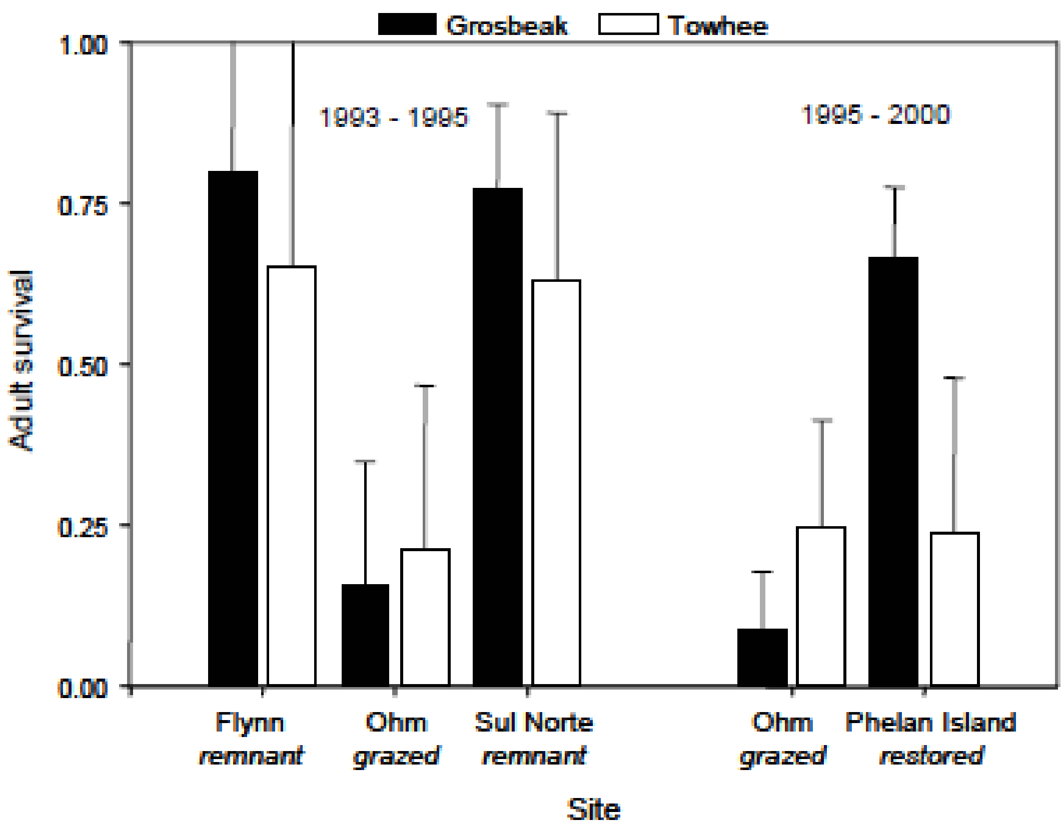
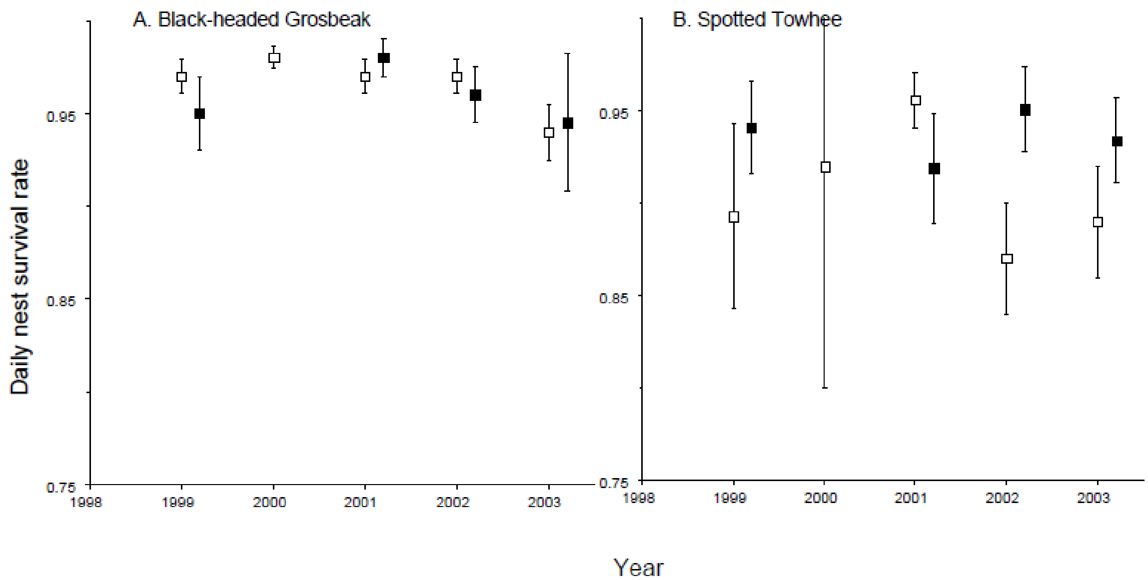


Figure 21. Site-specific adult survival of Black-headed Grosbeaks and Spotted Towhees at four sites within the Sacramento River Project area, California. Site types are indicated on the x-axis below the site names. Data from PRBO Conservation Science. Figure reprinted from Gardali and Nur (2006) with permission.

Interpretation: Reasons for the different survival response of these species remain to be determined, however, it is plausible that the lack of a well developed native understory layer at the restoration site affected the understory nesting towhee more than the mid-canopy breeding grosbeak.

LANDBIRD NEST SURVIVAL RATE:

Reproductive success of Black-headed Grosbeaks, as measured by daily survival rates of nests for all years combined, was not statistically different between restored and remnant sites. Rates varied annually, however 95% confidence intervals for restored and remnant sites overlapped in all years. For Spotted Towhees, daily nest survival rates were also not statistically different between restored and remnant sites over all years combined (Fig. 22A & 22B, Golet et al. 2008).



Figures 22A & 22B. Mayfield estimates of nest survival rates for: (A) Black-headed Grosbeak; and (B) Spotted Towhee at restoration and remnant sites within the Sacramento River Project area, California. Solid squares identify restoration sites, and hollow squares indicate remnant sites. Vertical bars indicate 95% confidence intervals. Data from PRBO Conservation Science. Figure reprinted from Golet et al. (2008) with permission.

Interpretation: Similar nest survival rates between restoration and remnant habitats suggest that restoration sites are providing functional habitat for reproduction for these landbird species.

BEE SPECIES RICHNESS:

Mean species richness pooled from netting and pan traps was not statistically different between restored (mean = 39, se= 6.5) and remnant (mean = 42, se= 1.6) sites (Williams 2007).

Interpretation: Results suggest that restored sites are providing habitat for a wide diversity of bee species, although interestingly the bee communities are restoration sites and remnant sites are quite different. Such differences highlight the importance of a mosaic landscape composed of habitat in different successional stages for promoting species diversity. One cause of dissimilarity between bees from restored and remnant sites may be differences in flowering plant communities at these two site types. However, paired sites with greater similarity of plants did not have more bee species in common with one another (Williams 2007), suggesting that other factors are also influencing the distribution of bees among Sacramento River habitat types.

b) Changes in restoration sites over time

In some instances comparisons are made at the same site over time. In others the approach was that of a chronosequence, taking "snapshots" in time from sites of different successional ages and projecting these changes onto a temporal sequence.

SOIL ORGANIC CARBON

Soil organic carbon was compared at two restoration sites of varying ages (Brown and Wood 2002). Site II was 8-9 years old and site VII was 2 years old. At all three depths (2, 10 and 24 cm) where soil carbon was measured, the older site had higher soil carbon than the younger site when averaged across the four seasons. See for example the results for samples taken at 10 cm (Fig. 17).

Interpretation: An increase in soil carbon at the older restoration site suggests that this ecosystem process becomes more active as sites mature. Soil carbon is of fundamental importance to biological systems and plays a central role in water retention, which directly affects site productivity. Soil carbon is composed of humic materials which are leached down into the soil profile where they taken up by fungi and other soil microbes for growth.

NATIVE UNDERSTORY SPECIES FREQUENCY OF OCCURRENCE:

Table 9 reports values for native understory frequency in restored sites in 2001, the same restored sites measured again in 2007.

Interpretation: There was a modest 8 percentage point increase at restoration sites over 6 years between surveys, suggesting that some improvement in habitat conditions for wildlife. However, the value is still far below remnant sites, and the colonization and spread of native understory species at restoration sites has been slower than was hoped for. Also there is a wide range of values among restoration sites with some being very low, even in 2007. The current practice of planting native understory species should help improve this parameter.

RELATIVE NATIVE UNDERSTORY COVER:

Table 8 reports values for relative native understory cover in restored sites in 2001, the same restored sites measured again in 2007.

For the 15 restored sites sampled in 2001 and 2007 the mean increase in relative native cover is 11.6% and the median increase is 3.6%. The range was a decrease of 12% to an increase of 62%.

Interpretation: There was a 12 percentage point increase at restoration sites over 6 years between surveys, suggesting an improvement in habitat conditions at these sites. However, the value is still far below remnant sites, and the colonization and spread of native understory species has been slower than was hoped for. Also there is a wide range of values among restoration sites with some being very low. The current practice of planting native understory species should help improve this parameter.

NATIVE UNDERSTORY SPECIES RICHNESS:

Table 8 reports values for native species richness in restored sites in 2001, the same restored sites measured again in 2007.

Interpretation: Mean richness increased by 2 over 6 years between surveys, suggesting some improvement in habitat conditions at restoration sites. However, the value is still considerably below what was observed at remnant sites, and the colonization and spread of native understory species has been slower than was hoped for. Also there is a wide range of values among restoration sites with some being very low. The current practice of planting native understory species should help improve this parameter.

BASAL AREA OF WOODY SPECIES:

Restored sites had a mean value of 12.7 m^2/ha as of August 2008. This is an increase from a mean value of 6.5 m^2/ha measured at these same (permanent) plots in August 2003.

At the restoration site level there is substantial variability (Table 9). One restoration site (Phelan Island) already has a mean basal area above the desired rating of 28 m^2/ha. Forest development at other restoration sites (e.g., Rio Vista) is hindered by poor soils.

Table 9. Basal area of woody species at Sacramento River restoration sites over three time periods. Data and table from D. Wood (unpublished).

Restoration Site	# plots)	Mean Basal Area 2003	Mean Basal Area 2006	Mean Basal Area 2008
River Unit	25	9.4		16.8
Princeton Ferry	21	4.8		11.4
Rio Vista	27	3.1		6.9
Sam Slough	29	8.5		15.7
Shaw	5		12.2	
Phelan Island	3		29.3	
Flynn	3		13.9	
Kopta Slough	3		13.2	
Lohman	3		15.5	

Interpretation: Despite considerable variability among sites, basal area of woody species is increasing over time with the mean value increasing by 6.2 m^2/ha. This corresponds to a 95% increase over five years, and suggests that woody species are responding favorably to growing conditions at many of the restoration sites. Increased growth of woody species leads to greater structural complexity of habitat which favors many wildlife species.

IMPORTANCE VALUES FOR WOODY SPECIES:

Importance values were calculated for the most common woody species that occur at restoration sites in both 2003 and 2008 (Table 10). All species listed were planted with the exception of non-native black walnut.

Table 10. Importance values of woody species at Sacramento River restoration sites over two time periods. Data and table from D. Wood (unpublished).

	Mean Restoration Site* Importance Value 2003	Mean Restoration Site* Importance Value 2008
Arroyo willow	42.9	40.2
Black walnut	0.4	0.6
Blue elderberry	50.1	39.5
Box elder	9.3	13.7
Coyote brush	4.6	13.7
Fremont cottonwood	17.1	16.5
Goodding's black willow	6.8	7.3
Valley oak	58.1	65.2
Western sycamore	7	5.6

*Restoration sites are River Unit, Sam Slough, Princeton, and Rio Vista.

The same plots sampled in 2003 were re-sampled in 2008.

Interpretation: Increases were observed for coyote brush (198%), box elder (47%), valley oak (12%) and Gooddings black willow (7%). The nonnative black walnut also increased (by 50%). Decreases in importance values were observed for arroyo willow (6%), blue elderberry (21%), Fremont cottonwood (4%) and western sycamore (20%). Increases in importance values are considered desirable for all but non-native species, however, the effects on different wildlife species will vary depending upon their specific habitat requirements.

AVERAGE NUMBER OF RECENT VELB EXIT HOLES PER ELDERBERRY SHRUB:

The valley elderberry longhorn beetle (VELB) is a federally threatened endemic of California's Central Valley that occupies blue elderberry bushes (*Sambucus mexicana*) during all stages of its life cycle (Barr 1991). VELB abundance was measured in 2003 to determine the extent to which restoration sites were providing habitat for this species (River Partners 2004).

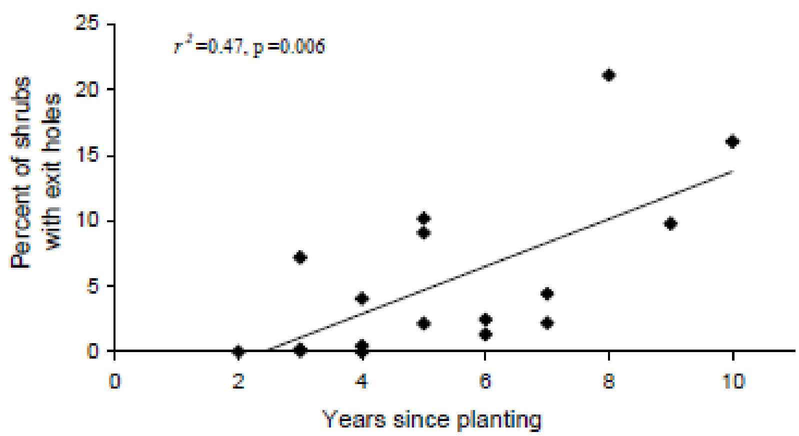


Figure 23. Percent of elderberry shrubs with exit holes diagnostic of Valley elderberry longhorn beetle emergence. All shrubs surveyed were within the Sacramento River Project area, California Data from River Partners. Figure reprinted from Golet et al. (2008) with permission).

Interpretation: Older restoration sites had significantly higher levels of VELB occupancy than younger sites (Fig. 23, Golet et al. 2008) suggesting that VELB colonize and proliferate at restoration sites as the plant community matures.

BEETLE SPECIES RICHNESS:

Comparisons of ground-dwelling, surface-active beetle assemblages (Order: Coleoptera) among restoration sites of different ages revealed that older restoration sites (6-10 years post planting) had significantly higher species diversity than young restoration sites (1-3 years post planting, Fig. 29, Hunt 2004, Golet et al. 2008).

Interpretation: As restoration sites matured they gained species becoming more similar to remnant habitats in morphospecies richness. In addition Hunt (2004) compared community compositions and found that Coleoptera species assemblages appear to transition predictably as a function of forest age such that older restoration sites were more similar to remnant riparian sites than were young restoration sites. This suggests that restoration is successful in establishing beetle fauna.

LANDBIRD SPECIES RICHNESS:

Species richness increased as the sites matured (Fig. 24), and the abundance of many species, with diverse life-history requirements, has dramatically increased as the sites have aged (Fig. 20; Gardali et al. 2006). An exception is the Lazuli Bunting (*Passerina amoena*) which has been declining at both restoration sites and in remnant habitats (Gardali et al. 2006). The increase in species richness at restoration sites is apparently due to certain species (e.g., House Wren [*Troglodytes aedon*]) being absent until the structural complexity of the sites increase beyond some threshold amount. Nur et al. (2004) found that the abundance of several species (e.g., Ash-throated Flycatcher [*Myiarchus cinerascens*], Tree Swallow [*Tachycineta bicolor*]) was positively associated with tree height and/or canopy cover, factors that typically increase as restoration sites mature. At about 10 years, restoration sites begin to be occupied by primary cavity nesting species (e.g., Nuttall's Woodpecker [*Picoides nuttallii*]).

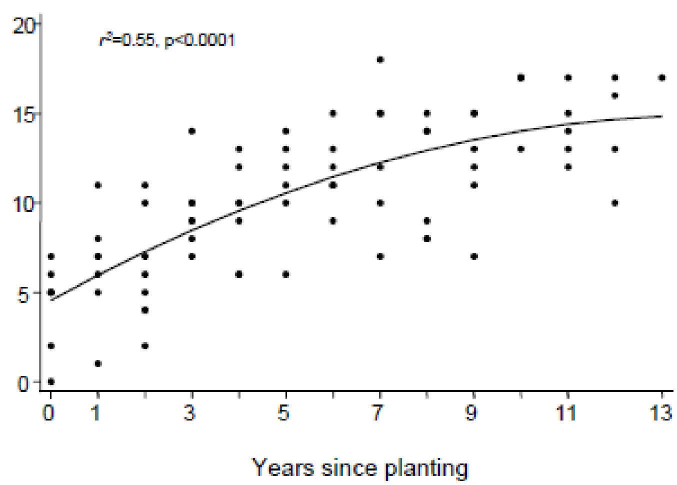


Figure 24. Landbird species richness at restoration sites of varying ages within the Sacramento River Project area, California. Data from PRBO Conservation Science. Figure reprinted from Golet et al. (2008) with permission.

Interpretation: Results indicate that restoration sites are providing habitat for a diverse community of landbirds, and that habitat value is increasing as the sites mature.

LANDBIRD ABUNDANCE:

The abundance of many bird species, with diverse life-history requirements, has dramatically increased as the sites have aged (Fig. 25). Detailed results on this, for a wide range of riparian landbird species, are presented in Gardali et al. 2006).

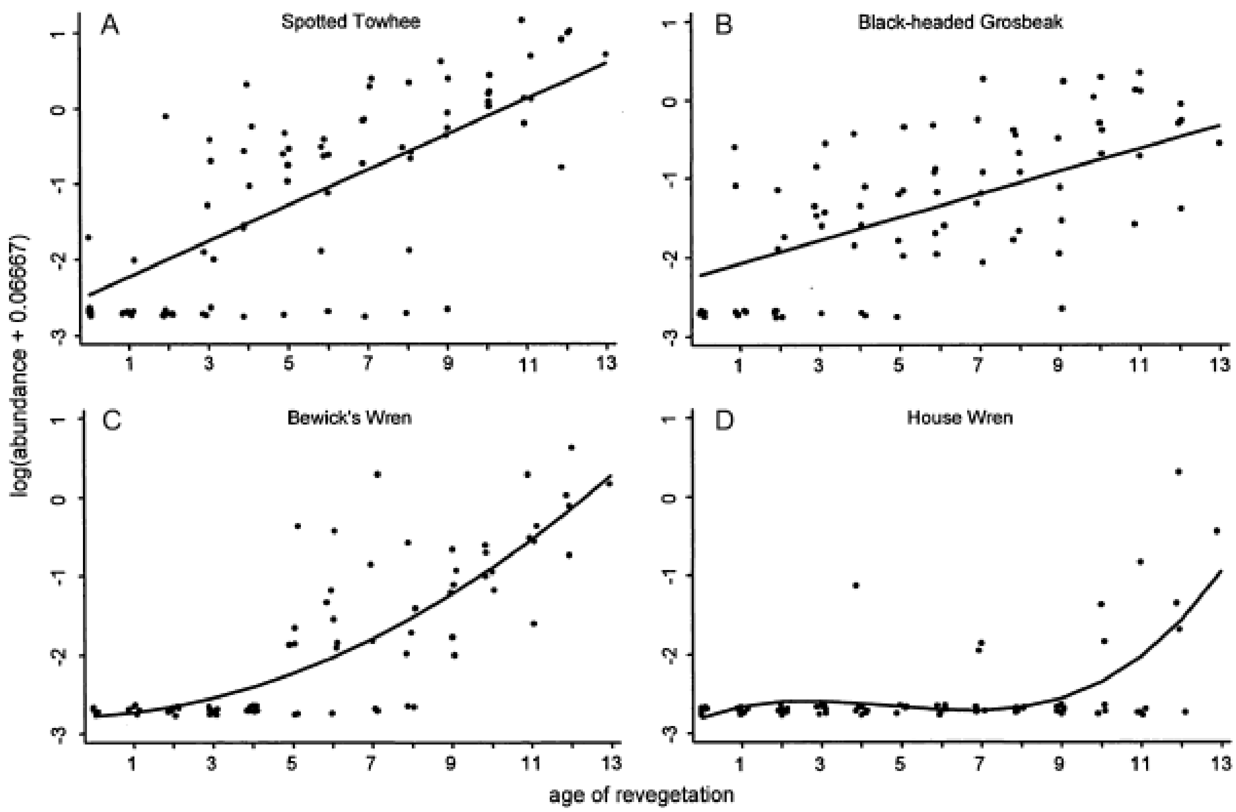


Figure 25. Abundance (point count detections) of four landbirds in relation to years since planting at restoration sites within the Sacramento River Project area, California. Lines show values predicted from log-linear regression; quadratic fit for Bewick's Wren and cubic fit for House Wren. Each point represents datum from 1 year for each site. Data from PRBO Conservation Science. Figure reprinted from Gardali et al. (2006) with permission.

Interpretation: These results suggest that restoration sites are increasing in habitat value for many species as they mature. Undoubtedly, this is related to the structural development of planted vegetation.

BAT ACTIVITY LEVEL:

A short-term investigation of bat response to restoration was conducted in fall 2002 (Stillwater Sciences et al. 2003). The investigation assessed bat activity during two time periods at young and older restoration sites (as well as at orchards and mature riparian remnant habitats). The older site (planted in 1991) tended to have higher levels of activity than the newly planted site (Fig. 26, Golet et al. 2008).

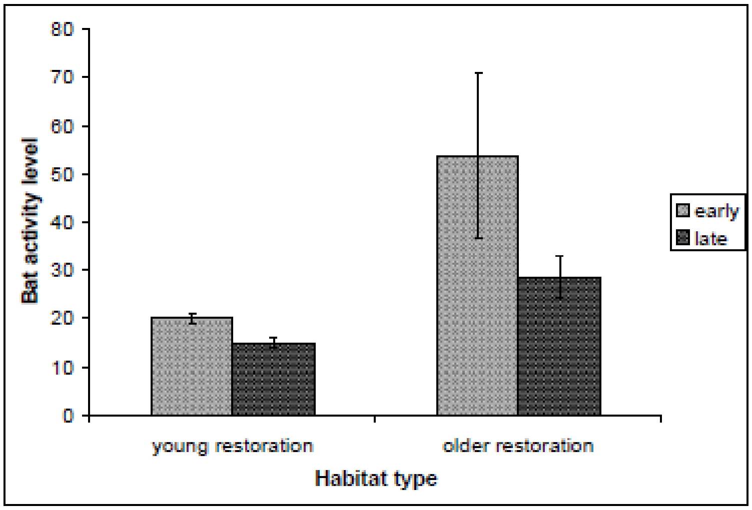


Figure 26. Bat activity levels (mean ± SE) at young (planted in 2002) and older (planted in 1991) restoration sites within the Sacramento River Project area, California. Bat activity is defined as the mean number of acoustic files per sampling period. "Early" refers to the September 12–14, 2002 sampling period, and "late" refers to the September 26–27, 2002 sampling period. At each site, detectors were deployed at three locations. Data from B. Rainey. Figure reprinted from Golet et al. (2008) with permission.

Interpretation: Higher recorded activity levels are strongly suggestive of higher bat abundances, although theoretically, they may also result simply from higher calling rates. Increases in abundance at older restoration sites relative to younger sites provide evidence that the habitat value of the restoration sites increases as the sites mature.

DISCUSSION AND CONCLUSIONS

Progress has been made in the restoration of some elements of the Sacramento River ecosystem, but not others. This is clearly shown in Appendix 3 which summarizes the individual indicator results partitioned into six topical categories. Overall, there has been positive change in *riparian habitats*, *native plant species and communities*, and for *birds and other wildlife*. However, for the remaining three categories (*invasive riparian and marsh plants, streamflows and flood processes,* and *river planform and geomorphic processes*), progress has either not been made, or there has been a continued decline in status. Implications of these findings are discussed below in the evaluation of progress toward specific ERP goals and visions, and the assessment of the status of the river's biodiversity.

Using Scorecard Indicators to Assess Progress toward ERP Goals and Visions

Scorecard indicators are used below to assess progress toward achieving the goals and visions of the CALFED Ecosystem Restoration Program for the Sacramento River Ecological Management Zone (CALFED 2000). These visions are restated below, and some individual indicators are discussed, however the reader is referred to an earlier section of this document for complete listings of indicators that were used to assess particular goals.

Progress toward achieving **ERP Vision for Habitats** was assessed for *Riparian and Riverine Aquatic Habitats* by synthesizing information on 12 indicators (see Goals and Visions section). Overall, progress has been "Fair". Mild increases were observed over the past 20 years in the percent of historical riparian zone currently in conservation ownership, and the percent of historical riparian zone currently in natural habitat. Landscape metrics such as the Forest patch proximity, Forest patch core size have shown positive changes with implemented restoration. Additional indicators such as Length of river frontage in conservation ownership on both sides of the river, and Percent of riparian shoreline bordered by >500 meters of natural habitat have also increased. Importantly, analyses have shown that many of these indicators have the potential to increase quite dramatically if strategic acquisitions and subsequent restoration takes place. Indicators that prevented progress toward this vision being rated as "Good" include Total river length and whole river sinuosity. Both have declined since the early 1900s, and have not changed significantly in recent decades.

Progress toward achieving **ERP Visions for Species and Communities** was assessed for *Plant Species and Communities, Neotropical Migratory Birds* (including the Yellow-billed cuckoo and bank swallow), and the *Valley Elderberry Longhorn Beetle*. Status was also assessed for a suite of other species (bees, beetles, bats, rats, herons and egrets) that were not specifically identified in ERP goal statements.

To measure progress toward achieving the vision for *Plant Species and Communities,* information was synthesized on 19 indicators (see Goals and Visions section). Overall, progress has been "Good". There have been significant increases in the acreage of native vegetation, largely as a result of all the planting that has been done at restoration sites. At restoration sites there have been positive responses in terms of habitat development. Basal area of woody species has increased, as has diameter at breast height. Changes in importance values of different species suggest that the sites are proceeding along a successional pathway with certain species (e.g., coyote brush, box elder and valley oak) increasing, while others (e.g., elderberry and sycamore) are decreasing. Less encouraging is the status of understory vegetation. At restoration sites native understory species have been slow to colonize, and frequency of occurrence has been low. These findings have led to the implementation of an understory component to the more recent (post-1999) restoration plantings. Survival of understory plantings has generally been good.

To measure progress toward achieving the vision for *Neotropical Migratory Birds* (including the Yellow-billed cuckoo, bank swallow,) information was synthesized on 13 indicators (see Goals and Visions section). Overall, progress has been "Fair". Nest survival does not appear to have increased and is low at least for the Lazuli Bunting. Apparent adult survival is variable, with Black-headed Grosbeaks faring better than Spotted Towhees. PRBO cautions, however, that more data are needed to accurately report trends in these parameters. In contrast, bird species richness has increased, quite dramatically, at restoration sites as has abundance for certain species (e.g., Black-headed Grosbeak, Common Yellowthroat), although not others (e.g., Yellow Warbler and Yellow-breasted Chat). The Sacramento River corridor is the major population center for both Yellow-billed Cuckoo and Bank Swallow. For both species there is cause for concern. For cuckoos, there is a very low number of occupied territories, and for Bank Swallows, there has been a dramatic decline in the number of burrows at active colonies.

To measure progress toward achieving the vision for *Valley Elderberry Longhorn Beetle* information was synthesized on 2 indicators (see Goals and Visions section). Overall, progress has been “Good”. At restoration sites there has been a dramatic increase in the percent of elderberry shrubs that are occupied by the VELB. However the Importance value for the VELB’s host plant has declined as the sites have matured, raising the question as to what the long-term habitat suitability will be at these sites.

Progress toward restoring healthy populations of other native terrestrial fauna (not specifically called out in the ERP Program Plan, CALFED 2000) was assessed by synthesizing information on 4 indicators. Overall, progress has been “Good”. Similar to what was found with landbirds, species richness of bees, beetles and bats was found to be higher at older restoration sites than at younger sites. And overall, the aerial extent of waterbird colonies was found to be fairly extensive.

Progress toward achieving **ERP Visions for Ecological Processes** was assessed for *Central Valley Streamflows*, *Stream Meander*, and *Natural Floodplain and Flood Processes*.

To measure progress toward achieving the vision for *Central Valley Streamflows* information was synthesized on 3 indicators. In the case of the streamflows for the Sacramento River, ‘progress’ can perhaps best to understood in the context of preserving the dynamic range of the existing flow regime, and in the future, restoring some of the lost dynamics.

The first indicator is bed mobility, expressed as days exceeding the flow needed to fully mobilize the bed, for which 55,000 cfs is used, based on empirical studies. The second indicator is floodplain inundation (to reestablish lateral connectivity between channel and floodplain), for which we use 70,000 cfs based on prior work along the middle reach of the river, and based on the flow at which Fremont weir overflows and the Yolo Bypass is watered. The third indicator is periodic connection of secondary channels with the mainstem, which drives hydrodynamics and ecological processes in the secondary channels.

For the first three of these indicators, the status is measured by number of days above a threshold value, determined based on empirical observations by various researchers over the past three decades. The type of water year (wet, normal, dry) needs to be accounted for, because the river experienced large natural variability in these variables prior to human alterations. The status of the fourth objective is measured by the artificiality of changes in flow, such as unnatural increased in flow in the summer caused by increases in irrigation releases. The goal with all these indicators is to achieve flow regimes more closely based on the natural flow regime for the river. The vision for these flow patterns can be attained first by avoiding further loss of flow dynamics in the Sacramento River system, and more selectively, by supplemental short-term releases from the major storage reservoirs to provide flows that emulate natural peak flow events. The indicators are not such that ever-increasing values are necessarily good.

Overall, progress for achieving the vision has been “Poor”. The current status for bed mobility is “Poor”. During the ten years prior to, and including, water year 2010, an average of only 4.6 days per year were greater than 55,000 cfs, and six of those prior ten years had no flows above the bed mobility threshold.

The current indicator value for side channel reconnection, reflecting a 10-year average of inundation of three different elevational classes of side channels, is “Fair”. This is a combined result of two “Poor” and one “Good” rating for the number of days with flows exceeding 50,000cfs, 6,000cfs, and 22,000cfs, respectively. Thus flows were sufficient over the past decade to connect only the mid-elevation side channels at the recommended frequency.

As of the end of WY 2010 there had been an average of 0.7 days per year above 70,000 cfs and 8 of the previous ten years had zero days above 70,000 cfs. This places the current condition of the floodplain inundation indicator in the “Poor” category. The extent of floodplain inundation is even worse when actual flood extent is considered, due to effect of levees along the channel.

To measure progress toward achieving the vision for *Stream Meander* information was synthesized on 10 indicators (see Goals and Visions section). Overall, progress has been “Poor”. Although there has been considerable variability in indicator values among time periods (in part due to variations in flows), and most of the indicators that were studied to assess progress toward this vision are only meaningful over long time frames, the collective weight of evidence presents a clear picture. Channel dynamics and channel complexity have shown reductions over the period of record (1906 to 2007), and there has been no appreciable improvement in recent years. Far from it, some of the most important indicators of stream meander (e.g., meters of bank with riprap) have continued to decline, despite goals being set to achieve the opposite. On a brighter note, the length of river with conservation ownership on both banks has increased, suggesting an increase in opportunities for restoration of natural channel processes.

To measure progress toward achieving the vision for *Natural Floodplain and Flood Processes* information was synthesized on 4 indicators (see Goals and Visions section). Overall, progress has been “Poor”. The frequency of floodplain inundation and side-channel connection is reduced relative to what is recommended based upon the historical record, actual floodplain extent has decreased, and riprap has increased steadily. A positive outcome is the fairly rapid increase in soil organic carbon observed at restoration sites.

Progress toward achieving **ERP Visions for Reducing or Eliminating Stressors** was assessed for *Levees, bridges and bank protection*, and *Invasive riparian and marsh plants*.

To measure progress toward achieving the vision for *Levees, bridges and bank protection* information was synthesized on 2 indicators (see Goals and Visions section). Overall, progress has been *“Poor”.* Riprap has increased, and although the Length of river with conservation ownership on both banks has increased, little on-the-ground work has been done. Infrastructure that currently limits natural river processes has yet to be removed, although there have been a few improvements (e.g., small levee breaches at restoration sites). Several projects (e.g., Hamilton City and Kopta Slough), currently at the planning stage, may help lead to progress toward achieving this vision in years to come.

To measure progress toward achieving the vision for *Invasive riparian and marsh plants* information was synthesized on 6 indicators (see Goals and Visions section). Overall, progress has been *“Poor”.* Reductions have not been observed in the area of non-native riparian and marsh plants. Quite the contrary, *Arundo.* black walnut, Himalayan blackberry, and *Ludwigia* have all increased in aerial extent from 1999 to 2007. Relative native understory cover, an indicator of restoration site success has remained virtually unchanged from one survey period to the next. Thus competition that native flora face from non-native species is likely increasing.

Using Scorecard Indicators to Assess the Status of Biodiversity on the Sacramento River

In addition to using scorecard indicators to evaluate progress toward attaining goals and visions of the CALFED Ecosystem Restoration Program, they were also used with TNC's workbook framework to assess the status of biodiversity on the Sacramento River. The foundation of the framework is a suite of ecological indicators that are used to assess the conservation status of a set of conservation targets. The framework can be applied to other ecological systems, but may be best suited to landscape-scale ecological restoration projects. Depending upon the level of detail desired, ratings values for individual indicators can be rolled up to provide a characterization of the overall status of conservation targets (Table 11), or considered individually to provide more detailed information.

The overall status of biodiversity, as determined by the application of this framework to the Sacramento Project area is "Fair". When considering the conservation targets individually, two of them (terrestrial riparian habitats and birds) ranked as "Fair", and one (aquatic riverine habitats) ranked as "Poor". Examining the status of the individual indicators that were rolled up to produce these conservation target ratings can help explain why the conservation targets received the overall ratings.

In short, the riparian habitats and the terrestrial species that inhabit them (including birds) are in "Fair" condition due to all of the efforts that have been put towards reestablishing native vegetation throughout the Sacramento River Project area. Many positive outcomes have been observed as a result of these efforts. This report details such outcomes by reporting changes in ecological indicators that have been observed through time at restoration sites, and in comparison to remnant habitats.

Table 11. Overall Status of Sacramento River Project Conservation Targets. Each of the three categories (landscape context, condition, and size) displayed in columns of the table below was evaluated with a suite of ecological indicators. See Appendix 2 for the complete list of indicators and their individual ratings values.

Sacramento River Project Conservation Targets		Landscape Context	Condition	Size	Combined Viability Rank
Target #	Current Rating				
1	terrestrial riparian habitats	Fair	Fair	Fair	**Fair**
2	aquatic riverine habitats	Fair	Poor	Poor	**Poor**
3	birds (resident and migratory)	-	Fair	Poor	**Fair**
Overall Project Biodiversity Health Rank					**Fair**

In contrast, the status of the third conservation target, aquatic riverine habitats was determined to be "Poor". This is the direct result of the hydrologic and geomorphic processes being constrained by anthropogenic alterations to the river. Of particular concern is the steady increase in riprap that has been observed since the 1930s, and the alteration of the natural flow regime since the mid 1900s. As more and more riprap has been installed, and the hydrology has been increasingly altered, the river has lost much of its natural dynamism, and with that, a reduction in its ability to create and maintain the habitats that are essential to native species and communities. Planting of native vegetation has been an important "stop gap" measure, and has kept the status of the two other conservation targets from dropping to "Poor", however, their continued persistence, even at this level, is uncertain.

Clearly the future of Sacramento River terrestrial resources is dependent upon the degree to which the elemental natural riverine processes of erosion, sediment deposition, and flooding can be restored. Future conservation efforts should focus on restoring these processes where it is possible to do so without adversely impacting important functions that rivers provide to people. Fortunately, opportunities exist to implement projects that provide benefits to both the ecosystem and society at large (Golet et al. 2006).

Application of a recent software decision analysis tool may help realize some of the potential that restoration of river processes has for benefiting the ecosystem. This tool was developed by ESSA Technologies and The Nature Conservancy. The Sacramento River Ecological Flows Tool (SacEFT) is now available for download at **www.essa.com/tools/EFT/download.html.** The approach taken with SacEFT is to model how a suite of focal species (e.g., bank swallow, Fremont cottonwood, Chinook salmon, steelhead) are affected, positively or negatively, by management actions (including restoration). Management actions that the tool was designed to model the effects of include modifications of flow, sediment augmentation, and selective riprap removal. The main utility of SacEFT is in drawing comparisons between alternative management scenarios, as opposed to making predictions about specific outcomes of particular actions. It is hoped that this tool can allow the health of the ecosystem to be better represented in resource management decisions.

Application of Scorecard Indicator Information for Development of a Sacramento River Monitoring Plan

The suite of scorecard indicators and associated information (Appendix 2) provides a solid base to draw upon for developing a Sacramento River Monitoring Plan. Clearly, not all of the indicators that are included in this scorecard report need be monitored into the future; however, a broad suite is now available to choose from. The approach taken in this scorecard project was to take full advantage of all available information, and to be as comprehensive as possible in drawing from existing quantitative data on Sacramento River terrestrial resources and floodplain dynamics. A Sacramento River monitoring plan may well include indicators that were not a part of this scorecard project, however, selecting from among those indicators included in this report will allow newly collected information to be compared with past data. A monitoring plan that identifies a range of data collection options that could be scaled relative to available funding would be most useful to the agencies that have management responsibilities for natural resources along the river (J. Silveira, *personal communication*). In addition to providing detailed scorecard information for development of a Sacramento River monitoring plan, The Nature Conservancy has contributed component monitoring plans for a suite of important parameters. These include landbirds (Howell 2010), VELB (Holyoak 2010) and flow regime (Kondolf and Minear 2011).

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Appendix 1. Ecological Scorecard Summary for Terrestrial Resources and Channel Processes of the Middle Sacramento River, California.

Assessment of Target Viability
Sacramento River

Double-click opens entry form

#	Conservation Targets	Category	Key Attribute	Indicator	Indicator Ratings (**Bold = Current**, *Italics = Desired*): Poor	Fair	Good	Very Good	Ratings Source	Indicator Measurements (latest measurement only): Date	Current Indicator Measurement	Current Rating	Trend	Source	Desired Rating	Date for Desired Rating
1	terrestrial riparian habitats	Landscape Context	Connectivity among communities & ecosystems	Forest edge contrast	**> 70**	50-70	30-50	< 30	Expert Knowledge	Jun-07	72	Poor	Strong Increase	Intensive Assessment	Good	Jun-20
			Connectivity among communities & ecosystems	Forest patch proximity	<20	20-100	**100-300**	>300	Expert Knowledge	Jun-07	205	Good	Strong Increase	Intensive Assessment	Very Good	Jun-20
		Condition	Pollination	Bee species richness	<25 species	25 - 35 species	**35 - 40 species**	>40 species	Onsite Research	Aug-03	39 species	Good	Unknown	Intensive Assessment	Very Good	Aug-20
			Presence / abundance of key functional guilds	Ground Beetle Species Richness	< 37 species	37-44 species	**45-52 species**	> 52 species	Onsite Research	Nov-01	45 species	Good	Mild Increase	Intensive Assessment	Very Good	Nov-20
			Primary productivity	Soil organic carbon	< 1.5 percent carbon	1.5 – 2.0 percent carbon	**2.0 - 2.5 percent carbon**	>2.5 percent carbon	Onsite Research	Aug-03	2.25%	Good	Mild Increase	Intensive Assessment	Very Good	Aug-20
			Species composition / dominance	Area of Black walnut	**>2,000 acres**	1,000 - 2,000 acres	500 - 1,000 acres	< 500 acres	Onsite Research	Aug-07	2,538 acres	Poor	Strong Increase	Intensive Assessment	Fair	Jun-20
			Species composition / dominance	Area of giant reed	**>100**	60 - 100 acres	30 - 60 acres	< 30 acres	Onsite Research	Jun-07	136 acres	Poor	Mild Increase	Intensive Assessment	Good	Jun-30
			Species composition / dominance	Area of Himalayan blackberry	> 500 acres	**250 - 500 acres**	50 - 250 acres	< 50 acres	Onsite Research	Aug-07	310 acres	Fair	Strong Increase	Intensive Assessment	Good	Jun-20
			Species composition / dominance	Basal area of woody species	<10 m2/ha	**10-20 m2/ha fair**	20-25 m2/ha good	>25 m2/ha	Onsite Research	Aug-08	12.7 m2/ha	Fair	Mild Increase	Intensive Assessment	Good	Aug-17
			Species composition / dominance	Bat species richness	< 8 spp	8 - 10 spp	**10 - 13 spp**	> 13 spp	Onsite Research	Oct-02	10 species	Good	Unknown	Intensive Assessment	Very Good	Oct-20
			Species composition / dominance	Importance value of Arroyo willow	< 5	5 - 7	7 - 8	**>8**	Onsite Research	Jun-08	40.2	Very Good	Mild Decrease	Intensive Assessment	Very Good	Aug-17

Appendix 1 (continued). Ecological Scorecard Summary for Terrestrial Resources and Channel Processes of the Middle Sacramento River, California.

Assessment of Target Viability Sacramento River			Double-click opens entry form		Indicator Ratings **Bold = Current** *Italics = Desired*					Indicator Measurements (latest measurement only)						
#	Conservation Targets	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Ratings Source	Date	Current Indicator Measurement	Current Rating	Trend	Source	Desired Rating	Date for Desired Rating
			Species composition / dominance	Importance value of Black walnut	> 25	15 - 25	5 - 15	**1 - 5**	Onsite Research	Aug-08	0.6	Very Good	Flat	Intensive Assessment	Very Good	Aug-17
			Species composition / dominance	Importance value of Blue elderberry	< 4	4 - 7	7 - 9	**> 9**	Onsite Research	Aug-08	39.5	Very Good	Mild Decrease	Intensive Assessment	Very Good	Aug-17
			Species composition / dominance	Importance value of Box elder	**< 15**	15 - 30	30 - 46	> 46	Onsite Research	Aug-08	13.7	Poor	Mild Increase	Intensive Assessment	Good	Aug-17
			Species composition / dominance	Importance value of Coyote brush	< 5	5 - 10	**10 - 14**	> 14	Onsite Research	Aug-08	13.7	Good	Mild Increase	Intensive Assessment	Good	Aug-17
			Species composition / dominance	Importance value of Fremont cottonwood	**< 30**	30- 50	50 - 65	65	Onsite Research	Aug-08	16.5	Poor	Flat	Intensive Assessment	Good	Aug-17
			Species composition / dominance	Importance value of Goodding's black willow	< 7	**7- 12**	12 - 16	> 16	Onsite Research	Aug-08	7.3	Fair	Flat	Intensive Assessment	Good	Aug-17
			Species composition / dominance	Importance value of Valley oak	< 25	25 - 50	**50 - 75**	> 75	Onsite Research	Aug-08	65.2	Good	Mild Increase	Intensive Assessment	Good	Aug-17
			Species composition / dominance	Importance value of Western sycamore	< 4	**4 - 6**	6 - 8	> 8	Onsite Research	Aug-08	5.6	Fair	Flat	Intensive Assessment	Good	Aug-17
			Species composition / dominance	Native understory species frequency of occurrence	< 50%	**50-70%**	70 - 85%	> 85%	Onsite Research	May-07	56.0%	Fair	Mild Increase	Intensive Assessment	Good	May-20
			Species composition / dominance	Native understory species richness	> 4 species	**4 - 7 species**	8 - 10 species	> 10 species	Onsite Research	May-08	6.7 species	Fair	Mild Increase	Intensive Assessment	Very Good	May-20
			Species composition / dominance	Relative native understory cover	> 25%	**25 - 45%**	45 - 65%	> 65%	Onsite Research	May-07	32.3%	Fair	Mild Increase	Intensive Assessment	Very Good	May-20

Appendix 1 (continued). Ecological Scorecard Summary for Terrestrial Resources and Channel Processes of the Middle Sacramento River, California.

Assessment of Target Viability Sacramento River				Double-click opens entry form	Indicator Ratings **Bold = Current** *Italics = Desired*					Indicator Measurements (latest measurement only)						
#	Conservation Targets	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Ratings Source	Date	Current Indicator Measurement	Current Rating	Trend	Source	Desired Rating	Date for Desired Rating
			Successional dynamics	Frequency of Box elder with a DBH > 10 cm	< 10%	**10 - 20%**	20 - 34%	> 34%	Onsite Research	Aug-08	19%	Fair	Unknown	Intensive Assessment	Good	Aug-17
			Successional dynamics	Frequency of Fremont cottonwood with a DBH > 40 cm	< 15	15 - 30%	**30 - 54%**	> 54 %	Onsite Research	Aug-08	32 %	Good	Unknown	Intensive Assessment	Very Good	Aug-17
			Successional dynamics	Frequency of Gooding's black willow with a DBH > 20 cm	< 20%	20 - 35%	35 - 57%	**> 57%**	Onsite Research	Aug-08	62%	Very Good	Unknown	Intensive Assessment	Very Good	Aug-17
			Successional dynamics	Frequency of Valley oak with a DBH > 20 cm	< 15%	15 - 30%	30 - 44%	**> 44 %**	Onsite Research	Aug-08	50%	Very Good	Unknown	Intensive Assessment	Very Good	Aug-17
		Size	Community architecture	Forest patch core size	<40	40-80	**80-120**	>120	Expert Knowledge	Jun-07	88.1 +/- 15.3	Good	Strong Increase	Intensive Assessment	Very Good	Jun-20
			Community architecture	Patch morphology	> 20	10-20	**5-10**	< 5	Expert Knowledge	Jun-07	6.14 +/- 1.19	Good	Mild Decrease	Intensive Assessment	Very Good	Jun-20
			Population size & dynamics	Number of VELB exit holes per shrub	< 1 hole per shrub	**1 -1.9 holes per shrub**	1.9 - 2.2 holes per shrub	>2.2 holes per shrub	External Research	Jun-04	1.50 holes per shrub	Fair	Unknown	Intensive Assessment	Very Good	Oct-20
			Size / extent of characteristic communities / ecosystems	Area of annual and perennial grasses and forbs	< 2,500 acres	**2,500 - 5,000 acres**	5,000 - 7,500 acres	> 7,500 acres	Expert Knowledge	Jun-07	4,396 acres	Fair	Mild Increase	Intensive Assessment	Good	Jun-20
			Size / extent of characteristic communities / ecosystems	Area of fremont cottonwood forest	< 6,000 acres	**6,000 - 8,000 acres**	8,000 - 11,000	> 11,000	Expert Knowledge	Jun-07	7,692 acres	Fair	Strong Increase	Intensive Assessment	Good	Jun-20
			Size / extent of characteristic communities / ecosystems	Area of mixed riparian forest	**< 2,000 acres**	2,000 - 3,500 acres	3,500 - 5,000	> 5,000 acres	Expert Knowledge	Jun-07	1,126 acres	Poor	Unknown	Intensive Assessment	Good	Jun-20
			Size / extent of characteristic communities / ecosystems	Area of riparian scrub	**< 2,500 acres**	2,500 - 5,000 acres	5,000 - 7,500 acres	> 7,500 acres	Expert Knowledge	Jun-07	2,401 acres	Poor	Mild Increase	Intensive Assessment	Good	Jun-20

Appendix 1 (continued). Ecological Scorecard Summary for Terrestrial Resources and Channel Processes of the Middle Sacramento River, California.

Assessment of Target Viability Sacramento River				Double-click opens entry form	Indicator Ratings **Bold = Current** *Italics = Desired*					Indicator Measurements (latest measurement only)						
#	Conservation Targets	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Ratings Source	Date	Current Indicator Measurement	Current Rating	Trend	Source	Desired Rating	Date for Desired Rating
			Size / extent of characteristic communities / ecosystems	Area of valley oak woodland	**< 4,000**	4,000 - 6,000 acres	6,000 - 8,000 acres	> 8,000 acres	Expert Knowledge	Jun-07	3,938 acres	Poor	Mild Increase	Intensive Assessment	Good	Jun-20
			Size / extent of characteristic communities / ecosystems	Percent of historical riparian zone currently in conservation ownership	< 15 %	**15 - 20 %**	20 - 25 %	> 25 %	Expert Knowledge	May-04	16.20%	Fair	Mild Increase	Intensive Assessment	Good	Jun-20
			Size / extent of characteristic communities / ecosystems	Percent of historical riparian zone currently in natural habitat	< 15 %	**15 - 20 %**	20 - 25 %	> 25 %	Expert Knowledge	May-04	17.7%	Fair	Mild Increase	Intensive Assessment	Very Good	Jun-20
2	aquatic riverine habitats	Landscape Context	Connectivity among communities & ecosystems	Length of river with conservation ownership on both banks	<20,000 meters	**20,000 - 50,000 meters**	50,000 - 80,000 meters	>80,000 meters	Expert Knowledge	Jun-07	34,889 meters	Fair	Strong Increase	Intensive Assessment	Very Good	Jun-20
			Hydrologic regime - (timing, duration, frequency, extent)	Frequency of flow connection with former river channels	Index rating of 1	**Index rating of 2**	Index rating of 3	Index rating of 4	Onsite Research	Jun-10	Index rating of 2	Fair	Mild Decrease	Intensive Assessment	Good	Jun-20
			Hydrologic regime - (timing, duration, frequency, extent)	Frequency of inundation of the floodplain	**<3 days exceeding 70,000cfs; and >5 yrs without floodplain inundation**	3-5 days exceeding 70,000cfs; and 4-5 years without floodplain inundation	5-6 days exceeding 70,000cfs; and 3-4 years without floodplain inundation	>6 days exceeding 70,000cfs, and <3 years without floodplain inundation	Onsite Research	Jun-10	0.7 days per yr above 70,000 cfs; and 8 of the previous ten yrs had no flows above 70,000 cfs.	Poor	Mild Decrease	Intensive Assessment	Good	Jun-20
			Hydrologic regime - (timing, duration, frequency, extent)	Frequency of mobilization of the river bed	**<6 days exceeding 55,000 cfs; and >3 years without any flows >55,000 cfs.**	6-9 days exceeding 55,000 cfs; and 2-3 years without any flows >55,000 cfs.	9-11 days exceeding 55,000 cfs; and 2-3 years without any flows >55,000 cfs	>11 days exceeding 55,000 cfs; and <2 years without any flows >55,000 cfs	Onsite Research	Jun-10	4.6 days per yr were greater than 55,000 cfs, and six of the previous ten yrs had no flows above 55,000 cfs	Poor	Mild Decrease	Intensive Assessment	Good	Jun-20
			Landscape pattern (mosaic) & structure	Length of riparian shoreline	<500,000 meters	**500,000-750,000 meters**	750,000 - 1,000,000 meters	>1,000,000 meters	Expert Knowledge	Jun-07	598,625 meters	Fair	Strong Decrease	Rapid Assessment	Good	Jun-20
			Landscape pattern (mosaic) & structure	Number of bends with sinuosity greater than 2.0	**< 5 bends**	5 bends	6-7 bends	> 7 bends	Onsite Research	Jun-07	4 bends	Poor	Mild Decrease	Intensive Assessment	Fair	Jun-20

Appendix 1 (continued). Ecological Scorecard Summary for Terrestrial Resources and Channel Processes of the Middle Sacramento River, California.

Assessment of Target Viability Sacramento River				Double-click opens entry form	Indicator Ratings **Bold = Current** *Italics = Desired*					Indicator Measurements (latest measurement only)						
#	Conservation Targets	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Ratings Source	Date	Current Indicator Measurement	Current Rating	Trend	Source	Desired Rating	Date for Desired Rating
		Condition	Landscape pattern (mosaic) & structure	Percent of riparian shoreline bordered by >500 meters of natural habitat	<10%	**10 - 25%**	25-40%	>40%	Onsite Research	Jun-07	22.25%	Fair	Mild Increase	Intensive Assessment	Good	Jun-20
			Soil / sediment stability & movement	Meters of bank with riprap	> 80,000 meters	**60,000 - 80,000 meters**	30,000 - 60,000 meters	< 30,000 meters	Onsite Research	Aug-02	77,000 meters	Fair	Mild Increase	Intensive Assessment	Good	Jun-20
			Species composition / dominance	Area of water primrose	> 400 acres	**200 - 400 acres**	50 - 200 acres	< 50 acres	Onsite Research	May-07	387 acres	Fair	Mild Increase	Intensive Assessment	Good	Jun-20
			Successional dynamics	Area of floodplain reworked	**< 700,000 square meeters per yr**	700,000 - 900,000 square meeters per yr	900,000 - 1,000,000 square meeters per yr	> 1,000,000 square meeters per yr	Onsite Research	Jun-07	636,451 sq meters per year	Poor	Mild Decrease	Intensive Assessment	Good	Jun-30
			Successional dynamics	Channel bend meander migration rate	**< 4.5 m/yr**	4.5 - 5.75 m/yr	5.75 - 6.5 m/yr	> 6.5 m/yr	Onsite Research	Jun-07	4.13 m/yr	Poor	Mild Decrease		Fair	Jun-20
		Size	Community architecture	Bend entrance angle	**< 41 degrees**	41 - 44 degrees	44 - 46 degrees	> 46 degrees		Jun-07	39.5 degrees	Poor	Mild Decrease	Intensive Assessment	Fair	Jan-20
			Community architecture	Half-wavelength	**> 1100 meters**	1050 - 1100 meters	1000-1050 meters	< 1000 meters	Onsite Research	Jun-07	1110 meters	Poor	Mild Increase	Intensive Assessment	Good	Jun-30
			Community architecture	Number of in-channel large woody debris aggregations	< 200 snag aggregations	**200 - 600 snag aggregations**	600- 1,000 snag aggregations	> 1,000 snag aggregations	Onsite Research	Jun-07	387 aggregations	Fair	Strong Decrease	Rapid Assessment	Good	Jun-20
			Community architecture	Total river length	**< 156,000**	156,000-158,000 meters	158,000 - 160,000 meters	> 160,000 meters	Onsite Research	Jun-07	154,229 meters	Poor	Mild Decrease	Intensive Assessment	Fair	Dec-30
			Community architecture	Whole river sinuosity	**< 1.25**	1.25 - 1.27	1.27 - 1.29	> 1.29	Onsite Research	Jun-07	1.24	Poor	Mild Decrease	Intensive Assessment	Fair	Jun-20
3	birds (resident and migratory)	Condition	Depredation & parasitism	Nest survival for Black-headed Grosbeak	<25%	**25 to 40%**	40 to 60%	>60%	Onsite Research	Aug-00	33%	Fair	Mild Decrease	Intensive Assessment	Very Good	Aug-15
			Depredation & parasitism	Nest survival for Lazuli Bunting	**<20%**	20 to 30%	30 to 40%	>40%	Onsite Research	Aug-97	6%	Poor	Mild Decrease	Intensive Assessment	Good	Aug-15

Appendix 1 (continued). Ecological Scorecard Summary for Terrestrial Resources and Channel Processes of the Middle Sacramento River, California.

Assessment of Target Viability Sacramento River				Double-click opens entry form	Indicator Ratings **Bold = Current** *Italics = Desired*					Indicator Measurements (latest measurement only)						
#	Conservation Targets	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Ratings Source	Date	Current Indicator Measurement	Current Rating	Trend	Source	Desired Rating	Date for Desired Rating
			Depredation & parasitism	Nest survival for Spotted Towhee	<15%	**15 – 25%**	25 – 35%	>35%	Onsite Research	Aug-03	21%	Fair	Unknown	Intensive Assessment	Good	Aug-15
			Population structure & recruitment	Adult survival for Black-headed Grosbeak	<40%	40 to 60%	**60 to 70%**	>70%	Onsite Research	Jul-00	62%	Good	Mild Decrease	Intensive Assessment	Very Good	Aug-15
			Population structure & recruitment	Adult survival for Spotted Towhee	**<40%**	40 to 50%	50 to 60%	>60%	Onsite Research	Aug-00	25%	Poor	Strong Decrease	Intensive Assessment	Good	Aug-15
			Species composition / dominance	Bird species richness	< 25	**25 to 35**	35 to 45	>45	Onsite Research	Apr-04	48.7 species	Fair	Strong Increase	Intensive Assessment	Good	Aug-14
		Size	Population size & dynamics	Abundance for Black-headed Grosbeak	0 - 0.44 birds/ha	**0.44 - 0.89 birds/ha**	0.89 - 1.34 birds/ha	>1.34 birds/ha	Onsite Research	Aug-02	0.5956 (± 0.0395) birds/ha	Fair	Strong Increase	Intensive Assessment	Good	Aug-15
			Population size & dynamics	Abundance for Common Yellowthroat	0 - 0.09 birds/ha	0.09 - 0.17 birds/ ha	**0.17 - 0.25 birds/ha**	>0.25 birds/ha	Onsite Research	Dec-02	0.1338 (± 0.0173) birds/ha	Good	Mild Increase	Intensive Assessment	Very Good	Aug-15
			Population size & dynamics	Abundance for Spotted Towhee	0 - 0.64 birds/ha	**0.64 - 1.28 birds/ha**	1.28 - 1.92 birds/ha	>1.92 birds/ha	Onsite Research	Aug-02	0.7999 (± 0.0342) birds/ha	Fair	Strong Increase	Intensive Assessment	Good	Aug-15
			Population size & dynamics	Abundance for Yellow Warbler	**0 - 0.10 birds/ha**	0.10 - 0.21 birds/ha	0.21 - 0.32 birds/ha	>0.32 birds/ha	Onsite Research	Dec-02	0.0208 (± 0.0103) birds/ha	Poor	Unknown	Intensive Assessment	Fair	Aug-15
			Population size & dynamics	Abundance for Yellow-breasted Chat	**0 - 0.31 birds/ha**	0.31 - 0.62 birds/ha	0.62 - 0.93 birds/ha	>0.93 birds/ha	Onsite Research	Aug-02	0.1377 (± 0.0096) birds/ha	Poor	Unknown	Intensive Assessment	Fair	Aug-15
			Population size & dynamics	Aerial extent of colonial waterbird rookeries	< 20,000 square meters	20,000 – 30,000 square meters	**30,000 – 50,000 square meters**	> 50,000 square meters	Onsite Research	Jun-07	35,009 square meters	Good	Unknown	Rapid Assessment	Very Good	Jul-20
			Presence / abundance of keystone species	Number of bank swallow burrows	**<20,000 burrows**	20,000 - 30,000 burrows	30,000 - 40,000 burrows	> 40,000 burrows	Onsite Research	Jul-10	10,662 burrows	Poor	Strong Decrease	Intensive Assessment	Fair	Jul-20
			Presence / abundance of keystone species	Number of Bank Swallow colonies	**< 50 colonies**	50 - 75 colonies	75 - 100 colonies	> 100 colonies	Onsite Research	Jul-10	38 colonies	Poor	Strong Decrease	Intensive Assessment	Fair	Jul-20
			Presence / abundance of keystone species	Number of occupied Yellow-billed Cuckoo territories	**<25 territories occupied**	25-51 territories occupied	52-76 territories occupied	>76 territories occupied	Onsite Research	Apr-04	<25 territories occupied	Poor	Unknown	Intensive Assessment	Good	Aug-15

Appendix 2. Background information for indicators of the Sacramento River Ecological Scorecard. These forms were filled out by knowledgeable researchers (contact information provided within) with expertise on the subjects discussed. To varying degrees, the forms were edited and revised (by G. Golet, TNC), however, most of the original work was done by others. The order of presentation follows the listing of indicators in Appendix 1.

Appendix 2. Table of Contents.

Appendix 2. Table of Contents (continued).

Appendix 2. Table of Contents (continued).

Appendix 2. Table of Contents (continued).

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Forest Edge Contrast

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

This landscape pattern indicator refers to the contrast between one type of habitat and another along the adjoining patch edges. A high contrast edge would be one between a row crop field and a remnant patch of mature riparian forest. A low contrast edge would be between mature riparian forest and older restored riparian forest. For core-forest dependent species, high edge contrast extends edge effects into the forest patch interior, disturbing the core-dependent species. Low edge contrast would lead to reduced edge effects and less impact on edge-sensitive species.

2. What is the rationale for it being a meaningful indicator?

It can be used to identify patches where edge contrast is high or low. It can quantify the relative contrast among all patches and among types of patches (e.g., typed by plant community type)/ This allows an estimation of effects on edge-sensitive species and prioritization of future actions to reduce edge contrast (where desired).

3. What references support its use? Provide citations.

Birds: Influence of landscape pattern on breeding distribution and success in a threatened Alcid, the marbled murrelet: model transferability and management implications. Zharikov, Y., Lank, D. B., Cooke, F. 2007. Journal of Applied Ecology [J. Appl. Ecol.]. Vol. 44, no. 4, pp. 748-759.

Ants: Effect of fragmentation, habitat loss and within-patch habitat characteristics on ant assemblages in semi-arid woodlands of eastern Australia. Debuse, V. J, King, J., House, A. P.N. Landscape Ecology [Landscape Ecol.]. Vol. 22, no. 5, pp. 731-745.

Plants: The role of landscape patterns of habitat types on plant species diversity of a tropical forest in Mexico. Hernandez-Stefanoni, J.L. 2006. Biodiversity and Conservation [Biodivers. Conserv.]. Vol. 15, no. 4, pp. 1441-1457.

Mammals: Relationships between landscape pattern and space use of three mammalian carnivores in central Mississippi. Constible, J. M., Chamberlain, M. J., Leopold, B.D. 2006. American Midland Naturalist [Am. Midl. Nat.]. Vol. 155, no. 2, pp. 352-362.

Siberian flying squirrel responses to high- and low-contrast forest edges. 2003. Desrochers, A, Hanski, I.K, Selonen, V. Landscape Ecology [Landscape Ecol.]. Vol. 18, no. 5, pp. 543-552.

Landscape heterogeneity at differing scales: Effects on spatial distribution of mule deer. Kie, J.G., Bowyer, R.T., Nicholson, M.C., Boroski, B.B., Loft, E.R.2002. Ecology [Ecology]. Vol. 83, no. 2, pp. 530-544.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

The indicator is useful at the site/patch/reach (characterization of each patch and collection of patches) to whole river/landscape (characterization of all patches or all patch/habitat types) scale.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

The edge contrast calculation is dependent on how the patches are coded relative to each other. Usually, a range of 0-1 or 0-100 is used, where 0 would be one habitat type (say bare ground) and 1 or 100 would be another (say mature riparian forest). Because a continuous value is obtained, there is no need for cutoffs. Also, cutoffs depend on species and species need. Some species benefit from high contrast edges and others don't. In general, the core-dependent and edge sensitive species will not do well with high contrasts, so high contrast would be "poor".

In our case, the contrast values range from 0 to 100, with the highest contrast between patches having a value of 100. For example, a developed patch neighboring an herbaceous patch would have a value of 100, while forest and herbaceous could have a lower value of 80, while shrub and herbaceous could have even a lower value of 40.

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

See above

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

Methods are included in the FRAGSTATS user manual and other publications.

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to?

1997 mapping by Nelson, modified by Girvetz, analyzed by Schott and Shilling

TYPE	Edge Contrast Index Area Weighted Mean ECON_AM	Edge Contrast Index Standard Deviation ECON_SD
Herbaceous	78.5	10.7
Forest	48.8	23.1
Developed	93.2	7.7
Orchard	69.0	16.4
Row Crop	64.9	14.2
Scrub	61.8	16.4
Gravel Bar	59.6	26.9
Wetland	73.6	24.4

2007 mapping by Nelson, modified by TNC/UCD, analyzed by Schott and Shilling

TYPE	Edge Contrast Index Area Weighted Mean ECON_AM	Edge Contrast Index Standard Deviation ECON_SD
Herbaceous	63.4	13.8
Forest	72.0	13.0
Developed	94.5	7.0
Orchard	66.3	15.9
Row Crop	55.7	17.7
Scrub	50.7	11.9
Gravel Bar	44.3	20.7
Wetland	59.7	21.6

In general, between 1997 and 2007, edge contrast has increased dramatically for forested patches and decreased for herbaceous, scrub, and wetland patches. Given that the total forest core area has increased 5 fold in extent in that time, it is likely that the increase in edge contrast is due to new forest establishment in areas with patches of agriculture.

9. What is the desired rating and by when should this be achieved?

Desired rating would be for mature and older restored riparian forest, where "good" would be lower edge contrast and could be achieved in many areas within 20 years through natural and horticultural recruitment/restoration.

<u>Step 7</u>.

10. Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)?

Yes

11. When were the data collected that yielded these other values? Describe the history of data collection.

1997 and 2007 mapping (delineation and veg classification) of the study reach

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Calculated based upon 1997 and 2007 maps. Geographic area = study area

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

Maps: 1997 (Evan Girvetz; Girvetz@u.washington.edu); 2007 (Chuck Nelson; cwnelson@csuchico.edu)

Analyses: 1997 and 2007 (Heidi Schott heschott@ucdavis.edu and Fraser Shilling fmshilling@ucdavis.edu)

14. What is the rationale for the desired rating?

Although certain species benefit from greater edge contrast, it is more likely that species that have depended on intact, interior riparian forest are lacking in extensive appropriate habitat. Therefore, it would be preferable to decrease edge contrast while expanding total area, primarily through contiguity with natural or horticulturally restored patches of forest.

<u>Step 8</u>

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

This indicator is related to the other landscape indicators: patch core size, patch morphology, and patch isolation.

More information on the viability assessment part of the workbook can be found at: http://conserveonline.org/workspaces/cbdgateway/cap/practices/bp_3

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Forest Patch Proximity

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

Patch isolation is a landscape pattern indicator that characterizes the isolation of a patch relative to other patches of the same type. Patch proximity is the corollary and is the metric used here. Type in this case could be a very specific plant community type (e.g., cottonwood-dominated forest), or a more general habitat type (e.g., “forest”).

2. What is the rationale for it being a meaningful indicator?

Patch isolation or proximity can determine the value of patches for particular taxa and ecological processes – the more isolated the patch, the less likely it will provide habitat value to species dependent on proximity and connections among patches. Highly fragmented landscape will tend to have more isolated, lower proximity, patches, reducing overall habitat value.

3. What references support its use? Provide citations.

E. Johannesen , H.P. Andreassen & R.A. Ims. 2002. Spatial explicit demography: The effects habitat patch isolation have on vole matrilines. Ecology Letters. Volume 3 Issue 1, Pages 48 – 57.

BENDER D.J.; TISCHENDORF L.; FAHRIG L. 2003. Using patch isolation metrics to predict animal movement in binary landscapes. Landscape ecology, vol. 18, n°1, pp. 17-39

SWYSTUN M. B.; PSYLLAKIS J. M.; BRIGHAM R. M.. 2001.The influence of residual tree patch isolation on habitat use by bats in central British Columbia. Acta chiropterologica , vol. 3, n°2, pp. 197-201

P.-E. Betzholtz, A. Ehrig, M. Lindeborg and P. Dinnétz· 2007. Food plant density, patch isolation and vegetation height determine occurrence in a Swedish metapopulation of the marsh fritillary *Euphydryas aurinia* (Rottemburg, 1775) (Lepidoptera, Nymphalidae). J insect Conservation. 11(4): 343-350.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

The indicator is useful at the site/patch/reach (characterization of each patch and collection of patches) and at whole river/landscape (characterization of all patches or all patch/habitat types) scale.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

Because a continuous value is obtained, there is no need for cutoffs. Also, cutoffs depend on species and species need. Most species will benefit from less isolation of patches they depend upon for foraging, dispersal, and reproductive needs. In general, the core-dependent and edge sensitive species will do very poorly when patches are even slightly isolated. Edge-preferring or edge-insensitive species may benefit from increased isolation.

The indicator value = 0 if a patch has no neighbors of the same patch type within the specified search radius. Indicator value increases as the neighborhood (defined by the specified search radius) is increasingly occupied by patches of the same type and as those patches become closer and more contiguous (or less fragmented) in distribution. The upper limit of the indicator is affected by the search radius and the minimum distance between patches.

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

See above

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

Methods are included in the FRAGSTATS user manual and other publications. They have been used and confirmed in studies (e.g., those above).

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to?

1997

TYPE	Area-Weighted Mean Proximity Index PROX_AM	Proximity Standard Deviation PROX_SD
Herbaceous	146.77	226.74
Forest	15.58	31.11
Developed	103.51	173.01
Orchard	813.07	746.23
Row Crop	43.73	117.13
Scrub	368.98	477.78
Gravel Bar	440.74	4339.13
Wetland	2.73	6.13

2007

TYPE	Area-Weighted Mean Proximity Index PROX_AM	Proximity Standard Deviation PROX_SD
Herbaceous	30.98	53.53
Forest	204.87	588.86
Developed	46.89	73.45
Orchard	584.98	825.96
Row Crop	271.12	327.89
Scrub	17.13	19.96
Gravel Bar	6.89	20.01
Wetland	6.17	8.37

Forested patches were dramatically improved in their proximity to other forested patches (indicated by increase in the proximity index from 1997 to 2007). Herbaceous and scrub vegetation patches dramatically worsened in terms of their proximity. Wetlands had very low proximity and did not change much from 1997 to 2007.

9. What is the desired rating and by when should this be achieved?

Desired rating is best determined for habitat classes, but can also be determined for individual patches. A high rating would be for high mean proximity index value and would be preferable for almost all riparian species. The values are comparable within a particular analysis (including between time points), there are no absolutely good or poor values. Instead, the higher the number the better for native vegetation types.

Step 7.

10. Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)?

Yes

11. When were the data collected that yielded these other values? Describe the history of data collection.

1997 and 2007 mapping (delineation and veg classification) of the study reach

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Calculated based upon 1997 and 2007 maps. Geographic area = study area

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

Maps: 1997 (Evan Girvetz; Girvetz@u.washington.edu); 2007 (Chuck Nelson; cwnelson@csuchico.edu)

Analysis: 1997 and 2007 (Heidi Schott, heschott@ucdavis.edu and Fraser Shilling; fmshilling@ucdavis.edu)

14. What is the rationale for the desired rating?

The higher the proximity among patches of a similar type, the more likely the patch type is to serve habitat needs of interior-dependent species.

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

This indicator is related to the other landscape indicators: patch edge contrast, patch core area, and patch morphology.

More information on the viability assessment part of the workbook can be found at: http://conserveonline.org/workspaces/cbdgateway/cap/practices/bp_3

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Bee Species Richness

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   Bee Species Richness is defined as the total number of different species of bees

2. What is the rationale for it being a meaningful indicator?

   Bees are an important pollinator. More generally, insects have tremendous taxonomic and functional diversity and play essential roles in ecosystems as pollinators, predators, prey, herbivores, and scavengers. Hence, they are useful focal species for studies that seek to characterize the degree to which ecosystem function is restored in restoration projects (Wilson 1987, Williams 1993). However, in a review of 68 restoration case studies, only 32% measured some component of arthropod diversity (Ruiz-Jaen and Aide 2005). Restoration monitoring programs often exclude insects for several reasons: they are small, innocuous and generally viewed as non-charismatic; the functional roles that individual species play in ecosystem processes are often not well understood; and the shear diversity of taxa may be overwhelming to the researcher (Williams 2000).

   On the Sacramento River there have been three investigations of terrestrial insect responses to restoration which have focused on individual taxa or specific insect orders. These include studies of the federally threatened Valley elderberry longhorn beetle (VELB), ground-dwelling beetles, and bees.

   Above text if from: Golet et al. 2008

3. What references support its use as an indicator of river health? Provide citations.

Golet, G.H., T. Gardali, C. Howell, J. Hunt, R. Luster, B. Rainey, M. Roberts, H. Swagerty, N. Williams. 2008. Wildlife Response to Restoration on the Sacramento River. San Francisco Estuary and Watershed Science. Vol. 6, Issue 2 (June), Article 1. http://repositories.cdlib.org/jmie/sfews/vol6/iss2/art1.

Ruiz-Jaen, M.C., and T. M. Aide. 2005. Restoration success: How is it being measured? *Restoration Ecology* 13:569-577.

Williams, K.S. 1993. Use of terrestrial arthropods to evaluate restored riparian woodlands. *Restoration Ecology* 1:107-118.

Williams, K.S. 2000. Assessing success of restoration attempts: What can terrestrial arthropods tell us? Pages 237-244 *in* Keeley, J.E. M. Baer-

Keeley and C.J. Fotheringham (eds). 2nd interface between ecology and land development in California. USGS Open-File Report 00-62.

Wilson, E.O. 1987. The little things that run the world (the importance of conservation of invertebrates). *Conservation Biology* 1:344-346.

Williams N.M. 2007. Restoration of Native Bee Pollinators within the Sacramento River System (California). Ecological Restoration 25:67-68.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   It is useful at multiple scales. Interpretations of the data are in part a function of the geographic range of the sampling sites.

<u>Step 5</u>

5. What cutoffs are appropriate for poor, fair, good and very good?

   <u>The status indicator ratings are defined as:</u>
   Very Good: >40 species
   Good: 35 - 40 species
   Fair: 25 - 35 species
   Poor: <25 species

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

   Expert opinion, based upon consideration of the data collected onsite, presented in Williams 2007

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

   Bee (Order: Hymenoptera) species richness was compared within 1-ha plots at five 8-year-old restoration sites and five remnant riparian forest/scrub habitats geographically paired along 72 river kilometers (Table 1, Williams 2007). Paired sites were separated by 0.5-3.8 km. Plots were surveyed every six weeks from late February through August, 2003 (five sampling periods). At each site bees were netted at flowering plants and captured in 30 water-filled pan traps spaced regularly along two crossed 100m transects (see http://online.sfsu.edu/~beeplot/ for details on trapping methods). Abundance of all plant species within the plots was measured with quadrat sampling.

   Results suggest that restored sites are providing habitat for a wide diversity of bee species (Williams 2007). Bees of a variety of life histories were captured: 5% social to some degree, 73% solitary/gregarious, and 13% clepto-parasitic. Mean species richness pooled from netting and pan traps was not statistically different between restored (mean=39, SE= 6.5) and remnant (mean=42, SE =1.6) sites (t=0.335, df=4, P=0.78). Interestingly, the 8-year-old restoration sites contained many different bee species than what was identified at remnants habitats (Sorensen index mean ± SE similarity between paired sites = 0.45 ± 0.022). Bee communities sampled with netting at restored and remnant sites cluster separately based on non-metric multidimensional scaling (Fig. 7A, Golet et al. 2007), such that only about half of the bees species among paired sites overlapped.

Bee communities sampled with netting at restored and remnant sites cluster separately based on non-metric multidimensional scaling (Fig. 7A), such that only about half of the bees species among paired sites overlapped. Such differences highlight the importance of a mosaic landscape composed of habitat in different successional stages for promoting species diversity. One cause of dissimilarity between bees from restored and remnant sites may be differences in flowering plant communities at these two site types (mean similarity 0.32 ±0.043, Sorensen index; Fig. 7B). However, paired sites with greater similarity of plants did not have more bee species in common with one another (Williams 2007), suggesting that other factors are also influencing the distribution of bees among Sacramento River habitat types.

Golet, G.H., T. Gardali, C. Howell, J. Hunt, R. Luster, B. Rainey, M. Roberts, H. Swagerty, N. Williams. 2008. Wildlife Response to Restoration on the Sacramento River. San Francisco Estuary and Watershed Science. Vol. 6, Issue 2 (June), Article 1. http://repositories.cdlib.org/jmie/sfews/vol6/iss2/art1.

Williams, N.M. 2007. Restoration of native bee pollinators within the Sacramento River system (California). Ecological Restoration 25:67-68.

Step 6

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   39 species, sampling done Feb-Aug 2003

9. What is the desired rating and by when should this be achieved?

   Very good, by August 2020

Step 7.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

    To our knowledge, no similar data have been collected in this area.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    Data were collected at five 8-year-old restoration sites and five remnant riparian forest/scrub habitats geographically paired along 72 river kilometers. The sites, from north to south are: La Barranca, Flynn, Rio Vista, Pine Creek and Phelan Island.

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

    I wrote this up, but the expert is:
    Neal M. Williams, Ph.D.
    Assistant Professor
    Pollination Ecology (Pollination biologist and native pollinator specialist)
    UC Davis
    Department of Entomology
    Office: 380B Briggs
    Lab: 380 Briggs
    Phone: 530-752-9358
    Email: nmwilliams@ucdavis.edu
    Fax: 530-752-1537

13. What is the rationale for the desired rating?

    This is what was observed at remnant sites.

<u>Step 8</u>

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Ground Beetle Species Richness

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   Ground Beetle Species Richness is defined as the total number of different morphospecies of beetles. Morphospecies are the lowest taxon that can be distinguished based on morphology, and are surrogates for species (Oliver and Beattie 1996a).

2. What is the rationale for it being a meaningful indicator?

   Beetles are an important member of the insect community. More generally, insects have tremendous taxonomic and functional diversity and play essential roles in ecosystems as pollinators, predators, prey, herbivores, and scavengers. Hence, they are useful focal species for studies that seek to characterize the degree to which ecosystem function is restored in restoration projects (Wilson 1987, Williams 1993). However, in a review of 68 restoration case studies, only 32% measured some component of arthropod diversity (Ruiz-Jaen and Aide 2005). Restoration monitoring programs often exclude insects for several reasons: they are small, innocuous and generally viewed as non-charismatic; the functional roles that individual species play in ecosystem processes are often not well understood; and the shear diversity of taxa may be overwhelming to the researcher (Williams 2000).

   On the Sacramento River there have been three investigations of terrestrial insect responses to restoration which have focused on individual taxa or specific insect orders. These include studies of the federally threatened Valley elderberry longhorn beetle (VELB), ground-dwelling beetles, and bees.

3. What references support its use as an indicator of river health? Provide citations.

Golet, G.H., T. Gardali, C. Howell, J. Hunt, R. Luster, B. Rainey, M. Roberts, H. Swagerty, N. Williams. 2008. Wildlife Response to Restoration on the Sacramento River. San Francisco Estuary and Watershed Science. Vol. 6, Issue 2 (June), Article 1. http://repositories.cdlib.org/jmie/sfews/vol6/iss2/art1.

Hunt, J.W. 2004. Comparison of Epigeal beetle assemblages in remnant and restored riparian forests on the middle Sacramento River, California. MS Thesis. California State University, Chico.

Ruiz-Jaen, M.C., and T. M. Aide. 2005. Restoration success: How is it being measured? *Restoration Ecology* 13:569-577.

Williams, K.S. 1993. Use of terrestrial arthropods to evaluate restored riparian woodlands. *Restoration Ecology* 1:107-118.

Williams, K.S. 2000. Assessing success of restoration attempts: What can terrestrial arthropods tell us? Pages 237-244 *in* Keeley, J.E. M. Baer-Keeley and C.J. Fotheringham (eds). 2nd interface between ecology and land development in California. USGS Open-File Report 00-62.

Wilson, E.O. 1987. The little things that run the world (the importance of conservation of invertebrates). *Conservation Biology* 1:344-346.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   It is useful at multiple scales. Interpretations of the data are in part a function of the geographic range of the sampling sites.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

   The status indicator ratings are defined as:
   Very Good: > 52 species
   Good: 45-52 species
   Fair: 37-44 species
   Poor: < 37 species

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

   Expert opinion, based upon consideration of the data collected onsite, presented in Hunt 2004.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

   John Hunt did the pioneering work on this on the Sacramento River. See Hunt (2004) for detailed methods. Brief methods summarized in Golet et al. (2008) are below:

   Sampling was conducted from December 2000 through November 2001 with pitfall traps along a 31- km stretch of the Sacramento River. At each site 12 traps were placed 15 meters apart in a 3×4 grid. Traps were left open for collections for seven consecutive days each month. Following collection, beetles were identified to the lowest taxonomic level practicable, and then classified as morphospecies (*sensu* Oliver and Beattie 1996a, 1996b).

Golet, G.H., T. Gardali, C. Howell, J. Hunt, R. Luster, B. Rainey, M. Roberts, H. Swagerty, N. Williams. 2008. Wildlife Response to Restoration on the Sacramento River. San Francisco Estuary and Watershed Science. Vol. 6, Issue 2 (June), Article 1. http://repositories.cdlib.org/jmie/sfews/vol6/iss2/art1.

Hunt, J.W. 2004. Comparison of Epigeal beetle assemblages in remnant and restored riparian forests on the middle Sacramento River, California. MS Thesis. California State University, Chico.

Oliver, I., and A.J. Beattie. 1996a. Invertebrate morphospecies as surrogates for species: A case study. *Conservation Biology* 10:99-109.

Oliver, I., and A.J. Beattie. 1996b. Designing a cost-effective invertebrate survey: A test of methods for rapid assessment of biodiversity. *Ecological Applications* 6:594-607.

Step 6

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   Morphospecies richness, averaged across restoration sits was 45 species based on sampling done from December 2000 through November 2001. The corresponding rating is *"Good".*

9. What is the desired rating and by when should this be achieved?

   Very good, by November 2020.

Step 7.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

    To our knowledge, no similar data have been collected in this area.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    Sampling was done along a 31- km stretch of the Sacramento River at Kopta Slough, Rio Vista, Merril's Landing, Pine Creek, and Phelan Island. Data are presumed to be representative on the Red Bluff to Colusa stretch of the river.

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

    I wrote this up, but the local expert is:
    John W. Hunt

1724 Normal Avenue
Chico, CA 95928
(530) 228-8907
cottonwood@sbcglobal.net

13. What is the rationale for the desired rating?

    This is what was observed at remnant sites.

Step 8

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Soil Organic Carbon

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

Soil organic carbon is the percent of carbon in soil as measured at 10-cm depth in spring with Total Organic Carbon (TOC) analytical equipment.

It is important that are compared be collected at the same time of year, as there is a seasonal pulse observed. This is expected in these forests—plant litter accumulates on the forest floor during the fall, decomposes with the onset of the fall rains in November/December, soil organic matter (SOM; humus) is formed, and these humic materials are leached down into the soil profile where they exhibit a peak during spring. Following this flush of SOM, fungi and other soil microbes take up this carbon for their own growth and thus soil carbon levels decline once again.

2. What is the rationale for it being a meaningful indicator?

Soil organic carbon was selected as an indicator for its importance in ecosystem function, and because it is reliably quantified through instrumental analysis. Soil carbon and nutrient cycling are of fundamental importance to biological systems and play a central role in water retention, which directly affects site productivity (Aber and Melillo 2001). Soil carbon pools and dynamics are a critical component of the global carbon cycle, and plant residues comprise the largest source of organic carbon entering soils (Paul and Clark, 1989). The dense vegetation of mature riparian forests provides a constant source of plant litter that will decompose to become humic substances that comprise soil organic matter (SOM). Afforestation is generally thought to increase soil carbon and by correlation SOM, but more study is needed (Bashkin and Binkley 1998).

The development of soil profiles from riparian/floodplain sediments can significantly affect and potentially reflect riparian restoration progress. Soil horizon development can be a slow process measured on the time scale of decades or more. However, since mature riparian forests can develop on the time-scale of 30 years, some soil development processes may be detectable over shorter time scales. As of 2002 the journal literature did not appear to contain any studies of soil development corresponding to riparian restoration efforts. A few studies related studies focus on natural pedogenic processes Brock, 1985) or upland meadow riparian systems (Blank et al., 1995).

3. What references support its use as an indicator of river health? Provide citations.

Aber, J. D. and J.M. Melillo. 2001. Terrestrial Ecosystems, Second edition. Harcourt Academic

Bashkin, M.A. and D. Binkley. 1998. Changes in soil carbon following afforestation in Hawaii. Ecology 79: 828-833.

Blank, R.R., Svejcar, T.J., and Riegel, G.M., 1995. Soil genesis and morphology of a montane meadow in the northern Sierra Nevada range. Soil Sci., 160(2):136-152.

Brock, J.H., 1985. Physical characteristics and pedogenesis of soils in riparian habitats along the upper Gila River Basin. Gen. Tech. Rep. Rocky Mt. For. Range. Exp. Stn. U.S.F.S. Fort Collins, CO. GTR RM-120 p. 49-53.

Brown, D.L, and D.M. Wood. 2002 Measure key connections between the river and floodplain. Final Project Report to The Nature Conservancy, Sacramento River Project.

Paul, E.A. and F.E. Clark. 1989. Soil microbiology and biochemistry. Academic Press, Inc., New York, NY, pp. 93-116.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

This indicator is most useful at comparing specific sites, or even particular areas within sites, as soil parameters can be highly heterogeneous over even small spatial scales.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

The status indicator ratings are defined as:
Very Good: > 2.5 percent carbon
Good: 2.0 - 2.5 percent carbon
Fair: 1.5 – 2.0 percent carbon
Poor: < 1.5 percent carbon

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

By visual inspection of data collected by Brown and Wood (2002) on Sacramento River restoration and remnant sites.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

Methods summary (from Brown and Wood 2002):

Triplicate subsamples of approximately 50 g from each soil horizon observed in the soil pits at Site VII and WCB sites were used in the analysis. Additional soil sampling for carbon content was performed on a quarterly basis. Nine samples were collected in a 3x3 grid with sample locations 75 m apart (corresponding to litter sampling described above). Analysis for soil carbon was performed using Shimadzu 5050A Total Organic Carbon analytical equipment. Visible large rocks or debris were removed from the subsamples prior to drying the samples in an oven for 24 hours. Subsamples were then pulverized and homogenized before being placed in the instrument.

Brown, D.L, and D.M. Wood. 2002 Measure key connections between the river and floodplain. Final Project Report to The Nature Conservancy, Sacramento River Project.

Step 6

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

Mean soil carbon was 2.25% at two restoration sites in spring 2002. This corresponds to the “good condition” ranking. Ideally this indicator would be calculated at a larger representative sample of restoration sites and an average value would be reported.

9. What is the desired rating and by when should this be achieved?

Very good by 2020.

Step 7.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

Soil carbon concentration results from Brown and Wood’s (2002) study of restoration sites and remnant habitats on the Sacramento River are presented at depths of 2 cm, 10 cm, and 24 cm on Figures 1, 2, and 3, respectively. Each seasonal carbon concentration represents a mean of the nine samples collected for each location.

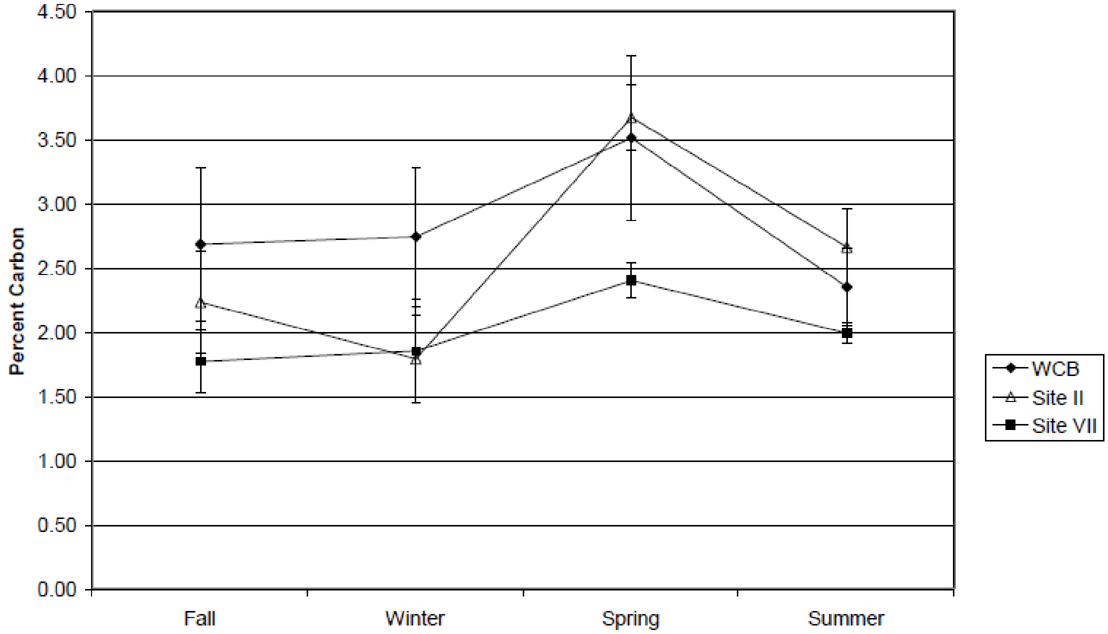

Figure 1. Soil carbon at 2-cm depth. Values are means +/- 95% confidence intervals.

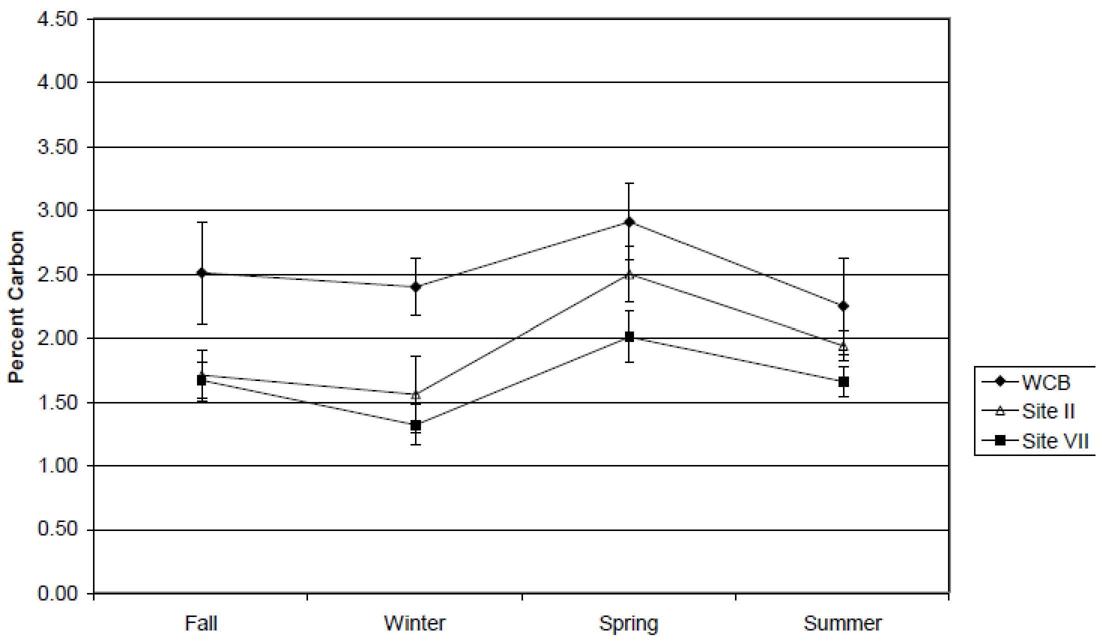

Figure 2. Soil carbon at 10-cm depth. Values are means +/- 95% confidence intervals.

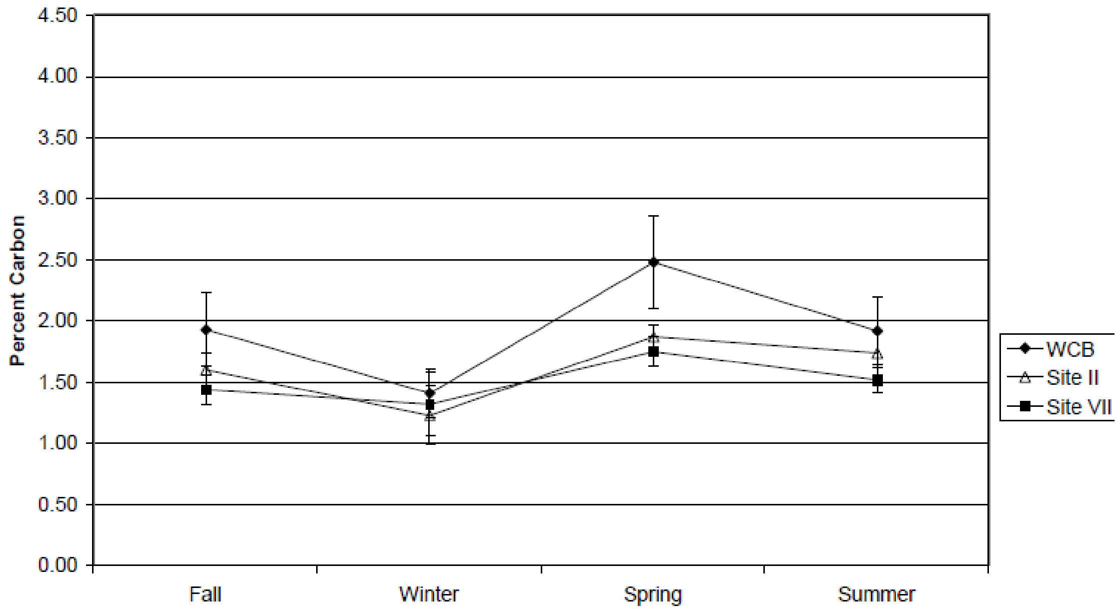

Figure 3. Soil carbon at 24-cm depth. Values are means +/- 95% confidence intervals.

Given the greater amount of standing biomass and subsequent leaf litterfall in the WCB site, it is not surprising that this site should contain a greater amount of soil carbon than the restoration sites. Still, the restoration sites are not deficient in soil carbon and indeed exhibit an increasing trend from the youngest site to the oldest site.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

These data were collected at the Rio Vista restoration site and at the WCB Merril's landing site which is directly adjacent and downstream.

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

This indicator information was input by G. Golet following review of relevant materials. Experts on this subject matter as it pertains to application on the Sacramento River are:

David L. Brown
Department of Geosciences, California State University, Chico, CA 95929

Dr. David M. Wood
Dept. of Biological Sciences, California State University, Chico, CA 95929
E-mail dmwood@csuchico.edu. Phone 530-898-6311.

13. What is the rationale for the desired rating?

The desired rating is based on the value observed at the remnant (reference) site.

Step 8

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

This parameter was studied on the Sacramento River by Brown and Wood (2002) as part of a larger project that asked whether the success of riparian forest restoration be measured in terms of functional ecosystem processes. Selected conclusions from their report follow:

In spite of the limited time period and time gaps in our sampling regime due to the fallow pre-restoration period, soil carbon nonetheless appears to be a sensitive indicator of riparian forest ecosystem development. Our data do exhibit a trend of increasing soil carbon with increasing forest development and do exhibit the expected seasonal pulse during the spring months. Data collection and analysis, although time-consuming, is much easier than for N mineralization. When combined with data on litterfall (e.g. this project) or standing biomass, and leaf decomposition timing and rate, additional soil carbon analyses will be valuable in documenting positive changes in ecosystem function during the maturation of restoration sites.

The results of monthly N-mineralization sampling showed no site differences between the three sites. Other, simpler ecosystem metrics such as soil carbon or soil bulk density appear to be more informative as far as ecosystem indicators of riparian forest restoration success.

Soil development monitoring should be continued albeit on a 3- to 5-year interval, emphasizing soil carbon and color changes.

Beyond the time frame of pedogenisis (decades to millennia), one of the challenges in monitoring soil development is selection of appropriate metrics. Clay weathering and accumulation, development of cemented layers, and development of structural peds may be useful, albeit on a time-scale beyond the current study. Color change may be useful on young soils such as the Entisols present at Site VII. In the fluvial deposition environment along the Sacramento River, changes (increases) in soil organic matter can contribute to color changes as soil development proceeds.

Previous agricultural practices will influence the quantity and characteristics of plant litter inputs to riparian soils prior to restoration. For example, almond orchards are “swept” nearly free of any litter while some prune orchards have grass planted between the trees for weed control. Such differences in initial conditions at the time of planting should be considered when evaluating this parameter at restoration sites.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Area of Giant Reed *(Arundo donax)*

Remnant riparian invaded by Arundo, west side of Sacramento River near the Capay Unit

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Introduction

Arundo donax (Arundo, giant reed or giant cane) is a perennial in the Grass family (*Poaceae*). It is a tall plant that resembles bamboo and can grow to 25 feet or more. Arundo stems or culms are erect or arching with hollow internodes. Branching occurs with stem growth in later years and when stems are cut or laid over. Its fleshy, creeping rootstocks form compact masses from which tough, fibrous roots emerge that penetrate deeply into the soil. New shoots arise from rhizomes in nearly any season but are most common in spring. Leaves are elongate, 1-2 inches wide and 1 foot long. The inflorescence, appearing in late summer to early fall, is a 1-2 foot panicle that stands above the foliage. Arundo prefers moist places such as ditches and stream and riverbanks but can also be found growing along road sides and waste places. It is a native of tropical Asia and the Mediterranean region and is now widely naturalized in warm temperate to tropical areas.

1 How specifically is the indicator defined?

This indicator is defined 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. Generally speaking, this area is 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. For further definition of the mapped area see Nelson et al. (2008).

Giant reed is fairly easy to spot on the 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. Arundo is mapped in the shape file; nv_riparian_07_z1083m as GR (Giant Reed).

2 What is the rationale for it being a meaningful indicator?

Arundo donax is a meaningful indicator because of its abundance and distribution in the riparian forest and is indicative of the degree to which native riparian species are displaced and its tendency to easily spread downstream and create monocultures.

Arundo donax is not listed on the Federal or State Noxious Weed List but is listed in the California Invasive Plant Inventory Database (Cal-IPC) with a "high" rating (high = This species has severe ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal and establishment. Most are widely distributed ecologically). It is also listed with the California Exotic Pest Plant Council (CalEPPC) with a rating List A-1 (List A: Most Invasive Wildland Pest Plants; documented as aggressive invaders that displace natives and disrupt natural habitats. Sublist List A-1: Widespread pests that are invasive in more than 3 Jepson regions.) In A Manual of California Vegetation second edition (2009), it is stated (under Management Considerations pg. 771-772) that *A. donax* is considered the greatest threat to southern California, and millions of dollars were spent in the past 10 years to remove *A. donax* from river systems and estuaries in the state. The Ventura Planning Division (2003) has developed an effective guide to restoration and management, including four different treatments of *A. donax*: (1) cut-stump, (2) foliar spray, (3) cut – apply herbicide to sprouts, and (4) cut canes – dig roots – use no herbicides.

Arundo has a rapid growth rate and under optimal conditions can grow from 1.5 to 4 inches per day. It spreads through asexual regeneration which occurs by both underground rhizomes and plant fragments. Stems can produce roots along the nodes of the stalk. Because Arundo propagates from both rhizomes and stems, it is aggressively invasive in disturbance situations such as flooding. Flood waters carry the rhizome or stems downstream where they can readily sprout to establish new plants. Arundo can establish and spread in areas of various successional stages and can be an early-successional pioneer species, and a late-successional dominant.

The non-native Arundo competes with and displaces native riparian vegetation. Once Arundo is established it can form monoculture stands that physically inhibit the growth of native species. There is no evidence that it provides either food or habitat for native wildlife species. The plant structure is unlike any native riparian plant and offers little useful cover or nest placement opportunities for birds. It has also been shown to lack canopy structure to provide shading of bank-edge river habitats.

Arundo is extremely flammable due to its large amount of biomass or dry material and will burn even when green. Native riparian microclimates may act as a fire barrier because of cooler air temperature and higher relative humidity than the adjacent uplands. If Arundo becomes abundant in the riparian system, it can effectively change riparian forests from a flood-defined to a fire-defined natural community, as has occurred on the Santa Ana River in Riverside County, California. (*Arundo donax* is estimated to transpire 56,200 acre-feet of water per year on the Santa Ana River, compared to an estimated 18,700 acre-feet that would be used by native vegetation.) Arundo rhizomes are likely to survive and sprout after fire kills the upper portion of the plant. If Arundo regenerates quickly after a fire it has the advantage to out-compete slower regenerating native riparian plants. Arundo may bring fire into areas not adapted to fire such as riparian habitats where native riparian vegetation may not be able to recover or out-compete the non-native.

Arundo donax was once planted as a bank stabilizer to help in erosion control. It is now considered detrimental to stream banks. When the rhizomatous root mass is undercut during floods, it can take soil with it leaving the bank prone to slumping and adding sedimentation to the river or stream. The long, fibrous, interconnecting root mats that wash downstream can form a framework for debris dams behind bridges, culverts, and other structures that lead to damage.

In addition to the negative side of Arundo, it does have a few commercial benefits. It has long been a source for the best reeds for clarinets, saxophones, bassoons, oboes and even bagpipes. Arundo is grown commercially in the south of France for the musical reed business. In South Australia, Arundo has been grown for bio-remediation purposes to clean up industrial contaminated areas and has also been tested and proved effective in eliminating salinity in soils that could then be used for agriculture. Biomass Gas and Electric (BG&E) considers it to be a great bioenergy crop with an energy content of 8,000 – 8,400 Btu per pound.

3 What references support its use as an indicator of ecosystem health? Provide citations.

Bell, G. 1997, Ecology And Management of *Arundo donax*, And Approaches To Riparian Habitat Restoration In Southern California
http://ceres.ca.gov/tadn/ecology_impacts/arundo_ecology.html

Biomass Gas & Electric: The Truth About Arundo Donax
http://www.biggreenenergy.com/default.aspx?tabid=4269

Cal-IPC. 2006. California Invasive Plant Inventory. Cal-IPC Publication 2006-02 California Invasive Plant Council: Berkeley, CA. Available: www.cal-ipc.org/

Dudley, T. 1998, Noxious Wildland Weeds Of California: *Arundo donax.* In: Noxious Wildland Weeds of California. C. Bossard, J. Randall, and M. Hoshovsky, eds. Available: http://www.ceres.ca.gov/tadn/arundoWW.html

Hickman, J. C. 1997, The Jepson Manual: Higher Plants of California. University of California Press, Berkeley, CA

Invasive and Exotic Plants Center for Invasive Species and Ecosystem Health http://www.invasive.org/species/weeds.cfm

McWilliams, John D. 2004. *Arundo donax*. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2009, December 16]. FEIS ABBREVIATION: ARUDON http://www.fs.fed.us/database/feis/plants/graminoid/arudon/all.html

Nelson, C., M. Carlson, R. Funes. 2008. Rapid Assessment Mapping in the Sacramento River Ecological Management Zone – Colusa to Red Bluff. Report to the CALFED Ecosystem Restoration Program, Sacramento, CA.

Sawyer, J.O., T. Keeler-Wolf, and J. M. Evens. 2009. A Manual of California Vegetation Second Edition. California Native Plant Society. Sacramento, CA.

Ventura County Arundo Task Force, 2003. Ventura River Arundo Removal Project http://www.arundotaskforce.org/Ventura%20River%20Arundo%20Removal%20Demo.html

4 Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

It is useful at multiple scales. Interpretations of the data are in part a function of the geographic range of the mapping effort.

5 What cutoffs are appropriate for poor, fair, good, and very good?

The status indicator ratings are defined as:

Very Good: < 30 acres
Good: 30 - 60 acres
Fair: 60 - 100 acres
Poor: > 100

6 How were the particular rating cutoffs selected?

Expert opinion and based on what previous mapping efforts have revealed.

7 Are the methods for calculating the indicator described in published documents or reports?

They are described in Nelson et al. (2008), as cited above.

8 What is the indicator value (and status)?

There are 1,830 *Arundo donax* polygons totaling 136 acres in the Red Bluff to Colusa reach in the Sacramento River riparian shape file. Thus the status is poor. *Arundo donax* is coded as GR (Giant Reed) in the classification table. Arundo was mapped as it was found on the 2007 true color aerial photographs. The air photos were flown at the nominal scale of RF=1:15,840 (1" = 1320') and scanned at 800 dots per inch (DPI). Individual plants are polygoned regardless of size. When it occurs in clumps or in close proximity to other Arundo plants, they are mapped together as one polygon. The smallest individual Arundo polygon is 0.000473 acre. The largest clumped polygon is 5.75 acres. Arundo is found throughout the Red Bluff to Colusa Sacramento River riparian area. The northern most *A. donax* polygon is found on Altube Island just south of the Red Bluff Diversion Dam. The southern most Arundo polygon is located in the northern portion of the Colusa SRA.

What is the month and year that this corresponds to?

The 2007 aerial photographs were on flown 26 June 2007. In total there were 298 aerial photos taken in the Red Bluff to Colusa reach, and 347 over the larger area. To amend coverage, ten additional aerial photographs scattered through-out the Colusa to Red Bluff area were flown on 17 June 2008.

9 What is the desired rating and by when should this be achieved?

The desired status is good. And this should be achieved by 2030. Attaining this will only be possible with a concerted effort to remove this species. A removal program should initially start upstream and focus on infested tributaries (e.g., Stony Creek).

10 Are there additional indicator values derived in the past that correspond to the scale of reporting (parcel, reach, etc)? When were the data collected that yielded these values? Describe the history of data collection.

A Sacramento River riparian map was completed in 2002 by the Geographical Information Center (GIC) using 1999 aerial photographs for the mainstem of the Sacramento River between Keswick Dam and Colusa. It was intended as an update to the 1991-1998 Sacramento River Riparian Mapping Project. It is located in the Sacramento River Conservation Area (SRCA) approximately between river mile 300 and river mile 129. The aerial photos were flown at the nominal scale of RF= 1:7200 (1:600). The

1999 riparian shape file is referenced as nv_riparian_99_z1083m. The 1999 riparian shape file also calls out GR (Giant Reed) polygons. In addition, the 1999 map was edited with the current 2007 riparian shape file to make sure all visible Arundo was captured in the shape file. There are 752 GR polygons (122 acres) mapped in the Red Bluff to Colusa portion of the 1999 shape file.

The earliest Sacramento River riparian shape file created by the GIC was began in 1991 and completed in 1998. It also includes GR. This map is referenced as nv_riparian_z1083m. The 1991 to 1998 map beginning at Keswick Dam and ending at Suisun Bay has 238 GR polygons. This map has not been edited to update Arundo. This map was developed to inventory and map riparian lands along the Sacramento River and its tributaries (see below). The study was confined to streams in the Sacramento Valley. The mapping effort began in 1991 and ended in 1998 with color infrared aerial photography.

The Department of Water Resources, Northern District has available on their website at Cal Atlas (http://www.atlas.ca.gov), georeferenced, mosaiced images of the Sacramento River Maps compiled by the U.S. Army Corps of Engineers for the years and areas:
1909 - Chico Landing to Colusa,
1923 (ca.) - Red Bluff to Chico Landing, and
1938 - Battle Creek confluence to Llano Seco (GIC has downloaded from FTP site).
1958 – Colusa County with portions of Glenn County.

Mapping of the mainstem Sacramento River:
2007 Sacramento River riparian shape file: Aerial photos were flown 6-26-07 with amended photos flown 6-17-08. Field work consisting of Rapid Assessments (RA) and field verification was conducted through the summer and fall of 2008. The riparian map shape file was completed in 2008 with a final edited version in 2009.

1999 Sacramento River riparian shape file: Aerial photos were flown May 21, 1999, field work was limited to several initial field visits and the riparian shape file was created in 2001 to 2002.

1991 to 1998 shape file, the Sacramento River riparian portion contains the photos for the years and locations 1993 to 1996:
Tehama County, 1993, nominal scale RF=1:12000.
Butte County, Glenn County side of Sacramento River, 1994, nominal scale RF=1:12000.
Sacramento River mainstem-Butte County line to American River, 1996, nominal scale RF=1:12000
Tisdale Weir, 1996, nominal scale RF=1:12000.
Sutter Bypass, Butte Slough, 1996, nominal scale RF=1:12000.
Other images for the tributaries are also a part of the 1991 to 1998 Sacramento River Riparian mapping project.

Mapping of the tributaries of the Sacramento River (part of the 1991 to 1998 shape file):

Although outside of the SRMAP project area, additional nearby mapping has taken place:
Lower Stony Creek to Black butte Dam, 1996, nominal scale RF=1:12000,
Lower Butte Creek from Butte County line, to Butte Sink, 1996, nominal scale RF=1:12000,
Feather River from Verona to Butte County line and Yuba River, 1996, nominal scale RF=1:12000
Feather River from Butte County line to Oroville, 1997, nominal scale RF=1:1200.
Bear River – Feather River to Camp Far West Reservoir, 1996, nominal scale RF=1:12000,
American River – American River to Folsom Lake, 1996, nominal scale RF=1:12000,
Cache Creek – Cache Creek from Capay Valley, 1996, nominal scale RF=1:12000,
Putah Creek – Putah Creek from Montecello Dam to Yolo Bypass, 1998, nominal scale RF =1:12000.

11 Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Data for the 2007 shape file was collected from Keswick Dam to Verona and includes; initial field visits, rapid Assessments, field verification and edited shape files. However the data analyzed and presented here are for a subset of the area (Red Bluff to Colusa).

12 What is the source of the current indicator data? Who is the contact person? Provide contact info.

The 2007 edited shape file was created at the GIC in Chico, CA.

Data for the 1999 shape file from Keswick to below Verona was created at the GIC in Chico, CA.

Data for the 1991 – 1998 shape file from Keswick to the Delta (including tributaries in the Sacramento Valley) was created at the GIC in Chico, CA.

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13 What is the rational for the desired rating?

The desired rating was selected based upon the perceived importance of this indicator in influencing Sacramento River natural resources, and with consideration of what may be possible with a concerted restoration effort.

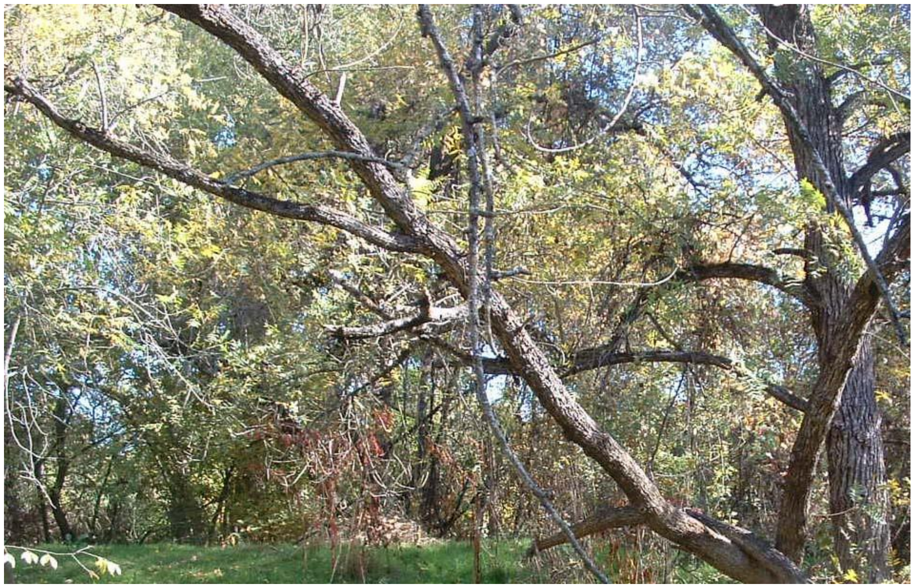
14 Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc.)

Arundo donax is visually difficult to see on the aerial photographs when it is under a tree a taller shrub canopy. When small patches of the mint green color signature for Arundo is seen through the canopy, it would be polygoned to the dominant classification of the tree or shrub canopy. In these instances, where Arundo is hidden or omitted, it is probable that a lower count for GR is generated than what is actually present in the riparian vegetation of the Sacramento River.

At times, aerial photos can be difficult to read making vegetation signatures hard to interpret. A few examples that may cause this are glare, shadows, very dark or very light photo colors, or distortion on the edges when there is inadequate overlap from photo to photo. When photos are encountered with interpretation difficulties, it has been helpful to look at other sources (of same or similar year). Examples of other sources include but are not limited to Google Earth, Live Search Map and 2005 NAIP Imagery.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Area of Black Walnut *(Juglans hindsii x)*



West of Chico off River Road

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Introduction
The naturalized *Juglans hindsii x* (Hinds x), is a deciduous tree in the *Juglandaceae* (walnut) family that is found throughout the riparian vegetation on the mainstem of the Sacramento River and its tributaries. It is found as far north as Redding, CA (above Caldwell Park) and continues south to Verona, CA in the riparian of the Sacramento River Ecological Management Zone. Hinds x is a hybrid of the native *Juglans hindsii* (Hinds walnut) 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.

A brief overview of the two native *Juglans* species in California
The two native black walnuts in California have been named in two ways. As noted by Hickman, 1996 in The Jepson Manual: Higher Plants of California, there is only one *Juglans* species, *Juglans californica* with two varieties; *J. californica* var. *californica* and *J. californica* var. *hindsii* (treatment by Dieter H. Wilken in Hickman 1993). A 2007 genetic study by Aradhya et al. affirmed that distance between *J. californica* and *J. hindsii* is not only geographic, but also genetic, showing the two species as distinct from each other. In contrast, according to the sixth edition, 2001 of The California Native Plant Society (CNPS) Inventory of Rare And Endangered Plants of California (among other authorities) treats these two taxa as distinct species: *Juglans californica* and *Juglans hindsii*. This document follows the latter treatment.

Juglans californica (California black walnut or Southern California black walnut), is limited to the Santa Clarita River drainage in the vicinity of Sulphur Mountain, small stands in the Simi Hills and Santa Susana Mountains, the north slope of the Santa Monica Mountains, and the San Jose, Puente, and Chino Hills in California. CNPS ranks it as List 4.2 (List 4: Limited distribution (Watch List), 0.2: Fairly endangered in California). The state rank is S3.2 (S3: 21-80 occurrences, or 3,000-10,000 individual, or 10,000-50,000 acres). The global rank is G3 (same as S3).

Juglans hindsii (Hinds walnut or Northern California black walnut) was collected by botanist Richard Brinsley Hinds, while traveling up the Sacramento River from San Francisco on the British ship HMS Sulphur during the exploration of 1836-1842. The native Hinds walnut is now believed to be limited to a few areas in California and Jackson County in Oregon. CNPS lists it as List 1B.1 (Rare, threatened, or endangered in California and elsewhere). Its state rank is S1.1 (Less than 6 occurrences OR less than 1,000 individuals OR less than 2,000 acres) and the global ranking is G1 (Less than 6 occurrences OR less than 1,000 individuals OR less than 2,000 acres).

Black walnut hybrids

Persian (English) walnuts have been grown commercially in California since the 1850's. Luther Burbank's "Paradox" hybrid of Persian and Hinds walnut (*J. regia x J. hindsii*) was developed for high nut production but proved to have poor nut yields. It grew and matured in 15 years instead of 50 to 60 years, had strong wood and proved to be more resistant to soil born pests and diseases than the Persian walnut. It has become the choice for rootstock in over 95% of Persian walnut orchards. In 1997 a study by the Department of Plant Pathology, UC Davis on Paradox rootstock seedlings described as Northern California black (Hinds) x Persian walnut hybrids, suggests morphological and molecular evidence obtained by the Walnut Improvement Program (WIP) that Paradox hybrids are quite diverse genetically. And, several black walnut species, such as southern California black walnut and Eastern black (*J. nigra*), may be serving as maternal parents of commercial Paradox rootstock seedlings.

In the 1800s many settlers in the Sacramento Valley planted the Eastern black walnut for its lumber, fire wood, nut and shade values. John Bidwell was an early proponent of *J. nigra* and planted them throughout Chico, California and sold them to Northern California clients from his nursery. In about 1888 Burbank crossed *J. nigra* and *J. hindsii* and called the resulting hybrid "Royal" walnut. Royal begins to bear seed by age 5 and produces exceptionally high yields with large nuts. The Eastern black walnuts and hybrids have become widely naturalized in riparian habitats and along the streets of many Central Valley towns in northern California.

The Hinds black walnut hybrids or crosses have naturalized in the riparian areas of the Sacramento River and are likely to be hybrids of the eastern black walnut and Hinds walnut but may also include crosses and back crosses of Persian walnut, and Southern California walnut and possibly *J. major* (Arizona walnut).

1 How specifically is the indicator defined?

This indicator is defined 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. Generally speaking, this area is between Colusa and Red Bluff along the mainstem of the Sacramento River. The mapped area extends outward from the river to include most of the current riparian zone. For further definition of the mapped area see Nelson et al. (2008).

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*). All *J. hindsii* hybrids are mapped in the shape file; nv_riparian_07_z1083m as BW (Black Walnut).

2 What is the rationale for it being a meaningful indicator?

The naturalized *Juglans hindsii x* is a meaningful indicator because its abundance and distribution in the riparian forest is indicative of the degree to which certain native riparian species are displaced. There is particular concern over the displacement of the native Valley oak (*Quercus lobata*) by this species which appears to colonize sites approximately 10 years after they become forested (Wood 2003).

Currently Hinds walnut x does not have a rating on the Federal or California Noxious Weed List, the Invasive, Noxious Weeds list or the California Invasive Plant Inventory published by the California Invasive Plant Council even though it is considered a non-native that is displacing native vegetation in riparian habitats. In A Manual of California Vegetation Second Edition (2009), it is stated (under Management Considerations pg.131) that the hybrid walnuts should be added to the list of invasive taxa when considering restoration of riparian forests in northern California. California Department of Parks and Recreation have already started removing Hinds x from state owned lands.

Most introduced species of black walnut can hybridize with Hinds walnut and Hinds x. All hybrids are likely fertile and can backcross to produce a variety of hybrids. Dispersal of the hybrid nut is by water or animals. Wind pollination from near-by commercial Persian walnut orchards is also a consideration for continued hybridizing and crosses of Hinds x. Also when Persian walnut orchards are abandoned, the hearty rootstock may begin to sprout, and if left to mature, may be another source to cross pollinate with the existing Hinds x hybrids in the riparian ecosystem.

All *Juglans* species are allelopathic to other plants. They produce a toxic substance called juglone. The mild toxin keeps most other vegetation from growing in the area to reduce competition for nutrients and moisture. Juglone is found in all parts of the walnut, but is most concentrated in the flower buds, nut hulls, and roots. The toxin can remain in the soil after trees are removed especially if the roots have not been removed.

3 What references support its use as an indicator of ecosystem health? Provide citations.

Anderson, E. N. 2002, Some preliminary observations on the California black walnut (*Juglans californica*) in Fremontia: A Journal of the California Native Plant Society.

Aradhya, M.A., D. Potter, F. Gao, and C. J. Simon, 2007, Tree Genetics and Genomes. Molecular Phylogeny of *Juglans* (*Juglandaceae*): A Biogeographic Perspective.

California Native Plant Society. 2001. CNPS Inventory- 6th Edition (D. Tibor, ed.) California Native Plant Society. Sacramento, CA

Callahan, F. 2008, Hinds Walnut in Oregon
www.npsoregon.org/kalmiopsis/kalmiopsis15/callahan.pdf

Dempsey, J. 2003. *Juglans hindsii* (Northern California black walnut) and hybrids in wildlands of State Park Units in the upper Sacramento Valley. Draft Resource Management Analysis, Northern Buttes District, California Department of Parks and Recreation. Unpublished document.

Hickman, J. C. 1997, The Jepson Manual: Higher Plants of California. University of California Press, Berkeley, CA

Nelson, C., M. Carlson, R. Funes. 2008, Rapid Assessment Mapping in the Sacramento River Ecological Management Zone – Colusa to Red Bluff. Report to the CALFED Ecosystem Restoration Program, Sacramento, CA

Sawyer, J.O., T. Keeler-Wolf, and J. M. Evens. 2009. A Manual of California Vegetation Second Edition. California Native Plant Society. Sacramento, CA.

Hybridization between native and non-native plant species in the riparian ecosystem
http://zipcodezoo.com/Plants/J/Juglans_hindsii/

Strahan Jan; Regeneration of Riparian Forests of the Central Valley
http://www.escholarship.org/editions/view?docId=ft1c6003wp&chunk.id=d0e6668&toc.depth=1&toc.id=d0e6668&brand=eschol

USDA Agricultural Research Service; Walnut Rootstock Selection for Resistance to Phytophthora spp. http://www.ars.usda.gov/is/np/mba/april98/walnut.htm

Wood, D.M. 2003. The distribution and composition of woody species in riparian forests along the middle Sacramento River, CA. Report to the Nature Conservancy. Chico, CA.

4 Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

It is useful at multiple scales. Interpretations of the data are in part a function of the geographic range of the mapping effort.

5 What cutoffs are appropriate for poor, fair, good and very good?

The status indicator ratings are defined as:
Very Good: < 5,000 acres
Good: 500 - 1,000 acres
Fair: 1,000 - 2,000 acres
Poor: > 2,000

6 How were the particular rating cutoffs selected?

Expert opinion and based on what previous mapping efforts have revealed.

7 Are the methods for calculating the indicator described in published documents or reports?

They are described in Nelson et al. (2008) as cited above.

8 What is the current indicator value (and Status)?

There are 645 Hinds x polygons totaling 2,538 acres in the Red Bluff to Colusa reach in the Sacramento River riparian shape file. The status is poor. Hinds x is coded as BW (Black Walnut) in the classification table. Hinds x is mapped as it is found on the 2007 true color aerial photographs. The largest BW polygon is 81.94 acres. Hinds walnut x is found continuously throughout the Red Bluff to Colusa riparian shape file. The northern most polygon is found just below the Red Bluff Diversion Dam in the Lake Red Bluff RA and the southern most polygon is in the Colusa SRA.

What is the month and year that this corresponds to?

The 2007 aerial photographs were on flown 26 June 2007. In total there were 298 aerial photos taken in the Red Bluff to Colusa reach, and 347 over the larger area. To amend coverage, ten additional aerial photographs scattered through-out the Colusa to Red Bluff area were flown on 17 June 2008.

9 What is the desired rating and by when should this be achieved?

Fair by June 2020

10 Are there additional indicator values derived in the past that correspond to the scale of reporting (parcel, reach, etc)? When were the data collected that yielded these values? Describe the history of data collection.

A Sacramento River riparian map was completed in 2002 by the Geographical Information Center (GIC) using 1999 aerial photographs for the mainstem of the Sacramento River between Keswick Dam and Colusa. It was intended as an update to the 1991-1998 Sacramento River Riparian Mapping Project. It is located in the Sacramento River Conservation Area (SRCA) approximately between river mile 300 and river mile 129. The aerial photos were flown at the nominal scale of RF=1:7200 (1:600). The 1999 riparian shape file is referenced as nv_riparian_99_z1083m. The 1999 riparian shape file placed Black Walnut (BW) into a Mixed Riparian Hardwood (MRH) classification. In other words BW was not called out as a separate vegetation type. In March 2010, the 1999 riparian coverage was edited to separate out BW. The edits were focused in the Colusa to Red Bluff reach. Black walnut was delineated using the original 1999 aerial photographs. 453 polygons of black walnut were mapped totaling 226 acres in the Red Bluff to Colusa reach.

The earliest Sacramento River riparian shape file created by the GIC was begun in 1991 and completed in 1998. It also includes MRH and has not been edited to separate out black walnut. This riparian map is referenced as nv_riparian_z1083m. The map was developed to inventory and map riparian lands along the Sacramento River and its tributaries within the Sacramento Valley. This mapping effort used color infrared aerial photos that were flown in a series of flights beginning in the year 1991 and ending in 1998 with color infrared aerial photography. In 2009, restoration sites were edited in and include size class in the comment column in the table.

The Department of Water Resources, Northern District has available on their website at Cal Atlas (http://www.atlas.ca.gov), georeferenced, mosaiced images of the Sacramento River Maps compiled by the U.S. Army Corps of Engineers of the years and areas:
1909 - Chico Landing to Colusa,
1923 (ca.) - Red Bluff to Chico Landing, and
1938 - Battle Creek confluence to Llano Seco (GIC has downloaded from FTP site)
1958 – Colusa County with portions of Glenn County.

<u>Mapping of the mainstem Sacramento River:</u>
2007 Sacramento River riparian shape file: Aerial photos were flown June 26, 2007 with 10 additional photos flown 6-17-08 to amend coverage. The nominal scale RF = 1:5000. Field work consisting of Rapid Assessments (RA) and field verification was conducted through the summer and fall of 2008. The riparian map shape file was created throughout 2008 with a final edited version in 2009.

1999 Sacramento River riparian shape file: Aerial photos were flown May 21, 1999, field work was limited to several initial field visits and the riparian shape file was completed in 2002.

1991 to 1998 shape file, the Sacramento River riparian portion contains the photos for the years 1993 to 1996 and locations:
Tehama County, 1993, nominal scale RF=1:12000.
Butte County and Glenn County side of Sacramento River, 1994, nominal scale RF=1:12000.
Sacramento River mainstem from Butte County line to the American River, 1996, nominal scale RF=1:12000
Tisdale Weir, 1996, nominal scale RF=1:1200.
Sutter Bypass to Butte Slough, 1996, nominal scale RF=1:12000.
Other images for the tributaries are also a part of the 1991 to 1998 Sacrament River Riparian mapping project.

<u>Mapping of the tributaries of the Sacramento River (part of the 1991 to 1998 shape file):</u>
Although outside of the SRMAP project area, additional nearby mapping has taken place:
Lower Stony Creek to Black butte Dam, 1996, nominal scale RF=1:12000,
Lower Butte Creek from Butte County line, to Butte Sink, 1996, nominal scale RF=1:12000,
Feather River from Verona to Butte County line and Yuba River, 1996, nominal scale RF=1:12000,
Feather River to Highway 20 bridge, 1996, nominal scale RF=1:12000,
Bear River - Feather River confluence to Camp Far West Reservoir, 1996, nominal scale RF=1:12000,
American River – American River to Folsom Lake, 1996, nominal scale RF=1:12000,
Cache Creek – Cache Creek from Capay Valley to Yolo Bypass, 1998, nominal scale RF=1:12000,
Putah Creek – Putah Creek from Montecello Dam to Yolo Bypass, 1998, nominal scale RF=1:12000.

11 Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

> Data for the 2007 shape file was collected from Keswick Dam to Verona and includes; initial field visits, rapid Assessments, field verification and edited shape files. However the data analyzed and presented here are for a subset of the area (Red Bluff to Colusa).

12 What is the source of the current indicator data? Who is the contact person? Provide contact info.

> The 2007 edited shape file was created at the GIC in Chico, CA.
>
> Data for the 1999 shape file from Keswick to below Verona was created at the GIC in Chico, CA.

Data for the 1991 – 1998 shape file from Keswick to the Delta (including tributaries in the Sacramento Valley) was created at the GIC in Chico, CA.

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13 What is the rational for the desired rating?

The desired rating was selected based upon the perceived importance of this indicator in influencing Sacramento River natural resources, and with consideration of what may be possible with a concerted restoration effort.

14 Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc.)

Juglans hindsii x can be difficult to see on the aerial photographs when it is under a taller tree canopy. In these instances, if the taller tree type is dominant, it would be polygoned to reflect the taller tree type. On some aerial photos, *Juglans hindsii x* is not always clearly distinguishable from Valley Oak. These areas should be field checked if access is possible. In many areas, however, access is prohibited due to private property ownership, or physical access.

At times, aerial photos can be difficult to interpret making vegetation signatures challenging. A few examples that may cause this are glare, shadows, too dark or too light of photo color, or distortion on the edges when there is inadequate overlap from photo to photo. When photos are encountered that are difficult to interpret, it is sometimes useful to look at another source (of same or similar year). Examples of other sources include but are not limited to Google Earth, Live Search Map and 2005 NAIP Imagery.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Area of Himalayan Blackberry *(Rubus discolor)*

Himalayan blackberry thicket (foreground) at Hiatt Lake

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Introduction
Rubus discolor is a perennial, woody, shrub in the (*Rosaceae*) Rose Family. Common names are Himalayan blackberry, Himalaya berry, or Armenian blackberry. The evergreen sprawling shrub can grow up to 10 feet tall. Leaves are compound with 3-5 leaflets. The stout canes (stems) are 5-angled and armed with many recurved, sharp, thorns. The white to pinkish flowers are in clusters of 5 to 20 and bloom from late May to July. The edible fruits are black, aggregates of drupelets about 1 inch long and usually ripen later than the native blackberry (*R. ursinus*). Himalayan blackberry is an aggressive, non-native that grows in riparian habitats and disturbed sites throughout the northwest.

1 How specifically is the indicator defined?

This indicator is defined 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. Generally speaking, this area is 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. For further definition of the mapped area see Nelson et al. (2008).

Rubus 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.

2 What is the rationale for it being a meaningful indicator?

The naturalized *Rubus discolor* is a meaningful indicator because its abundance and distribution in the riparian forest is indicative of the degree to which certain native riparian species are displaced.

Rubus discolor is not rated on the Federal or California Noxious Weed List or the Invasive and Noxious Weeds list. It is listed with a “high” rating in the California Invasive Plant Inventory published by the California Invasive Plant Council.

Rubus discolor (synonyms: *R. armeniacus* and *R. procerus*) is native to western Europe. According to the California Invasive Plant Council, there is no botanical evidence that it is native to the Himalayan region. It was first introduced to North America in 1885 by Luther Burbank as a cultivar. (It is reported that Burbank obtained his first plants in India and believed them to be of Asian origin). After its release to gardeners, it quickly spread to wildlands on the West Coast and later to other parts of the United States. It has also escaped to Hawaii, parts of Europe, Australia, New Zealand and possibly South America.

Rubus discolor seeds heavily, and the seeds are dispersed by mammals and birds. Seeds can also be spread long distances by streams and rivers. Seeds in the ground remain viable for several years and seedlings commonly appear after fire or other disturbances that expose the soil to sunlight. Once seedlings become established, most reproduction is vegetative. Plants reproduce by sprouts from rhizomes and by layering (rooting) when canes come in contact with the ground. Primocanes, develop the first year from buds at or below the ground surface. They do not bloom during the first year in which they make the most of their growth. Primocanes can root when the tips touch the soil. Floricanes develop in the axils of the primocanes and bloom and fruit in the second and sometimes third year and then die. The dead canes provide a supporting structure for live canes to sprawl over, ultimately forming impenetrable thickets. Individual root crowns live about

7.5 years. By suckering from rhizomes and layering, Himalayan blackberry plants can endure almost indefinitely. Horticulture propagation is by sowing seed, digging up and replanting suckers, and root cuttings.

Rubus discolor commonly occurs as an early seral species in relatively open disturbed areas. Himalayan blackberry grows rapidly in favorable (sunny) conditions, spreading 20 to 50 feet in a growing season and having canes as long as 22 feet. The canes grow more upright at first then cascade onto surrounding vegetation, shading out other shrubs and small trees.

The *Rubus discolor* thickets create dense shade, reducing native species diversity in the area. In addition, the tangled mass of thorny stems, block access to humans, livestock, equipment, and vehicles to pastures and waterways.

The dense Himalayan blackberry thickets are a desirable source of food and shelter for rats. Vigorously growing thickets develop layers of dead canes and leaves at a point where the supporting canes cross. As the thicket matures, the layers of dead canes coalesce to create a single dense, thick mass. These accumulations or mid-layers of canes and leaves provide ideal nesting sites for rats where they are well protected from predators and adverse weather.

The dense thickets of mature brambles with dead canes and litter buildup pose a potential fire hazard. Blackberries are well adapted to invade recently burned sites. An abundance of seeds readily germinate after fire and below ground regenerative structures may also sprout. Once the blackberries start to establish, vigorous growth gives them the ability to out-compete native riparian vegetation in burned or disturbed areas.

Himalayan blackberry is one of the host plants for Pierce's disease which affects the viticulture industry. Pierce's disease is caused by *Xylella fastidiosa* bacteria, a lethal disease of grapevines, and is spread by insects. Riparian habitat near vineyards contains plants that are feeding and breeding hosts for the blue-green sharpshooter (*Graphocephala atropunctata*), the most efficient vector of Pierce's disease.

Rubus discolor does have some wildlife benefits. Fruits are highly palatable to many birds and mammals. Thickets of blackberry form suitable nesting sites for many species of birds. Mammals, such as rabbit, squirrel and beaver use blackberry thickets as cover or resting sites.

3 What references support its use as an indicator of ecosystem health? Provide citations.

The Association of the Roof Rat with Himalayan Blackberry and Algerian Ivy in CA
Val J. Dutson, California Health Department, Berkeley, CA
http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1009&context=vpc6

California Invasive Plant Inventory Database
http://www.cal-ipc.org/ip/inventory/weedlist.php

GLOBAL INVASIVE SPECIES DATABASE Rubus discolor
http://www.invasivespecies.net/database/species/ecology.asp?si=994&fr=1&sts=&lang=EN

Hickman, J. C., The Jepson Manual: Higher Plants of California. University of California Press, Berkeley, CA

Nelson, C., M. Carlson, and R. Funes. 2008. Rapid Assessment Mapping in the Sacramento River Ecological Management Zone – Colusa to Red Bluff. Report to the CALFED Ecosystem Restoration Program, Sacramento, CA.

Sawyer, J.O., T. Keeler-Wolf, and J. M. Evens. 2009. A Manual of California Vegetation Second Edition. California Native Plant Society. Sacramento, CA.

Significance of Riparian Plants in the Epidemiology of Pierce's Disease
http://files.piercesdisease.org/proceedings/2004/2004_18-21.pdf

Weihe & Nees, *Rubus discolor*
http://www.fs.fed.us/global/iitf/pdf/shrubs/Rubus%20discolor.pdf

4 Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

> It is useful at multiple scales. Interpretations of the data are in part a function of the geographic range of the mapping effort.

5 What cutoffs are appropriate for poor, fair, good and very good?

The status indicator ratings are defined as:
Very Good: < 50 acres
Good: 50 - 250 acres
Fair: 250 - 500 acres
Poor: > 500

6 How were the particular rating cutoffs selected?

Expert opinion and based on what previous mapping efforts have revealed.

7 Are the methods for calculating the indicator described in published documents or reports?

They are described in Nelson et al. (2008), as sited above.

8 What is the current indicator value (and status)?

There are 250 *Rubus discolor* polygons totaling 310 acres in the Red Bluff to Colusa reach in the Sacramento River riparian shape file. The corresponding condition is "fair". *Rubus discolor* is coded as BS (Blackberry Scrub) in the classification table. *R. discolor* is mapped as it is found on the 2007 true color aerial photographs. The smallest individual polygon is 0.06 acre. The largest polygon is 14.27 acres. *R. discolor* is found throughout the Red Bluff to Colusa riparian shape file. The northern most polygon is located south of the Red Bluff Diversion Dam just north of Salt Creek. The farthest south polygon is across from Cobb's Bend in the Colusa area.

What is the month and year that this corresponds to?

The 2007 aerial photographs were on flown 26 June 2007. In total there were 298 aerial photos taken in the Red Bluff to Colusa reach, and 347 over the larger area. To amend coverage, ten additional aerial photographs scattered through-out the Colusa to Red Bluff area were flown on 17 June 2008.

9 What is the desired rating and by when should this be achieved?

"Good" by June 2020.

10 Are there additional indicator values derived in the past that correspond to the scale of reporting (parcel, reach, etc)? When were the data collected that yielded these values? Describe the history of data collection.

A Sacramento River riparian map was completed in 2002 by the Geographical Information Center (GIC) using 1999 aerial photographs for the mainstem of the Sacramento River between Keswick Dam and Colusa. It was intended as an update to the 1991-1998 Sacramento River Riparian Mapping Project. It is located in the Sacramento River Conservation Area (SRCA) approximately between river mile 300 and river mile 129. The aerial photos were flown at the nominal scale of RF=1:7200 (1:600). The 1999 riparian shape file is referenced as nv_riparian_99_z1083m. There are 453 Blackberry polygons in the 1999 shape file that covers the Colusa to Red Bluff reach totaling 226 acres.

The earliest Sacramento River riparian shape file created by the GIC was begun in 1991 and completed in 1998. It also includes BS (Blackberry Scrub). This map is referenced as nv_riparian_z1083m. The map has 378 polygons of Blackberry scrub totaling 32 acres. It begins at Keswick Dam and ends at Suisun Bay. This map was developed to inventory and map riparian lands along the Sacramento River and its tributaries (see below). The study was confined to streams in the Sacramento Valley. The mapping effort used color infrared aerial photos that were flown in a series of flights beginning in the year 1991 and ending in 1998.

The Department of Water Resources, Northern District has available on their website at Cal Atlas (http://www.atlas.ca.gov), georeferenced, mosaiced images of the Sacramento River Maps compiled by the U.S. Army Corps of Engineers of the years and areas:
1909 - Chico Landing to Colusa,
1923 (ca.) - Red Bluff to Chico Landing, and
1958 – Colusa County with portions of Glenn County.

1938 - Battle Creek confluence to Llano Seco (GIC has downloaded from FTP site).

Mapping of the mainstem Sacramento River:
2007 Sacramento River riparian shape file: Aerial photos were flown June 26, 2007 with 10 additional photos flown 6-17-08 to amend coverage. The nominal scale RF = 1:5000. Field work consisting of Rapid Assessments (RA) and field verification was conducted through the summer and fall of 2008. The riparian map shape file was created throughout 2008 with a final edited version in 2009.

1999 Sacramento River riparian shape file: Aerial photos were flown May 21, 1999, field work was limited to several initial field visits and the riparian shape file was completed in 2002.

1991 to 1998 shape file, the Sacramento River riparian portion contains the photos for the years 1993 to 1996 and locations:
Tehama County, 1993, nominal scale RF=1:12000.
Butte County and Glenn County side of Sacramento River, 1994, nominal scale RF=1:12000.
Sacramento River mainstem from Butte County line to the American River, 1996, nominal scale RF=1:12000
Tisdale Weir, 1996, nominal scale RF=1:1200.
Sutter Bypass to Butte Slough, 1996, nominal scale RF=1:12000.
Other images for the tributaries are also a part of the 1991 to 1998 Sacramento River Riparian mapping project.

Mapping of tributaries of the Sacramento River (part of the 1991 to 1998 shape file):
Although outside of the SRMAP project area, additional nearby mapping has taken place:
Lower Stony Creek to Black butte Dam, 1996, nominal scale RF=1:12000,
Lower Butte Creek from Butte County line, to Butte Sink, 1996, nominal scale RF=1:12000,
Feather River from Verona to Butte County line and Yuba River, 1996, nominal scale RF=1:12000,
Feather River to Highway 20 bridge, 1996, nominal scale RF=1:12000,
Bear River - Feather River confluence to Camp Far West Reservoir, 1996, nominal scale RF=1:12000,

American River – American River to Folsom Lake, 1996, nominal scale RF=1:12000,
Cache Creek – Cache Creek from Capay Valley to Yolo Bypass, 1998, nominal scale RF=1:12000,
Putah Creek – Putah Creek from Montecello Dam to Yolo Bypass, 1998, nominal scale RF=1:12000.

11 Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Data for the 2007 shape file was collected from Keswick Dam to Verona and includes; initial field visits, rapid Assessments, field verification and edited shape files. However the data analyzed and presented here are for a subset of the area (Red Bluff to Colusa).

12 What is the source of the current indicator data? Who is the contact person? Provide contact info.

The 2007 edited shape file was created at the GIC in Chico, CA.

Data for the 1999 shape file from Keswick to below Verona was created at the GIC in Chico, CA.

Data for the 1991 – 1998 shape file from Keswick to the Delta (including tributaries in the Sacramento Valley) was created at the GIC in Chico, CA.

Melinda Carlson
GIS Biologist
Geographical Information Center
Chico, California 95929-0327
mcarlson@gic.csuchico.edu
530 898-3212 office
530 898-6317 fax

13 What is the rational for the desired rating?

The desired rating was selected based upon the perceived importance of this indicator in influencing Sacramento River natural resources, and with consideration of what may be possible with a concerted restoration effort.

14 Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc.)

Rubus discolor is difficult to see on the aerial photographs when it is under tree canopy. At times tiny patches of the color signature for Blackberry might be detected through the canopy but in those instances it would likely be polygoned to reflect the dominant tree classification of the canopy.

At times, some aerial photos can be difficult to read making vegetation signatures hard to interpret. A few examples that may cause this are glare, shadows, too dark or too light of photo color, or distortion on the edges when there is inadequate overlap from photo to photo. When photos are encountered that are difficult to interpret, it is helpful to look at another source (of same or similar year). Examples of sources include but are not limited to Google Earth, Live Search Map and 2005 NAIP Imagery.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Basal Area of Woody Species

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   Basal Area is defined as the total cross-sectional area of woody species. The diameter of all stems in plots of size 20 x 30 m are measured at 1.5 m ("breast height) above the ground (dbh) and then diameters are converted to an area (m^2) basis. Here, 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 here includes all tree species as well as shrubs with woody stems such as willows, elderberry, and coyote brush. Shrubs were 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.

2. What is the rationale for it being a meaningful indicator?

   Basal area is an absolute measure of forest structure, and is useful because it generally is proportional to foliage coverage (Barbour, M.G. et al. 1999 Terrestrial Plant Ecology, Addison Wesley Longman). 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. Low values of basal area in restoration sites with no upward trend over time would indicate that forest development is poor, whereas an upward trend towards that of reference conditions indicates that forest development is occurring. 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, K. 1961. Riparian forests of the Sacramento Valley, California. Annals of the Association of American Geographers 51: 294-315).

3. What references support its use? Provide citations.

   Bailey J.D. and W.W. Covington. 2002. Evaluating ponderosa pine regeneration rates following ecological restoration treatments in northern Arizona, USA. Forest Ecology and Management 155: 271-278.

   Barbour, M.G. et al. 1999 Terrestrial Plant Ecology, Addison Wesley Longman

Minore, D. and H.G. Weatherly. 1994. Riparian trees, shrubs, and forest regeneration in the coastal mountains of Oregon. New Forests 8: 249-263.

Pabst, R.J. and T.A. Spies.1999. Structure and composition of unmanaged riparian forests in the coastal mountains of Oregon, U.S.A**.** Canadian Journal of Forest Research 29: 1557-1573.

Thompson, K. 1961. Riparian forests of the Sacramento Valley, California. Annals of the Association of American Geographers 51: 294-315

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   Basal area is most useful at the site and whole-river levels. It can be used to compare forest development in sites of similar age with different planting approaches or locations and with reference forests. Average across sites it is useful to characterize restoration success in general in this system.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

Ratings: >25 m^2/ha very good; 20-25 m^2/ha good; 10-20 m^2/ha fair; <10 m^2/ha poor.

6. How were the particular rating cutoffs selected?

Rating cutoffs were based on remnant forest data collected by Wood in 25 plots at 11 reference sites, all between Red Bluff and Colusa. Remnant forest sites (number of plots in parentheses) are Chico Landing (n=2), Pine Creek East (n=5), Shaw (n=2), Capay (n=3), Deadman's Reach (n=1), Jacinto (n=4), Phelan Island (n=1), Sul Norte (n=2), Rio Vista (n=2), Princeton Ferry (n=1), Flynn (n=2).

Mean of all remnant forest plots = 28.3 m^2/ha (range: 8.3 to 67.2), and median =25.3. The value for median and above was selected as "very good" and the remaining values were scaled down from there. Only one remnant forest site had a basal area <10 m^2/ha.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations.

   Methods for collecting basal area are standardized in forest ecology and can be found in the journal articles listed above as well as textbooks such as Barbour et al. 1999.

Barbour, M.G. et al. 1999 Terrestrial Plant Ecology, Addison Wesley Longman

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to?

Restored sites had a mean value = 12.7 m^2/ha as of August 2008. This is an increase from a mean = 6.5 m^2/ha for these same (permanent) plots in August 2003.

9. What is the desired rating and by when should this be achieved?

Desired mean basal area for restoration sites = 28.0 m^2/ha by August 2017, this value being the mean value for measured remnant forests. By this date most plots in the database used for this analysis will be 25 years old.

Step 7.

10. Are there additional indicator values that correspond to the scale of reporting (parcel, reach, etc.)?

At the restoration Site level there is substantial variability (see Table below). One restoration site (Phelan Island) already has a mean basal area above the desired rating of 28 m^2/ha. Forest development at other restoration sites such as River Vista is hindered by poor soils.

Restoration Site	# plots)	Mean Basal Area 2003	Mean Basal Area 2006	Mean Basal Area 2008
River Unit	25	9.4		16.8
Princeton Ferry	21	4.8		11.4
River Vista	27	3.1		6.9
Sam Slough	29	8.5		15.7
Shaw	5		12.2	
Phelan Island	3		29.3	
Flynn	3		13.9	
Kopta Slough	3		13.2	
Lohman	3		15.5	

11. When were the data collected that yielded these values? Describe the history of data collection.

    Data for restoration sites were collected in the year indicated. Date for reference sites (remnant forest) were collected in 2003, 2003, and 2006.

12. Where were the data collected? And over what geographic area is the indicator presumed to be representative of?

Both restored and remnant sites were collected from Sacramento River floodplain sites from Red Bluff to Colusa at the locations indicated. Restoration sites are listed above in the table in Step 7. Remnant sites are listed above in Step 5 and were sampled in 2002, 2003 and 2006.

13. What is the source of the info? Who is the contact person? Provide contact info.

    Data were analyzed by Dr. David M. Wood.
    Contact Dr. Wood at Dept. of Biological Sciences, California State University, Chico, CA 95929=0515.
    E-mail dmwood@csuchico.edu. Phone 530-898-6311.

14. What is the rationale for the desired rating?

    Mature forests with large-diameter trees (and thus a high basal area) are important because they have high foliage cover which creates required shade for understory plant species as well as foraging and nesting opportunities for wildlife (e.g cavity-nesting birds).

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Bat Species Richness

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   Bat species richness is the total number of different species of bats occurring in the area.

2. What is the rationale for it being a meaningful indicator?

   In recent years bats have received increased attention, reflecting a wider recognition of their role in ecosystem function (Wickramasinghe et al. 2003). Bats are appropriate as indicator species for river-riparian-floodplain restoration efforts. Like birds, bats have complex habitat needs. They are relatively abundant, a substantial fraction of the community can be monitored remotely, and they are responsive to changes in habitat quality. Also, they rely upon both terrestrial and aquatic habitats, with most of the species known to roost in trees, and forage in association with water.

   Because bats are volant, and even the smallest species can travel large distances, these organisms respond readily to changes in habitat quality, disappearing when habitat is lost, and recruiting readily when suitable habitat becomes available.

   Bats also lend themselves to landscape-scale inquiries. Although they are small and nocturnal, they tend to be ubiquitous, fairly abundant, and easy to detect. Acoustic surveys for red bats conducted in the Sacramento Valley revealed a more abundant and diverse bat assemblage along the river than was previously known (Pierson et al. 2000).

   Because all the species of bats use echolocation for navigation and foraging, they can be monitored acoustically using relatively inexpensive hardware that records and stores their calls, and can operate for a number of nights without human attendance. A single tool can be used to detect the majority of species.

   Additionally, bats are unique because the majority of the species assemblage is reliant on both the aquatic and adjacent terrestrial habitats, using the river for foraging and the forest for both roosting and foraging. Thus, they offer the potential to be ecological indicators for both aquatic and terrestrial restoration efforts.

3. What references support its use as an indicator of river health? Provide citations.

Golet, G.H., T. Gardali, C. Howell, J. Hunt, R. Luster, B. Rainey, M. Roberts, H. Swagerty, N. Williams. 2008. Wildlife Response to Restoration on the Sacramento River. San Francisco Estuary and Watershed Science. Vol. 6, Issue 2 (June), Article 1. http://repositories.cdlib.org/jmie/sfews/vol6/iss2/art1.

Pierson, E.D., W.E. Rainey, and C. Corben. 2000. Distribution and status of red bats, *Lasiurus blossevilli*, in California. Report to the Species Conservation and Recovery Program, Habitat Conservation Planning Branch, California Department of Fish and Game, Sacramento, CA.

Stillwater Sciences, W. Rainey, E. Pierson, and C. Corben. 2003. Sacramento River ecological indicators pilot study. Report to The Nature Conservancy.

Wickramasinghe, L.P., S. Harris, G. Jones, and N. Vaughan. 2003. Bat activity and species richness on organic and conventional farms: Impact of agricultural intensification. *Journal of Animal Ecology* 40:984-993.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   It is useful at multiple scales. Interpretations of the data are in part a function of the geographic range of the sampling sites.

<u>Step 5</u>

5. What cutoffs are appropriate for poor, fair, good and very good?

   <u>The status indicator ratings are defined as:</u>
   Very Good: >13 species
   Good: 10 - 13 species
   Fair: 8 - 10 species
   Poor: <8 species

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

   My informed guess (expert opinion?), based upon consideration of the data collected onsite by Rainey and others, presented in Stillwater Sciences et al. 2003.

   I should check in with Bill Rainey (UCB) to see if these rating guesses are appropriate to him. Table 1 p. 11 of the report lists 16 spp as potentially occurring (roosting and/or foraging) in the Sacramento River corridor.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

   Stillwater Sciences, W. Rainey, E. Pierson, and C. Corben. 2003. Sacramento River ecological indicators pilot study. Report to The Nature Conservancy.

   Golet, G.H., T. Gardali, C. Howell, J. Hunt, R. Luster, B. Rainey, M. Roberts, H. Swagerty, N. Williams. 2008. Wildlife Response to Restoration on the Sacramento River. San Francisco Estuary and Watershed Science. Vol. 6, Issue 2 (June), Article 1. http://repositories.cdlib.org/jmie/sfews/vol6/iss2/art1.

Step 6

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   10 species.

   A short-term investigation of bat response to restoration was conducted in fall 2002 (Stillwater Sciences et al. 2003). The investigation assessed bat activity at orchards, young and older restoration sites, and mature riparian remnant habitats with the aid of the Anabat detection system.

   We deployed three Anabat II ultrasound detectors at each site over extended periods. Two replicate orchard and mature riparian forest sites were sampled over one long period (September 12-13 through October 21-22, 2002), and young and older restoration sites were sampled over two short periods (September 12-14 and September 26-27).

   Some species (e.g., Pallid bat [*Antrozous pallidus*]) recorded at the older restoration site were not detected at the newer site. No red bat activity was recorded at the newly planted 2002 forest immediately after sunset, but both the 1991 forest and the adjacent mature forest showed a peak in activity immediately following sunset, suggesting that red bats were roosting in the latter two habitat types. Also, researchers were able to identify California myotis (*Myotis californicus*) emerging from near the tree canopy.

   Four special-status species (western mastiff bat [*Eumops perotis*], pallid bat, western red bat [*Lasiurus blossevilli*], and yuma myotis [*Myotis yumanensis*]) were detected through capture or by visual or acoustic record at riparian forest habitats in this study.

   Results are from a study conducted by Bill Rainey et al. in 2002. Results reported in Golet et al. 2008.

9. What is the desired rating and by when should this be achieved?

   Very good, by October 2020.

Step 7.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

    There are no comparable data. Relatively little was known about the bat assemblage in the Central Valley when this study was initiated (Pierson et al. 2000)

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    Sampling was done at La Barranca, Woodson Bridge SRA, Phelan Island, all on the Middle Sacramento River

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

13. This indicator information was input by G. Golet following review of relevant materials. Experts on this subject matter as it pertains to application on the Sacramento River are:

    William Rainey
    Associate Specialist
    Power Lab
    Office location: 4180 VLSB
    Email: rainey@berkeley.edu
    lab phone: 510 643-9294
    Mailing address:
    Department of Integrative Biology
    3060 Valley Life Sciences Bldg #3140
    Berkeley, CA 94720-3140

14. What is the rationale for the desired rating?

    Based upon what is known to occur in the valley from museum records and documented observations.

<u>Step 8</u>

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

The following is from the biological indicators report that focused in part on bats on the Sacramento River. For further details see the complete report.

Results of the Indicators project strongly indicate that despite limited riparian forest roosting habitat, bat foraging activity along the Sacramento River is substantial and locally greater than the investigators have observed anywhere else in California.

Overall levels bat activity (regardless of species identification) are positively correlated with age and structural complexity of terrestrial habitats. Our data are consistent with bat studies elsewhere in suggesting that vegetative structure is important in determining suitable roosting and foraging habitat.

Particular species may help track different stages of forest restoration, with the foliage-roosting bats (e.g., Lasiurus blossevillii and Lasiurus cinereus) as early responders, followed by non-colonial crevice roosting species (e.g., Myotis californicus as observed in a 1991 restoration plot). The colonial, crevice-roosting species, which require a larger roosting space (e.g., 25-kHz bats as observed at core sampling locations), would only be expected to roost in the forest once it had achieved considerable structural complexity and trees began to accumulate defects (bole cavities and partially detached bark).

Certain species may also help track seasonal patterns. Data obtained in an earlier study suggested that mature riparian forests along the Sacramento River were particularly important during the summer for breeding red bats, and that the river drainage served as a significant migratory corridor during the fall for hoary bats, and possibly other species (e.g., silver-haired bats). Night observations of large numbers of migrating hoary bats suggest that riparian forest remnants are important as diurnal refuges for migrants.

The results of the pilot study also indicate that existing technology for passive acoustic detection can be used reliably for long–term bat monitoring, although knowledgeable bat biologists and equipment technicians are needed to inspect systems periodically and download data, ensure that the systems remain operational, analyze the acoustic data, and interpret data patterns.

Visual surveys conducted in tandem with the passive monitoring helped confirm identifications of species and is a recommended component of these types of studies. Long-term monitoring must be designed with specific issues in mind, including how detectors should be placed to best answer specific monitoring questions and the maximum duration between field checks of the detectors and whether there might be habitats or seasons during which detection efficiency could be compromised.

One limitation of this study was that it was initiated after the maternity season had ended, and thus did not encompass the most critical phase in the life history cycle for most species found along the river. More intensive focal studies, conducted during the summer, and using other methods (radio-tracking and more extensive netting efforts) would be needed to document the roosting requirements of reproductive females and their young. More extensive sampling along the river for a longer period of time would likely elucidate seasonal patterns for a number of the species, and would be especially important for those using the river as a migration corridor.

The mainstem bat monitoring stations for all four study sites were similar in channel position. Given evidence of differences in invertebrate density with position in relation to meander bends (Chapter 4), sampling bat and flying insect activity, along with aquatic insect emergence at other shoreline positions and mid-channel in both the mainstem and backwaters would contribute to a more realistic picture of the spatial distribution of foraging activity, resource-tracking, and the scale of river to forest productivity transfer.

Stillwater Sciences, W. Rainey, E. Pierson, and C. Corben. 2003. Sacramento River ecological indicators pilot study. Report to The Nature Conservancy.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Importance Value of Woody Species

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   Importance Value for a species is defined as the sum of (relative density + relative basal area) with a theoretical maximum of 200. It is calculated for all woody species within a study plot. Plot values are averaged within and across sites. Within a plot of size 20 x 30 m, the diameter of all woody stems >2.5 cm dbh are measured at 1.5 m above the ground and then diameters are converted to an area basis (basal area). All tree species as well as shrubs with woody erect stems such as willows, elderberry, and coyote brush are counted. Shrubs are included because of their high planting density in this system, which contributes greatly to foliage cover especially in early-stage restoration sites, and because of their high wildlife value (e.g. willow and elderberry).

2. What is the rationale for it being a meaningful indicator?

   The Importance Value is widely used in forest ecology as a measure of forest structure and species composition because it combines different elements of relative species abundance. A high importance value may be due to a woody species being either very dense or very dominant (high basal area), or both. Because importance values are relativized within each plot, their values do not depend on overall cover, and thus changes in species composition can be tracked over time without being confounded by varying levels of growth among plots. 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, K. 1961. Riparian forests of the Sacramento Valley, California. Annals of the Association of American Geographers 51: 294-315).

   Importance Value may be calculated in different ways depending on the goal of the study. Often a third measure, relative frequency, is summed together with relative density and relative basal area. Relative frequency is the percentage of times that species occurs across all study plots. Sometimes relative frequency is summed with relative basal area, omitting density. Other studies use the method employed here, that of relative density plus relative dominance (basal area). Relative frequency is a useful measure of patchiness in natural systems, whereby a species may be common in a few portions of the study area but not others (a low relative frequency), or present at small densities consistently throughout the study site (high relative frequency). In a restoration context, however, relative frequency can be misleading—some species (e.g. arroyo willow) were planted in virtually every location, and thus its high frequency reflects a management decision, not a natural process of forest development. Thus, this study uses relative density and relative basal area to measure change over time. Frequency of occurrence will be listed separately.

3. What references support its use? Provide citations.

   Barkera, J.R., P. L. Ringold, and M. Bollman. 2002. Patterns of tree dominance in coniferous riparian forests. Forest Ecology and Management 166: 311-329.

   Pabst, R.J. and T.A. Spies.1999. Structure and composition of unmanaged riparian forests in the coastal mountains of Oregon, U.S.A**.** Canadian Journal of Forest Research 29: 1557-1573.

   DeWalt, S.J., S. K. Maliakala, and J. S. Denslow. 2003. Changes in vegetation structure and composition along a tropical forest chronosequence: implications for wildlife. Forest Ecology and Management 182: 139-151.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   Importance Value is most useful at the site and whole-river levels. It 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.

<u>Step 5</u>

5. What cutoffs are appropriate for poor, fair, good and very good?

Cutoffs are based on values for remnant forest found in the table in Step 6, as well as expert opinion from Dr. Wood.

	Cutoff IV's Based on Remnant Forest			
	Poor	Fair	Good	Very good
Arroyo willow	5	7	8	9
Black walnut	25	15	5	1
Blue elderberry	0	4	7	9
Box elder	0	15	30	46

Coyote brush	0	5	10	14
Fremont cottonwood	18	30	50	65
Goodding's black willow	3	7	12	16
Valley oak	13	25	50	75
Western sycamore	2	4	6	8

6. How were the particular rating cutoffs selected?

Rating cutoffs are based on reference data collected by Wood in 25 remnant forest plots at 11 reference sites, all sites between Red Bluff and Colusa. Remnant forest sites (number of plots in parentheses) are Chico Landing (n=2), Pine Creek East (n=5), Shaw (n=2), Capay (n=3), Deadman's Reach (n=1), Jacinto (n=4), Phelan Island (n=1), Sul Norte (n=2), Rio Vista (n=2), Princeton Ferry (n=1), Flynn (n=2). In general, the mean value for remnant forest for a species was selected for the "Very Good" cutoff and the remaining values were scaled down from there. For black walnut, an undesirable species, a value of "Very Good" was selected from the low value of existing restoration sites and then scaled upwards.

	Mean Remnant IV	Range (not including 0's)	Frequency of Occurrence (% of plots)
Arroyo willow	9.3	2-123	32
Black walnut	25	2-135	88
Blue elderberry	8.6	4-90	36
Box elder	46	9-123	88
Coyote brush	0	0	0
Fremont cottonwood	65	18-191	72
Goodding's black willow	16	3-93	52
Narrow leaf willow	4.9	2-57	28
Valley oak	13	1-186	20
Western sycamore	0	3-3	4

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations.

   Methods for calculating importance value are standardized in forest ecology and can be found in the journal articles listed above as well as textbooks such as Barbour et al. 1999.

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to?

	Mean Restoration Site* Importance Value 2003	Mean Restoration Site* Importance Value 2008
Arroyo willow	42.9	40.2
Black walnut	0.4	0.6
Blue elderberry	50.1	39.5
Box elder	9.3	13.7
Coyote brush	4.6	13.7
Fremont cottonwood	17.1	16.5
Goodding's black willow	6.8	7.3
Valley oak	58.1	65.2
Western sycamore	7	5.6

*Restoration sites are River Unit, Sam Slough, Princeton, and Rio Vista.
The same plots sampled in 2003 were re-sampled in 2008.

9. What is the desired rating and by when should this be achieved?

Desired mean importance values in the "Good" to "Very Good" should be achieved by August 2017. By this date most plots in the data used for this analysis will be 25 years old.

Step 7.

10. Are there additional indicator values that correspond to the scale of reporting (parcel, reach, etc.)?

Recommended cutoff values for species' importance value in Step 5 above are averages across the entire Red Bluff to Colusa reach. However, there is a wide range of variability among restoration sites as shown in the table below listing mean importance values for selected species in 2008. This variability mostly reflects planting design. For example, Sam Slough was planted as valley oak forest with little or no Fremont cottonwood; thus cottonwood's desirable value at this site is not expected to be >0.

	Mean Importance Value Restoration Site			
	River Unit	Rio Vista	Princeton	Sam Slough
Arroyo willow	71.6	20.6	77.9	1.3
Blue elderberry	10.3	139.3	0.3	5.03

Box elder	12.6	0	11.4	3.9
Fremont cottonwood	52.1	10.0	6.1	0
Goodding's black willow	24.8	0	2.3	0
Valley oak	7.0	10.4	72.6	142.3
Western sycamore	11.6	0	6.9	2.3

11. When were the data collected that yielded these values? Describe the history of data collection.

    Restoration site data were collected in the year indicated. Remnant forest data were collected in 2003, 2003, and 2006.

12. Where were the data collected? And over what geographic area is the indicator presumed to be representative of?

    Both restored and remnant sites were collected from Sacramento River floodplain sites from Red Bluff to Colusa. Restoration sites are given in the table above. Remnant sites are Chico Landing, Pine Creek East, Shaw, Capay, Deadman's Reach, Jacinto, Phelan Island, Sul Norte, Rio Vista, Princeton Ferry, Flynn.

13. What is the source of the info? Who is the contact person? Provide contact info.

    Data were analyzed by Dr. David M. Wood.
    Contact Dr. Wood at Dept. of Biological Sciences, California State University, Chico, CA 95929-0515.
    E-mail dmwood@csuchico.edu. Phone 530-898-6311.

14. What is the rationale for the desired rating?

    Pre-European riparian forests along the Sacramento River were characterized by large, old-growth trees of valley oak and Fremont cottonwood, and to a lesser extent Gooding's black willow, box elder and western sycamore (Thompson 1961). Desired ratings include high importance values for these species.

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Native Understory Species Frequency of Occurrence

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   Native understory species frequency of occurrence is the proportion of quadrats (1 m^2) in which at least one native species is present. It is the frequency of all individual plant species ≤1.5 m tall, including shrubs, vines, and woody seedlings that are ≤1.5 m tall.

   The values presented here are all for forest and savannah sites, although it could potentially be used for grassland sites.

2. What is the rationale for it being a meaningful indicator?

   Frequency of occurrence provides information on abundance and spatial dispersion of native understory plants that complements information on relative native cover.

3. What references support its use? Provide citations.

   Bratton, S. P., Hapeman, J. R., and A. R. Mast. 1994. The lower Susquehanna river gorge and floodplain (U.S.A.) as a riparian refugium for vernal, forest-floor herbs. Conservation Biology 8: 1069-1077.

   Czerepko, J. 2008. A long-term study of successional dynamics in the forest wetlands. Forest Ecology and Management 255: 630-642.

   Fonda, R. W. 1974. Forest succession in relation to river terrace development in Olympic National Park, Washington. Ecology 55: 927-942.

   Holl, K. D. 2002. Long-term vegetation recover on reclaimed coal and surface mines in the eastern USA. Journal of Applied Ecology 39: 960-970.

   Williams, C. E., Moriarity, W. J., Walters, G. L., and L. Hill. 1999. Influence of inundation potential and forest overstory on the ground-layer vegetation of Allegheny Plateau riparian forests. American Midland Naturalist 141: 323-338.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   Frequency of occurrence is useful for site-level comparisons. It can be used to compare sites of similar age with different planting approaches and with reference forests. It could be used to compare the relative success of restoration efforts across the landscape.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

   Indicator ratings: >85% very good; 70-85% good; 50-70% fair; <50% poor

6. How were the particular rating cutoffs selected?

Through consultation with Charles McClain and Karen Holl based on the data they collected at 10 reference and 35 restoration sites between Red Bluff and Colusa.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations.

   The methodology is currently being written up for publication by McClain and Holl. Frequency is a common vegetative indicator that is discussed in common vegetation texts such as Mueller-Dombois and Ellenberg 1974.[1]

   Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Method in Vegetation Ecology. Wiley and Sons, New York.

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to?

Restored sites 2007 – mean: 56.0%

9. What is the desired rating and by when should this be achieved?

   Improve to good at 90% of sites within 10 years.

Step 7.

10. Are there additional indicator values that correspond to the scale of reporting (parcel, reach, etc.)?

The following are the values for native understory frequency in restored sites in 2001, the same restored sites measured again in 2007, and in reference sites:

Restored sites 2001- mean: 48.1%, median: 47.1%, range: 21.4-94.9

Restored sites 2007 – mean: 56.0%, median: 55.3%, range: 19.0-100.0

Reference sites – mean: 87.2%, median: 88.9%, range: 82.5-97.5

SITE	Year Surveyed	Year Restored	Native frequency	Native frequency
Beehive Bend 2	2007	1999-2000	67.6	47.5
Flynn 2	2001	1996	48.1	50.4
Flynn 2	2007	1996	50.0	50.5
Flynn 4	2007	1998	34.0	47.9
Jacinto	2007	2001-2002	78.0	41.9
Kopta 2	2001	1989-1990	63.3	49.0
Kopta 2	2007	1989-1990	55.3	50.4

[1]Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Method in Vegetation Ecology. Wiley and Sons, New York.

Kopta 4.1	2001	1991-1992	47.1	50.7
Kopta 4.1	2007	1991-1992	69.8	46.5
Kopta 4.2	2001	1991-1992	36.8	48.9
Kopta 4.2	2007	1991-1992	44.7	50.4
La Barranca 2	2007	1997	22.9	42.5
La Barranca 3	2007	2001	56.7	49.9
La Barranca 4.1	2007	2003	58.1	49.9
Lohman	2001	1994	55.0	51.0
Lohman	2007	1994	75.0	44.2
McIntosh	2007	2001	9.5	29.7
MoulWeir	2007	2002	65.2	48.2
Ord Bend 6	2007	1998-1999	12.9	34.1
Packer 2.1	2007	2000	21.2	41.5
Packer 2.3	2007	2000	23.7	42.9
Phelan 2	2001	1996	61.5	49.6
Phelan 2	2007	1996	86.2	35.1
Phelan 5	2007	1999	67.5	47.4
Phelan 6.1	2007	2001	67.6	47.5
Phelan 6.2	2007	2001	56.4	50.2
Pine Creek East 2	2007	1998	59.5	49.4
Pine Creek East 3	2007	1999	47.9	50.5
Pine Creek West 3	2007	2003	61.1	49.4
Princeton East - Mixed Riparian Forest	2001	1993	76.5	43.1
Princeton East - Mixed Riparian Forest	2007	1993	59.4	49.9
Princeton East - Valley Oak Forest	2001	1993	32.0	47.6
Princeton East - Valley Oak Forest	2007	1993	18.2	39.5
Princeton South	2007	2002	58.3	50.4
Rio Vista 2	2001	1993	51.5	50.8
Rio Vista 2	2007	1993	32.5	47.4
Rio Vista 4	2001	1995	21.4	41.3
Rio Vista 4	2007	1995	19.0	39.5
Rio Vista 5	2001	1996	29.9	46.1
Rio Vista 5	2007	1996	37.1	48.7
River Unit	2001	1991	94.9	22.3
River Unit	2007	1991	86.8	34.3
Sam Slough 2	2001	1992	22.8	42.3
Sam Slough 2	2007	1992	55.9	50.1
Shaw - Cottonwood/Willow Forest	2001	1996	38.1	49.8
Shaw - Cottonwood/Willow Forest	2007	1996	100.0	0.0
Shaw - Mixed Riparian Forest	2001	1996	42.1	50.7
Shaw - Mixed Riparian Forest	2007	1996	50.0	51.0
Sul Norte - Mixed Riparian Forest	2007	2002	67.5	47.4
Thomas	2007	1999	62.1	49.4
Codora	2001	Ref	91.7	28.2
Flynn	2008	Ref	59.0	49.8
Kopta	2001	Ref	82.9	38.2
Merrill's Landing	2008	Ref	82.5	38.5
Moony	2001	Ref	84.0	37.4
Ord Bend	2008	Ref	97.0	17.4

Pine Creek East	2001	Ref	94.9	22.3
Pine Creek West	2008	Ref	86.2	35.1
River Unit	2001	Ref	96.7	18.3
Sul Norte	2008	Ref	97.5	15.8

11. When were the data collected that yielded these values? Describe the history of data collection.

    Data from 2001 were collected in 15 restored (1989-1996) and five remnant sites. Data from 2007 were collected in the same 15 restored sites surveyed in 2001, plus 20 additional sites restored 1997-2003. Data from 2008 were collected in five remnant sites that were different from the sites surveyed in 2001.

12. Where were the data collected? And over what geographic area is the indicator presumed to be representative of?

    Both restored and remnant sites were collected from Sacramento River floodplain sites from Red Bluff to Colusa

13. What is the source of the info? Who is the contact person? Provide contact info.

    Data are being analyzed by Charles McClain and Karen Holl. Contact: Karen D. Holl, Environmental Studies Department, University of California, Santa Cruz, CA 95064. E-mail kholl@ucsc.edu or cdmcclain@gmail.com.

14. What is the rationale for the desired rating?

Native understory species contribute to the forest biodiversity and function by mediating energy flow and nutrient cycling with high net primary productivity and rapidly decomposable leaf litter (Gilliam 2007). Faunal surveys, particularly birds, emphasize the importance of native understory species for improving habitat quality.

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

    Native understory species richness and relative cover are two other indicators that should be used in addition to frequency of occurrence.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Native Understory Species Richness

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   Native understory species richness is the number of native herbs, shrubs, and vines $\leq$1.5 m tall observed in quadrats (1 m^2) in the sites. It does not include tree species such as *Acer negundo* and *Quercus lobata* seedlings of which may be found in the understory.

   The values presented here are all for forest and savannah sites, although it could potentially be used for grassland sites.

2. What is the rationale for it being a meaningful indicator?

   Commonly used as a measure of species composition and ecosystem complexity. Useful for making comparisons with reference systems.

3. What references support its use? Provide citations.

Czerepko, J. 2008. A long-term study of successional dynamics in the forest wetlands. Forest Ecology and Management 255: 630-642.

de Souza, F. M. and J. L. F. Batista. 2004. Restoration of seasonal semideciduous forests in Brazil: influence of age and restoration design on forest structure. Forest Ecology and Management 191: 185-200.

Gilliam, F. S. 2007. The ecological significance of the herbaceous layer in temperate forest ecosystems. Bioscience 57: 845-858.

Holl, K. D. and E. E. Crone. 2004. Applicability of landscape and island biogeography theory to restoration of riparian understorey plants. Journal of Applied Ecology 41: 922-933.

Kamisako, M., Sannoh, K., and T. Kamitani. 2007. Does understory vegetation reflect the history of fluvial disturbance in a riparian forest? Ecological Research 22: 67-74.

Norman, M. A., Koch, J. M., Grant, C. D., Morald, T. M., and S. C. Ward. 2006. Vegetation succession after bauxite mining in Western Australia. Restoration Ecology 14: 278-288.

Økland, T., Rydgren, K., Økland, R. H., Storaunet, K. O., and J. Rolstad. 2003. Variation in environmental conditions, understorey species number, abundance and composition among natural and managed *Picea abies* forest stands. Forest Ecology and Management 177: 17-37.

Palmer, M. A., Bernhardt, E. S., Allan, J. D., Lake, P. S., Alexander, G., Brooks, S., Carr, J., Clayton, S., Dahm, Follstad Shah, J., Galat, D. L., Loss, S. G., Goodwin, P., Hart, D. D., Hassett, B., Jenkinson, R., Kondolf, G. M., Lave, R., Meyer, J. L., O'Donnell, T. K., Pagano, L., and E. Sudduth. 2005. Standards for ecologically successful river restoration. Journal of Applied Ecology 42: 208-217.

Pensa, M., Sellin, A., Luud, A., and I. Valgma. 2004. An analysis of vegetation restoration on opencast oil shale mines in Estonia. Restoration Ecology 12: 200-206.

Rayfield, B., Anand, M., and S. Laurence. 2005. Assessing simple versus complex restoration strategies for industrially disturbed forests. Restoration Ecology 13: 639-650.

Wassenaar, T. D., Ferreira, S. M., and R. J. van Aarde. 2007. Flaggin aberrant sites and assemblages in restoration projects. Restoration Ecology 15: 68-76.

Williams, C. E., Moriarity, W. J., Walters, G. L., and L. Hill. 1999. Influence of inundation potential and forest overstory on the ground-layer vegetation of Allegheny Plateau riparian forests. American Midland Naturalist 141: 323-338.

Woolsey, S., Capelli, F., Gonser, T., Hoehn, E., Hostmann, M., Junker, B., Paetzold, A., Roulier, C., Schweizer, S., Tiegs, S. D., Tockner, K., Weber, C., and A. Peter. 2007. A strategy to assess river restoration success. Freshwater Biology 52: 752-769.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   Native understory plant species richness can be a site-specific indicator for comparing sites, and it can be used 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. Species richness is a commonly used indicator in evaluating vegetation.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

   Site level: >10 very good; 8-10 good; 4-7 fair; <4 poor

6. How were the particular rating cutoffs selected?

Through consultation with Charles McClain and Karen Holl based on the data they collected at 10 reference and 35 restoration sites between Red Bluff and Colusa.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations.

   Holl and E. E. Crone. 2004. Applicability of landscape and island biogeography theory to restoration of riparian understorey plants. Journal of Applied Ecology 41: 922-933.

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to?

Restored sites 2007 - mean: 6.7

9. What is the desired rating and by when should this be achieved?

Very good within 10 years.

Step 7.

10. Are there additional indicator values that correspond to the scale of reporting (parcel, reach, etc.)?

The following are the values for native species richness in restored sites in 2001, the same restored sites measured again in 2007, and in reference sites:

Restored sites 2001- mean: 4.7, median: 5.0, range: 2-6

Restored sites 2007 - mean: 6.7, median: 6.0, range: 3-10

Reference sites - mean: 10.1, median: 10.5, range: 8-13

11. When were the data collected that yielded these values? Describe the history of data collection.

    Data from 2001 were collected in 15 restored (1989-1996) and five remnant sites. Data from 2007 were collected in the same 15 restored sites surveyed in 2001, plus 20 additional sites restored 1997-2003. Data from 2008 were collected in five remnant sites that were different from the sites surveyed in 2001.

    In May and June 2007, Charles McClain and Karen Holl resurveyed 15 restorations sites restored between 1989 and 1996 and previously surveyed in 2001 (Holl and Crone 2004) and also surveyed 25 additional sites restored 1997-2003. McClain and Holl also surveyed five remnant sites in June 2008.

12. Where were the data collected? And over what geographic area is the indicator presumed to be representative of?

    Both restored and remnant sites were collected from Sacramento River floodplain sites from Red Bluff to Colusa

13. What is the source of the data? Who is the contact person? Provide contact info.

    Contact: Karen D. Holl, Environmental Studies Department, University of California, Santa Cruz, CA 95064. E-mail kholl@ucsc.edu

14. What is the rationale for the desired rating?

    A goal of restoration should be to restore the full complement of species.

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

    Note that the values presented here are based on what was recorded in specified sampling quadrats, so it is lower than total native understory species richness in sites. A different sampling methodology could be used to collect native understory species richness but it needs to be systematic and sample a predefined area, given differences in detectability of species depending on the density of vegetation in a site. In other words, casual counts of species richness are not comparable unless sampling thoroughness is equal.

Special attention should be directed towards identifying native species with dispersal limitations, e.g. *Aristolochia californica* (California pipevine). Relative native cover and frequency of occurrence are two other related indicators that should be used in addition to native understory species richness.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Relative Native Understory Cover

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   Relative native understory cover is defined as percent native cover divided percent total cover (native + exotic + unknown species cover) measured at 1 m^2 quadrat level. It is the cover of all individual native plant species ≤1.5 m tall, including shrubs and vines that are ≤1.5 m tall.

   The values presented here are all for forest and savannah sites, although it could potentially be used for grassland sites.

2. What is the rationale for it being a meaningful indicator?

   Native understory species contribute to the forest biodiversity and function by mediating energy flow and nutrient cycling with high net primary productivity and rapidly decomposable leaf litter (Gilliam 2007[2]). A major focus of restoration in this system is to increase cover of native species.

   Relative native cover allows for comparisons across years and accounts for phenological differences, as absolute cover varies greatly depending on interannual rainfall and when during the growing season it is measured.

3. What references support its use? Provide citations.

   Bakker, J. P., Olff, H., Willems, J. H., and M. Zobel. 1996. Why do we need permanent plots in the study of long-term vegetation dynamics? Journal of Vegetation Science 7: 147-155.

   Cook, W. M., Yao, J., Foster, B. L., Holt, R. D., and L. B. Patrick. 2005. Secondary succession in an experimentally fragmented landscape: community patterns across space and time. Ecology 86: 1267-1279.

   Holl, K. D. 2002. Long-term vegetation recover on reclaimed coal and surface mines in the eastern USA. Journal of Applied Ecology 39: 960-970.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   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

[2]Gilliam, F. S. 2007. The ecological significance of the herbaceous layer in temperate forest ecosystems. BioScience 57: 845-858

forests. It could be used to compare the relative success of restoration efforts across the landscape.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

   Ratings: >65% very good; 45-65% good; 25-45% fair; <25% poor

6. How were the particular rating cutoffs selected?

Through consultation with Charles McClain and Karen Holl based on the data they collected at 10 reference and 35 restoration sites between Red Bluff and Colusa.

Note that a single widespread, native species *Galium aparine* can be quite dominant in this system. Therefore, it may also be useful to compare relative cover of all native species besides *Galium aparine* or to use relative native cover in combination with species richness. Appropriate ratings for relative native species cover excluding *Galium aparine* are: >45% very good; 25-45% good; 15-25% fair; <15% poor

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations.

   Methods for collecting cover data can be found in:

Holl, K. D. and E. E. Crone. 2004. Applicability of landscape and island biogeography theory to restoration of riparian understorey plants. Journal of Applied Ecology 41: 922-933.

McClain and Holl are in the process of preparing a manuscript on their work which will provide more detail.

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to?

Restored sites: mean: 32.3% as of May, 2007. The corresponding rating is “Fair”.

9. What is the desired rating and by when should this be achieved?

“Good” by 2020.

Step 7.

10. Are there additional indicator values that correspond to the scale of reporting (parcel, reach, etc.)?

The following are the values for relative native understory cover in restored sites in 2001, the same restored sites measured again in 2007, and in reference sites:

Restored sites 2001- mean: 20.7%, median: 22.0%, range: 2.5-61.3

Restored sites 2007 – mean: 32.3%, median: 24.5%, range: 4.3-79.8

Reference sites – mean: 65.1%, median: 61.9%, range: 45.1-87.9

For the 15 restored sites sampled in 2001 and 2007 the mean increase in relative native cover is 11.6% and the median increase is 3.6%. The range was a decrease of 12 to an increase of 62%. Values for all sites in all years are included below.

SITE	Year Surveyed	Year Restored	Relative native cover Mean	STD
Beehive Bend 2	2007	1999-2000	66.3	40.3
Flynn 2	2001	1996	8.8	19.6
Flynn 2	2007	1996	12.5	25.0
Flynn 4	2007	1998	16.7	31.5
Jacinto	2007	2001-2002	39.9	40.9
Kopta 2	2001	1989-1990	30.3	37.4
Kopta 2	2007	1989-1990	14.4	30.1
Kopta 4.1	2001	1991-1992	27.7	41.4
Kopta 4.1	2007	1991-1992	55.3	43.0
Kopta 4.2	2001	1991-1992	28.7	42.1
Kopta 4.2	2007	1991-1992	24.5	33.7
La Barranca 2	2007	1997	3.6	14.3
La Barranca 3	2007	2001	19.6	34.7
La Barranca 4.1	2007	2003	11.2	24.2
Lohman	2001	1994	35.9	43.5
Lohman	2007	1994	62.4	41.1
McIntosh	2007	2001	2.3	10.7
MoulWeir	2007	2002	35.5	40.3
Ord Bend 6	2007	1998-1999	6.9	25.3
Packer 2.1	2007	2000	5.0	17.7
Packer 2.3	2007	2000	0.3	0.9
Phelan 2	2001	1996	21.9	32.2
Phelan 2	2007	1996	67.7	39.5
Phelan 5	2007	1999	28.6	37.3
Phelan 6.1	2007	2001	27.2	36.3
Phelan 6.2	2007	2001	14.6	25.0
Pine Creek East 2	2007	1998	28.6	36.5
Pine Creek East 3	2007	1999	35.3	43.2
Pine Creek West 3	2007	2003	12.9	25.0
Princeton East - Mixed Riparian Forest	2001	1993	22.4	29.5
Princeton East - Mixed Riparian Forest	2007	1993	37.1	45.5
Princeton East - Valley Oak Forest	2001	1993	2.5	5.5
Princeton East - Valley Oak Forest	2007	1993	5.0	21.3
Princeton South	2007	2002	31.9	39.3
Rio Vista 2	2001	1993	25.7	35.0
Rio Vista 2	2007	1993	13.9	31.7
Rio Vista 4	2001	1995	8.1	23.8
Rio Vista 4	2007	1995	4.3	16.5
Rio Vista 5	2001	1996	10.5	27.0
Rio Vista 5	2007	1996	12.1	26.0

River Unit	2001		1991	61.3	38.6
River Unit	2007		1991	51.6	42.4
Sam Slough 2	2001		1992	3.3	12.0
Sam Slough 2	2007		1992	26.8	32.8
Shaw - Cottonwood/Willow Forest	2001		1996	17.7	32.8
Shaw - Cottonwood/Willow Forest	2007		1996	79.8	27.8
Shaw - Mixed Riparian Forest	2001		1996	5.6	11.7
Shaw - Mixed Riparian Forest	2007		1996	17.0	31.4
Sul Norte - Mixed Riparian Forest	2007		2002	34.1	40.5
Thomas	2007		1999	18.2	30.3
Codora	2001	Ref		88.0	29.0
Flynn	2008	Ref		45.7	43.9
Kopta	2001	Ref		53.9	38.6
Merrill's Landing	2008	Ref		48.1	41.4
Moony	2001	Ref		45.1	41.4
Ord Bend	2008	Ref		58.5	37.4
Pine Creek East	2001	Ref		76.4	34.3
Pine Creek West	2008	Ref		86.4	30.2
River Unit	2001	Ref		84.6	29.8
Sul Norte	2008	Ref		65.2	38.1

11. When were the data collected that yielded these values? Describe the history of data collection.

    Data from 2001 were collected in 15 restored (1989-1996) and five remnant sites. Data from 2007 were collected in the same 15 restored sites surveyed in 2001, plus 20 additional sites restored 1997-2003. Data from 2008 were collected in five remnant sites that were different from the sites surveyed in 2001.

    Understory plant cover data were collected in April-May 2001 and May-June 2007.

12. Where were the data collected? And over what geographic area is the indicator presumed to be representative of?

    Both restored and remnant sites were collected from Sacramento River floodplain sites from Red Bluff to Colusa

13. What is the source of the info? Who is the contact person? Provide contact info.

    Data are being analyzed by Charles McClain and Karen Holl. Contact: Karen D. Holl, Environmental Studies Department, University of California, Santa Cruz, CA 95064. E-mail kholl@ucsc.edu or cdmcclain@gmail.com.

14. What is the rationale for the desired rating?

    Karen said she has "no idea how to answer this. Perhaps that PRBO has suggested that native species are important to birds."

    I added this: If restoration sites can approach or even better remnant sites, then we will likely be reducing the spread of some problematic invasives, such as pepperweed and Johnson grass.

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

    Native understory species richness and frequency of occurrence are two other indicators that should be assessed in addition to relative native cover.

    It is important to note that there is huge variation among relative native cover at restored sites. It is also important to note that even the reference forests have some exotics so the target levels are set relative to what is reasonable for this system.

    We should probably have another indicator of cover of problematic invasives. Karen can do this, but I need tell her me what species to put on the list.

    Ideally we would be able to characterize the extent to which natives vs exotics dominate at different successional stages and in different terrestrial riparian habitat types (e.g. forest, savanna).

    Dave Wood's survey work may also be relevant to consider for this indicator. The extent to which native species dominate is largely a function of overstory cover. At the savannah sites exotics dominate and that isn’t changing much. Where there is native overstory forest cover there are generally more natives.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Stem Size Distribution
(Frequency of Various Woody Species with Stem Diameters > XX cm)

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   Stem Size Distribution is the frequency distribution of stem diameters of the major tree species in this system. 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 x 30 m. Species included here are Fremont cottonwood, valley oak, box elder, and Goodding's black willow. The size classes (in cm dbh) used for the frequency distribution are <5, 5-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, and >70.

2. What is the rationale for it being a meaningful indicator?

   Stem size distribution is useful because it directly tracks tree growth. The attainment of large trees in restoration sites is a goal of restoration. As restoration sites age, stem size distributions should shift towards a higher percentage of larger trees, approximating that found in reference (remnant) forests. A desirable endpoint of restoration in this system is to re-create forests with large trees (e.g. Fremont cottonwood and valley oak), simulating the conditions that existed prior to habitat alteration (e.g. Thompson, K. 1961. Riparian forests of the Sacramento Valley, California. Annals of the Association of American Geographers 51: 294-315). Large diameter trees have a high degree of canopy cover and leaf surface area to promote insect and bird populations, can yield coarse woody debris to the forest floor to provide cover for small mammals, reptiles and amphibians, and provide nest opportunities.

3. What references support its use? Provide citations.

   Bailey J.D. and W.W. Covington. 2002. Evaluating ponderosa pine regeneration rates following ecological restoration treatments in northern Arizona, USA. Forest Ecology and Management 155: 271-278.

   Barbour, M.G. et al. 1999 Terrestrial Plant Ecology, Addison Wesley Longman

   Minore, D. and H.G. Weatherly. 1994. Riparian trees, shrubs, and forest regeneration in the coastal mountains of Oregon. New Forests 8: 249-263.

   Pabst, R.J. and T.A. Spies.1999. Structure and composition of unmanaged riparian forests in the coastal mountains of Oregon, U.S.A. Canadian Journal of Forest Research 29: 1557-1573.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   Stem size distribution is most useful at the site and whole-river levels. They 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 they are useful to characterize restoration success in general in this system.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

The table below gives species-specific values for the "Very Good" category in all size classes. These values are obtained from reference (remnant) forest data.

Diameter at Breast Height (cm) for the "Very Good" category. Values Derived from Remnant Forest Sampling

	<5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	>70
Box elder	32%	34%	30%	3%	1%				
Fremont cottonwood	1%	0%	6%	19%	20%	21%	15%	6%	12%
Gooding's black willow	3%	11%	29%	32%	16%	8%	0%	0%	1%
Valley oak	20%	36%	33%	3%	8%				

For the remaining categories, a size class of 30-40 cm dbh is used (see table below). The Very Good category is the same as in the table above for all six species and is repeated below for clarity.

Rating Category Cutoff Values for Diameter at Breast Height (cm) in the 30-40 cm dbh Size Class

	Poor	Fair	Good	Very Good
Box elder	0%	0%	1%	1%
Fremont cottonwood	5%	10%	15%	20%
Gooding's black willow	4%	8%	12%	16%
Valley oak	2%	4%	6%	8%

6. How were the particular rating cutoffs selected?

Rating cutoffs were based on existing values in reference (remnant) forests. Remnant forest data were collected by Wood in 25 plots during 2002, 2003, and 2006 at 11 reference sites, all between Red Bluff and Colusa. Remnant forest sites (number of plots in parentheses) are Chico Landing (n=2), Pine Creek East (n=5), Shaw (n=2), Capay (n=3), Deadman’s Reach (n=1), Jacinto (n=4), Phelan Island (n=1), Sul Norte (n=2), Rio Vista (n=2), Princeton Ferry (n=1), Flynn (n=2). Restoration data were collected in 2008 at River Unit, Rio Vista, Sam Slough, and Princeton Ferry.

		Diameter at Breast Height (cm)								
	# stems	**<5**	**5-10**	**10-20**	**20-30**	**30-40**	**40-50**	**50-60**	**60-70**	**>70**
Arroyo willow REMNANT	113	46%	39%	14%	1%					
Arroyo willow RESTORED (2008)	1628	31%	44%	24%	1%					
Black walnut REMNANT	121	19%	17%	33%	18%	9%	2%	2%	1%	
Black walnut RESTORED (2008))	22	59%	27%	9%	0%	0%	5%	0%	0%	
Blue elderberry REMNANT	92	38%	37%	24%	1%					
Blue elderberry RESTORED (2008)	796	13%	43%	39%	5%					
Box elder REMNANT	428	32%	34%	30%	3%	1%				
Box elder RESTORED (2008))	607	48%	32%	16%	3%	0%				
Fremont cottonwood REMNANT	140	1%	0%	6%	19%	20%	21%	15%	6%	12%
Fremont cottonwood RESTORED (2008)	133	2%	2%	18%	26%	21%	27%	1%	2%	2%
Gooding's black willow REMNANT	75	3%	11%	29%	32%	16%	8%	0%	0%	1%
Gooding's black willow RESTORED (2008)	105	7%	12%	19%	35%	25%	2%	0%	0%	0%
Valley oak REMNANT	87	20%	36%	33%	3%	8%				
Valley oak RESTORED (2008)	2261	16%	33%	38%	11%	1%				

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations.

   Methods for measuring diameter at breast height are standardized in forest ecology and can be found in the journal articles listed above as well as textbooks such as Barbour, M.G. et al. 1999 Terrestrial Plant Ecology, Addison Wesley Longman.

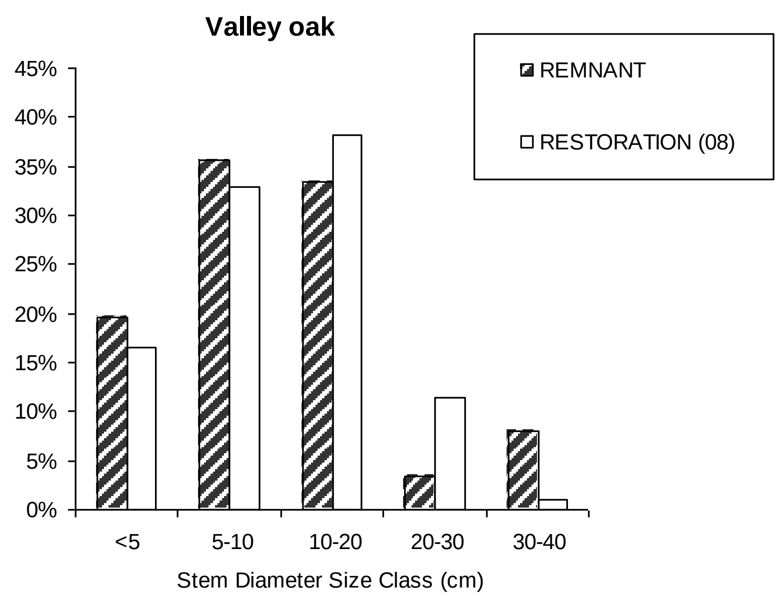
Step 6

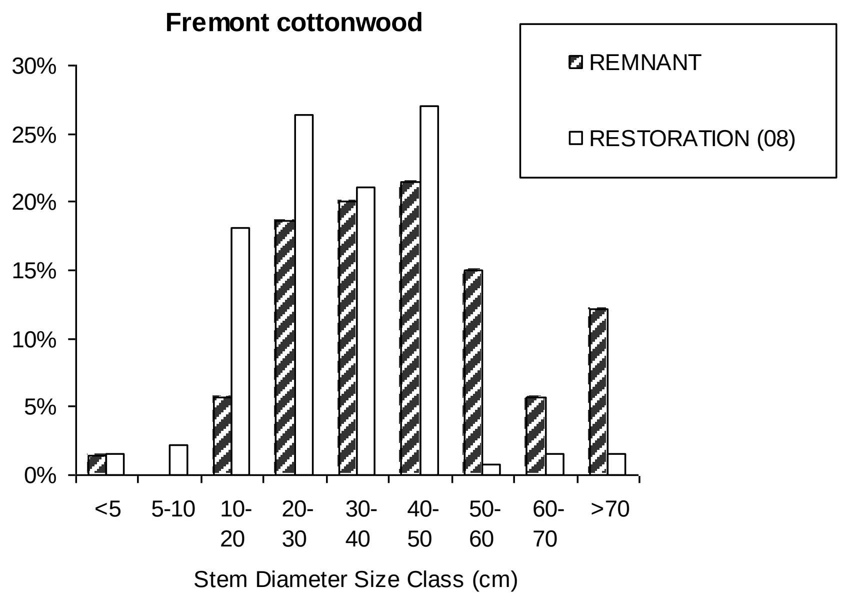
8. What is the current indicator status? What is the month and year that this corresponds to?

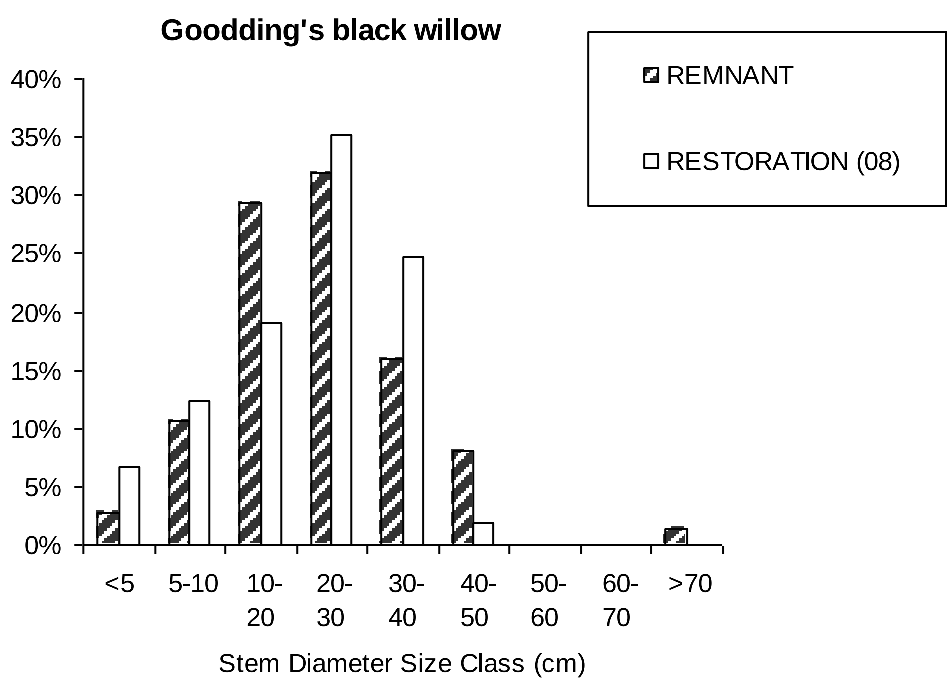
The graphs below compare restoration sites as of 2008 (River Unit, Rio Vista, Princeton Ferry, Sam Slough) to remnant forest.

Valley oak and box elder are rated as Very Good because the distribution of restoration sites closely approximates that of remnant forest.

Fremont cottonwood and Goodding's black willow are rated as Fair because their tree size distribution is shifted to the left (i.e. smaller trees) from that of remnant forest. However, given more time the size distribution of these species should come to match that of remnant forest.




Fremont cottonwood
REMNANT
RESTORATION (08)
30%
25%
20%
15%
10%
5%
0%
<5
5-10
10-20
20-30
30-40
40-50
50-60
60-70
>70
Stem Diameter Size Class (cm)


Goodding's black willow
REMNANT
RESTORATION (08)
40%
35%
30%
25%
20%
15%
10%
5%
0%
<5
5-10
10-20
20-30
30-40
40-50
50-60
60-70
>70
Stem Diameter Size Class (cm)

9. What is the desired rating and by when should this be achieved?

Desired ratings will be achieved when the tree size distributions of restoration forest species match that of remnant forest trees. This is already achieved for valley oak and box elder, and should be achieved by August 2017. By this date most restoration plots in this analysis will be 25 years old.

Step 7.

10. Are there additional indicator values that correspond to the scale of reporting (parcel, reach, etc.)?

11. When were the data collected that yielded these values? Describe the history of data collection.

    Data for restoration sites were collected in 2008. Date for reference sites (remnant forest) were collected in 2003, 2003, and 2006.

12. Where were the data collected? And over what geographic area is the indicator presumed to be representative of?

    Both restored and remnant sites were collected from Sacramento River floodplain sites from Red Bluff to Colusa at the locations indicated. Restoration sites are listed above in the table in Step 7 and were sampled in 2008. Remnant sites are listed above in Step 5 and were sampled in 2002, 2003 and 2006.

13. What is the source of the info? Who is the contact person? Provide contact info.

Data were analyzed by Dr. David M. Wood.
Contact Dr. Wood at Dept. of Biological Sciences, California State University, Chico, CA 95929=0515.
E-mail dmwood@csuchico.edu. Phone 530-898-6311.

14. What is the rationale for the desired rating?

Pre-European forests were dominated by large-diameter individuals of Fremont cottonwood and valley oak (Thompson 1961). Such large trees exert a high degree of ecological dominance in a site and thus are a critical component of ecosystem integrity. By examining stem size distributions in restoration sites, and comparing them to reference forests, we can determine whether the dominant species in restoration forests are increasing in size to an acceptable level.

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

There are too few valley oak reference sites in the reference forest plot inventory. More sites would strengthen the analysis by increasing sample size. Additional valley oak plots are currently (12.08) being located and sampling will take place during 2009.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Forest Patch Core Size

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

<u>Step 4</u>

1. How specifically is the indicator defined?

This landscape pattern indicator refers to the size of the core of patches, which is the patch area minus the edge effect zone determined by the GIS-user. Defining core is species-dependent, depending on how sensitive specific taxa are to patch edges. This indicator is related directly to patch size, though it does not vary linearly with patch size because of the dependence on patch morphology and the edge effect dimension.

2. What is the rationale for it being a meaningful indicator?

Patch size can determine the value of patches for particular taxa and ecological processes. Because of potential edge-sensitivity of certain taxa, especially riparian taxa of management concern, the patch core size may be more meaningful than just total patch size. Both are useful and can be used together.

3. What references support its use? Provide citations.

Hansen, A., and F. di Castri (eds). 1992. Landscape Boundaries. Springer, New York.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

The indicator is useful at the site/patch/reach (characterization of each patch and collection of patches) to whole river/landscape (characterization of all patches or all patch/habitat types) scale.

<u>Step 5</u>

5. What cutoffs are appropriate for poor, fair, good and very good?

Because a continuous value is obtained, there is no need for cutoffs. Also, cutoffs depend on species and species need. Some species benefit from larger absolute core area sizes than others. In general, the core-dependent and edge sensitive species will not do well with small patches and core area sizes, so small sizes (<10 acres) would be “poor”. This can be refined better for taxonomic groups or functional groups (e.g., size – feeding based classification)

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

See above

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

Methods are included in the FRAGSTATS user manual and other publications.

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to?

1997

TYPE	Core Area Weighted Mean CORE_AM	Core Area Standard Deviation CORE_SD
Herbaceous	31.1	7.9
Forest	12.4	4.1
Developed	85.2	16.4
Orchard	220.7	86.1
Row Crop	60.3	12.1
Scrub	139.6	58.0
Gravel Bar	2234.4	136.5
Wetland	6.5	2.5

2007

TYPE	Core Area Weighted Mean CORE_AM	Core Area Standard Deviation CORE_SD
Herbaceous	19.4	3.8
Forest	88.1	15.3
Developed	72.5	6.5
Orchard	201.7	71.5
Row Crop	101.1	37.0
Scrub	1.2	0.6
Gravel Bar	8.5	2.8
Wetland	3.9	1.2

Mean core area for forested patches has increased dramatically; wither because of the creation of large patches of forest, or because of the augmentation of existing patches. Herbaceous, scrub, and wetland have all decreased in mean patch core area. Differences between 1997 and 2007 in gravel bar and wetland may be related to differences in height of inundation, as opposed to real changes in actual extent.

9. What is the desired rating and by when should this be achieved?

Desired rating is best determined for both habitat classes and individual patches. A high rating would be for larger patches of mature and older restored riparian forest, where “good” would be means of >50 acres of core area size and has been achieved (as a mean value) through natural and horticultural recruitment/restoration.

Step 7.

10. Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)?

Yes

11. When were the data collected that yielded these other values? Describe the history of data collection.

1997 and 2007 mapping (delineation and veg classification) of the study reach

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Calculated based upon 1997 and 2007 maps. Geographic area = study area

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

Maps: 1997 (Evan Girvetz; Girvetz@u.washington.edu); 2007 (Chuck Nelson; cwnelson@csuchico.edu)

Analysis: 1997 and 2007 (Fraser Shilling; fmshilling@ucdavis.edu)

14. What is the rationale for the desired rating?

The larger the core area size, the more likely the patch type is to serve habitat needs of interior-dependent species.

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

This indicator is related to the other landscape indicators: patch edge contrast, patch morphology, and patch isolation.

More information on the viability assessment part of the workbook can be found at: http://conserveonline.org/workspaces/cbdgateway/cap/practices/bp_3

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Patch Morphology

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

<u>Step 4</u>

1. How specifically is the indicator defined?

Patch morphology is a landscape pattern indicator that provides information on the shape of the patch. One common way of describing patch shape is relative roundness (where a circle is the roundest) because this minimizes the amount of edge to core, important for edge-sensitive species. Because many patches are very complex, several patch morphology metrics have been developed. Most center around the concept of distance between the center of the shape and the edge.

2. What is the rationale for it being a meaningful indicator?

Patch shape can determine the value of patches for particular taxa and ecological processes – the more complex the shape, the more likely edge occurs near points in the interior of the patch. Because of potential edge-sensitivity of certain taxa, especially riparian taxa of management concern, patch shape may be more meaningful than just patch size by itself.

3. What references support its use? Provide citations.

Buechner, M. 1989. Are small-scale landscape features important factors for field studies of small mammal dispersal sinks? Landscape Ecology 2:191-199.

Hardt, R. A., and R. T. T. Forman. 1989. Boundary form effects on woody colonization of reclaimed surface mines. Ecology 70:1252-1260.

Forman, R. T. T., and M. Godron. 1986. Landscape Ecology. John Wiley & Sons, New York. 619 pp.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

The indicator is most useful at the site/patch/reach (characterization of each patch and collection of patches) and is somewhat useful at whole river/landscape (characterization of all patches or all patch/habitat types) scale.

<u>Step 5</u>

5. What cutoffs are appropriate for poor, fair, good and very good?

Because a continuous value is obtained, there is no need for cutoffs. Also, cutoffs depend on species and species need. Some species benefit from more complex patch shapes than others. In general, the core-dependent and edge sensitive species will not do well with convoluted patches, so complex shapes would be “poor”.

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

See above

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

Methods are included in the FRAGSTATS user manual and other publications.

<u>Step 6</u>

8. What is the current indicator status? What is the month and year that this corresponds to?

1997

TYPE	Area-Weighted Mean Shape Index SHAPE_AM	Shape Standard Deviation SHAPE_SD
Herbaceous	4.75	1.08
Forest	2.92	0.72
Developed	4.39	1.38
Orchard	2.50	0.60
Row Crop	2.85	0.61
Scrub	1.91	0.43
Gravel Bar	26.46	1.77
Wetland	3.37	0.92

2007

TYPE	Area-Weighted Mean Shape Index SHAPE_AM	Shape Standard Deviation SHAPE_SD
Herbaceous	3.26	0.76
Forest	6.14	1.19
Developed	2.66	0.51
Orchard	2.62	0.63
Row Crop	2.16	0.53
Scrub	2.93	0.74
Gravel Bar	2.82	0.71
Wetland	2.69	0.63

Forested patches have become more convoluted, on average, between 1997 and 2007. This means that they will tend to have more edge length relative to core area. Herbaceous and wetland areas became less convoluted in shape between 1997 and 2007, on average, and scrub became more convoluted. Not surprisingly, row crops and orchards stayed unchanged, primarily because they tend to be square fields.

9. What is the desired rating and by when should this be achieved?

Desired rating is best determined for both habitat classes and individual patches. A high rating would be for larger patches of mature and older restored riparian forest, where “good” would be relatively round patches, indicated by values around 2, and could be achieved in many areas within 20 years through natural and horticultural recruitment/restoration targeted toward less-round (e.g., long and thin) patches. The caveat to this is that by their very nature, riparian areas will tend toward longer and possibly more convoluted shapes, so the riparian may improve biologically, while still exhibiting convoluted vegetation patches. This is where this metric is best viewed in combination with other patch and landscape metrics describing fragmentation and connectivity.

Step 7.

10. Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)?

Yes

11. When were the data collected that yielded these other values? Describe the history of data collection.

1997 and 2007 mapping (delineation and veg classification) of the study reach

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Calculated based upon 1997 and 2007 maps. Geographic area = study area

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

Maps: 1997 (Evan Girvetz; Girvetz@u.washington.edu); 2007 (Chuck Nelson; cwnelson@csuchico.edu)

Analysis: 1997 and 2007 (Heidi Schott, heschott@ucdavis.edu, and Fraser Shilling, fmshilling@ucdavis.edu)

14. What is the rationale for the desired rating?

The rounder the patch, the more likely the patch type is to serve habitat needs of interior-dependent species.

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

This indicator is related to the other landscape indicators: patch edge contrast, patch core area, and patch isolation.

More information on the viability assessment part of the workbook can be found at: http://conserveonline.org/workspaces/cbdgateway/cap/practices/bp_3

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Number of VELB Exit Holes per Shrub

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

INTRODUCTION
The Valley Elderberry Longhorn Beetle (VELB, *Desmocerus californicus dimorphus*) is a federally threatened subspecies that is protected by the federal Endangered Species Act. The species occurs at very low densities but fortunately its occupancy of a single host plant type, elderberry (primarily *Sambucus mexicana*, and *S. racemosa* to a lesser extent) and the fact that larvae leave distinctive emergence holes in elderberry stems make the species feasible to monitor.

Step 4

1. How specifically is the indicator defined?

   This indicator, **average number of VELB exit holes per shrub**, is more specifically defined as the average number of recent VELB exit holes per elderberry shrub with a main stem of at least 2.5cm diameter, averaged across all elderberry shrubs within the habitat area (parcel) including unoccupied shrubs. Recent exit holes are 1-2 years old and provide the best available estimate of prior use of a stem by the beetle, and each emerging beetle makes one exit hole. Recent exit holes are defined as being in live wood and having light-colored wood that has not yet darkened, nor has the hole become completely grown over in actively growing shrubs.

2. What is the rationale for it being a meaningful indicator?

   Blue elderberry (*Sambucus mexicana*) and red elderberry (*Sambucus racemosa*) are the sole host plants of federally threatened VELB. Additionally elderberry is an important resource for a wide diversity of species, providing habitat, nectar (and floral) resources, and berries that are used by a wide range of taxa (e.g., Vaghti et al. 2009).

   The number of recent beetles exit holes per shrub is a basic measure of population density for the VELB. It is a time-delayed measure in that it is the number of beetles that emerged from a shrub in either this year or the prior year. Beetle emergence occurs from April to July (Barr 1991) and surveys are either performed during this time or later in the year, and holes remain recent in appearance (light-colored wood and not being grown over by the plant) for about a year: surveys can usually identify holes from the current year (moist, light-colored, no signs of regrowth) from those that are 1-year old (light-colored, little regrowth by the plant), and older holes (darker brown wood, usually dry in appearance, abraded edges, often partly or completely grown over by the plant).

Recent holes consist of holes in the current year and previous year (Collinge et al. 2001).

3. What references support its use as an indicator of river health? Provide citations.

Barr, C. B. 1991. The distribution, habitat and status of the valley elderberry longhorn beetle *Desmocerus californicus dimorphus* Fisher (Insecta: Coleoptera: Cerambycidae). U.S. Fish and Wildlife Service, Sacramento, CA. http://www.fws.gov/sacramento/es/documents/VELB_Report/velb_report.htm

Collinge, S. K., M. Holyoak, C. B. Barr, and J. T. Marty. 2001. Riparian habitat fragmentation and population persistence of the threatened valley elderberry longhorn beetle in central California. Biological Conservation 100:103-113.

Holyoak, M. and M. Koch-Munz. 2008. The Effects of Site Conditions and Mitigation Practices on Success of Establishing the Valley Elderberry Longhorn Beetle and Its Host Plant, Blue Elderberry. Environmental Management 42:444-457.

Talley, T. S., D. Wright, and M. Holyoak. 2006. Assistance with the 5-Year Review of the Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*).1-89. http://www.fws.gov/sacramento/es/5_year_reviews.htm

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

The indicator is sufficiently general that it can be applied at a variety of levels (site, reach, parcel or habitat patch). The results can be generalized only within the areas chosen for study but results can also be compared to other study areas (rivers, watersheds) to generalize.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

   The average number of recent VELB exit holes per elderberry shrub

   Very good: 2.2 holes per shrub or more

   Good: 1.9 to 2.2 holes per shrub

   Fair: 1 to 1.9 holes per shrub

   Poor: <1 hole per shrub.

6. How were the particular rating cutoffs selected?

VELB holes per shrub are based on values given in Talley et al. (2006). The very good value is the value given by Talley et al. (2006) based on mean densities of VELB per shrub at sites along the American River Parkway. The good value is Talley et al. (2006)'s mean value for non-riparian sites. The value of 1 hole per shrub as a minimum for "fair" is an arbitrary value.

Greg asked if the American River Parkway is good habitat. It is the best habitat area available for the VELB and represents critical habitat for the species. Talley et al. (2007) in Biological Conservation give a range of density values observed for the beetle. I used the value for narrow riparian corridor habitats:

Table 2 – Density of valley elderberry longhorn beetle exit holes within each of the four habitat types

Habitat type	Holes per shrub mean ± SD	Holes per 100 m^2 shrub area mean ± SD
Lower alluvial plain	2.7 ± 3.2	2.5 ± 3.4[b]
Narrow riparian corridor	2.2 ± 2.2	2.0 ± 2.3[b]
Upper riparian terrace	2.9 ± 3.5	2.5 ± 2.9[b]
Non-riparian scrub	1.6 ± 1.1	5.3 ± 5.8[a]
p	0.17	0.03
$\chi^2_{df=3}$	5.1	8.9

Values are Kruskal–Wallis rank sums. Different letters indicate significance at $p \leqslant 0.05$.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

Talley, T. S., D. Wright, and M. Holyoak. 2006. Assistance with the 5-Year Review of the Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*).1-89. (URL given above.)

Step 6

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   Based on occupied shrubs, River Partners (2004, full reference below) found 449 holes in 299 shrubs in fall 2003 from various Sacramento NWR units (see 10. below for details). Hence this was an average of 1.50 exit holes per shrub. Hence the rating is "Fair" in 2004.

   I also have 2007 and 2008 data from Meghan Gilbart's work that I can calculate values from but the data were not given in her MSc thesis that are in a comparable form.

9. What is the desired rating and by when should this be achieved?

Very good by 2020

Step 7.

10. Are there additional value for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

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.

Staff at River Partners can be contacted for further information: the report was authored by Helen Swagerty and Scott Chamberlain, and Helen Swagerty still works for River Partners.

River Partners. 2004. Survey of planted elderberry on Sacramento River National Wildlife Refuge riparian restoration sites for use by Valley elderberry longhorn beetles. Tehama, Butte and Glenn County, California. Helen Swagerty and Scott Chamberlain. River Partners: Report to USFWS., Chico, CA.

Meghan Gilbart's (2009) M.Sc. Thesis and the data contained have already been supplied to me. These data represent surveys of 432 shrubs conducted during March to July 2007 and 2008. A wide variety of metrics were collected including elderberry condition and size, and numbers of VELB exit holes in each shrub divided into age classes. The sites visited are presented in the following table.

Table 1 Surveyed restoration fields of the Sacramento River NWR

Field	Unit	River mile	Age of Field*	Field area (ha)	Distance to remnant (m)**
ryan 2	La Barranca	240	5	45.9	152
ryan rest 1	La Barranca	240	11	14.7	340
ryan rest 2	La Barranca	240	7	33.8	625
flynn 2	Flynn	233	12	21.2	142
flynn 5	Flynn	233	8	14.1	166
flynn 4	Flynn	231	10	64.8	204
rio 4	Rio Vista	218	12	49.1	285
rio 5	Rio Vista	217	11	55.8	166
rio 6	Rio Vista	217	10	53.2	334
rio 8.1	Rio Vista	217	8	16.3	150
rio 7	Rio Vista	216.5	9	82.4	296
rio 1	Rio Vista	216	15	9.6	200
rio 2	Rio Vista	216	14	44.4	251
rio 3	Rio Vista	216	13	49.7	283
mc annex	McIntosh	202	7	5.7	106
pc 2	Pine Creek	198.5	10	32.1	399
pc 3	Pine Creek	198.5	9	79.4	277
pc 4	Pine Creek	198.5	4	3.4	377
ord1	Ord Bend	184	9	7.9	169
ord3	Ord Bend	184	9	4.4	226
ord4	Ord Bend	184	9	2.6	171
ord6	Ord Bend	184	9	3.1	319

*At time of survey
**Average distance of points in field to nearest patch of remnant riparian habitat

Gilbart, M. 2009. The health of blue elderberry (*Sambucus mexicana*) and colonization by the Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) in restored riparian habitat. California State University, Chico, California.

A third data source outside of the Sacramento River but which represents comparable data from other watersheds is the data collected by Theresa Talley and available to me (Talley 2007, Talley et al. 2007, Fremier and Talley 2009). This dataset is from the American River Parkway, Cosumnes River, Putah Creek, and Cache Creek and represents natural sites, whereas the datasets reported above represent restoration sites. Fremier and Talley (2009) give full details of this dataset and the data is available to me.

Fremier, A. and T. Talley. 2009. Scaling riparian conservation with river hydrology: Lessons from blue elderberry along four California rivers. Wetlands 29:150-162.

Talley, T. S. 2007. Which spatial heterogeneity framework? Consequences for conclusions about patchy population distributions. Ecology 88:1476-1489.

Talley, T. S., E. Fleishman, M. Holyoak, D. D. Murphy, and A. Ballard. 2007. Rethinking a rare-species conservation strategy in an urban landscape: The case of the valley elderberry longhorn beetle. Biological Conservation 135:21-32.

A fourth dataset is the data collected by Holyoak and Molly Koch-Munz (2008, and Koch-Munz and Holyoak 2008) for 30 mitigation sites distributed throughout the Central Valley. This is perhaps the most broad comparison data available. Data fields collected are listed in the table below, and are in Holyoak's possession:

Table 1 Data from field surveys and GIS layers measured during this project

Characteristic	Year of survey
	Mitigation sites
Measured for/at each elderberry	
Presence/absence of VELB (new, 1-yr old, old holes)	2005, 2006
Abundance of VELB (new, 1-yr old, old holes)	2005, 2006
Stems per shrub of ≥2.5 cm per shrub	2005, 2006
Basal diameter of stems of ≥2.5 cm diameter (cm)	2005, 2006
Shrub height (m)	2005, 2006
Canopy length and width (m)	2005, 2006
Elderberry habitat quantity index	2005, 2006
Elderberry condition index (0 = dead, 4 = most healthy)	2005, 2006
% and type of leaf damage (herbivory)	2005, 2006
% and type of nonelderberry canopy cover	2005
% and type of nonelderberry shrub cover	2005
% and type of ground cover (understorey)	2005
% and type of overgrowth by vines	2005
Irrigation type	2005
Site characteristics	
County	Fixed
Waterway/watershed	Fixed
Within FEMA 100-year floodplain	Fixed
Site age (years since planting)	Fixed
Argentine ant presence and relative abundance	2006
Distance to nearest VELB population	2006
Distance to nearest water way/body	Fixed

Holyoak, M. and M. Koch-Munz. 2008. The Effects of Site Conditions and Mitigation Practices on Success of Establishing the Valley Elderberry Longhorn Beetle and Its Host Plant, Blue Elderberry. Environmental Management 42:444-457.

Koch-Munz, M. and M. Holyoak. 2008. An Evaluation of the Effects of Soil Characteristics on Mitigation and Restoration Involving Blue Elderberry, *Sambucus mexicana*. Environmental Management 42:49-65.

2003 and 2007-2008 to the extent that data from River Partners (2004) is comparable with that from Gilbart (2009). Data from 2007 and 2008 are also somewhat comparable from Gilbart (2009).

Data are comparable for 2005-2006 for Mitigation Sites and sampling was designed to determine change.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    River Partner's (2004) reported in 8 above collected data at:

- 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.

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

    Marcel Holyoak (or Tom Griggs at River Partners)

13. What is the rationale for the desired rating?

2020 is a reasonable period for site establishment but not so long that severe long-term effects of climate change might be expected.

<u>Step 8</u>

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

None.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Area of Annual and Perennial Grasses and Forbs

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

This indicator is defined as the total area mapped as **California annual grassland/herbaceous alliance** (CA) within the area that was photographed and mapped in 2007 as part of the Sacramento River Monitoring and Assessment Project. Generally speaking, this area is between Colusa and Red Bluff along the mainstem of the Sacramento River. The mapped area extends outward from the river to include most of the current riparian zone. For further definition of the mapped area see Nelson et al. (2008).

California annual grassland/herbaceous alliance is found in uplands, i.e., all topographic locations. Composition varies greatly and it may have many alien and non-native annual grasses and herbs. Bromes, rye grasses, foxtail, oats, mustards, star thistle, clovers, lupines, hedge parsley and filaree may be present plus numerous others. This alliance is affected by light, shading, litter and differences in micro topography.

2. What is the rationale for it being a meaningful indicator?

   Although largely composed of exotic plant species, this habitat type is supportive of various native grassland animals (e.g., northern harrier). Also it is a relatively large component of the mapped area of natural vegetation along the river.

3. What references support its use as an indicator of river health? Provide citations.

Hunter, J.C.; Willett, K.B.; McCoy, M.C.; Quinn, J.F.; Keller, K.E. 1999. Prospects for preservation and restoration of riparian forests in the Sacramento Valley, California, USA. Environmental Management 24: 65-75.

Katibah, E.F. 1984. A brief history of the riparian forests in the central valley of California. In: Warner, R.E.; Hendrix, K.M., editors. California riparian systems: ecology conservation and productive management. Berkeley, CA: University of California Press; 23-29.

Scott, L.B.; Marquiss, S.K. 1984. An historical overview of the Sacramento River. In: Warner, R.; Hendrix, K., editors. California riparian systems: ecology conservation and productive management. Berkeley, CA: University of California Press; 51-57.

Thompson, K. 1961. Riparian forests of the Sacramento Valley, California. Annals of the Association of American Geographers 51: 294-315.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   It is useful at multiple scales. Interpretations of the data are in part a function of the geographic range of the mapping effort.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

   The status indicator ratings are defined as:
   Very Good: > 7,500 acres
   Good: 5,000 - 7,500 acres
   Fair: 2,500 - 5,000 acres
   Poor: < 2,500 acres

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

   They are described in Nelson et al. (2008):

   Nelson, C., M. Carlson, R. Funes. 2008, Rapid Assessment Mapping in the Sacramento River Ecological Management Zone – Colusa to Red Bluff. Report to the CALFED Ecosystem Restoration Program, Sacramento, CA

Step 6

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   4,396 acres were mapped as California annual grassland/herbaceous alliance during analysis of the 2007 photos.

   The 2007 aerial photographs were on flown 26 June 2007. In total there were 298 aerial photos taken in the Red Bluff to Colusa reach, and 347 over the larger area. To amend coverage, ten additional aerial photographs scattered through-out the Colusa to Red Bluff area were flown on 17 June 2008.

9. What is the desired rating and by when should this be achieved?

   Very good (> 7,500 acres), by June 2020

   Step 7.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when

were they collected and what were the values? Describe the history of data collection.

There were 3,425 acres mapped during analysis of the 1999 photos (as herbland).

A Sacramento River riparian map was completed in 2002 by the Geographical Information Center (GIC) using 1999 aerial photographs for the mainstem of the Sacramento River between Keswick Dam and Colusa. It was intended as an update to the 1991-1998 Sacramento River Riparian Mapping Project. It is located in the Sacramento River Conservation Area (SRCA) approximately between river mile 300 and river mile 129. The aerial photos were flown at the nominal scale of RF=1:7200 (1:600). The 1999 riparian shape file is referenced as nv_riparian_99_z1083m.

The earliest Sacramento River riparian shape file created by the GIC was begun in 1991 and completed in 1998. This riparian map is referenced as nv_riparian_z1083m. The map was developed to inventory and map riparian lands along the Sacramento River and its tributaries within the Sacramento Valley. This mapping effort used color infrared aerial photos that were flown in a series of flights beginning in the year 1991 and ending in 1998 with color infrared aerial photography. In 2009, restoration sites were edited in and include size class in the comment column in the table.

1999 Sacramento River riparian shape file: Aerial photos were flown May 21, 1999, field work was limited to several initial field visits and the riparian shape file was completed in 2002.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    Data for the 2007 shape file was collected from Keswick Dam to Verona and includes; initial field visits, rapid Assessments, field verification and edited shape files. However the data analyzed and presented here are for a subset of the area (Red Bluff to Colusa).

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

    The 2007 edited shape file was created at the GIC in Chico, CA.

    Data for the 1999 shape file from Keswick to below Verona was created at the GIC in Chico, CA.

    Data for the 1991 – 1998 shape file from Keswick to the Delta (including tributaries in the Sacramento Valley) was created at the GIC in Chico, CA.

    This indicator information was input by G. Golet following review of relevant materials. Experts on this subject matter as it pertains to application on the Sacramento River are:

    Melinda Carlson
    GIS Biologist
    Geographical Information Center

Chico, California 95929-0327
mcarlson@gic.csuchico.edu
530 898-3212 office
530 898-6317 fax

13. What is the rationale for the desired rating?

    The desired rating was established based on determinations of what is possible in terms of horticultural restoration along the river, with consideration to what has been accomplished to date.

Step 8

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

    At times, aerial photos can be difficult to interpret making vegetation signatures challenging. A few examples that may cause this are glare, shadows, too dark or too light of photo color, or distortion on the edges when there is inadequate overlap from photo to photo. When photos are encountered that are difficult to interpret, it is sometimes useful to look at another source (of same or similar year). Examples of other sources include but are not limited to Google Earth, Live Search Map and 2005 NAIP Imagery.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Area of Fremont Cottonwood Forest

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   Populus fremontii alliance

   Fremont cottonwood alliance

   In this alliance, Fremont cottonwood dominates the overstory tree layer. Box elder, Goodding's black willow, Northern California black walnut, Oregon ash and white alder are often subdominants. California wild grape, California pipevine, blackberries, and narrow-leaved willow may be present in the shrub layer. Santa Barbara sedge and mugwort may be present in the herb layer. Fremont cottonwood is found in areas with soils intermittently or seasonally flooded, or saturated along riparian corridors.

2. What is the rationale for it being a meaningful indicator?

   Often fremont cottonwood forest develops as an early successional community on young floodplain deposits. On rivers that have meander migration constrained there are few areas for this community type to form.

3. What references support its use as an indicator of river health? Provide citations.

Hunter, J.C.; Willett, K.B.; McCoy, M.C.; Quinn, J.F.; Keller, K.E. 1999. Prospects for preservation and restoration of riparian forests in the Sacramento Valley, California, USA. Environmental Management 24: 65-75.

Katibah, E.F. 1984. A brief history of the riparian forests in the central valley of California. In: Warner, R.E.; Hendrix, K.M., editors. California riparian systems: ecology conservation and productive management. Berkeley, CA: University of California Press; 23-29.

Scott, L.B.; Marquiss, S.K. 1984. An historical overview of the Sacramento River. In: Warner, R.; Hendrix, K., editors. California riparian systems: ecology conservation and productive management. Berkeley, CA: University of California Press; 51-57.

Thompson, K. 1961. Riparian forests of the Sacramento Valley, California. Annals of the Association of American Geographers 51: 294-315.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

It is useful at multiple scales. Interpretations of the data are in part a function of the geographic range of the mapping effort.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

The status indicator ratings are defined as:
Very Good: > 11,000
Good: 8,000 - 11,000
Fair: 6,000 - 8,000 acres
Poor: < 6,000 acres

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

   They are described in Nelson et al. (2008):

   Nelson, C., M. Carlson, R. Funes. 2008, Rapid Assessment Mapping in the Sacramento River Ecological Management Zone – Colusa to Red Bluff. Report to the CALFED Ecosystem Restoration Program, Sacramento, CA

Step 6

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   7,692 acres were mapped as Fremont cottonwood forest during analysis of the 2007 photos.

   The 2007 aerial photographs were on flown 26 June 2007. In total there were 298 aerial photos taken in the Red Bluff to Colusa reach, and 347 over the larger area. To amend coverage, ten additional aerial photographs scattered through-out the Colusa to Red Bluff area were flown on 17 June 2008.

9. What is the desired rating and by when should this be achieved?

   Good, by June, 2020

   Step 7.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

    This represents an increase from 4,147 acres determined from analysis of the 1999 aerial photos. It is probable however that some of this increase is not real.

Melinda Carlson who did the mapping suggested that some of what was mapped as mixed riparian forest in 1999 should have been instead mapped as cottonwood. Apparently she learned how to separate the two out better when analyzing the 2007 photos. Nonetheless there is likely a significant increase due primarily to the restoration projects that have been implemented.

A Sacramento River riparian map was completed in 2002 by the Geographical Information Center (GIC) using 1999 aerial photographs for the mainstem of the Sacramento River between Keswick Dam and Colusa. It was intended as an update to the 1991-1998 Sacramento River Riparian Mapping Project. It is located in the Sacramento River Conservation Area (SRCA) approximately between river mile 300 and river mile 129. The aerial photos were flown at the nominal scale of RF=1:7200 (1:600). The 1999 riparian shape file is referenced as nv_riparian_99_z1083m.

The earliest Sacramento River riparian shape file created by the GIC was begun in 1991 and completed in 1998. This riparian map is referenced as nv_riparian_z1083m. The map was developed to inventory and map riparian lands along the Sacramento River and its tributaries within the Sacramento Valley. This mapping effort used color infrared aerial photos that were flown in a series of flights beginning in the year 1991 and ending in 1998 with color infrared aerial photography. In 2009, restoration sites were edited in and include size class in the comment column in the table.

1999 Sacramento River riparian shape file: Aerial photos were flown May 21, 1999, field work was limited to several initial field visits and the riparian shape file was completed in 2002.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    Data for the 2007 shape file was collected from Keswick Dam to Verona and includes; initial field visits, rapid Assessments, field verification and edited shape files. However the data analyzed and presented here are for a subset of the area (Red Bluff to Colusa).

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

    The 2007 edited shape file was created at the GIC in Chico, CA.

    Data for the 1999 shape file from Keswick to below Verona was created at the GIC in Chico, CA.

    Data for the 1991 – 1998 shape file from Keswick to the Delta (including tributaries in the Sacramento Valley) was created at the GIC in Chico, CA.

    The 2007 edited shape file was created at the GIC in Chico, CA.

    Data for the 1999 shape file from Keswick to below Verona was created at the GIC in Chico, CA.

Data for the 1991 – 1998 shape file from Keswick to the Delta (including tributaries in the Sacramento Valley) was created at the GIC in Chico, CA.

This indicator information was input by G. Golet following review of relevant materials. Experts on this subject matter as it pertains to application on the Sacramento River are:

Melinda Carlson
GIS Biologist
Geographical Information Center
Chico, California 95929-0327
mcarlson@gic.csuchico.edu
530 898-3212 office
530 898-6317 fax

13. What is the rationale for the desired rating?

The desired rating was established based on determinations of what is possible in terms of horticultural restoration along the river, with consideration to what has been accomplished to date.

Step 8

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

None.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Area of Mixed Riparian Forest

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   Mixed riparian forest is an essential habitat element of riparian communities. Here it is defined as a composite of the following alliances that were mapped during analyses of the 2007 photos:

   Acer negundo alliance
   Box Elder alliance
   Box elder is the characteristic or dominant canopy tree. Fremont cottonwood, Northern California black walnut, valley oak and Oregon ash may also be present in the overstory. Mexican elderberry, California pipevine, California wild rose may be present in the shrub layer. Mugwort and Santa Barbara sedge may be found in the herb layer.

   Platanus racemosa alliance
   California sycamore alliance
   California sycamore is the dominant canopy tree. Fremont cottonwood, Goodding's black willow, and valley oak may also be found in the overstory. Arroyo willow, California wild rose and mule fat may be present in the shrub layer. Slender wild oats and bromes are commonly occurring species in the herb layer. California sycamore is found in riparian corridors, braided, depositional channels of intermittent streams, gullies, seeps, springs and river banks, and terraces adjacent to floodplains subject to high intensity flooding. Soils are alluvial, open cobbly to rocky.

   Salix gooddingii alliance
   Goodding's black willow alliance
   Goodding's black willow is the dominant canopy tree. Fremont cottonwood and Oregon ash may be subdominants. Poison oak, blackberries, narrow-leaved willow, arroyo willow, buttonbush and California wild rose are common in the shrub layer. Stinging nettle, mugwort and Santa Barbara sedge are often found in the herb layer. Goodding's black willow is found in wetland habitats that may be seasonally flooded or saturated and flood plains with low gradient depositions along rivers, streams and meadow edges.

2. What is the rationale for it being a meaningful indicator?

   Mixed riparian forest is a fundamental element of riparian communities in the Central Valley. This vegetation type supports a wide diversity of wildlife.

3. What references support its use as an indicator of river health? Provide citations.

Hunter, J.C.; Willett, K.B.; McCoy, M.C.; Quinn, J.F.; Keller, K.E. 1999. Prospects for preservation and restoration of riparian forests in the Sacramento Valley, California, USA. Environmental Management 24: 65-75.

Katibah, E.F. 1984. A brief history of the riparian forests in the central valley of California. In: Warner, R.E.; Hendrix, K.M., editors. California riparian systems: ecology conservation and productive management. Berkeley, CA: University of California Press; 23-29.

Pavlik, B.M.; Muick, P.C.; Johnson, S.G.; Popper, M. 2000. Oaks in California. Los Olivos, CA: Cachuma Press.

Thompson, K. 1961. Riparian forests of the Sacramento Valley, California. Annals of the Association of American Geographers 51: 294-315.

Scott, L.B.; Marquiss, S.K. 1984. An historical overview of the Sacramento River. In: Warner, R.; Hendrix, K., editors. California riparian systems: ecology conservation and productive management. Berkeley, CA: University of California Press; 51-57.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   It is useful at multiple scales. Interpretations of the data are in part a function of the geographic range of the mapping effort.

<u>Step 5</u>

5. What cutoffs are appropriate for poor, fair, good and very good?

   <u>The status indicator ratings are defined as:</u>
   Very Good: > 5,000 acres
   Good: 3,500 - 5,000
   Fair: 2,000 - 3,500 acres
   Poor: < 2,000 acres

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

   They are described in Nelson et al. (2008):
   Nelson, C., M. Carlson, R. Funes. 2008, Rapid Assessment Mapping in the Sacramento River Ecological Management Zone – Colusa to Red Bluff. Report to the CALFED Ecosystem Restoration Program, Sacramento, CA

<u>Step 6</u>

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   1,126 acres were mapped as alliances which make up the mixed riparian forest category during analysis of the 2007 photos.
   The 2007 aerial photographs were on flown 26 June 2007. In total there were 298 aerial photos taken in the Red Bluff to Colusa reach, and 347 over the larger area. To amend coverage, ten additional aerial photographs scattered through-out the Colusa to Red Bluff area were flown on 17 June 2008.

9. What is the desired rating and by when should this be achieved?

Good (3,500 - 5,000 acres) by June 2020

Step 7.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

    This value went down considerably from 5,476 acres, the value derived from analysis of the 1999 photos (the last mapping). The decline may not be real, but rather a result of how the classifications were done in the mapping. More specifically, Melinda Carlson, who did the mapping suggested that some of the areas that were called out as cottonwood forest and valley oak woodland in 2007 was likely coded mixed riparian in 1999. This would explain the apparent decline in mixed riparian forest as well as some of the pronounced increase in acreage of both cottonwood forest and valley oak woodland between the two time periods.
    A Sacramento River riparian map was completed in 2002 by the Geographical Information Center (GIC) using 1999 aerial photographs for the mainstem of the Sacramento River between Keswick Dam and Colusa. It was intended as an update to the 1991-1998 Sacramento River Riparian Mapping Project. It is located in the Sacramento River Conservation Area (SRCA) approximately between river mile 300 and river mile 129. The aerial photos were flown at the nominal scale of RF=1:7200 (1:600). The 1999 riparian shape file is referenced as nv_riparian_99_z1083m.
    The earliest Sacramento River riparian shape file created by the GIC was begun in 1991 and completed in 1998. This riparian map is referenced as nv_riparian_z1083m. The map was developed to inventory and map riparian lands along the Sacramento River and its tributaries within the Sacramento Valley. This mapping effort used color infrared aerial photos that were flown in a series of flights beginning in the year 1991 and ending in 1998 with color infrared aerial photography. In 2009, restoration sites were edited in and include size class in the comment column in the table.
    1999 Sacramento River riparian shape file: Aerial photos were flown May 21, 1999, field work was limited to several initial field visits and the riparian shape file was completed in 2002.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    Data for the 2007 shape file was collected from Keswick Dam to Verona and includes; initial field visits, rapid Assessments, field verification and edited shape files. However the data analyzed and presented here are for a subset of the area (Red Bluff to Colusa).

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

    The 2007 edited shape file was created at the GIC in Chico, CA.
    Data for the 1999 shape file from Keswick to below Verona was created at the GIC in Chico, CA.

    Data for the 1991 – 1998 shape file from Keswick to the Delta (including tributaries in the Sacramento Valley) was created at the GIC in Chico, CA.

    This indicator information was input by G. Golet following review of relevant materials. Experts on this subject matter as it pertains to application on the Sacramento River are:

    Melinda Carlson
    GIS Biologist
    Geographical Information Center
    Chico, California 95929-0327
    mcarlson@gic.csuchico.edu
    530 898-3212 office
    530 898-6317 fax

13. What is the rationale for the desired rating?

    The desired rating was established based on determinations of what is possible in terms of horticultural restoration along the river, with consideration to what has been accomplished to date.

<u>Step 8</u>

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

    At times, aerial photos can be difficult to interpret making vegetation signatures challenging. A few examples that may cause this are glare, shadows, too dark or too light of photo color, or distortion on the edges when there is inadequate overlap from photo to photo. When photos are encountered that are difficult to interpret, it is sometimes useful to look at another source (of same or similar year). Examples of other sources include but are not limited to Google Earth, Live Search Map and 2005 NAIP Imagery.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Area of Riparian Scrub

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   Riparian scrub is characterized by a variety of different shrubs and small trees of sapling to pole size. Common shrub species may include Mexican elderberry, poison oak, California wild grape, buttonbush, coyote-brush, mule fat, American black nightshade and, to a lesser degree, Himalayan and California blackberries and willows. Small trees may include Fremont cottonwood, white alder, box elder, Northern California black walnut, Oregon ash and Goodding's black willow. The herbaceous layer is various native and non-native perennials and annuals. Riparian scrub is common in seasonally flooded areas and low gradient depositions along rivers.

2. What is the rationale for it being a meaningful indicator?

   Often riparian scrub develops as an early successional community on young floodplain deposits. On rivers that have meander migration constrained there are few areas for this community type to form.

   As reflected in the definition above, this habitat type contains many native plant species. In addition it is supportive of a wide assemblage of native animals (e.g., songbirds, mammals). Also it is a relatively large component of the mapped area of natural vegetation along the river.

3. What references support its use as an indicator of river health? Provide citations.

Hunter, J.C.; Willett, K.B.; McCoy, M.C.; Quinn, J.F.; Keller, K.E. 1999. Prospects for preservation and restoration of riparian forests in the Sacramento Valley, California, USA. Environmental Management 24: 65-75.

Katibah, E.F. 1984. A brief history of the riparian forests in the central valley of California. In: Warner, R.E.; Hendrix, K.M., editors. California riparian systems: ecology conservation and productive management. Berkeley, CA: University of California Press; 23-29.

Pavlik, B.M.; Muick, P.C.; Johnson, S.G.; Popper, M. 2000. Oaks in California. Los Olivos, CA: Cachuma Press.

Thompson, K. 1961. Riparian forests of the Sacramento Valley, California. Annals of the Association of American Geographers 51: 294-315.

Scott, L.B.; Marquiss, S.K. 1984. An historical overview of the Sacramento River. In: Warner, R.; Hendrix, K., editors. California riparian systems: ecology

conservation and productive management. Berkeley, CA: University of California Press; 51-57.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   It is useful at multiple scales. Interpretations of the data are in part a function of the geographic range of the mapping effort.

<u>Step 5</u>

5. What cutoffs are appropriate for poor, fair, good and very good?

   <u>The status indicator ratings are defined as:</u>
   Very Good: > 7,500 acres
   Good: 5,000 - 7,500 acres
   Fair: 2,500 - 5,000 acres
   Poor: < 2,500 acres

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

   They are described in Nelson et al. (2008):

   Nelson, C., M. Carlson, R. Funes. 2008, Rapid Assessment Mapping in the Sacramento River Ecological Management Zone – Colusa to Red Bluff. Report to the CALFED Ecosystem Restoration Program, Sacramento, CA

<u>Step 6</u>

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   2,401 acres were mapped as riparian scrub during analysis of the 2007 photos.

   The 2007 aerial photographs were on flown 26 June 2007. In total there were 298 aerial photos taken in the Red Bluff to Colusa reach, and 347 over the larger area. To amend coverage, ten additional aerial photographs scattered through-out the Colusa to Red Bluff area were flown on 17 June 2008.

9. What is the desired rating and by when should this be achieved?

   Good, 5,000 - 7,500 acres, by June 2020.

<u>Step 7</u>.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

    There were 2,206 acres mapped during the analysis of the 1999 aerial photos.

    A Sacramento River riparian map was completed in 2002 by the Geographical Information Center (GIC) using 1999 aerial photographs for the mainstem of the Sacramento River between Keswick Dam and Colusa. It was intended as an update to the 1991-1998 Sacramento River Riparian Mapping Project. It is located in the Sacramento River Conservation Area (SRCA) approximately between river mile 300 and river mile 129. The aerial photos were flown at the nominal scale of RF=1:7200 (1:600). The 1999 riparian shape file is referenced as nv_riparian_99_z1083m.

    The earliest Sacramento River riparian shape file created by the GIC was begun in 1991 and completed in 1998. This riparian map is referenced as nv_riparian_z1083m. The map was developed to inventory and map riparian lands along the Sacramento River and its tributaries within the Sacramento Valley. This mapping effort used color infrared aerial photos that were flown in a series of flights beginning in the year 1991 and ending in 1998 with color infrared aerial photography. In 2009, restoration sites were edited in and include size class in the comment column in the table.

    1999 Sacramento River riparian shape file: Aerial photos were flown May 21, 1999, field work was limited to several initial field visits and the riparian shape file was completed in 2002.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    Data for the 2007 shape file was collected from Keswick Dam to Verona and includes; initial field visits, rapid Assessments, field verification and edited shape files. However the data analyzed and presented here are for a subset of the area (Red Bluff to Colusa).

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

    The 2007 edited shape file was created at the GIC in Chico, CA.

    Data for the 1999 shape file from Keswick to below Verona was created at the GIC in Chico, CA.

    Data for the 1991 – 1998 shape file from Keswick to the Delta (including tributaries in the Sacramento Valley) was created at the GIC in Chico, CA.

    This indicator information was input by G. Golet following review of relevant materials. Experts on this subject matter as it pertains to application on the Sacramento River are:

    Melinda Carlson

GIS Biologist
Geographical Information Center
Chico, California 95929-0327
mcarlson@gic.csuchico.edu
530 898-3212 office
530 898-6317 fax

13. What is the rationale for the desired rating?

    The desired rating was established based on determinations of what is possible in terms of horticultural restoration along the river, with consideration to what has been accomplished to date.

Step 8

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

    At times, aerial photos can be difficult to interpret making vegetation signatures challenging. A few examples that may cause this are glare, shadows, too dark or too light of photo color, or distortion on the edges when there is inadequate overlap from photo to photo. When photos are encountered that are difficult to interpret, it is sometimes useful to look at another source (of same or similar year). Examples of other sources include but are not limited to Google Earth, Live Search Map and 2005 NAIP Imagery.

More information on the viability assessment part of the workbook can be found at: http://conserveonline.org/workspaces/cbdgateway/cap/practices/bp_3

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Area of Valley Oak Woodland

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

<u>Step 4</u>

1. How specifically is the indicator defined?

   Quercus lobata alliance

   Valley oak alliance

   Valley oak is the dominate tree in the canopy. Oregon ash, Fremont cottonwood, box elder and California sycamore may also be present. Mexican elderberry, poison oak, California pipevine and California wild grape are common in the shrub layer. Structure is an intermittent deciduous tree canopy and an open to intermittent shrub layer. The herbaceous layer may be open to intermittent. The herbaceous layer may contain mugwort and dock. Numerous non-native grasses and forbs also occur in the herbaceous layer. Valley oak appears in older floodplains, riparian corridors, uplands, valley bottoms, and gentle slopes with alluvial or residual soils. Soils are intermittently flooded, or seasonally saturated.

2. What is the rationale for it being a meaningful indicator?

   Prior to European contact riparian forests of the Sacramento Valley covered over 800,000 acres (Katibah 1984). Valley oaks were a primary component of these forests, typically growing on fine-textured soils on the higher portions of the floodplain. They are deciduous, quick growing trees that thrive in hot, sunny conditions when supplied with sufficient water and nutrients. The largest individuals have trunks of over 2 m in diameter, and typically support sets of massive craggy limbs soaring upwards of 30 m. Valley oak riparian forest has the most complex structure of any vegetation type in California, and as a result, is among the most diverse in terms of the animal life it supports (Pavlik and others 2000).

   In the late 1800s the rich soils of the Sacramento River floodplain were cleared of riparian vegetation to provide fencing, lumber, fuel for steamships, and open areas for agriculture (Thompson 1961, Scott and Marquiss 1984). In 1945 Shasta Dam was completed, bringing with it a reduction in the threat of catastrophic flooding and an associated increase in conversion of lower floodplain forests to farmlands. Today less than 20,000 acres of riparian woodlands remain, mostly in degraded condition (Katibah 1984, Hunter and others 1999). Because valley oak woodpland tends to occur higher on the floodplain, much more of it has been lost than with other vegetation types.

3. What references support its use as an indicator of river health? Provide citations.

Griggs F.T. and G.H. Golet. 2002. Riparian valley oak (*Quercus lobata*) forest restoration on the middle Sacramento River. Pages 543-550 *in* RB Standiford, D McCreary, and KL Purcell, (technical coordinators), Proceedings of the Fifth Symposium on Oak Woodlands: Oaks in California's Changing Landscape. October 22-25, 2001, San Diego, CA. Gen. Tech. Rep. PSW-GTR-184. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 846 p.

Hunter, J.C.; Willett, K.B.; McCoy, M.C.; Quinn, J.F.; Keller, K.E. 1999. Prospects for preservation and restoration of riparian forests in the Sacramento Valley, California, USA. Environmental Management 24: 65-75.

Katibah, E.F. 1984. A brief history of the riparian forests in the central valley of California. In: Warner, R.E.; Hendrix, K.M., editors. California riparian systems: ecology conservation and productive management. Berkeley, CA: University of California Press; 23-29.

Pavlik, B.M.; Muick, P.C.; Johnson, S.G.; Popper, M. 2000. Oaks in California. Los Olivos, CA: Cachuma Press.

Scott, L.B.; Marquiss, S.K. 1984. An historical overview of the Sacramento River. In: Warner, R.; Hendrix, K., editors. California riparian systems: ecology conservation and productive management. Berkeley, CA: University of California Press; 51-57.

Thompson, K. 1961. Riparian forests of the Sacramento Valley, California. Annals of the Association of American Geographers 51: 294-315.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   It is useful at multiple scales. Interpretations of the data are in part a function of the geographic range of the mapping effort.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

   The status indicator ratings are defined as:
   Very Good: > 8,000 acres
   Good: 6,000 - 8,000 acres
   Fair: 4,000 - 6,000 acres
   Poor: < 4,000

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

   They are described in Nelson et al. (2008):

   Nelson, C., M. Carlson, R. Funes. 2008, Rapid Assessment Mapping in the Sacramento River Ecological Management Zone – Colusa to Red Bluff. Report to the CALFED Ecosystem Restoration Program, Sacramento, CA

<u>Step 6</u>

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   3,938 acres were mapped as valley oak woodland during analysis of the 2007 photos.

   The 2007 aerial photographs were on flown 26 June 2007. In total there were 298 aerial photos taken in the Red Bluff to Colusa reach, and 347 over the larger area. To amend coverage, ten additional aerial photographs scattered through-out the Colusa to Red Bluff area were flown on 17 June 2008.

9. What is the desired rating and by when should this be achieved?

   Good (> 6,000 acres), by June 2020

<u>Step 7</u>.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

    Valley oak woodland was mapped as 1,638 acres from analyses of the 1999 aerials. Some of the increase may not be real, however, as Melinda said that some of what was mapped as mixed riparian forest in 1999 was mapped as valley oak woodland in 2007. For this reason I have called the trend a "mild" increase as opposed to a "strong" increase.

    A Sacramento River riparian map was completed in 2002 by the Geographical Information Center (GIC) using 1999 aerial photographs for the mainstem of the Sacramento River between Keswick Dam and Colusa. It was intended as an update to the 1991-1998 Sacramento River Riparian Mapping Project. It is located in the Sacramento River Conservation Area (SRCA) approximately between river mile 300 and river mile 129. The aerial photos were flown at the nominal scale of RF=1:7200 (1:600). The 1999 riparian shape file is referenced as nv_riparian_99_z1083m.

    The earliest Sacramento River riparian shape file created by the GIC was begun in 1991 and completed in 1998. This riparian map is referenced as nv_riparian_z1083m. The map was developed to inventory and map riparian lands along the Sacramento River and its tributaries within the Sacramento

Valley. This mapping effort used color infrared aerial photos that were flown in a series of flights beginning in the year 1991 and ending in 1998 with color infrared aerial photography. In 2009, restoration sites were edited in and include size class in the comment column in the table.

1999 Sacramento River riparian shape file: Aerial photos were flown May 21, 1999, field work was limited to several initial field visits and the riparian shape file was completed in 2002.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    Data for the 2007 shape file was collected from Keswick Dam to Verona and includes; initial field visits, rapid Assessments, field verification and edited shape files. However the data analyzed and presented here are for a subset of the area (Red Bluff to Colusa).

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

The 2007 edited shape file was created at the GIC in Chico, CA.

Data for the 1999 shape file from Keswick to below Verona was created at the GIC in Chico, CA.

Data for the 1991 – 1998 shape file from Keswick to the Delta (including tributaries in the Sacramento Valley) was created at the GIC in Chico, CA.

This indicator information was input by G. Golet following review of relevant materials. Experts on this subject matter as it pertains to application on the Sacramento River are:

Melinda Carlson
GIS Biologist
Geographical Information Center
Chico, California 95929-0327
mcarlson@gic.csuchico.edu
530 898-3212 office
530 898-6317 fax

13. What is the rationale for the desired rating?

    The desired rating was established based on determinations of what is possible in terms of horticultural restoration along the river, with consideration to what has been accomplished to date.

<u>Step 8</u>

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

At times, aerial photos can be difficult to interpret making vegetation signatures challenging. A few examples that may cause this are glare, shadows, too dark or too light of photo color, or distortion on the edges when there is inadequate overlap from photo to photo. When photos are encountered that are difficult to interpret, it is sometimes useful to look at another source (of same or similar year). Examples of other sources include but are not limited to Google Earth, Live Search Map and 2005 NAIP Imagery.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Percent of Historical Riparian Zone Currently in Conservation Ownership

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   Percent of historical riparian zone currently in conservation ownership is defined as the subset of former habitat area that is owned by a conservation entity. Such entities may be state, federal, or private (e.g., DFG, USFWS, DWR, BLM, TNC, River Partners, etc.).

2. What is the rationale for it being a meaningful indicator?

   Amount of land managed for conservation influences biodiversity health. Need this in addition to amount of natural habitats because some of the protected habitats are not yet natural habitat (restoration work needs to be done at agricultural lands that were recently acquired).

3. What references support its use as an indicator of river health? Provide citations.

   None that I am aware of.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   This indicator is most useful at the large scale, applied to the entire river reach.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

   The status indicator ratings are defined as:
   Very Good: > 35 %
   Good: 25 - 35 %
   Fair: 15 - 25 %
   Poor: < 15 %

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

   Cutoffs were selected based upon review of the existing data, and analyses of how this indicator value will to change if all of the tier 1 properties are acquired. These values should be viewed as working hypotheses to be refined as more information becomes available.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

   Greco provided the map of the historical riparian zone as determined from the Holmes et al. 1913 soil map of the Sacramento River Valley. This historical riparian vegetation GIS layer was clipped to include only the Sacramento River Project area between Colusa Bridge and Red Bluff Diversion Dam. Tributaries were also clipped. The resultant area was determined to be 181,468 acres, and this was deemed the historical riparian zone within the Project area. The percent of this clipped historical riparian area within the boundaries of conservation ownership was then calculated.

   An additional 9,631 acres are in conservation easement in this zone, however, these acres were not included in the total used to calculate this indicator (see comments for an explanation of why).

<u>Step 6</u>

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   In 2007, 16.20% of the historical riparian zone (within the mapped area) was in conservation ownership.

9. What is the desired rating and by when should this be achieved?

   Good, 25 - 35 %, by 2020.

<u>Step 7</u>.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

    Yes. This has been calculated for 1999 as well. Note however that the calculation of the percent of the historical riparian zone in conservation ownership in 1999 is a range (9.3% - 10.5%) rather than an absolute number. This is because some conservation ownership properties were purchased before 1999 but had more land added to them after 1999. Since the piece-by-piece breakdown of when each bit was added is unavailable, this metric was calculated both with and without those properties that were added to after 1999.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    These data are from the Sacramento Valley clipped to include only the Sacramento River area between Colusa Bridge and Red Bluff Diversion Dam. Tributaries were not included except in the vicinity of the mainstem. The indicator is presumed to be representative of the Middle Sacramento River riparian zone between Red Bluff and Colusa.

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

    This indicator information was input by G. Golet following review of relevant materials. Experts on this subject matter as it pertains to application on the Sacramento River are:

    Calculations based upon the 1999 and 2007 data were both performed by:
    Seth Paine, TNC Cons Science Tech,
    spaine@tnc.org
    (530) 897-6370 x 214
    Northern Central Valley office
    500 Main Street
    Chico, CA 95928

13. What is the rationale for the desired rating?

    Best guess at what is possible based upon a compromise of biological importance and political feasibility. Consideration was also given to what has been accomplished to date.

Step 8

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

More information on the viability assessment part of the workbook can be found at:
http://conserveonline.org/workspaces/cbdgateway/cap/practices/bp_3

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Percent of Historical Riparian Zone Currently in Natural Habitat

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   Percent of historical riparian zone currently in natural habitat is defined as a subset (defined below) of former habitat area that is in natural habitat. Some of this land may be being used for agricultural purposes (e.g., grazing), but generally there is not active clearing of vegetation (with the exception of exotics control) on these sites. Restoration sites where active planting of native species takes place, are included.

2. What is the rationale for it being a meaningful indicator?

   Amount of habitat influences biodiversity health for area sensitive species. Need this in addition to amount of lands in conservation ownership because: 1) some lands in conservation ownership are not natural habitat--they are currently managed as orchards or fallow (restoration work still needs to be done; and 2) because some land that is natural habitat is privately owned.

3. What references support its use as an indicator of river health? Provide citations.

   None that I am aware of.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   This indicator is most useful at the large scale, applied to the entire river reach. Other included indicators address fragmentation and patch size and morphology issues.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

   The status indicator ratings are defined as:
   Very Good: > 42 %
   Good: 30 - 42 %
   Fair: 17 - 30 %
   Poor: < 17 %

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

Best guess at what is possible based upon a compromise of biological importance and political feasibility. These values are slightly higher than for the indicator "Percent of historical riparian zone currently in conservation ownership" because it is expected and perhaps desired that some habitat will forever be in private ownership.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

   Greco provided a map of the historical riparian zone as determined from the Holmes et al. 1913 soil map.

   Both 1999 & 2007 CSU-GIC remnant riparian data layers were clipped to the extent of the 2007 CSU-GIC aerial photographs that were used to create the 2007 remnant riparian layer. A technician then calculated the percent of the CSU-GIC 1999 & 2007 remnant riparian data layers within the clipped mainstem Sacramento River historical riparian layer. This was done once including restored vegetation, and once excluding restored vegetation.

   The above value includes restored areas. If restored areas are excluded then the value is 14.9%.

<u>Step 6</u>

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   In 2007, 17.7% of the historical riparian zone (within the mapped area) was in natural habitat. The above value includes restored areas. If restored areas are excluded then the value is 14.9%.

9. What is the desired rating and by when should this be achieved?

   Good, 25 - 40 %, by 2020.

<u>Step 7</u>.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

    In 1999 the comparable values were 16.0% (including restoration sites) and 14.7 (without restoration).

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    These data are from the Sacramento Valley clipped to include only the Sacramento River area between Colusa Bridge and Red Bluff Diversion Dam. Tributaries were not included except in the vicinity of the mainstem. The indicator is presumed to be representative of the Middle Sacramento River riparian zone between Red Bluff and Colusa.

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

    This indicator information was input by G. Golet following review of relevant materials. Calculations based upon the 1999 and 2007 data were both performed by:

    Seth Paine, TNC Cons Science Tech,
    spaine@tnc.org
    (530) 897-6370 x 214
    Northern Central Valley office
    500 Main Street
    Chico, CA 95928

13. What is the rationale for the desired rating?

    Best guess at what is possible based upon a compromise of biological importance and political feasibility.

Step 8

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

As stated in the Sacramento River NWR CCP, the USFWS has a goal of owning in fee title 18,000 riparian zone acres of natural riparian habitat along the Sacramento River.

More information on the viability assessment part of the workbook can be found at: http://conserveonline.org/workspaces/cbdgateway/cap/practices/bp_3

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Length of River with Conservation Ownership on Both Banks

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   The indicator is defined as length of river with conservation ownership on both banks. This number is the sum length in meters of the banklines on both sides of the river where both sides have conservation ownership.

2. What is the rationale for it being a meaningful indicator?

   Having land in conservation ownership on both sides of the river increases the likelihood of rip-rap removal or deterioration over time and also reduces pressure for new rip-rap that comes from adjoining agricultural owners.

   This will increase the area where meander migration may take place allowing reworking of the land and supporting vegetation succession.

3. What references support its use as an indicator of river health? Provide citations.

   None that I am aware of. A novel indicator?

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   This indicator is most useful in characterizing the status of the river at the large scale, as an indicator of the health of reaches or the entire river Project Area (Red Bluff to Colusa).

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

   The status indicator ratings are defined as:
   Very Good: >120,000 meters
   Good: 80,000 - 120,000 meters
   Fair: 40,000 - 80,000 meters
   Poor: <40,000 meters

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

   Based upon what is desirable and considered possible in terms of acquisition (tier 1 property setting exercise), and the additional frontage this would confer.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

   The methods for calculating this metric are not published. They are as follows: The mainstem river channel GIS polygon layer was viewed on a computer screen at a 1:4000 scale. A technician (Seth Paine) scrolled 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. The Sacramento River Conservation Ownership GIS layer maintained by TNC was used to determine what lands were in conservation ownership. Parts of the river polygon without conservation ownership on both sides of the river were removed from the data layer. The remaining polygons were then converted to polylines. Line segments not contiguous to the bank of the river were deleted. The sum of the lengths of the remaining polylines was calculated as the final result.

Step 6

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   The most current indicator value is 69,777 meters (fair condition). This is from June 2007.

9. What is the desired rating and by when should this be achieved?

   Good, by June 2020

Step 7.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

    This value has also been calculated for 1999. In 1999 the value was between 33,626 and 40,806 meters. The calculation of the amount of river frontage in conservation ownership in 1999 is a range rather than absolute numbers. This is because some conservation ownership properties were purchased before 1999 but had more land added to them after 1999. Since the piece-by-piece breakdown of when each bit was added is unavailable, this metric was calculated both with and without those properties that were added to after 1999.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    The current indicator data are based upon an analysis of the entire mainstem Sacramento River between the Red Bluff Diversion Dam and the Colusa Bridge. It is representative only of this area.

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

    This indicator information was input by G. Golet following review of relevant materials. Calculations based upon the 1999 and 2007 data were both performed by:

    Seth Paine, TNC Cons Science Tech,
    spaine@tnc.org
    (530) 897-6370 x 214
    Northern Central Valley office
    500 Main Street
    Chico, CA 95928

13. What is the rationale for the desired rating?

If all of the 11,600 acres of tier 1 properties are acquired then this will add 119,478 meters of additional bank with conservation ownership on both sides. This would bring the total up to 189,255 meters. The feasibility of achieving this was used as a basis for setting the ratings values and the desired rating.

<u>Step 8</u>

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

More information on the viability assessment part of the workbook can be found at: http://conserveonline.org/workspaces/cbdgateway/cap/practices/bp_3

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Floodplain Inundation Flow Indicator

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

1. How specifically is the indicator defined?

The indicator is calculated based on two variables extracted from the USGS gauging records: the average number of days per year of floodplain inundation for the Red Bluff to Colusa reach of the Sacramento River, and the number of years in the previous decade in which no flows exceeded the threshold for inundation, here taken as a flow of 70,000 cfs. The threshold for floodplain inundation is the flow at which water is no longer contained within the channel and spills out over the floodplain. In the lower reaches of large rivers, the floodplain plays a crucially important role in conveying and storing floodwaters, as a locus for deposition of suspended sediments, and in providing habitat for juvenile fish to feed and grow on the rich terrestrial food resources found on the floodplain.

For the middle Sacramento River, overbank flow occurs at approximately the 2.5-year flood level, or about 70,000 cfs, based on research conducted for the Sacramento River Advisory Council (SRAC 2003:4-12) pursuant under the SB 1086 Program, to establish easements and reserve lands along the Sacramento River from Red Bluff to Colusa.

"In the Red Bluff to Chico Landing Reach a 2.5-year interval flood event is associated with inundation of more than 57 percent of the Conservation Area. For some localities, flooding occurs outside of the inner river zone guideline. Flood frequency at the 2.5-year recurrence could permit the natural regeneration of riparian forest if the timing of other factors such as seed dispersal and temperature regime are favorable."

The Q2.5 inundation area is mapped and quantified in Figure 4-6 and Table 4-6 of SRAC (2003), and SRAC (2003:4-13) refers to "the frequently flooded areas (defined here as a 2.5-year interval occurrence)".

Because natural flow variability year-to-year is so high, this indicator would not make sense to report on an annual basis, but instead is reported as a running total over the previous 10 years, using the same spreadsheet format as illustrated in the writeup for the bed mobility indicator. The indicator consists of two variables: the average number of days per year in which flow exceeded 70,000cfs, and the number of years in which there were no flows exceeding 70,000cfs, both over the previous 10-year period.

2. What is the rationale for it being a meaningful indicator?

Floodplain inundation is a key component of lateral connectivity in river systems (Kondolf et al. 2006). Overbank sedimentation is a key process in building floodplains, establishing riparian forests, and providing high-flow refugia for fish during floods. If flow diversions or storage result in reduction in frequency or duration of floodplain inundation, it may have negative consequences on geomorphic and ecological processes and the biota that depend upon them.

There is a considerable literature demonstrating the importance of floodplain inundation on the physical function and ecological health of river systems, including Junk et al. 1989, Poff et al, 1997, and Stanford et al. 2005. For the importance of inundated floodplain habitat in the lower Sacramento, Yolo Bypass, Ted Sommer and colleagues have clearly documented that juvenile fish grow faster and to larger size if they spend time on the floodplain (Sommer et al. 2001a, 2001b, 2004).

The floodplain plays a role as "pressure-relief valve" for the channel, because shear stress (force per unit area) increases in the channel with increased flow until the channel capacity is exceeded and flow goes overbank. With overbank flow, the shear stress on the bed is moderated, and peak flows are attenuated in the downstream direction, as floodwaters are effectively stored on the floodplain (Figure 1).Demonstrating the shear stress 'relief-valve' effect, stage-discharge curves often show inflections points at the stage corresponding to beginning of overflow (Figure 2).

3. What references support its use as an indicator of river health?

Junk W. J., P. B. Bayley, and R. E. Sparks. 1989. The flood pulse concept in river-floodplain systems. *Canadian Journal of Fisheries and Aquatic Sciences* 106:110-127.

Kondolf, G.M., A. Boulton, S. O'Daniel, G. Poole, F. Rahel, E. Stanley, E. Wohl, A. Bang, J. Carlstrom, C. Cristoni, H. Huber, S. Koljonen, P. Louhi, and K. Nakamura. 2006. Process-based ecological river restoration: Visualising three-dimensional connectivity and dynamic vectors to recover lost linkages. *Ecology and Society* 11 (2): 5. [online] URL: *http://www.ecologyandsociety.org/vol11/iss2/art5/*

Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. D. Richter, R. E. Sparks, and J. C. Stromberg. 1997. The natural flow regime. *BioScience* 47:769-784.

Sommer, T., B. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001a. California's Yolo Bypass: evidence that flood control can be compatible with fisheries, wetlands, wildife, and agriculture. *Fisheries* 26: 6-16.

Sommer, T., M.L. Nobriga, B. Harrell, W. Batham, and W.J. Kimmerer. 2001b. Floodplain rearing of juvenile chinook salmon: evidence of enhanced growth and survival, *Canadian Journal of Fisheries and Aquatic Sciences, 58*, 325-333.

Sommer, TR, Harrell, WC, Mueller Solger, A, Tom, B, Kimmerer, W. 2004. Effects of flow variation on channel and floodplain biota and habitats of the Sacramento River, California, USA. *Aquatic Conservation: Marine and Freshwater Ecosystems* 14:247-

261

SRAC (Sacramento River Advisory Council under Senate Bill 1086). 2003. *Sacramento River Conservation Area Forum Handbook*. Revised and updated for The Resources Agency State of California by the Sacramento River Conservation Area Forum September 2003.

Stanford, J.A., M.S. Lorang, and F.R. Hauer. 2005. The shifting habitat mosaic of river ecosystems, *Verhandlungen des Internationalen Verein Limnologie* **29**:123-136.

Williams, J.G. 2006. Central Valley Salmon: A Perspective on Chinook and Steelhead in the Central Valley of California. *San Francisco Estuary and Watershed Science* **4**:(3)

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

As proposed here, the indicator would be applied to the reach from Red Bluff to Colusa, based on flows measured at the US Geological Survey gauge at Red Bluff.. While specific floodplain reaches of the Sacramento would be subject to inundation at different flows, the generalizations summarized by SRAC (2003) strongly indicate that the Q2.5 flow, or 70,000cfs, is a good value as a reach-wide (Red Bluff- Colusa) indicator.

5. What cutoffs are appropriate for poor, fair, good and very good?

Cutoffs were determined based on tabulation of flows exceeding 70,000cfs over the previous 10-year period. The cutoffs are:

Very good: An average of seven (7) or more days exceeding 70,000cfs per year over the preceding decade, and no more than two (2) years without floodplain inundation over the preceding decade.

Good: An average of five (5) or more days exceeding 70,000cfs per year over the preceding decade, and no more than three (3) years without floodplain inundation over the preceding decade.

Fair: An average of three (3) or more days exceeding 70,000cfs per year over the preceding decade, and no more than four (4) years without floodplain inundation over the preceding decade.

Poor: An average of less than three (3) days exceeding 70,000cfs per year over the preceding decade and more than four (4) years without floodplain inundation over the preceding decade.

6. How were the particular rating cutoffs selected?

The 70,000cfs flow has decreased from being approximately a 1.4-year flood to being a 2.5-year flood since construction of Shasta Dam, indicating a significant reduction in flows capable of going overbank (Figure 3). Cutoffs based on analysis of gauge records at the USGS gauge at Red Bluff (Figures 4 and 5), and using the pre-Shasta-Dam condition as mostly *good* to *very good* (except for the dust-bowl drought years). The cut-offs between *very good* and *good*, *good* and *fair*, etc were based on professional judgment and inspection of historical patterns, with the pre-Shasta-Dam period serving as a reference condition, with the unusually dry Dust-Bowl period of 1919-1936 as reference for very dry (*poor*) conditions.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

Methods for calculating this indicator are not published. The procedure was to use flow data from the USGS gauge at Red Bluff, available online, to count the number of days in each water year in which flows exceeded 70,000 cfs. Setting up a spreadsheet table, the 10-year running total can be calculated as a separate column.

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

As of the end of WY 2010 there had been an average of 0.7 days per year above 70,000 cfs and 8 of the previous ten years had zero days above 70,000 cfs. This places the current condition in the *poor* category.

9. What is the desired rating and by when should this be achieved?

The desired rating is *good* to *very good*. However, without substantial changes to the flow regulation pattern by Shasta and other reservoirs, this desired condition is unlikely to be achieved.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

Given that the streamflow data have been collected since the turn of the 20^{th} century, it is a simple matter to use these historical data to calculate the indicator for past years. Resulting ratings for historical years are graphically illustrated in Figures 4 and 5, and summarized by year in Table 1. Values are based on flow data for the preceding ten-year period.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

The indicator data are collected at US Geological Survey gauging station at Red Bluff, and represent flows in the middle reach of the Sacramento River (Red Bluff to Colusa).

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

The contact person for the indicator in Matt Kondolf *kondolf@berkeley.edu*

USGS flow data available online at http://waterdata.usgs.gov/usa/nwis/uv?site_no=11377100 for the Red Bluff (station # 11377100) gauge.

13. What is the rationale for the desired rating?

The benefits of frequent and prolonged floodplain inundation, as reported above.

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

Just upstream of the city of Sacramento, the Fremont weir overtops and flood flows begin flowing down the Yolo Bypass at 70,000 cfs, and thus providing critically important inundated floodplain habitat (Williams 2006). Thus, in addition to using the flow of 70,000 cfs at Red Bluff as a good indicator of initiation of overbank flow in the middle Sacramento, a similar flow threshold could be used as an indicator of flow into the Yolo Bypass.

A more serious concern than the reduced flow regime is the extent of levees along the river, which can prevent floodplain inundation, even when sufficient flows occur.

Table 1. Historical analysis of bed floodplain inundation ratings

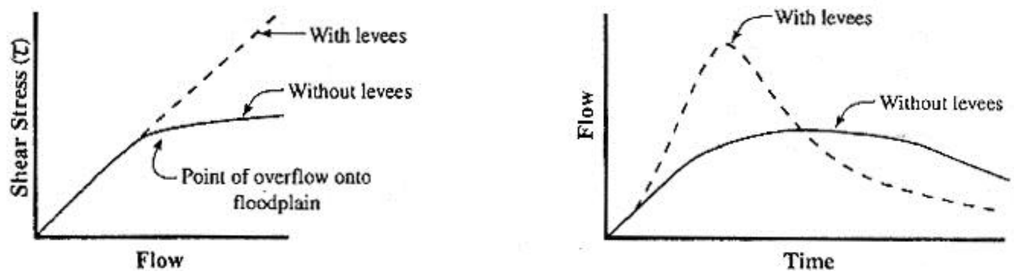
Year	# of days > 70,000 cfs	10-yr running average # of days > 70,000 cfs	# years of prevous 10 without flow >70,000 cfs	Rating	Notes
1892	0				
1893	10				
1894	2				
1895	6				
1896	10				
1897	3				
1898	0				
1899	1				
1900	3				
1901	6	4.1	2	G	int
1902	12	5.3	1	VG	u
1903	6	4.9	1	G	int
1904	27	7.4	1	VG	
1905	5	7.3	1	VG	
1906	6	6.9	1	VG	u
1907	13	7.9	1	VG	
1908	1	8	0	VG	
1909	18	9.7	0	VG	
1910	2	9.6	0	VG	
1911	2	9.2	0	VG	
1912	0	8	1	VG	
1913	0	7.4	2	VG	
1914	17	6.4	2	VG	u
1915	6	6.5	2	VG	u
1916	4	6.3	2	VG	u
1917	2	5.2	2	VG	u
1918	0	5.1	3	G	
1919	3	3.6	3	G	u
1920	0	3.4	4	F	
1921	3	3.5	4	F	
1922	0	3.5	4	F	
1923	0	3.5	4	F	
1924	0	1.8	5	P	
1925	5	1.7	5	P	
1926	1	1.4	5	P	
1927	7	1.9	5	P	
1928	2	2.1	4	F	u

1929	0	1.8	5	P	
1930	1	1.9	4	F	u
1931	0	1.6	5	P	
1932	1	1.7	4	F	u
1933	1	1.8	3	F	int
1934	0	1.8	3	F	int
1935	1	1.4	3	F	int
1936	5	1.8	3	F	int
1937	0	1.1	4	F	u
1938	16	2.5	4	F	u
1939	0	2.5	4	F	u
1940	8	3.2	4	F	
1941					
1942	Data not used from 1941-1943 while reservoir filling				
1943					
1944	0				
1945	0				
1946	0				
1947	0				
1948	0				
1949	0				
1950	0				
1951	0				
1952	1				
1953	10	1.1	8	P	
1954	0	1.1	8	P	
1955	0	1.1	8	P	
1956	6	1.7	7	P	
1957	0	1.7	7	P	
1958	21	3.8	6	F	u
1959	0	3.8	6	F	u
1960	0	3.8	6	F	u
1961	0	3.8	6	F	u
1962	0	3.7	7	F	u
1963	0	2.7	8	P	
1964	0	2.7	8	P	
1965	6	3.3	7	F	u
1966	0	2.7	8	P	
1967	1	2.8	7	P	
1968	0	0.7	8	P	
1969	5	1.2	7	P	
1970	16	2.8	6	P	
1971	1	2.9	5	P	

1972	0	2.9	5	P	
1973	0	2.9	5	P	
1974	14	4.3	4	F	
1975	0	3.7	5	F	u
1976	0	3.7	5	F	u
1977	0	3.6	6	F	u
1978	0	3.6	6	F	u
1979	0	3.1	7	F	u
1980	5	2	7	P	
1981	0	1.9	8	P	
1982	1	2	7	P	
1983	26	4.6	6	F	u
1984	1	3.3	6	F	u
1985	0	3.3	6	F	u
1986	15	4.8	5	F	u
1987	0	4.8	5	F	u
1988	0	4.8	5	F	u
1989	0	4.8	5	F	u
1990	0	4.3	6	F	u
1991	0	4.3	6	F	u
1992	0	4.2	7	F	u
1993	1	1.7	7	P	
1994	0	1.6	8	P	
1995	16	3.2	7	F	u
1996	0	1.7	8	P	
1997	7	2.4	7	P	
1998	11	3.5	6	F	u
1999	0	3.5	6	F	u
2000	1	3.6	5	F	u
2001	0	3.6	5	F	u
2002	0	3.6	5	F	u
2003	0	3.5	6	F	u
2004	3	3.8	5	F	u
2005	0	2.2	6	P	
2006	4	2.6	5	P	
2007	0	1.9	6	P	
2008	0	0.8	7	P	
2009	0	0.8	7	P	
2010	0	0.7	8	P	

[1)] u= rounded up between consecutive categories;
int= the intermediate category;
int-u= rounded up to the higher of two intermediate categories.

Figures Floodplain Inundation Flow Indicator



a) Shear stress on bed b) Downstream flow

Figure 1. a) Increase in shear stress on channel bed with increasing flow, with overbank flow onto adjacent floodplain (without levees), and intensification of shear stress on the bed resulting from levees cutting off overbank flow. b) flow downstream of alluvial reach under natural conditions (without levees), reflecting effect of overbank flow in storing floodwaters and attenuating peak flows, and with levees, which concentrate flow in-channel.

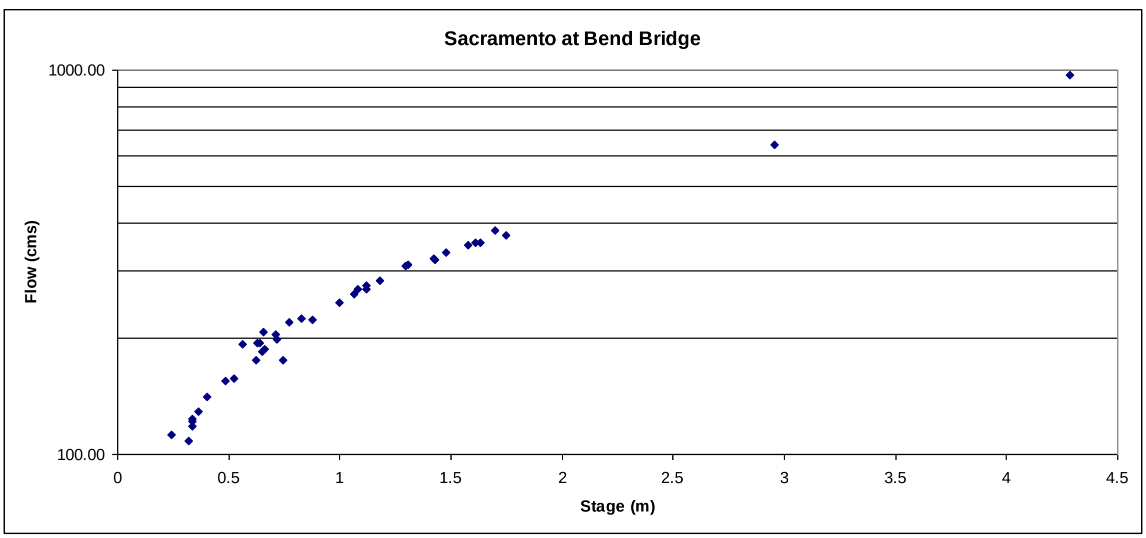


Figure 2. Stage-discharge curve for the Sacramento River at Bend Bridge (USGS gage #11377100). Note the subtle break in slope of the curve, which is a result of the small floodplain present at the site.

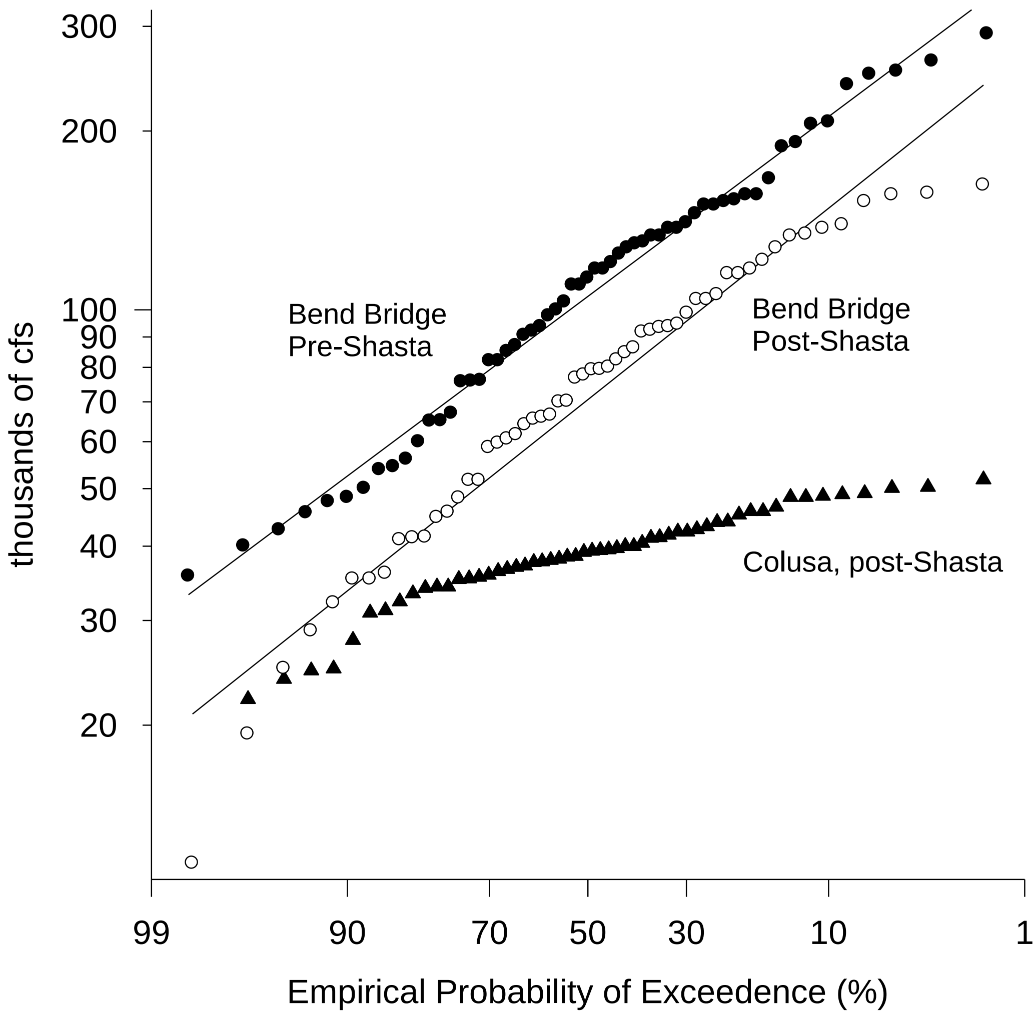


Figure 3. Flood-frequency curves for Sacramento River at Bend Bridge (Red Bluff) for pre- and post-Shasta Dam periods.

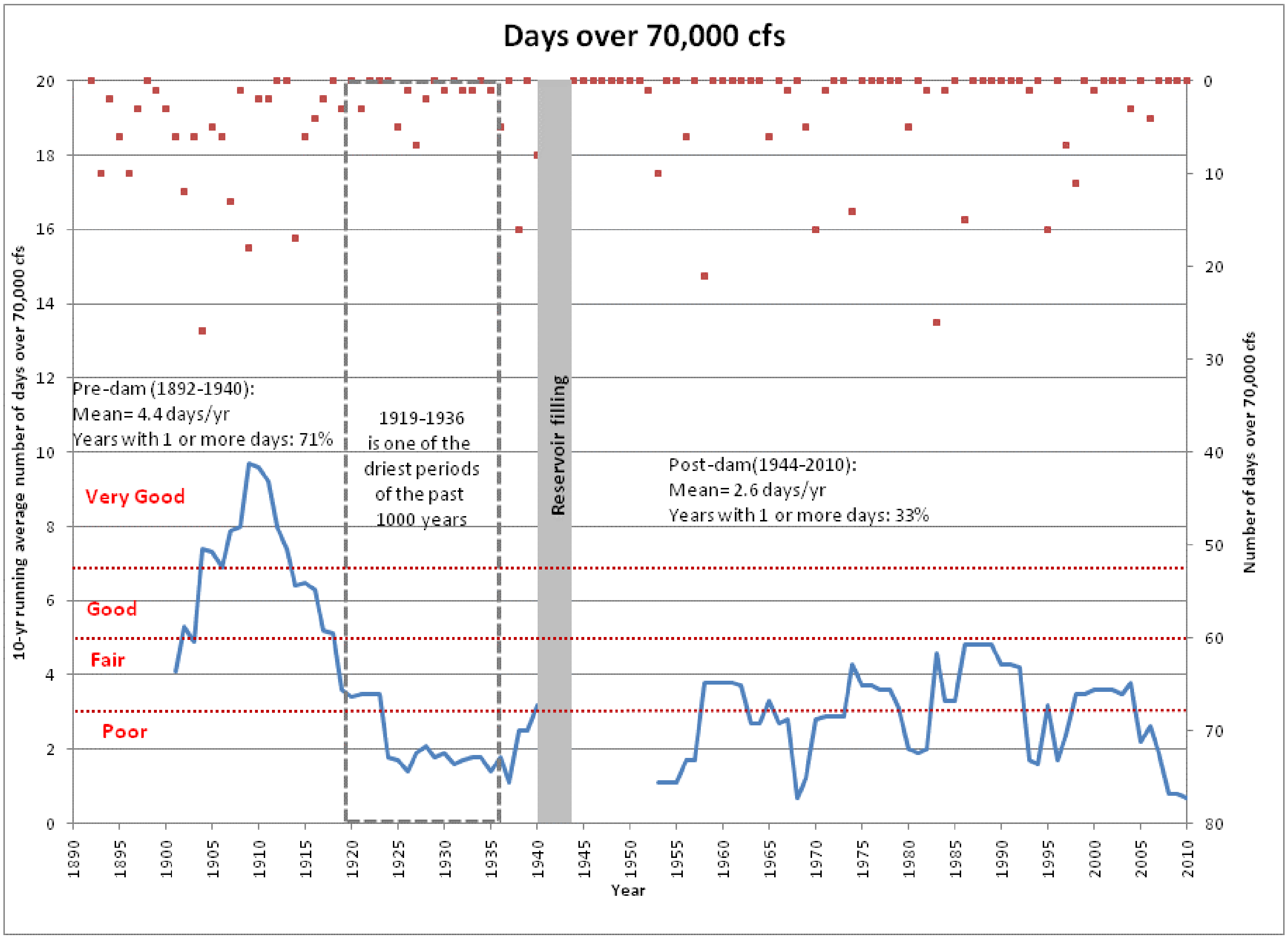


Figure 4. Ten-year running average of number of days with flows over 70,000 cfs recorded at the USGS gauge Sacramento River at Red Bluff (blue line, left labels y-axis), along with number of days with flows over 70,000cfs for each year (red data points, right labels y-axis).

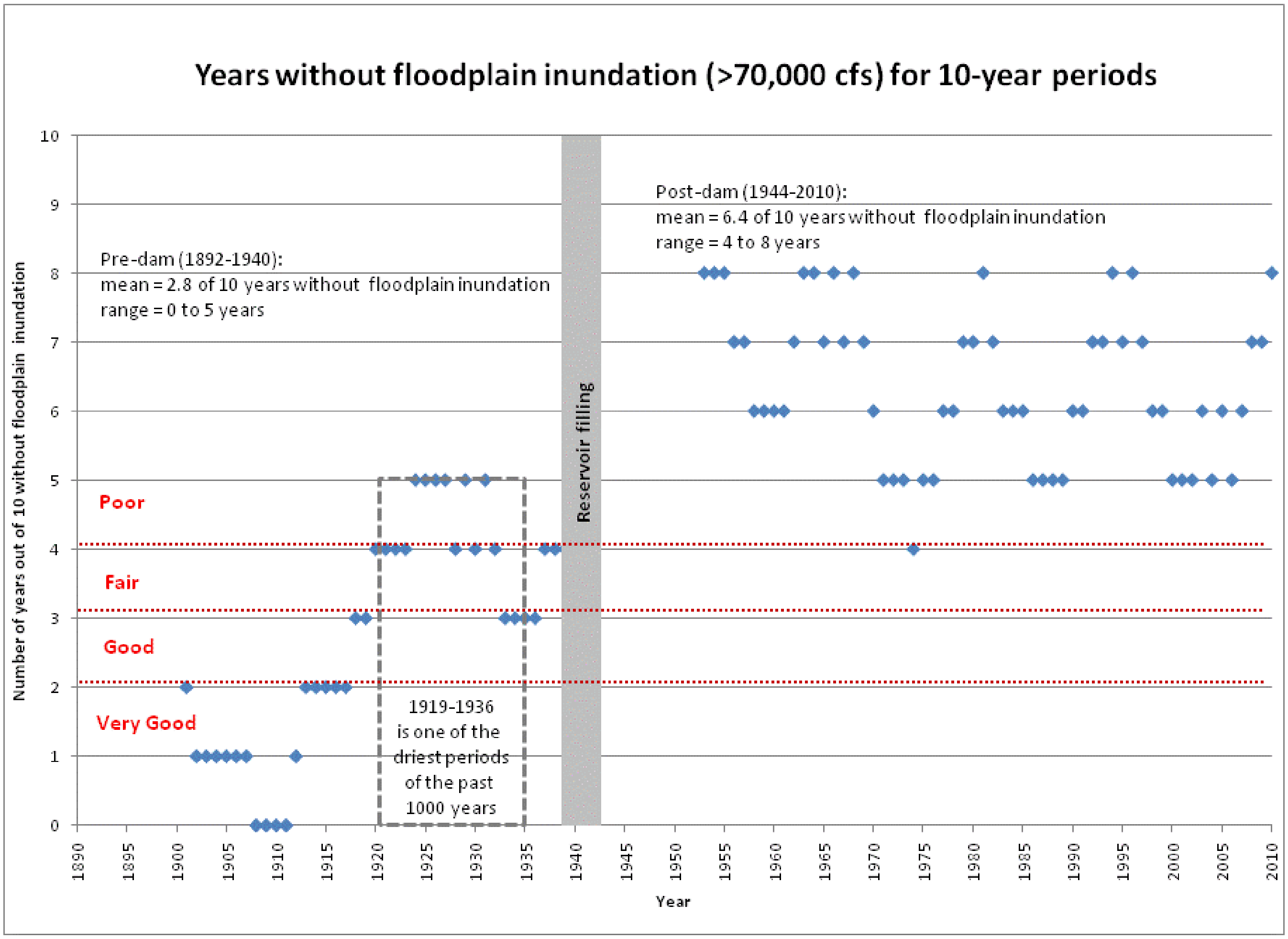


Figure 5. Number of years without floodplain inundation over prior ten-year period, based on analysis of USGS flow records, Sacramento River at Red Bluff.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Side-Channel Connection Flow Indicator

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

1. How specifically is the indicator defined?

The *Side Channel Connection* indicator is defined as a composite indicator taking into account the 10-year running average of the number of days with flows (measured at the USGS gauge at Red Bluff) exceeding 50,000cfs, the number of days with flows exceeding 22,000cfs, and number of days from July 15 to Sept 30th in which flows exceed 6,000cfs.

2. What is the rationale for it being a meaningful indicator?

Oxbow lakes and other floodplain water bodies, mostly former channels, provide important habitats for a range of species, and are in effect biodiversity hotspots in the river ecosystem. Side channels benefit from periodic, seasonal surface connection to the main channel, including scouring of encroaching vegetation (*Ludwigia*), refreshing sediments, improving water quality. When connected they provide important rearing habitats for native fishes (Limm and Marchetti 2009). Channels that are artificially cutoff and leveed will lose their periodic hydrologic connection, eliminating dynamic evolution of aquatic and riparian ecology, and ultimately reducing floodplain biodiversity. Similarly, if flows in the mainstem river are artificially reduced, the frequency and duration of hydrologic connection of side channels may be reduced, with loss of beneficial functions of connection.

These floodplain water bodies are the result of channel migration, and they undergo a progressive evolution over time, from fully aquatic, hydrologically-connected habitats, to hydrologically-disconnected habitats that become more terrestrial over time as they fill with sediment (Figure 1). As they evolve, these features provide habitat for a variety of species, and the species using a particular water body change over time as the feature's characteristics change. Superimposed over this long-term (i.e., years to decades to centuries) trend from aquatic to terrestrial is a seasonal change in hydrology. Side channels are commonly connected by surface flow during seasonal high flows, only to become disconnected as floodwaters recede. The chemistry of these water bodies can change substantially over the season, as a result of their changing hydrology.

Oxbow lakes, sloughs and side channels and other off-channel water bodies are created by channel cutoff or channel change, and typically go through an evolutionary sequence in which sedimentation gradually converts them from aquatic to terrestrial environments [*Piégay et al*., 2002]. The initial creation of an abandoned channel occurs through geomorphic processes such as development of tortuous meander bends leading to neck cutoff, overbank flood flows shortcutting bends and leading to chute cutoff, or avulsion caused by debris jams or by sedimentation and abandonment of braid channels. In one of many such examples, a meander bend along the Sacramento River near Hamilton City was cut off during a high flow in 1970 as a chute channel across the floodplain grew in dimensions, and by the time the flood receded, the main flow of the river had been captured by this cutoff channel (Figure 2).

Meander cutoffs on the Sacramento are dominantly chute cutoffs, probably owing to extensive clearing of riparian forests from floodplains, which has decreased hydraulic roughness and increased overbank flow velocities, accelerating erosion and expansion of chute channels (Brice 1977). The sinuosity of the Sacramento River decreased from 1.56 in 1896 to about 1.36 in 1942 (Brice 1977), and then slightly increased to 1.39 by 1999 (Michalková et al. 2011), while the data of Larsen suggest that sinuosity has continued to decrease since the 1940s. Whatever the actual change in sinuosity, it is clear that the size of cutoffs after about 1962 was significantly smaller, probably reflecting changes in flow regime and sediment supply due to dam construction and extensive bank revetments (Michalková et al., 2011).

Thus, abandoned channels owe their origins to dynamic channel migration and change. Once created, they evolve through sedimentation, vegetation colonization and succession, and the buildup of organic detritus from aquatic vegetation into progressively more terrestrial environments. The evolution of oxbow lakes is illustrated in Figure 1, which begins with the flowing river channel at the bottom of the diagram. During the initiation of a meander bend cutoff, the original main channel transitions to a side channel that is hydrologically connected at both ends. The upstream inlet to the side channel usually plugs with sediment first, creating an oxbow slough. When the downstream outlet of the side channel plugs as well, the feature becomes an oxbow lake, which begins as a fully aquatic feature. As the oxbow lake fills with sediment and vegetation establishes and undergoes succession, the oxbow lake evolves from fully aquatic to progressively more terrestrial habitat, with each stage providing distinct habitats (e.g., in vegetative structure, soil conditions, frequency and duration of inundation) that meet habitat needs for different faunal species and life stages. Colonization of recently abandoned channels is an important mechanism for renewing the riparian forest of the Sacramento River (Stella et al. 2011).

The rate at which a former channel evolves from fully aquatic to terrestrial determines its persistence as aquatic habitat and its value to different species. Within the Sacramento River corridor, some oxbow lakes (such as Packer Lake) have persisted as open-water habitat for over a century, while others (such as Hartley Island) completely filled within decades. Oxbow lakes and other off-channel water bodies provide important (and diverse) habitats, and can be regarded as ecological ‘hot spots’ on the landscape (Amoros et al.,2005). On the Sacramento

River, California, off-channel water bodies provide critical habitat a variety of native species, such as Western Pond Turtle (*Clemmys marmorata*), Sacramento sucker (*Catostomus occidentalis*), Sacramento pikeminnow (*Ptychochelilus grandis*), California roach (*Hesperoleucus symmetricus*) and Chinook salmon (*Oncorhynchus tshawytscha*) (Kondolf and Stillwater Sciences 2007).

As the oxbows become seasonally connected and then disconnected from the mainstem, their characteristics change, especially as the relative influence of groundwater seepage changes. Hydrologic isolation from the mainstem flow may increase or decrease diversity.

In many cases, groundwater seepage supports the water level in the side channel, creating distinct water conditions from those in the main river. Along the Rhone River, side channels have been documented to be dominated by clear groundwater, with different chemical signature from the usually turbid mainstem waters. In agricultural regions, drainage (surface or groundwater) from adjacent cultivated fields into oxbows can contain high concentrations of dissolved nutrients, herbicides, and pesticides. Reconnaissance-level water quality sampling of oxbow lakes along the Sacramento River indicated some significant water quality issues that were probably due to such agricultural drainage (Kondolf and Stillwater Sciences 2007), and would be exacerbated by being artificially isolated from periodic connection with the river. In this case, the real problem is the pollution from agricultural chemicals, and if this problem is not addressed, one might argue that we are faced with a choice between leaving the former channel disconnected and sacrificing its ecology to keep contaminants from the main river, vs connecting the former channel to flush contaminants, which would disperse in the much-larger flows of the main Sacramento River.

Thus, oxbow lakes and other side channels provide habitats over a range of conditions, from fully connected to the mainstem, seasonally connected, and disconnected. However, the ecosystem benefits are greatest when there are side channels over a range of connections. With flow regulation, many rivers have experienced a reduction in high flows, which results in a decrease in seasonal surface connection to the main channel. As a result, the side channel may lose the ecological benefits of periodic scour of encroaching vegetation (eg, *Ludwigia* on the Sacramento), refreshing sediments, improving water quality, and if not connected, the side channels cannot function as rearing habitats for native fish. Thus, the importance of periodic side channel connection to the mainstem river.

On the Sacramento River, storage of floodwaters by Shasta Reservoir and augmentation of baseflow by imported water from the Trinity River basin, has resulted in changed frequency and duration of mainstem flows (Figure 3), which in turn have changed the frequency and duration of connection of side channels. These changes are illustrated in Figure 4, which shows percent-of-time connected for the side channels studied by Gomez et al (in preparation), for both pre-Shasta-Dam and post-Shasta periods. Three distinct groups of side channels can be identified:

Side channels that connect at flows from 50,000-60,000 cfs. These side channels have experienced decreases in percentage time connected, as would be expected from the reduction in average monthly flows for winter and spring shown in Figure 3. At the scale of this plot in Figure 4, the changes do not appear to be pronounced, but they may still be significant ecologically, as the potentially important ecological benefits of infrequent inundation are lost. The next distinct set are:

Side channels that connect to the river at flows from 15,000-35,000cfs. These experience hydrologic connection with the mainstem much less frequently now than under pre-dam conditions (Figure 4), where the percent of time connected has decreased from over 10 percent to significantly less than 10 percent. This is likely to have significant ecological consequences. The third distinct set are:

Side channels that connect to the mainstem at flows of less than 10,000cfs. By contrast, these are connected longer. During the irrigation season from late spring to early autumn, the Sacramento River's baseflows are artificially increased by release of water from storage in Shasta Reservoir and from water imported from the Trinity River basin (Figure 3). Summer baseflows are artificially held at flows of around 8,000cfs to supply irrigation diversions. As a result, side channels with topographically low alluvial plugs (and thus low connection threshold flows) experience nearly continuous inundation and connection to the main channel. While these connected side channels provide some off-channel habitat for fish, the loss of natural seasonal changes in water level is likely to favor exotic species over natives.

Thus the indicator is based on the number of days with flows exceeding 50,000 cfs (the threshold to begin connecting these first group of side channels), the number of days with flows exceeding 22,000cfs (the flow at which about half of the second group of side channel are connected), and number of days from July 15 to Sept 30th in which flows exceed 6,000cfs (connecting the third group).

3. What references support its use as an indicator of river health?

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4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

As described here, the indicator refers to the entire reach Red Bluff – Colusa, but the flow required to connect side channels varies substantially from side channel to side channel, and is not related to distance along the channel.

5. What cutoffs are appropriate for poor, fair, good and very good?

Cutoffs for very good, good, fair and poor are identified for flows in each of the three discharge ranges, as detailed in Tables 1 and 2. The final indicator is a composite of these three variables. Specifically, the three metrics important for the ecological function of side channels were evaluated individually and then averaged to produce an overall assessment of side channel condition. For the average, 4 points were given to VG, 3 to G, 2 to F, and 1 to P. The mean was calculated, rounded, and assigned a category.

6. How were the particular rating cutoffs selected?

The rating cutoffs were selected based on inspection of hydrologic patterns and professional judgment.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

The indicator value is simply the number of days exceeding a certain flow, drawn from USGS flow records. The data for flows required to hydrologically connect side channels is currently unpublished, but will be published within the coming one-two years by Hervé Piégay, Chris Gomez, Matt Kondolf, and colleagues. Many of these data will be published in Gomez et al. (in prep)

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

The current indicator value (most recent calculation for WY 2010, reflecting 10-year average over WY 2001-2010) is Fair.

9. What is the desired rating and by when should this be achieved?

The desired rating would presumably be Very Good, but this is unlikely to be achieved. Even if higher flows could be released in winter and spring to connect the topographically higher side channels that have suffered from less frequent connection, it is unlikely that summer baseflows would be reduced to natural levels, given the dependence on the Sacramento River channel to convey flows southward from storage in Shasta and Trinity reservoirs to diversion points downstream.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

Historical values of this indicator are presented in Table 2.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

The indicator is calculated based on river flows data as measured at the Sacramento River gage at Red Bluff, but is based on the connection of side channels to the main stem based on field observations during floods and modeling for side channels along the Sacramento from RM 161-222, which are assumed to be representative for side channels along the reach from Red Bluff to Colusa. The flows at which each side channel becomes hydrologically connected to the mainstem were determined based on a combination of direct observation of connectivity at a range of flows, and modeling of connectivity based on surveyed elevations of upstream and downstream sediment plugs and hydrologic modeling.

The flow data are collected at the US Geological Survey gauging station at Red Bluff, and represent the middle reach of the Sacramento River (Red Bluff to Colusa).

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

The indicator is calculated by Matt Kondolf (*kondolf@berkeley.edu*). The occurrence of flows needed to connect side channels are based on flow data collected and reported by the US Geological Survey (Sacramento River at Red Bluff Gauge) and field observations over a range of flows by: Hervé Piégay, University of Lyon, UMR 5600 – CNRS, Site ENS Lyon, 15 Parvis R. Descartes BP 7000, 69362 Lyon, France (*Herve.Piegay@ens-lyon.fr)*

13. What is the rationale for the desired rating?

As stated above, the desired rating of VG would imply that the full range of side channels would be connected to the mainstem at a frequency resembling historical pre-dam conditions, excepting the unusually dry dust-bowl years.

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

Table 1. Cutoffs for Side Channel Connection Ratings for Three Flow Ranges

50,000 cfs

Condition	10-yr average days >50,000 cfs	# of past 10 years without flows>50,000 cfs
VG	11 or more	0 or 1
G	9-11	2
F	6-9	3
P	5.9 or less	4 or more

22,000 cfs

Condition	10-yr average days >22,000 cfs
VG	45 or more
G	25-45
F	20-25
P	less than 20

6,000 cfs- summer flows

Condition	10-yr running average # of days (July 15 to Sept 30) > 6,000 cfs
VG	0-20
G	20-30
F	30-40
P	40 or more

2. Calculation of Connection Indicator for Historical Years

WY	# of days >50,000 cfs	10-yr running average # of days >50,000 cfs	# years of previous 10 without Q>50k	Rating	Notes[1]	# of days >22,000 cfs	10-yr running average # of days >22,000 cfs	# days (July 15 to Sept 30) > 6,000 cfs	10-yr running average # of days (July 15 to Sept 30) > 6,000 cfs	Condition
1892	0					20		31		
1893	22					116		77		
1894	2					36		20		
1895	12					113		27		
1896	19					61		27		
1897	8					62		10		
1898	0					4		0		
1899	3					13		0		
1900	10					28		0		
1901	11	8.7	2	G	u	36	48.9	0	19.2	**VG**
1902	23	11	1	VG	u	51	52	0	16.1	**VG**
1903	11	9.9	1	VG	u	44	**44.8**	0	8.4	**VG**
1904	43	14	1	VG		107	51.9	40	10.4	**VG**
1905	12	14	1	VG		63	46.9	0	7.7	**VG**
1906	15	13.6	1	VG		72	48	25	7.5	**VG**
1907	22	15	1	VG		93	51.1	46	11.1	**VG**
1908	1	15.1	0	VG		26	53.3	0	11.1	**VG**
1909	35	18.3	0	VG		80	60	19	13.0	**VG**
1910	3	17.6	0	VG		42	61.4	0	13.0	**VG**
1911	9	17.4	0	VG		59	63.7	11	14.1	**VG**
1912	1	15.2	0	VG		12	59.8	4	14.5	**VG**
1913	3	14.4	0	VG		13	56.7	0	14.5	**VG**
1914	23	12.4	0	VG		97	55.7	12	11.7	**VG**
1915	22	13.4	0	VG		92	58.6	17	13.4	**VG**
1916	11	13	0	VG		71	58.5	6	11.5	**VG**
1917	3	11.1	0	VG		20	51.2	0	6.9	**VG**
1918	1	11.1	0	VG		10	49.6	2	7.1	**VG**
1919	6	8.2	0	VG	int	38	45.4	0	5.2	**VG**
1920	0	7.9	1	VG	int	2	41.4	0	5.2	**VG**
1921	13	8.3	1	G	int	94	44.9	0	4.1	**G**
1922	0	8.2	2	G	u	17	45.4	0	3.7	**VG**
1923	0	7.9	3	F		7	44.8	0	3.7	**G**
1924	0	5.6	4	P		1	35.2	0	2.5	**G**
1925	10	4.4	4	P		32	29.2	0	0.8	**G**

1926	2	3.5	4	P		22	24.3	0	0.2	**F**
1927	18	5	4	P		67	29	0	0.2	**G**
1928	5	5.4	4	P		28	30.8	0	0.0	**G**
1929	1	4.9	4	P		4	27.4	0	0.0	**G**
1930	4	5.3	3	F	u	17	28.9	0	0.0	**G**
1931	0	4	4	P		2	19.7	0	0.0	**F**
1932	2	4.2	3	F	u	8	18.8	0	0.0	**F**
1933	1	4.3	2	F	int	9	19	1	0.1	**F**
1934	2	4.5	1	G	int-u	11	20	0	0.1	**G**
1935	3	3.8	1	G	int-u	32	20	0	0.1	**G**
1936	8	4.4	1	G	int-u	27	20.5	0	0.1	**G**
1937	1	2.7	1	G	int-u	21	15.9	0	0.1	**G**
1938	34	5.6	1	G	int-u	116	24.7	0	0.1	**G**
1939	0	5.5	2	F	int	3	24.6	0	0.1	**G**
1940	17	6.8	2	G	u	61	29	0	0.1	**G**
1941										
1942	Data not used from 1941-1943 while reservoir filling									
1943										
1944	0					1		0		
1945	0					3		72		
1946	5					22		63		
1947	0					3		51		
1948	0					23		75		
1949	0					7		69		
1950	0					4		67		
1951	2					39		61		
1952	2					42		76		
1953	17	2.6	6	P		30	17.4	77	61.1	**P**
1954	13	3.9	5	P		31	20.4	77	68.8	**P**
1955	0	3.9	5	P		1	20.2	68	68.4	**P**
1956	33	6.7	5	F	u	62	24.2	77	69.8	**F**
1957	4	7.1	4	F	u	14	25.3	77	72.4	**F**
1958	40	11.1	3	G	int	65	29.5	77	72.6	**F**
1959	1	11.2	2	VG	u	18	30.6	76	73.3	**G**
1960	1	11.3	1	VG		5	30.7	77	74.3	**G**
1961	1	11.2	1	VG		12	28	77	75.9	**G**
1962	1	11.1	1	VG		12	25	77	76.0	**G**
1963	7	10.1	1	VG	u	30	25	77	76.0	**G**
1964	0	8.8	2	G	u	1	22	77	76.0	**F**
1965	13	10.1	1	VG	u	44	26.3	77	76.9	**F**
1966	1	6.9	1	G	int	6	20.7	77	76.9	**F**
1967	8	7.3	1	G	int	43	23.6	77	76.9	**F**
1968	4	3.7	1	G	int-u	16	18.7	77	76.9	**F**
1969	18	5.4	1	G	int-u	48	21.7	77	77.0	**F**
1970	27	8	1	G	int	58	27	77	77.0	**F**
1971	7	8.6	1	G	int	46	30.4	77	77.0	**F**

1972	0	8.5	2	G	u	2	29.4	77	77.0	**F**
1973	3	8.1	2	G	u	46	31	77	77.0	**F**
1974	25	10.6	1	VG	u	125	43.4	77	77.0	**G**
1975	7	10	1	VG	u	27	41.7	77	77.0	**G**
1976	0	9.9	2	G		1	41.2	68	76.1	**F**
1977	0	9.1	3	G	u	0	36.9	54	73.8	**F**
1978	10	9.7	3	G	u	34	38.7	77	73.8	**F**
1979	0	7.9	4	F	u	3	34.2	62	72.3	**F**
1980	18	7	4	F	u	44	32.8	77	72.3	**F**
1981	0	6.3	5	F	u	8	29	64	71.0	**F**
1982	21	8.4	4	F	u	83	37.1	77	71.0	**F**
1983	65	14.6	4	G	int-u	103	42.8	77	71.0	**F**
1984	7	12.8	4	G	int-u	59	36.2	77	71.0	**F**
1985	0	12.1	5	G	int-u	4	33.9	59	69.2	**F**
1986	27	14.8	4	G	int-u	42	38	73	69.7	**F**
1987	0	14.8	4	G	int-u	3	38.3	70	71.3	**F**
1988	0	13.8	5	G	int-u	1	35	77	71.3	**F**
1989	0	13.8	5	G	int-u	4	35.1	66	71.7	**F**
1990	0	12	6	G	int-u	1	30.8	69	70.9	**F**
1991	0	12	6	G	int-u	0	30	62	70.7	**F**
1992	0	9.9	7	F	int	4	22.1	77	70.7	**F**
1993	11	4.5	7	P		30	14.8	77	70.7	**P**
1994	0	3.8	8	P		0	8.9	77	70.7	**P**
1995	30	6.8	7	F	u	89	17.4	77	72.5	**P**
1996	11	5.2	7	P		46	17.8	77	72.9	**P**
1997	21	7.3	6	F	u	54	22.9	77	73.6	**F**
1998	39	11.2	5	G	int-u	95	32.3	77	73.6	**F**
1999	0	11.2	5	G	int-u	57	37.6	77	74.7	**F**
2000	22	13.4	4	G	int-u	42	41.7	77	75.5	**F**
2001	0	13.4	4	G	int-u	2	41.9	77	77.0	**F**
2002	1	13.5	3	G	int	8	42.3	77	77.0	**F**
2003	3	12.7	3	G	int	41	43.4	77	77.0	**F**
2004	18	14.5	2	VG	u	34	46.8	77	77.0	**G**
2005	2	11.7	2	VG	u	19	39.8	77	77.0	**G**
2006	33	13.9	2	VG	u	102	45.4	77	77.0	**G**
2007	0	11.8	3	G	int	1	40.1	77	77.0	**F**
2008	0	7.9	4	F	u	3	30.9	77	77.0	**F**
2009	0	7.9	4	F	u	2	25.4	77	77.0	**F**
2010	0	5.7	5	P		6	21.8	77	77.0	**F**

[1] u= rounded up between consecutive categories;
int= the intermediate category;
int-u= rounded up to the higher of two intermediate categories.

Figures Side Channel Connection Flow Indicator

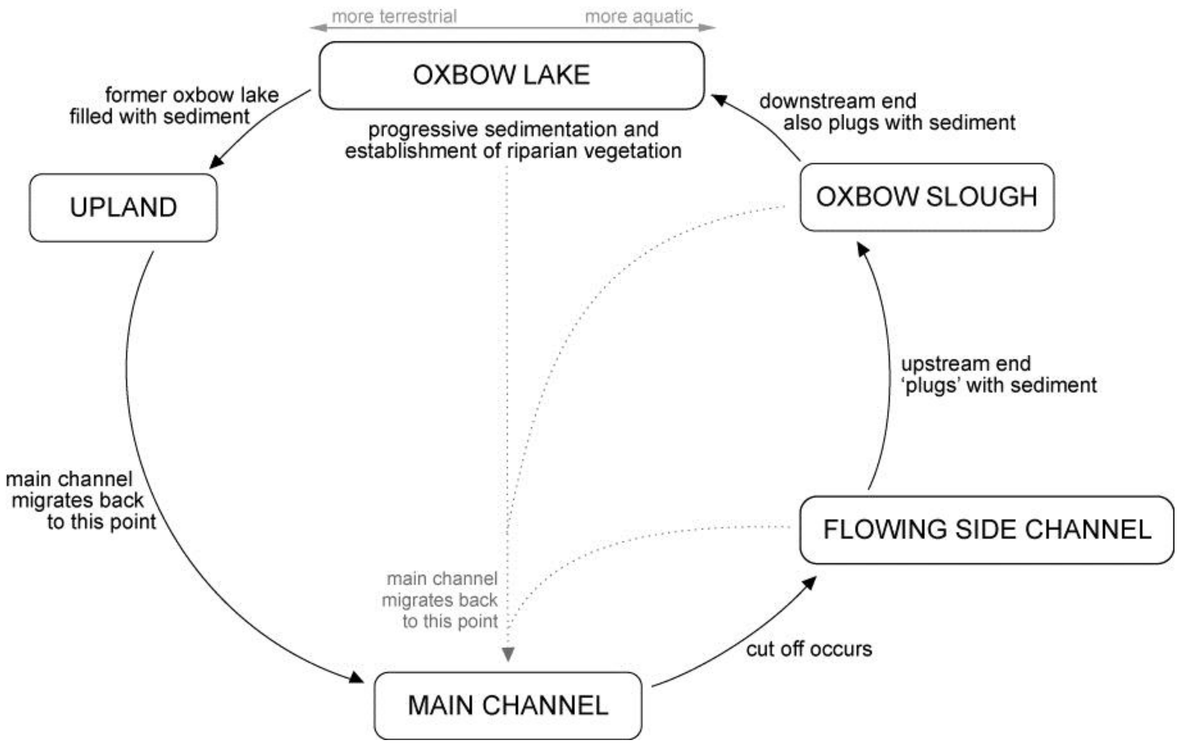


Figure 1. Conceptual model of evolution of cut-off meander bends, as they evolve from main channel (pre-cutoff), to flowing side channel (right after cutoff), to oxbow slough once the upstream end plugs with sediment, to oxbow lake once the downstream end also plugs with sediment, and then to terrestrialized oxbow lake as the lake fills with overbank sediment.

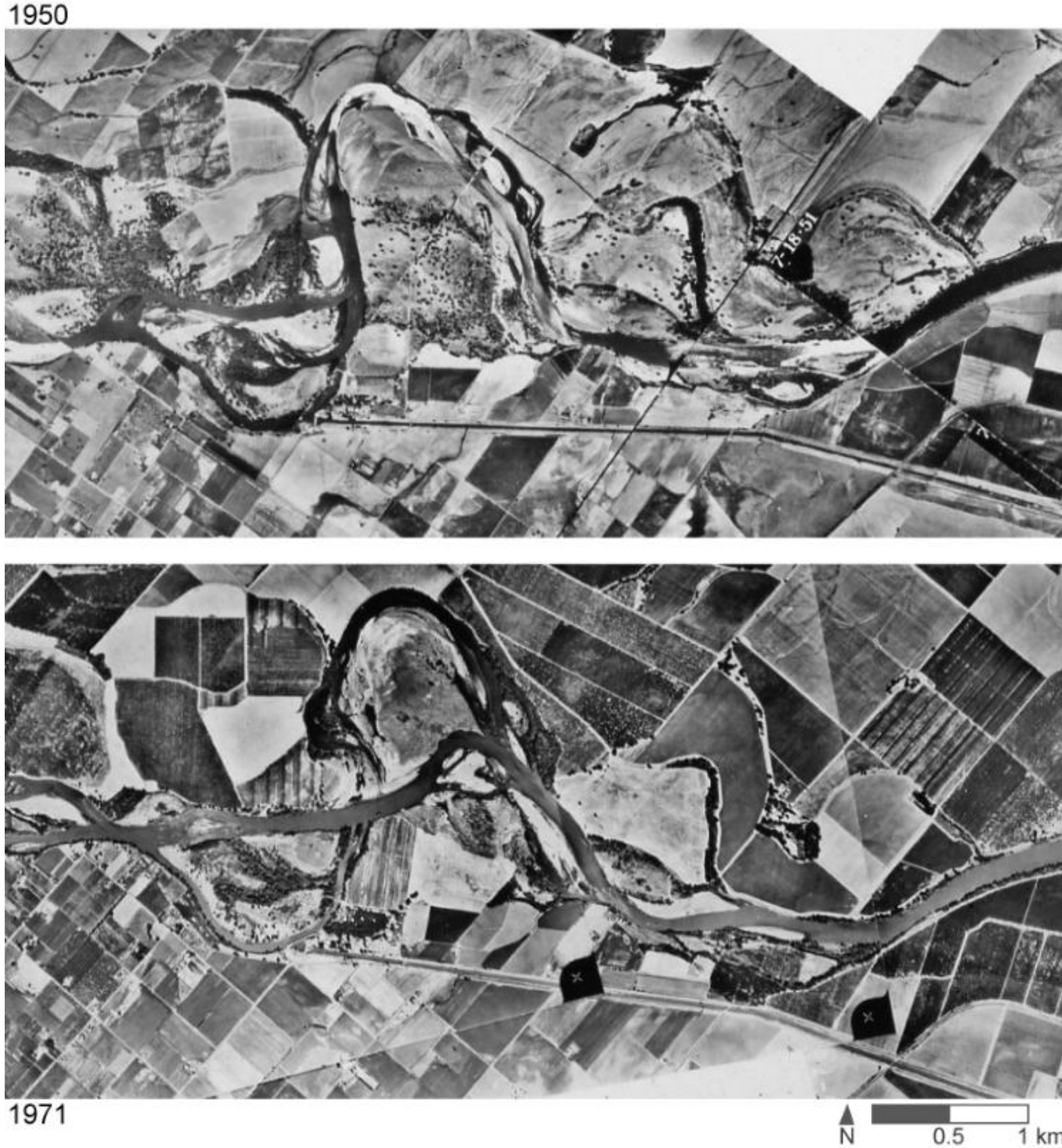


Figure 2. During the 1970 flood, an eastward meander bend cut off by chute cutoff, resulting in channel downcutting of appx 3 ft at the bifurcation point between the main channel and a side channel maintained to serve as the point of diversion for the Glenn-Colusa Irrigation District Canal.

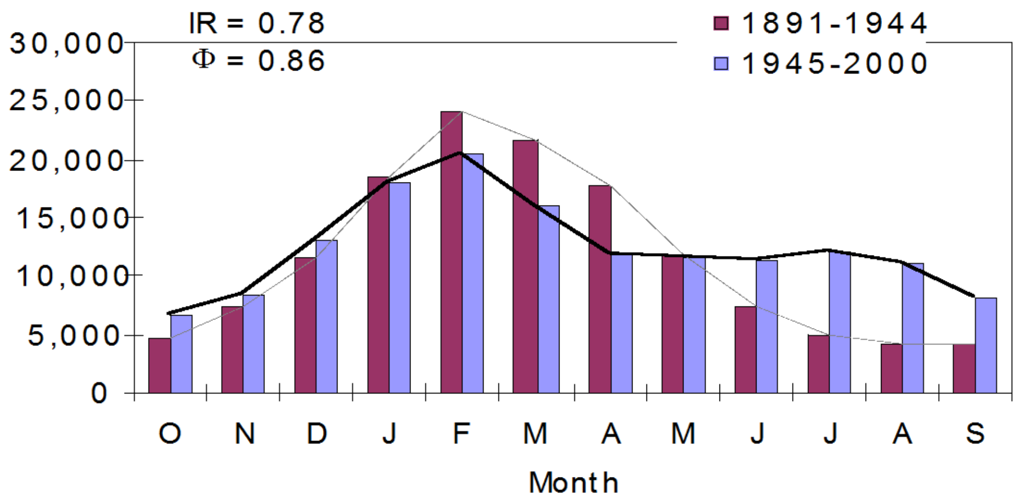


Figure 3. Mean monthly flows, Sacramento River at Red Bluff (Bend Bridge) pre-Shasta-Dam (1891-1944) and post-Shasta-Dam (1945-2000). Note that base flows increased even more than flood flows were decreased, reflecting the transfer of water from the Trinity River basin during summer irrigation months. Y-axis is mean monthly flow is cfs.

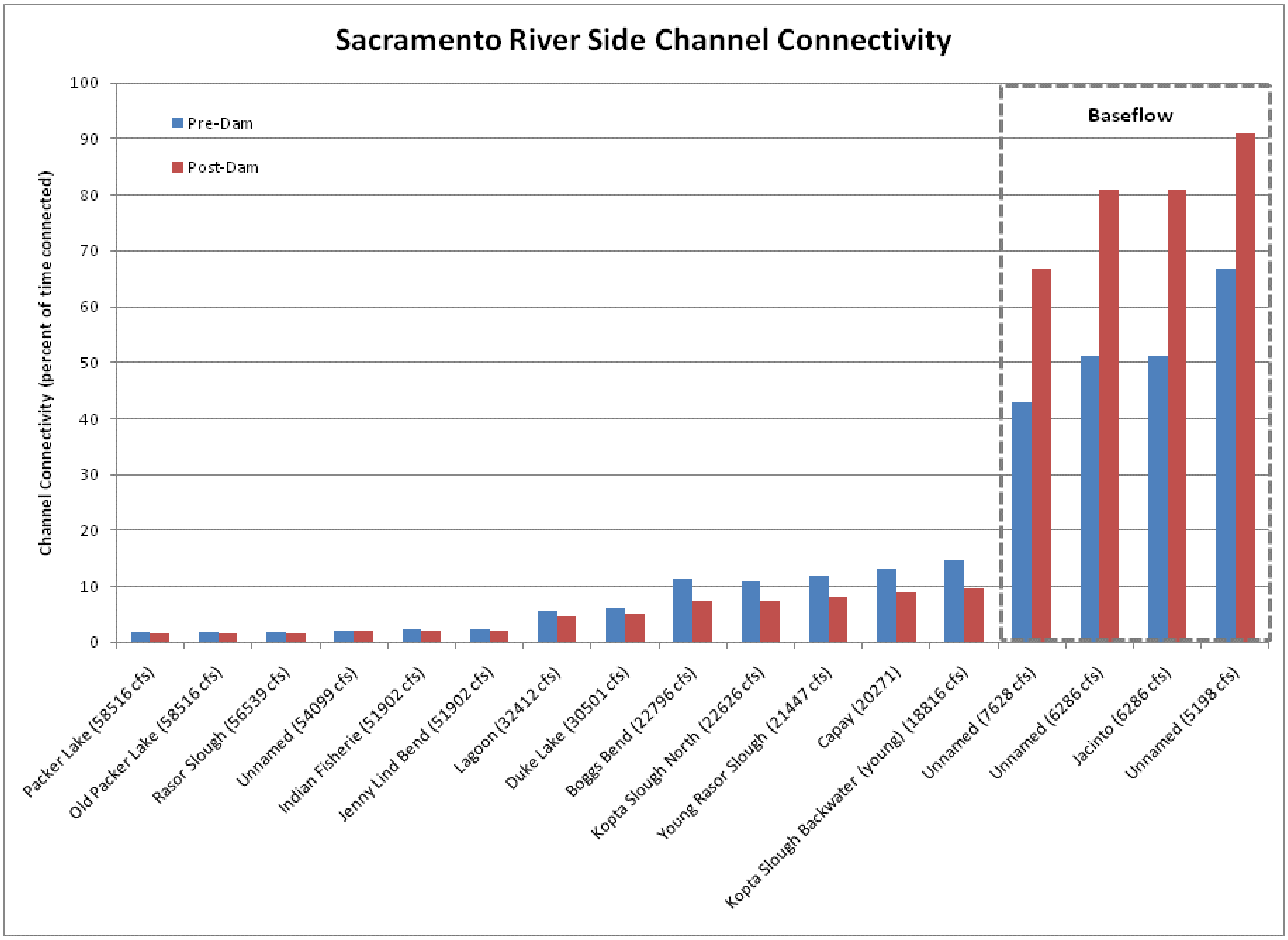


Figure 4. Percentage of time that side channels studied by Gomez et al (in prep) would be connected to the mainstem under pre-Shasta-Dam and post-Shasta-Dam conditions. Note that side channels with very low plugs and thus low thresholds for connection (under 8,000 cfs) actually stayed connected for longer than would be the case naturally because of artificially increased base flows, which would result in decreased diversity of habitat. All other side channels experienced less frequent connection than under natural conditions.

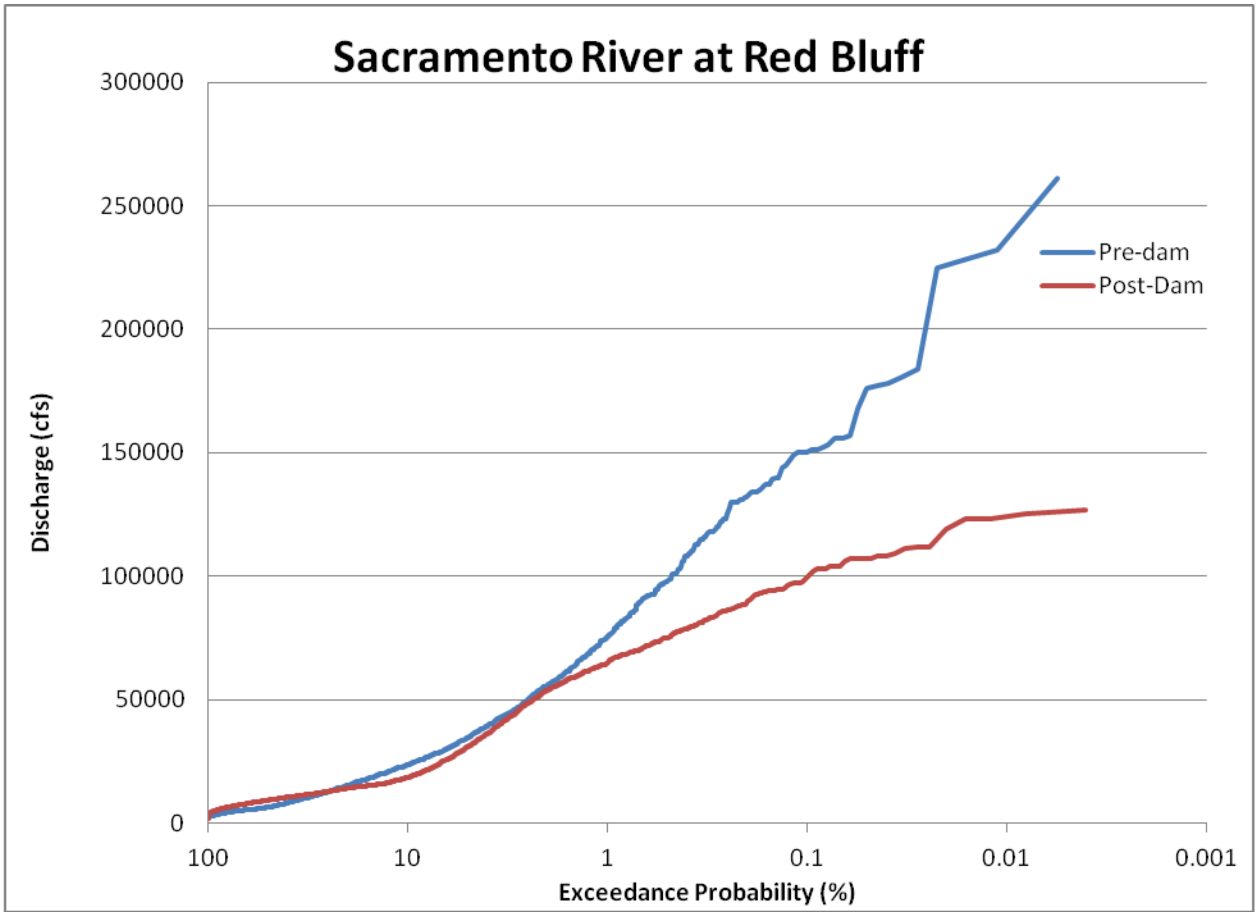


Figure 5. Flow duration curve, Sacramento River at Red Bluff, for pre- and post-dam conditions.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Bed Mobility Flow Indicator

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

1. How specifically is the indicator defined?

The *bed mobility flow indicator* is defined based on two statistics, both calculated as ten-year running averages: the number of days/yr with flows >55,000 cfs, and the number of years (over the previous decade) in which there were no days >55,000 cfs. 55,000 cfs is used as the flow which fully-mobilizes the bed, based on empirical observations at multiple sites along the study reach of the river. Gravel-bed rivers also experience *partial transport*, when the entire bed is not mobilized, but only different patches at any given time. If conditions of partial transport (during which flows do not exceed the normalized Shields stress) persist, significant bedload transport can occur, as demonstrated by Andrews (1990) on Sagehen Creek. These conditions are most likely on rivers whose flow variations are relatively muted, thanks to snowmelt or groundwater-fed runoff. On rivers with very even flows throughout the year, such as the Deschutes River, Oregon, partial transport can be responsible for most of the bedload transport (movement of coarse sediment along the bed) over the year, because flows may hover in the range at which the bed is partially mobile (Rovira and Kondolf 2008). However, peak flows on the Sacramento River are dominated by flashy, rainfall (or rain-on-snow) runoff, such that flood hydrographs rise and fall quickly, passing quickly through the partial transport phase into fully mobilized transport. Thus for the Sacramento, flow required for fully mobilized bed provides a useful indicator.

Bed material size on the Sacramento varies along its length, and as typical of many rivers, undergoes a transition from gravel to sand (Singer 2008, 2010, Singer and Dunne 2004). Within the reach Red Bluff to Colusa, it is dominantly gravel-bedded. Like most gravel bed rivers, it can be expected to vary widely along its length and across the channel in the flows needed to mobilize sediments, and transport is a function of particle size and channel form. Thus, there is naturally a strong spatial variability, which implies that generalized values based on empirical observations are more justified than attempts at precision in specifying a number that is inherently imprecise at the scale of the river. More importantly perhaps is the natural temporal variability in frequency of bed mobility that arises from variations in flow from year to year. The plot of raw data of the number of days with flows exceeding 55,000 cfs by water year shows strong variation from year to year, and shows a distinct change post-Shasta Dam. Not only do fewer days exceed this threshold per year, but the number of years failing to meet this threshold is greater post-dam (Figure 1).

Because of the large natural inter-annual variability, an indicator based on flows in a given year could shows swings up and down that were simply artifacts of natural variation in wetness from year-to-year, rather than a real change in river health. Accordingly, a 10-year running average could better detect real temporal trends, i.e, detecting a signal rather than noise. However, a 10-year running average is an inherently sluggish indicator, because it cannot pick up changes that occur over a few years time scale.

Calculation of the 10-year running average values for bed mobilization (ie flows >55,000cfs) on the Sacramento River are shown in Figure 1, which illustrates the procedure in which the number of days >55,000cfs each year are tabulated, and the next column displays the 10-year running average). By definition, the 10th year of the flow record is the first year for which this variable can be calculated.

Because frequent bed mobilization is important for many physical and ecological river processes, the number of years in which no bed mobilization occurs is potentially significant. Some processes are non-linear. For example, as seedlings of *Salix*, *Populus*, and other riparian plants establish in the bed of the active channel, they are easily scoured by the Q1.5 or Q2. However, as the roots of the plants establish over a period of several years, the plants' resistance to scour increases dramatically, such that after 5 years of establishment, 5-y old plants would not be scoured by the Q5. Scouring these plants would require a much larger flow, commonly the Q20.

The number of years without any scouring flows (ie without flows exceeding 55,000cfs) is tabulated for the preceding 10 years, so on the same timescale as the 10-year running average for days of bed mobilization (Figure 1).

2. What is the rationale for it being a meaningful indicator?

The importance of variable flow regimes in rivers in now widely accepted (Poff et al 1997). Within the geomorphic literature, it is well established that gravel-bedded rivers require periodic mobilization to maintain bed sediment quality, recruitment of large wood, undercut banks, and other complex features. The bed mobility flow indicator is a meaningful indicator because geomorphic processes are driven to a large extent by the movement of bed material, resulting in the formation of bars, pools, and other essential geomorphic features that form the building blocks for aquatic and riparian habitat. Movement of bed material results in a 'cleaning' of bed material, decreasing macrophytes and armored macroinvertebrates, allowing for the colonization of pioneering aquatic species (Milhous 1982, Suttle et al 2004, Power et al, 2008).

The bed mobility flow indicator has the advantage that it can be assessed from either empirical (bedload sampling or gravel tracer) or calculation methods. The input variables needed for equations to estimate flows to moblize (such as channel slope, cross sectional geometry, bed material size) can be made during low-flow periods, but the accuracy of such calculations depends in large measure on obtaining some empirical observations of the initiation of transport through use of tracers, detailed resurveys, and such. Inducing bed mobility is the main objective of flushing flows, deliberate high flow releases from dams (Kondolf and Wilcock 1996), designed to flush fine sediments from bed gravels.

3. What references support its use as an indicator of river health?

Andrews ED. 1994. Marginal bed load transport in a gravel bed stream, Sagehen Creek, California, *Water Resour. Res.* 30: 2241-2250.

Buer K, Forwalter D, Kissel M, and Stohler B. 1989. The middle Sacramento River: human impacts on physical and ecological processes along a meandering river. USDA Forest Service General Technical Report PSW-**110** : 22-32.

Buer K. 1994. Sacramento River Erosion Investigation Memo Progress Report. California Department of Water Resources, Red Bluff, September 1994.

CH2MHill. 2000. Flow regime requirements for habitat restoration along the Sacramento River between Colusa and Red Bluff. Report submitted to the Calfed Bay-Delta Program, Integrated Storage Investigation.

Kondolf GM, and Wilcock PR. 1996. The flushing flow problem: Defining and evaluating objectives. *Water Resources Research* 32(8):2589-2599.

Meko D. 2001. Reconstructed Sacramento River system runoff from tree rings, Report prepared for the California Department of Water Resources.

Milhous RT. 1982. Effect of sediment transport and flow regulation on the ecology of gravel bed rivers, in *Gravel Bed Rivers*, edited by R. D. Hey, J. C. Bathurst, and C. R. Thorne, pp. 819–841, John Wiley, New York.

Poff NL, Allan JD, Bain MB, Karr JR, Prestegaard KL, Richter BD, Sparks RE, Stromberg JC. 1997. The natural flow regime. *BioScience* 47:769-784.

Power, ME, Dietrich WE, and Finlay JC. 1996. Dams and downstream aquatic biodiversity: Potential food web consequences of hydrologic and geomorphic change. *Environmental Management* 20:887-895.

Power, ME, Parker MS, and Dietrich WE. 2008. Seasonal reassembly of a river food web: floods, droughts, and impacts of fish. *Ecological Monographs* 78(2): 263–282

Rovira A, and Kondolf GM. 2008. Bed mobility on the Deschutes River, Oregon: tracer gravel results. *Geodinamica Acta* 21:11-22.

Singer MB. 2008. Downstream patterns of bed material grain size in a large, lowland alluvial river subject to low sediment supply. *Water Resources Research* 44: W12202. doi:10.1029/2008WR007183.

Singer MB. 2010. Transient response in longitudinal grain size to reduced gravel supply in a large river. *Geophysical Research Letters* 37: L18403. doi:10.1029/2010GL044381

Singer MB, Dunne T. 2004. Modeling decadal bed material sediment flux based on stochastic hydrology. *Water Resources Research* 40: W03302. doi:10.1029/2003WR002723.

Suttle KB, Power ME, Levine JM, and McNeely C. 2004. How Fine Sediment in Riverbeds Impairs Growth and Survival of Juvenile Salmonids. *Ecological Applications* 14(4) 969–974.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

Depending on the question being posed, the mobility of the bed could be calculated to show differences from site to site within the river. However, in evaluating potential impacts of flow alterations, the indicator is probably best calculated as a river-wide value. One approach could be to specify flows to mobilize a range of conditions and take an average, but some geomorphic units are probably more important to mobilize than others. Moreover, empirical data are lacking for most sites. The best bed-mobilization data are those collected by Buer (1994, 1989, and unpublished), which were collected at riffle sites of likely habitat importance to fish. Thus, using these data probably provides a good mobility target for the river as a whole (CH2MHill 2000).

The indicator is useful at the scale of the reach, or the entire section of river from Colusa to Red Bluff.

5. What cutoffs are appropriate for poor, fair, good and very good?

Based on the empirical observations of Buer (1994, 1989, unpublished data), CH2MHill (2000) identified 55,000 cfs as the working estimate for the flow needed to mobilize the bed over most of the alluvial reach from Red Bluff to Colusa. While some bed movement would be expected at lower flows that produce 'partial transport' (sensu Wilcock 2004), for extensive reworking of the bed, flushing of fine sediment, and bank/erosion channel migration functions essential to maintain habitat quality, some flows above 55,000cfs should occur. Under pre-dam hydrologic conditions (1892-1940), there were an average of 7.7 days with flows exceeding this threshold, while under post-dam conditions (1944-2010) the average was 7 days per year (Figure 2).

The cutoffs, presented in Table 1 and the narrative description below, were based on professional judgment, and incorporate the two variables of number of days >55,000cfs and the number of years without bed mobilizing flows, and assuming pre-dam condition as representing mostly very good conditions. The pre-dam dust-bowl drought years (1919-1936) have been shown to be one of the driest periods of the past thousand years (Meko 2001) and therefore represent a useful guideline for defining extreme low-flows and "poor conditions"(Figure 3).

Very Good: Ten-year running average of 11days/year or more with flows >55,000 cfs, and no more than one year without any flows >55,000 cfs over the preceding decade is designated as *very good*, in that the pre-dam condition is assumed to have been favorable for the ecosystem adapted to it. (Exception was the dust-bowl drought during the pre-Shasta-Dam record.

Good: 9-11 days/year >55,000 cfs (as ten-year running average), and no more than 2 years without any flows >55,000 cfs over the prior decade.

Fair: 6-9 days >55,000 cfs (as ten-year running average), and no more than 3 years without any flows >55,000 cfs.

Poor: less than 6 days >55,000 cfs (as ten-year running average), and more than 3 years without any flows >55,000 cfs.

6. How were the particular rating cutoffs selected?

These cutoffs were based on professional judgment and analysis of flow records of deviation from pre-dam conditions. Under pre-dam hydrologic conditions (1892-1940), 78% of the years had at least one day exceeding 55,000cfs, while post-dam only 53% of the years exceeded this threshold. The pre-dam hydrology is take to represent the pre-disturbance condition to which species in the system are well adapted, which, while 'natural', these years were not favorable to many native species. Further, the dust-bowl years provide a useful marker of minimum flows in the historic range of variability.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

Methods for calculating the indicator per se are not described in published literature, but the hydrologic data from which the indicator is derived are widely available and the indicator is based on very simple measures: two statistics, both calculated as ten-year running averages: the number of days/yr with flows >55,000 cfs, and the number of years (over the previous decade) in which there were no days >55,000 cfs. The indicators were based on analysis of records for the USGS gauge on the Sacramento River at Red Bluff, on a water year (ie Oct 1- Sep 30) basis. The threshold flow used was based on bed mobility data (collected by Buer et al, 1989, Buer 1994, and Buer unpublished).

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

The current indicator refers to conditions in water year 2010. During the ten years prior to, and including, water year 2010, an average of 4.6 days per year were greater than 55,000 cfs, and six of those prior ten years had no flows above the bed mobility threshold. Current conditions are therefore assessed as *poor*.

9. What is the desired rating and by when should this be achieved?

The desired rating is *fair-to-very good*, a fairly wide range reflecting natural climatic variations. This is not being achieved now in most years because reservoir storage in the system has altered the hydrology. Specifying a date by which this should be achieved is difficult, because the deviation from desirable condition results from flow regulation that is closely tied to water diversions from the Central Valley Project and other diversions and storage.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

Given that the streamflow data have been collected since the turn of the 20th century, it is a simple matter to use these historical data to calculate the indicator for past years, as illustrated in Figure 2. Resulting ratings for historical years are graphically illustrated in Figures 3 and 4, and summarized by year in Table 2.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

The flow data are collected at the US Geological Survey gauging station at Red Bluff, and represent the middle reach of the Sacramento River (Red Bluff to Colusa).

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

Contact person is G. Mathias Kondolf, UC Berkeley *kondolf@berkeley.edu*

USGS flow data available online at http://waterdata.usgs.gov/usa/nwis/uv?site_no=11377100 for the Red Bluff (station # 11377100) gauge.

13. What is the rationale for the desired rating?

The rationale is that the bed should be mobile frequently enough to be free of excessive fine sediment accumulation and to avoid encroachment of riparian vegetation into naturally dynamic river beds. The value identified as the desired rating reflects conditions that supported native species, and thus should favor survival and recovery of native species.

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

Table 1. Indicator Cutoffs based on Days >55,000 cfs

Condition	10-yr average days >55,000 cfs	# of past 10 years without flows>55,000 cfs
Very Good	11 or more	0 or 1
Good	9-11	2
Fair	6-9	3
Poor	**5.9 or less**	**4 or more**

Table 2. Historical analysis of bed mobility ratings

WY	# of days > 55,000 cfs	10-yr running average # of days over 55,000 cfs	# years of previous 10 without Q>55k	Rating	
1892	0				
1893	14				
1894	2				
1895	9				
1896	17				
1897	8				
1898	0				
1899	3				
1900	8				
1901	9	7	2	G	u
1902	21	9.1	1	VG	u
1903	11	8.8	1	G	int
1904	40	12.6	1	VG	
1905	10	12.7	1	VG	
1906	11	12.1	1	VG	
1907	19	13.2	1	VG	
1908	1	13.3	0	VG	
1909	30	16	0	VG	
1910	2	15.4	0	VG	
1911	6	15.1	0	VG	
1912	1	13.1	0	VG	
1913	1	12.1	0	VG	
1914	21	10.2	0	VG	u
1915	17	10.9	0	VG	u
1916	11	10.9	0	VG	u
1917	3	9.3	0	VG	u
1918	0	9.2	1	VG	u
1919	5	6.7	1	G	int
1920	0	6.5	2	G	u
1921	9	6.8	2	G	u
1922	0	6.7	3	F	

1923	0	6.6	4	F	u
1924	0	4.5	5	P	
1925	9	3.7	5	P	
1926	2	2.8	5	P	
1927	15	4	5	P	
1928	4	4.4	4	P	
1929	1	4	4	P	
1930	4	4.4	3	F	u
1931	0	3.5	4	P	
1932	1	3.6	3	F	u
1933	1	3.7	2	F	int
1934	1	3.8	1	G	int- u
1935	2	3.1	1	G	int- u
1936	8	3.7	1	G	int- u
1937	1	2.3	1	G	int- u
1938	27	4.6	1	G	int- u
1939	0	4.5	2	F	int
1940	12	5.3	2	F	int
1941					
1942	Data not used from 1941-1943 while reservoir filling				
1943					
1944	0				
1945	0				
1946	2				
1947	0				
1948	0				
1949	0				
1950	0				
1951	0				
1952	2				
1953	15	1.9	7	P	
1954	9	2.8	6	P	
1955	0	2.8	6	P	
1956	21	4.7	6	P	
1957	3	5	5	P	
1958	35	8.5	4	F	u
1959	1	8.6	3	F	
1960	1	8.7	2	G	u
1961	0	8.7	2	G	u
1962	0	8.5	3	F	
1963	4	7.4	3	F	
1964	0	6.5	4	F	u
1965	12	7.7	3	F	
1966	1	5.7	3	F	u
1967	4	5.8	3	F	u
1968	3	2.6	3	F	u

1969	15	4	3	F	u
1970	23	6.2	3	F	
1971	4	6.6	2	G	u
1972	0	6.6	2	G	u
1973	3	6.5	2	G	u
1974	25	9	1	VG	u
1975	3	8.1	1	G	int
1976	0	8	2	G	u
1977	0	7.6	3	F	
1978	6	7.9	3	F	
1979	0	6.4	4	F	
1980	14	5.5	4	P	
1981	0	5.1	5	P	
1982	18	6.9	4	F	u
1983	59	12.5	4	G	int- u
1984	6	10.6	4	F	int
1985	0	10.3	5	F	int
1986	25	12.8	4	G	int- u
1987	0	12.8	4	G	int- u
1988	0	12.2	5	G	int- u
1989	0	12.2	5	G	int- u
1990	0	10.8	6	F	int
1991	0	10.8	6	F	int
1992	0	9	7	F	int
1993	6	3.7	7	P	
1994	0	3.1	8	P	
1995	27	5.8	7	P	
1996	8	4.1	7	P	
1997	19	6	6	F	u
1998	32	9.2	5	F	int
1999	0	9.2	5	F	int
2000	15	10.7	4	F	int
2001	0	10.7	4	F	int
2002	0	10.7	4	F	int
2003	2	10.3	4	F	int
2004	17	12	3	G	int
2005	1	9.4	3	G	u
2006	26	11.2	3	G	int
2007	0	9.3	4	F	int
2008	0	6.1	5	F	u
2009	0	6.1	5	F	u
2010	0	4.6	6	P	

[1)] u= rounded up between consecutive categories;
int= the intermediate category;
int-u= rounded up to the higher of two intermediate categories.

Figures Bed Mobility Flow Indicator

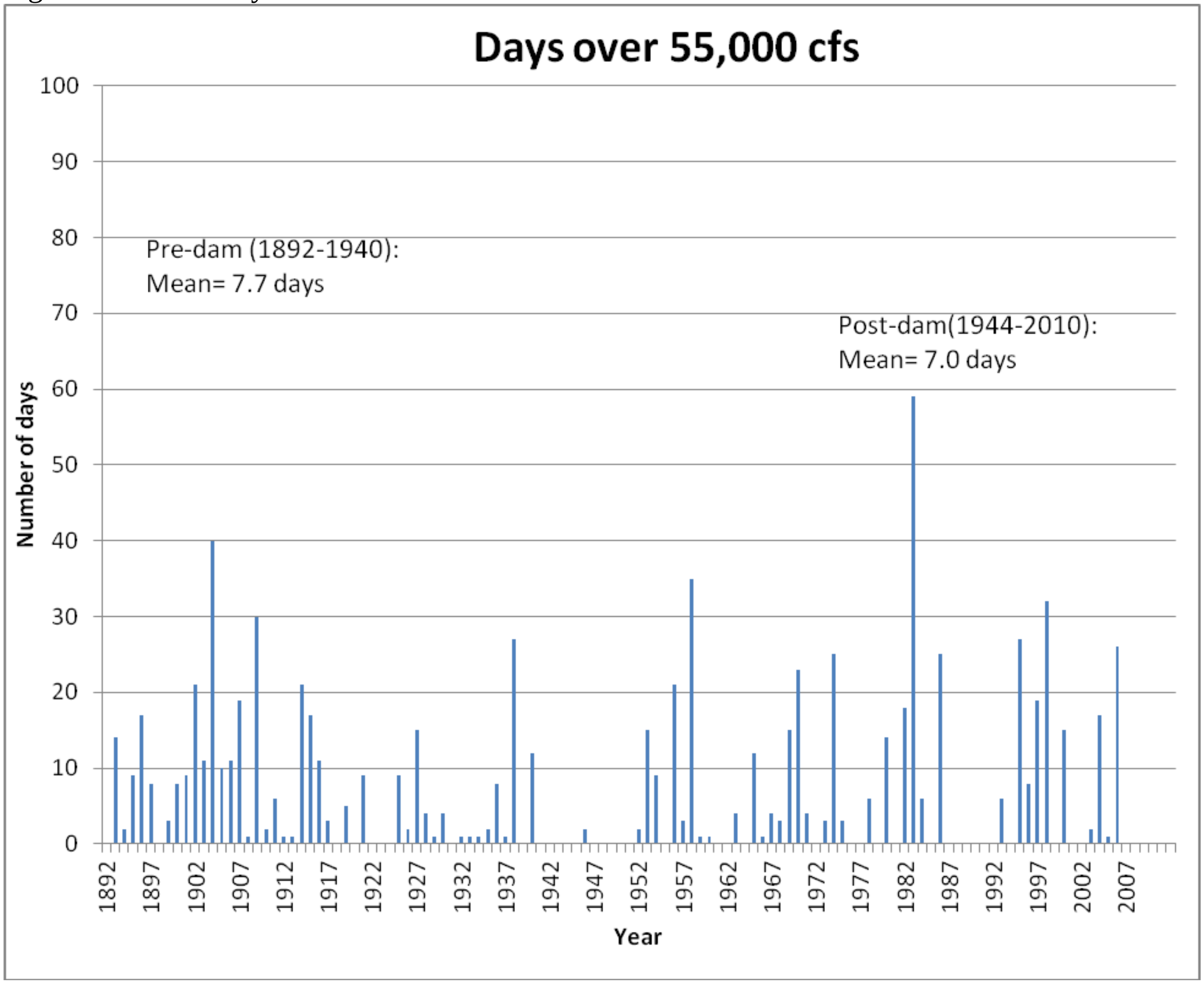


Figure 1. Number of days with flow exceeding 55,000 cfs by year, 1892 to present, at US Geological Survey gauge at Bend Bridge, Red Bluff. (source USGS online data)

Year	# of days over 55,000 cfs	10-yr average	# of years (of previous 10) without flow > 55,000 cfs
1892	0		
1893	14		
1894	2		
1895	9		
1896	17		
1897	8		
1898	0		
1899	3		
1900	8		
1901	9	7	2
1902	21	9.1	1
1903	11	8.8	1
⋮			

Figure 2 demonstrates the method for calculating the 10-year average number of days over 55,000 cfs (shown in Figure 2) and the calculation of the number of years of the past ten without bed mobilizing flows (Figure 3).

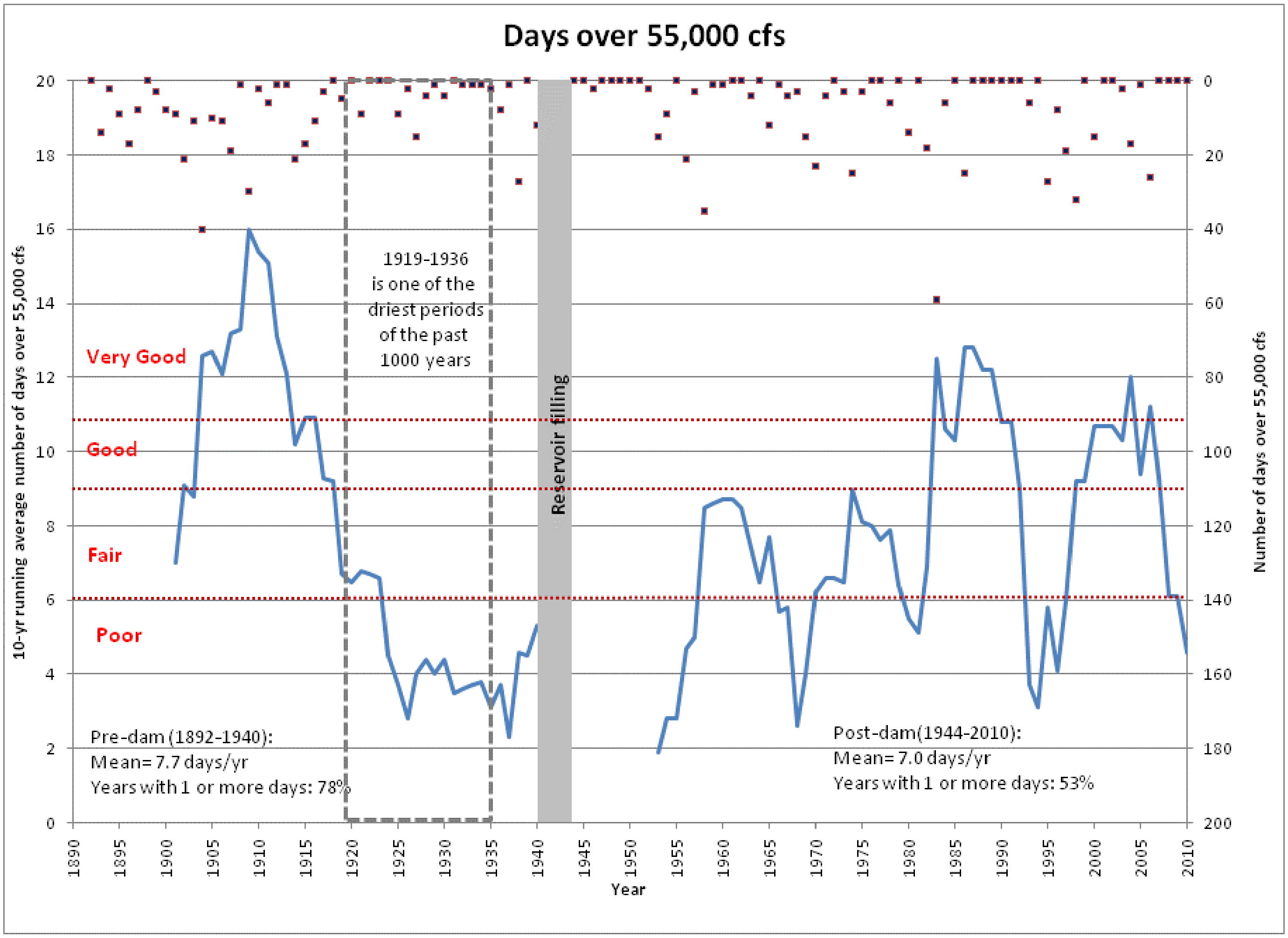


Figure 3. Red points represent the number of days that exceed 55,000 cfs in each individual year. The blue line shows the number of days exceeding 55,000 cfs averaged over the preceding ten years. Cutoffs ("very good", "good", "fair", and "poor") are indicated by dashed red lines.

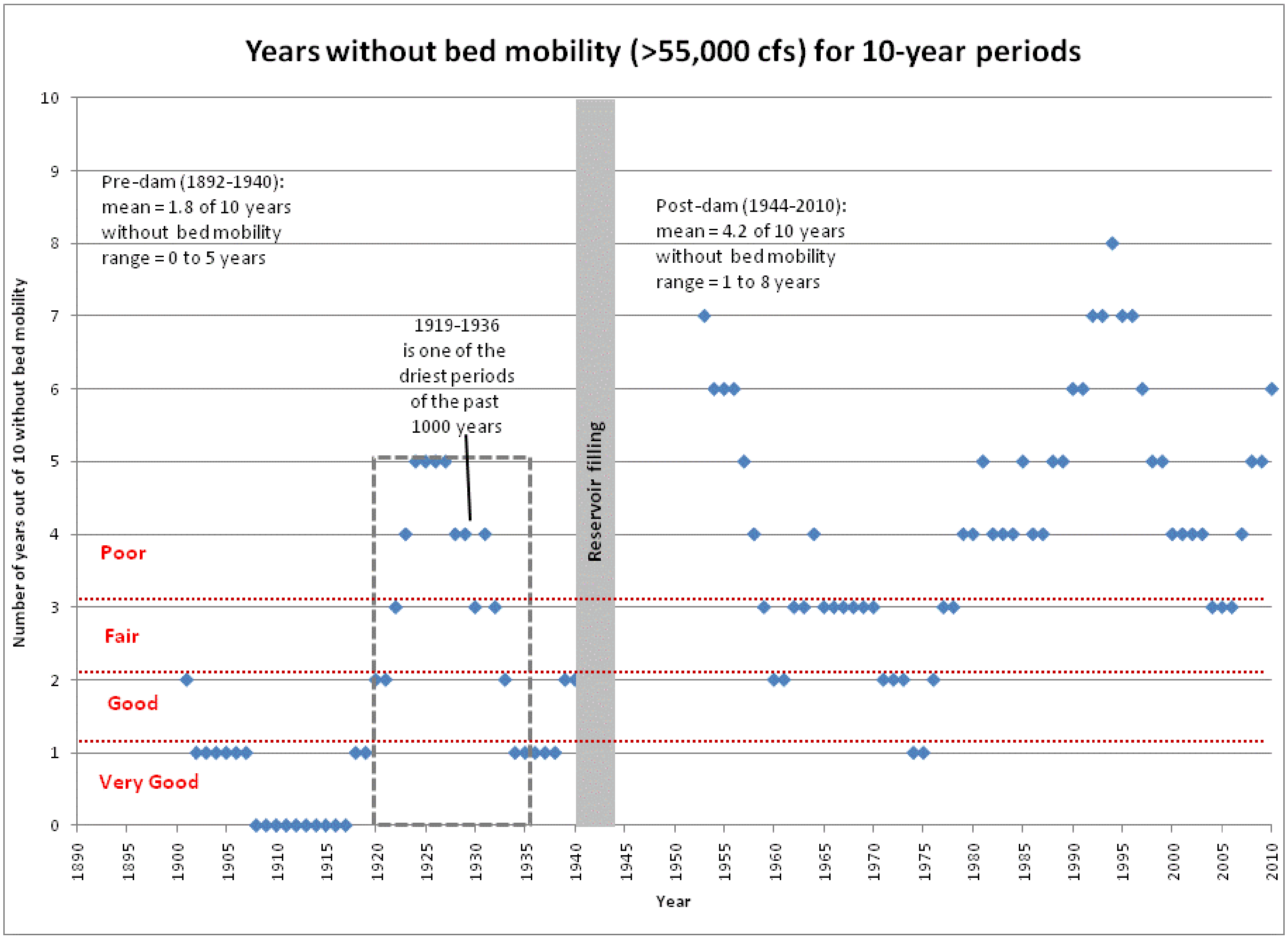


Figure 4. Blue points represent the number of years (of the previous ten) without any flows above 55,000 cfs. Cutoffs ("very good", "good", "fair", and "poor") are indicated by dashed red lines.

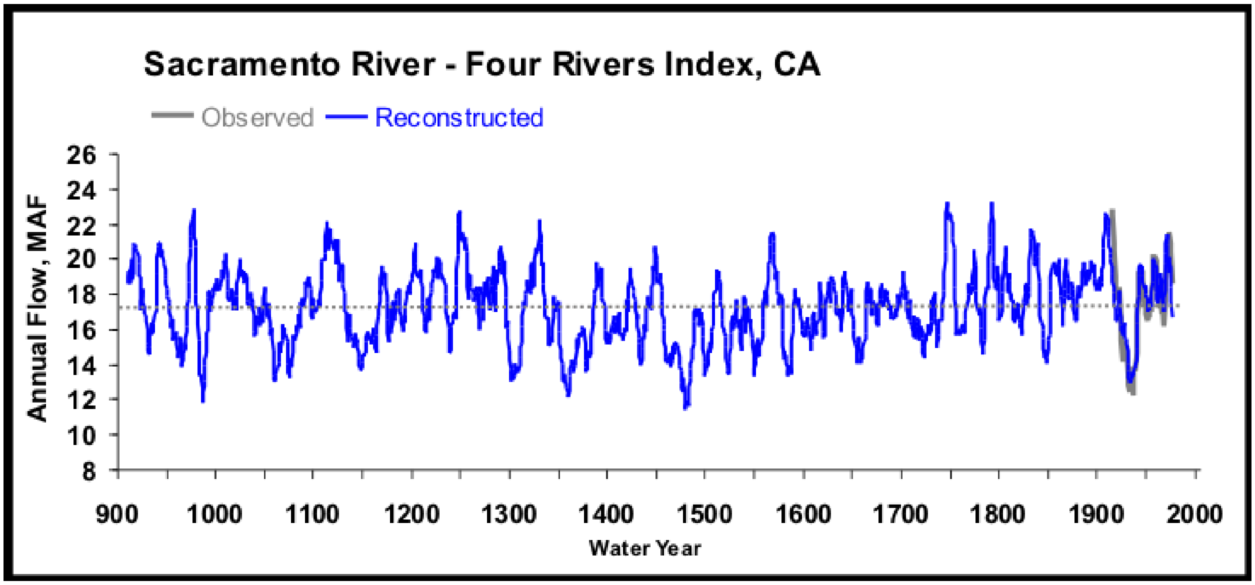


Figure 5. 10-yr averaged runoff reconstruction for the Sacramento, Feather, Yuba, and American Rivers "Four Rivers Index". The reconstruction is based on calibrated tree-ring runoff models [*Meko*, 2001].

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Length of Riparian Shoreline

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

<u>Step 4</u>

1. How specifically is the indicator defined?

   The length of riparian shoreline is simply the total length of riparian shoreline along the Sacramento River between Red Bluff and Colusa. Included are all shorelines along the mainstem, and associated side channels, sloughs and oxbows.

2. What is the rationale for it being a meaningful indicator?

   The length of riparian shoreline provides a measure of the amount of habitat, and conveys some information on habitat complexity in the riparian zone. The more shoreline there is between Red Bluff and Colusa, the more complex riverine habitat there is.

3. What references support its use as an indicator of river health? Provide citations.

   This indicator was used as a metric of river health on the Willamette River in Oregon (IMST 2002).

   Independent Multidisciplinary Science Team (IMST). 2002. Recovery of Wild Salmonids in Western Oregon Lowlands. Technical Report 2002-1 to the Oregon Plan for Salmon and Watersheds, Governor's Natural Resources Office, Salem, Oregon.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   This indicator is most useful in characterizing the status of the river at the large scale, as an indicator of the health of reaches or the entire river Project Area (Red Bluff to Colusa).

<u>Step 5</u>

5. What cutoffs are appropriate for poor, fair, good and very good?

   <u>The status indicator ratings are defined as:</u>
   Very Good: >1,000,000 meters
   Good: 750,000 - 1,000,000 meters
   Fair: 500,000-750,000 meters
   Poor: <500,000 meters

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents

(e.g., recovery plans for endangered species), in which case complete citations should be provided.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

   The methods for calculating this metric are not published. They are as follows:

   All polygons labeled as Open Water in the 2007 CSU-GIC remnant riparian GIS layer were selected. The sum of the length of these polygons was calculated as the final result.

<u>Step 6</u>

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   598,625 meters, fair condition, as of June 2007

9. What is the desired rating and by when should this be achieved?

   Good, June 2020

<u>Step 7</u>.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

    Analysis of the June 1999 aerials by the same method and the same technician yielded 739,437 meters of riparian shoreline.

    It is unknown why there is this difference. One possibility is that the river was mapped at different discharge levels.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    The current indicator data are based upon an analysis of the entire mainstem Sacramento River between the Red Bluff Diversion Dam and the Colusa Bridge. It is representative only of this area.

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

    This indicator information was input by G. Golet following review of relevant materials. Calculations based upon the 1999 and 2007 data were both performed by:

    Seth Paine, TNC Cons Science Tech,
    spaine@tnc.org
    (530) 897-6370 x 214
    Northern Central Valley office

500 Main Street
Chico, CA 95928

13. What is the rationale for the desired rating?

Best guess. Could be refined following further consideration.

Step 8

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

More information on the viability assessment part of the workbook can be found at: http://conserveonline.org/workspaces/cbdgateway/cap/practices/bp_3

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

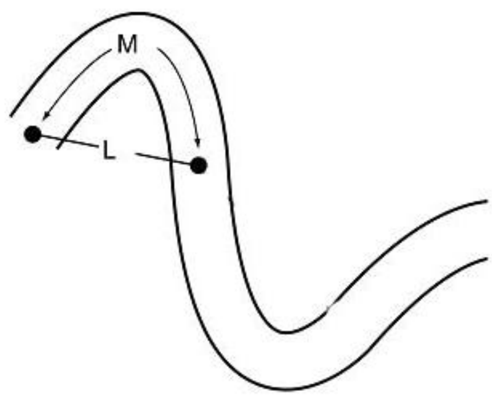
Number of Bends with Sinuosity > 2.0

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

1. *How specifically is the indicator defined?*

Bend sinuosity equals the ratio of the arc (curved) length of a channel bend to the half wavelength (M/L). Arc length of a channel bend is defined as the length of the channel centerline between sequential inflection points; half wavelength is the straight line distance between sequential inflection points.

Single bend sinuosity is calculated as M/L in the figure below. 2.0 or greater is achieved when M/L > 2.0.



2. *What is the rationale for it being a meaningful indicator?*

The sinuosity of a single bend indicates the degree to which the bend is curved. The degree to which a bend is curved correlates directly with the flow velocities and flow patterns in a river channel bend. The flow velocities and flow patterns are then directly related to the spatial pattern and magnitude of bank retreat (migration). The sinuosity represents the cumulative curvature throughout the bend.

Sinuosity provides a measure of channel complexity and river dynamism. In alluvial settings, a sinuous river has more cutbanks and point bars than a straight river. It is also likely to be a more active river in terms of riverine processes of meander migration, erosion and sediment deposition, although such processes may be constrained by the presence of riprap on the river bank. Because sinuous rivers have a greater complexity of habitats and ecological processes associated with them they are more supportive of natural species (e.g., bank swallows, salmon) and communities (cottonwood forests).

In general, the greater the sinuosity, the more benefit there is for ecosystem processes. One measure of the bend sinuosity is the number of bends with a sinuosity greater than 2.0.

3. *What references support its use? Provide citations.*

SINUOSITY IN GENERAL

Dunne, T. and L. B. Leopold (1978). Water in environmental planning. San Francisco, W. H. Freeman.

Larsen, E. W. (1995). The Mechanics and Modeling of River Meander Migration, University of California at Berkeley**:** 1-342.

Leopold, L. B. (1994). A view of the river. Cambridge, Harvard University Press.

Leopold, L. B., M. G. Wolman, et al. (1964). Fluvial Processes in Geomorphology. San Francisco, W. H. Freeman and Company.

Richards, K. (1982). Rivers: Form and Process in Alluvial Channels. New York, Methuen

ECOLOGICAL SIGNIFICANCE OF SINUOSITY

Brookes, A. (1987). "The distribution and management of channelized streams in Denmark." Regulated Rivers: Research & Management **1**(1): 3-16.

Jungwirth, M., O. Moog, et al. (1993). "Effects of river bed restructuring on fish and benthos of a fifth order stream, melk, Austria." Regulated Rivers: Research & Management **8**(1-2): 195-204.

Brunke, M. and T. Gonser (1997). "The ecological significance of exchange processes between rivers and groundwater." Freshwater Biology **37**(1): 1-33.

James, A. B. W. and I. M. Henderson (2005). "Comparison of coarse particulate organic matter retention in meandering and straightened sections of a third-order New Zealand stream." River Research and Applications **21**(6): 641-650.

Boano, F., C. Camporeale, et al. (2006). "Sinuosity-driven hyporheic exchange in meandering rivers." Geophys. Res. Lett. **33**(18): L18406.

Constantine, J. A. and T. Dunne (2008). "Meander cutoff and the controls on the production of oxbow lakes." Geology **36**(1): 23-26.

4. *Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?*

The number of bends of sinuosity > 2.0 is by definition an indicator for a length of river at a defined scale greater than a few bends in length. As defined in this case, it is used as an indicator of the river between Red Bluff and Colusa.

5. *What cutoffs are appropriate for poor, fair, good and very good?*

Very Good: *> 7 bends with M/L>2.0*

Good: *6 or 7 bends with M/L>2.0*

Fair: *5 bends with M/L>2.0*

Poor: *< 5 bends with M/L>2.0*

6. *How were the particular rating cutoffs selected?*

Following visual inspection of plotted data from a series of years on the Sacramento River.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

Sinuosity of a single bend is a fundamental measure and is widely documented.

Dunne, T. and L. B. Leopold (1978). Water in environmental planning. San Francisco, W. H. Freeman.

Larsen, E. W. (1995). The Mechanics and Modeling of River Meander Migration, University of California at Berkeley**:** 1-342.

Leopold, L. B. (1994). A view of the river. Cambridge, Harvard University Press.

Leopold, L. B., M. G. Wolman, et al. (1964). Fluvial Processes in Geomorphology. San Francisco, W. H. Freeman and Company.

Richards, K. (1982). Rivers: Form and Process in Alluvial Channels. New York, Methuen

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

In 2007, there were four bends with sinuosity greater than 2.0, which is considered "Poor". The data that were analyzed to produce this value were collected in June 2007.

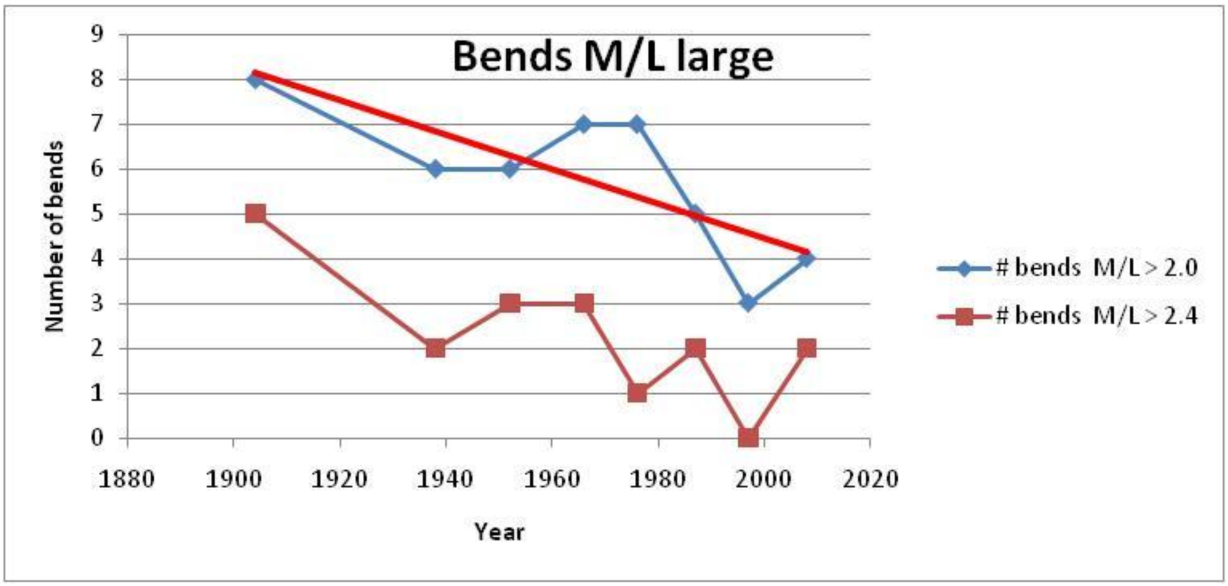
9. *What is the desired rating and by when should this be achieved?*

Six bends in the study reach would result in a rating of "Good." This should be achieved by 2020.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)?

All trends for sinuosities ranging from 2.0 to 2.4 (over eight time periods) show a decrease over time. 2.0, which will include the informaion for the higher sinuosities, was chosen as a metric to judge river health.

Year	Count	# bends M/L > 2.0	# bends M/L > 2.4
1904	119	8	5
1938	129	6	2
1952	119	6	3
1966	119	7	3
1976	124	7	1
1987	122	5	2
1997	120	3	0
2007	119	4	2
Mean	121	5.75	2.25



11. When were the data collected that yielded these other values? Describe the history of data collection.

The channel centerlines that were analyzed are from 8 time periods (see above table) distributed over 104 years. They were plotted by Larsen taken from aerial photos Greco (1904 to 1997) and Nelson (2007).

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Sacramento River Colusa to Red Bluff.

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

Eric Larsen, Research Scientist
Department of Geology
One Shields Ave
University of California Davis
Davis, CA 95616
UC Davis.
(530) 752-8336
ewlarsen@ucdavis.edu

Another person that is a source of data (channel centerlines) for this indicator:

Steve Greco
Dept of Environmental Design
University of California
Davis, CA 95616-8585
segreco@ucdavis.edu
(530) 754-5983

14. What is the rationale for the desired rating?

At this point, subjective judgment to return to a value of complexity of previous times, but not aiming at a return to "pristine" or the best.

15. *Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).*

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Percent of Riparian Shoreline Bordered by >500 meters of Natural Habitat

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

The percent of riparian shoreline bordered by >500 meters of natural habitat is defined to include all natural habitats as mapped by the CSUC Geographic Information Center (GIC).

2. What is the rationale for it being a meaningful indicator?

Terrestrial habitats surrounding wetlands are critical to the management of natural resources. Although the protection of water resources from human activities such as agriculture, silviculture, and urban development is obvious, it is also apparent that terrestrial areas surrounding wetlands are core habitats for many semiaquatic species that depend on mesic ecotones to complete their life cycle.

Having a riparian buffer provides benefits in terms of water quality (ag toxin sequestration), SRA habitat, connectivity for species that utilize both the aquatic and terrestrial realm.

Proximity of aquatic to upland habitat is important for many species such as bats that forage over the river but roost in trees, and turtles that nest in upland sites but that otherwise reside in the aquatic realm.

For purposes of conservation and management, it is important to define core habitats used by local breeding populations surrounding riparian areas.

In a literature review by Semlitsch & Bodie (2003), core terrestrial habitat ranged from 159 to 290 m for amphibians and from 127 to 289 m for reptiles from the edge of the aquatic site. Data from these studies indicated the importance of terrestrial habitats for feeding, overwintering, and nesting, and, thus, the biological interdependence between aquatic and terrestrial habitats that is essential for the persistence of populations.

3. What references support its use as an indicator of river health? Provide citations.

Semlitsch R.D & J. R. Bodie. 2003. Biological Criteria for Buffer Zones around Wetlands and Riparian Habitats for Amphibians and Reptiles. *Conservation Biology* 17:1219–1228.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

It is best as an indicator at the larger (reach or entire river) scale.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

   The status indicator ratings are defined as:
   Very Good: > 40%
   Good: 25 – 40%
   Fair: 10 – 25%
   Poor: < 10%

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

   Cutoffs were selected based upon review of the existing data, and analyses of how this indicator value will to change if all of the tier 1 properties are acquired. These values should be viewed as working hypotheses to be refined as more information becomes available.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

   Both 1999 & 2007 CSU-GIC remnant riparian data layers were clipped to the extent of the 2007 CSU-GIC aerial photographs that were used to create the 2007 remnant riparian layer. All polygons classified as Open Water by the 1999 & 2007 CSU-GIC remnant riparian data layer were isolated. Then all non-main channel polygons were removed. All remaining polygons were merged, forming a mainstem Sacramento River polygon. A 500 meter buffer polygon of the river was created and converted into a polyline. This polyline was visually cut into segments where there was continuous natural vegetation identified in the 2007 CSU-GIC remnant riparian layer perpendicular from the mainstem river bank all the way to the 500 meter buffer line. The final result was calculated to be the percent of the 500 meter buffer line with continuous natural vegetation perpendicular to the river. Natural vegetation includes all the CSU categories, not just forest.

Step 6

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   Fair, 22.25% as of June 2007.

   The above value includes restoration areas. Without including these areas the value is 14.25%.

9. What is the desired rating and by when should this be achieved?

   "Good" by 2020

Step 7.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

    In 1999 the comparable values were 15.6% with restoration, and 11.0% without.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    The current indicator data are based upon an analysis of the entire mainstem Sacramento River between the Red Bluff Diversion Dam and the Colusa Bridge. It is representative only of this area.

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

    This indicator information was input by G. Golet following review of relevant materials. Calculations based upon the 1999 and 2007 data were both performed by:

    Seth Paine, TNC Cons Science Tech,
    spaine@tnc.org
    (530) 897-6370 x 214
    Northern Central Valley office
    500 Main Street
    Chico, CA 95928

13. What is the rationale for the desired rating?

    If we acquire and restore all the Tier 1 properties then we will have an additional 11.8% of the total river bank with a border of riparian vegetation that is more than 500 meters. This would bring the total up to ~34%. The feasibility of achieving this was used as a basis for setting the ratings values and the desired rating.

<u>Step 8</u>

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

More information on the viability assessment part of the workbook can be found at:
http://conserveonline.org/workspaces/cbdgateway/cap/practices/bp_3

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Length of Bank with Riprap

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

Length of bank with riprap. This indicator is measured on both sides of the river 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 as lines from multiple sources. Riprap locations are derived from mapped products and field investigations. Location are mapped and documented in GIS datasets.

2. What is the rationale for it being a meaningful indicator of ecosystem health?

Riprap 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.

In this decade, riprap has been installed and is planned to be installed on banks to protect critical infrastructure (i.e. levees and bridges). These installations restrict fluvial physical processes and degrade or destroy critical habitats.

This indicator is only assumed to be representative of the condition of the Red Bluff to Colusa reach of the river, but it may impact species (e.g., salmon) that range much more widely and that utilize this area for only a portion of their lifecycle.

3. What references support its use as an indicator of ecosystem health? Provide citations.

USFWS. 1992. Shaded riverine aquatic cover of the Sacramento river system: Classification as resource category 1 under the FWS mitigation policy. Sacramento, CA: U.S. Department of the Interior, U.S. Fish and Wildlife Service.

USFWS. 2000. Impacts of riprapping to ecosystem functioning, lower Sacramento River, California: 40. Sacramento, CA: U.S. Department of the Interior, U.S. Fish and Wildlife Service.

USFWS. 2002. Sacramento Fish and Wildlife Office policy regarding riprap bank protection on Central Valley rivers, including the Sacramento River.

Sacramento, CA: U.S. Department of the Interior, U.S. Fish and Wildlife Service.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?
   Riprap can be used as both and maybe useful at multiple scales. Riprap has both site specific impacts, reach wide impacts, as well as river wide cumulative impacts.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

Very Good- Riprap removed from alluvial soils and areas that would otherwise allow physical processes to create and maintain critical habitats. Limit new riprap to appropriate soil and geology types (resistant materials), where critical habitats are not degraded or destroyed, and at where required to protect critical infrastructure hard points (e.g., levees and bridges). Move or modify critical infrastructure when appropriate to reduce negative impacts of riprap. New riprap follow these guidelines. Do not repair existing riprap that does not follow these guidelines and that "blows out" during flood events. Overall length of riprap is reduced significantly.< 30,000M

Good- Some riprap removed from alluvial soils and areas that would otherwise allow physical processes to create and maintain critical habitats. Limit riprap to appropriate soil and geology types (resistant materials), where critical habitats are not degraded or destroyed, and at where required to protect critical infrastructure hard points. New riprap would follow these guidelines. Overall length of riprap maybe reduced. More important maybe that riprap lengths preventing erosion on banks most likely to provide critical habitats and allow physical process are reduced while riprap at critical infrastructure hard points (e.g., levees and bridges) increases. 30,000-60,000

Fair- Current situation. Approximately 48 miles of riprap on the Sacramento River between Red Bluff and Colusa. In this decade, riprap has been installed and is planned to be installed on banks to limit and restrict fluvial physical processes. These installations continue to degrade or destroy critical habitats. Riprap has been installed and is planned to be installed to protect critical infrastructure hard points (i.e. levees and bridges). Two efforts are underway to study the feasibility of removing rock to protect infrastructure (e.g., Kopta Slough and Princeton Codora Irrigation pumps). The Butte County District Attorney's office has also forced the removal of small amounts "illegal" riprap on the Sacramento River. No cumulative effect analysis is being done to address the impact of riprap on the Sacramento River. 60,000-80,000m

Poor- Length of riprap increases on banks that limit and restrict fluvial physical processes. Critical habitats continue to be degraded or destroyed. Overall riprap length increases significantly. >80,000

6. How were the particular rating cutoffs selected?

These cutoffs are Adam Henderson's opinion and could be further refined.

7. Are there methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

   Methods are established in gray literature in technical memorandum reports at DWR Northern District.

   Department of Water Resources. 2005. Bank Survey of Reach 3, Chico Landing to Colusa, Sacramento River, California. California Department of Water Resources Memorandum Report from Stacy Cepello and Adam Henderson, California Department of Water Resources, Northern District, Red Bluff, CA, to Dwight Russell March 9.

<u>Step 6</u>

8. What is the current indicator status? What is the month and year that this corresponds to?

Last survey records indicate that approximately 77,000 meters of riprap was on the Sacramento River between Red Bluff and Colusa.

The riprap dataset was last completely updated in 2002 and should be updated. Rip rap has been added since 2002, approximately 500-1000m.

9. What is the desired rating and by when should this be achieved?

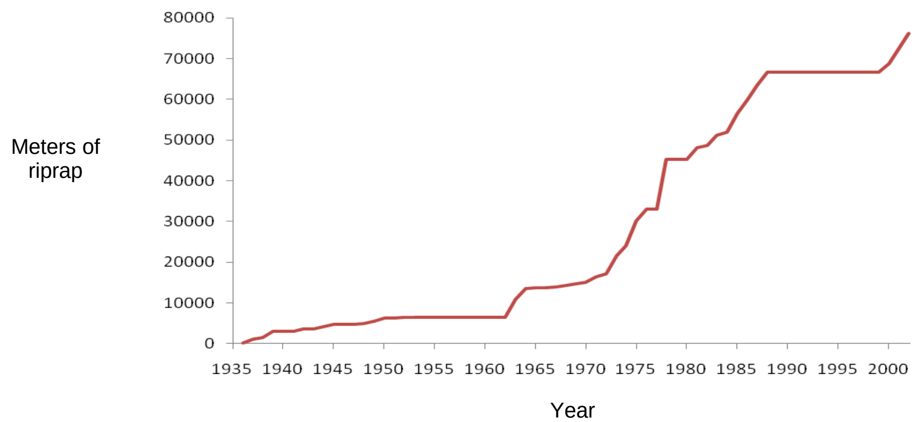
   Good-2035 years.

   Very good by 2060 years. Continued progress, longer time frame.

<u>Step 7</u>.

10. Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

There are maps and atlases that document some rip rap along the banks of the Sacramento River. These are from 1974-present. Although they have some rip rap mapped, often they were completed for another purpose. Adam has used these to give ranges to when the rip rap was placed. He has an inventory of these sources, and will provide it. Here is a figure of how it has increased over time.



11. What is the rationale for the desired rating?

This is the amount that was determined to be reasonable achievable over this time frame.

12. Where were these current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

The entire reach between Red Bluff and Colusa was surveyed, and thus the indicator speaks to the condition of the river over this entire area.

13. What is the source of the current indicator data? Who is the contact person? Provide complete contact info.

Adam Henderson
Environmental Services Section, Northern District
CA Department of Water Resources
2440 Main Street
Red Bluff, CA 96080
530.529.7319 Office
530.945.3173 Cell
530.529.7322 FAX

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.

Other agencies also may have information about riprap on the river. Currently, the United States Army Corps of Engineers has produced both digital files and paper maps describing locations of riprap installed as part of the Sacramento Bank Protection Project and the Red Bluff to Chico Landing project. Mike Deitl is a good contact at the USACE.

County public works departments (or equivalent) typically have Operations and Maintenance manuals that correspond to USACE sponsored rock within their area of responsibility.

The Department of Water Resources, Division of Flood Management is also responsible for maintaining rock on the Sacramento River and is especially interested in rock adjacent to State flood control levees. Bob Duffy is good contact at DWR.

Step 8

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

Within fifty years many critical infrastructure hard points maybe evaluated for major repairs or reach their engineered life span. This would provide opportunities to move or redesign hard points that require limiting physical processes to maintain their integrity. Natural attrition of riprap (failure and scour due to flood events) on alluvial soils will reduce riprap length over time if it is not repaired. Opportunities exist to work with willing landowners to maintain or allow physical processes on floodplain properties through either easement or acquisition. Other opportunities to restore physical fluvial processes removing riprap may exist on public conservation lands.

Currently, two efforts are underway to study the feasibility of removing rock to mitigate for new rock needs to be installed to protect infrastructure (e.g., Kopta Slough and Princeton Codora Irrigation District pumps). The Butte County District Attorney's office has also forced the removal of small amounts "illegal" riprap on the Sacramento River. Additionally critical erosion sites have been identified where riprap is planned on being installed. However, no cumulative effect analysis has been done to address the impact of riprap on the Sacramento River. Nor is there any good information available to identify where essential vs. nonessential riprap is located.

To prioritize sites for riprap removal land ownership needs to be considered. Public ownership is currently maintained by multiple agencies and current status of the data is unknown. This critical dataset is probably best maintained by TNC. The Sacramento River Conservation Area Forum (SRCAF) will have an updated public lands GIS dataset updated as part of their CalFed Working Lands Grant. The CSUC Geographic Information Center is updating riparian vegetation GIS mapping under an ERP monitoring grant (SRMAP).

During the bank surveys conducted by DWR other data was collected including characteristics of the riprap (e.g., type, size, amount, height) and natural banks (e.g., type, adjacent vegetation, salmonid habitat characteristics). Other data that is readily available could be used to refine the indicator are riparian vegetation, public ownership/easements and surface geology. Removal of riprap adjacent to public lands or easements maybe targeted and given different value as an indicator. Private lands with high quality habitat types on eroding banks maybe especially vulnerable to riprap installation. Current regulatory policies do not necessarily preclude private landowners from installing riprap on high quality habitats. Vegetation maybe important to weighting locations. Adjacent vegetation may be used to assess habitat impacts if banks are either riprapped or where riprap is removed. Surface geology or soils, should guide all riprap installation, removal, and impact assessments.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Area of Water Primrose (*Ludwigia peploides)*

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Introduction
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. Leaves appear in early spring and are alternate on reddish stems. In early summer the stems emerge and can be prostrate to erect and simple or branched. They flower from July to October and have five, yellow petals. Fruits are a cylindrical capsule containing many yellowish, oval seeds less than 1mm long. In late autumn, the aerial stems die back and winter persistent organs (buds) form. Both a native and an exotic *Ludwigia* species occur on the Sacramento River. However, they cannot be distinguished from each other during photo interpretation, and may be difficult to tell apart in the field as well.

1 How specifically is the indicator defined?

This indicator, is defined as the total area mapped as LP (*Ludwigia peploides*) within the area that was photographed and mapped in 2007 as part of the Sacramento River Monitoring and Assessment Project. Generally speaking this area is 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. For further definition of the mapped area see Nelson et al. (2008).

Ludwigia peploides stands out on the 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. *Ludwigia peploides* is found throughout the Red Bluff to Colusa riparian map and is mapped in the shape file; nv_riparian_07_z1083m as LP (Ludwigia peploides).

2 What is the rationale for it being a meaningful indicator?

Ludwigia peploides is a meaningful indicator because its abundance and distribution in the riparian areas is indicative of the degree to which certain native riparian species are displaced.

Currently *Ludwigia peploides* does not have a rating on the Federal or California Noxious Weed List or the Invasive and Noxious Weeds list. It is listed with a "high" rating in the California Invasive Plant Inventory published by the California Invasive Plant Council February 2006. (High – These species have severe ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal and establishment. Most are widely distributed ecologically.) In A Manual of California Vegetation second edition (2009), it is stated (under Observations pg. 966) that more surveys are needed with careful identification throughout the state to separate weedy stands from the native ones.

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 is spreading into regions of the United States where it was previously undocumented.

Ludwigia peploides is an aggressive invasive that poses a serious risk to aquatic habitats. It grows quickly in warm weather and can take over entire slow-flowing water bodies. It grows horizontal on mud and can emerge over the water surface. The plant favors the margins of lakes, ponds, ditches and streams. Growth forms vary from free floating, anchored and submersed, and anchored and floating leaves. Biomass doubling time under outdoor experimental conditions in California is 23 days and has been estimated at 15-20 days under stagnant, natural conditions and 70 days under flowing water conditions in France. It can tolerate water depths up to 3 meters and grow 80 cm above the water surface. A study in South Carolina in 2005 on Lake Murray showed that *Ludwigia* established during the extended drawdown of 2003 – 2004 and then continued to endure as water levels rose back to normal. Yeah, I thought so too. The deeper beds occupied the 10 to 12 foot depths but some beds persisted in as much as 17 feet of water.

Their rapid growth rate allowed them to keep up with the rising water levels as the lake refilled after the drawdown.

A recent study (Dandelot S. et al. 2008) of two *Ludwigia* species (*L. peploides* and *grandiflora*) showed that both possess allelochemicals. The study conducted throughout the growing season showed a decrease in germination of the target species lettuce and watercress, an increase in mortality for watercress (in the May period), a disturbance of seedling elongation for lettuce in all seasons, and seedling chlorosis in both targets in all seasons. This allelopathic activity that influences water quality throughout the year may contribute to the success of *Ludwigia* and its ability to out-compete native species and take over large areas so rapidly. They suggest more studies in regard to analyzing the allelochemicals of *Ludwigia*, and hydrophyte – microflora interactions (of target species).

Ludwigia is commonly thought to reproduce from plant fragments (stolons) but may also reproduce from seeds. There is little study of seed viability at present other than seeds having been sprouted in laboratory conditions. Dispersal methods are by water, birds and other wildlife, wind and human activities (and possibly through the aquarium and horticultural trade as it has been sold for pond and water gardens).

Because its leaves are above the water surface *Ludwigia sp* do not add much oxygen, if any, to the water column. With reduced dissolved oxygen and pH in the water it may eventually displace native submerged aquatic plants and grasses thus reducing biodiversity. *Ludwigia peploides* produces two types of roots; one type which adsorbs nutrients and attaches the plant to the soil, and adventitious roots located along the stems above the water level which ensure oxygen uptake and enhance rooting of plant fragments. Adventitious roots growing at leaf nodes enhance the probability that plant fragments will give rise to new plants after breaking off of parent plants, floating downstream and becoming lodged as debris.

Ludwigia peploides increases mosquito populations by providing habitat for the mosquito larvae. The dense mats of vegetation make it difficult for mosquito-eating fish to access the larvae. The dense mats can also block irrigation and drainage ditches and canals. When waterways become choked with *Ludwigia peploides* it can reduce accessibility of boaters, hunters, fishermen and swimmers. The sprawling mats can impede water flow which can increase sedimentation, and in turn further reduce water flow.

Ludwigia peploides may have limited wildlife benefits. They may provide good habitat conditions for western pond turtles. Seeds may occasionally be eaten by ducks and white-tailed deer have been observed browsing on the plant's foliage. Another possible benefit for *Ludwigia peploides* is that it has potential for wastewater treatment plants. Its nitrogen-absorbing capabilities exceed those of water hyacinth, (*Eichhornia crassipes*).

3 What references support its use as an indicator of ecosystem health? Provide citations.

California Native Plant Society. 2001. CNPS Inventory- 6th Edition (D. Tibor, ed.) California Native Plant Society. Sacramento, CA

Cal-IPC. 2006. California Invasive Plant Inventory. Cal-IPC Publication 2006-02 California Invasive Plant Council: Berkeley, CA. Available: www.cal-ipc.org/

Dandelot S., et al. 2008. Allelopathic potential of two invasive alien *Ludwigia* spp. Article from Aquatic Botany, 88 (4) pp. 311-316.

Hickman, J. C., The Jepson Manual: Higher Plants of California. University of California Press, Berkeley, CA

Nelson, C., M. Carlson and R. Funes. 2008, Rapid Assessment in the Sacramento River Ecological Management Zone – Colusa to Red Bluff. Report to the CALFED Ecosystem Restoration Program, Sacramento, CA.

Peconic Estuary Program http://www.peconicestuary.org/InvLudwigia.html

Research Example: The Invasion of the *Ludwigia peploides*
http://www.cemagref.fr/English/ex/hydrosystem/EVJussies/EVjussieex.htm

Sawyer, J.O., T. Keeler-Wolf, and J. M. Evens. 2009. A Manual of California Vegetation Second Edition. California Native Plant Society. Sacramento, CA.

Water Primrose 2005 Lake Murray, South Carolina
http://www.sceg.com/NR/rdonlyres/B72743ED-4C54-47A2-9B17-D3C5C0127BF3/0/primrose2005report.pdf

Written Findings of the Washington State Noxious Weed Control Board (2005)
http://www.nwcb.wa.gov/weed_info/Written_Findings1/Ludwigia%20peploides,%20final.pdf

4 Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

It is useful at multiple scales. Interpretations of the data are in part a function of the geographic range of the mapping effort.

5 What cutoffs are appropriate for poor, fair, good and very good?

The status indicator ratings are defined as:
Very Good: < 50 acres
Good: 50 - 200 acres

Fair: 200 - 400 acres
Poor: > 400

6 How were the particular rating cutoffs selected?

Expert opinion and based on what previous mapping efforts have revealed.

7 Are the methods for calculating the indicator described in published documents or reports?

They are described in Nelson et al. (2008), as cited above.

8 What is the indicator value (and Status)?

There are 234 *Ludwigia peploides* polygons totaling 387 acres in the Red Bluff to Colusa reach in the Sacramento River riparian shape file. The corresponding condition is "fair". *Ludwigia peploides* coded LP in the classification table is mapped as it is found on the 2007 true color aerial photographs. The smallest individual polygon is 0.008 acre. The largest polygon is 42 acres. The northern most polygon is south of the Red Bluff Diversion Dam on Blackberry Island near Craig Creek and the farthest south polygon is just south of Moulton Unit South.

What is the month and year that this corresponds to?

The 2007 aerial photographs were on flown 26 June 2007. In total there were 298 aerial photos taken in the Red Bluff to Colusa reach, and 347 over the larger area. To amend coverage, ten additional aerial photographs scattered through-out the Colusa to Red Bluff area were flown on 17 June 2008.

9 What is the desired rating and by when should this be achieved?
"Good" by June 2020.

10 Are there additional indicator values derived in the past that correspond to the scale of reporting (parcel, reach, etc)? When were the data collected that yielded these values? Describe the history of data collection.

A Sacramento River riparian map was completed in 2002 by the Geographical Information Center (GIC) using 1999 aerial photographs for the mainstem of the Sacramento River between Keswick Dam and Colusa. It was intended as an update to the 1991-1998 Sacramento River Riparian Mapping Project. It is located in the Sacramento River Conservation Area (SRCA) approximately between river mile 300 and river mile 129. The aerial photos were flown at the nominal scale of RF=1:7200 (1:600). The 1999 riparian shape file is referenced as nv_riparian_99_z1083m. The 1999 riparian shape file was edited to call out LP (*Ludwigia peploides*) polygons. The majority of areas where LP was located were originally classified as (M) Marsh. The 1999 map was edited to locate and map Ludwigia in the "Marsh" polygons and any other areas where it was located. There are now 177 Ludwigia polygons (338 acres) in the 1999 shape file that starts at Keswick Dam and ends several miles below Colusa.

The earliest Sacramento River riparian shape file created by the GIC was begun in 1991 and completed in 1998. It includes the classification M (Marsh) but has not been edited to separate out LP (*Ludwigia peploides*). This riparian map is referenced as nv_riparian_z1083m. The map has 1065 polygons of M. It begins at Keswick Dam and ends at Suisun Bay. This map was developed to inventory and map riparian lands along the Sacramento River and its tributaries within the Sacramento Valley. This mapping effort used color infrared aerial photography that was flown in a series of flights beginning in the year 1991 and ending in 1998. If funding should become available, this map should be updated to include *Ludwigia peploides* (LP).

The Department of Water Resources (DWR), Northern District has available on their website at Cal Atlas (http://www.atlas.ca.gov), georeferenced, mosaiced images of the Sacramento River Maps compiled by the U.S. Army Corps of Engineers for the years and areas:
1909 - Chico Landing to Colusa,
1923 (ca.) - Red Bluff to Chico Landing, and
1958 – Colusa County with portions of Glenn County.

The GIC has downloaded from the DWR FTP site:
1938 - Battle Creek confluence to Llano Seco.

Mapping of the mainstem Sacramento River:
2007 Sacramento River riparian shape file: Aerial photos were flown June 26, 2007 with 10 additional photos flown 6-17-08 to amend coverage. The nominal scale RF = 1:5000. Field work consisting of Rapid Assessments (RA) and field verification was conducted through the summer and fall of 2008. The riparian map shape file was created throughout 2008 with a final edited version in 2009.

1999 Sacramento River riparian shape file: Aerial photos were flown May 21, 1999 with a nominal scale RF = 1:7200. Field work was limited to several initial field visits and the riparian shape file was completed in 2002.

1991 to 1998 shape file, the Sacramento River riparian portion contains the photos for the years and locations1993 to 1996:
Tehama County, 1993, nominal scale RF=1:12000.
Butte County and Glenn County side of Sacramento River, 1994, nominal scale RF=1:12000.
Sacramento River mainstem from Butte County line to the American River, 1996, nominal scale RF=1:12000
Tisdale Weir, 1996, nominal scale RF=1:12000.

Sutter Bypass to Butte Slough, 1996, nominal scale RF=1:12000.
Other images for the tributaries are also a part of the 1991 to 1998 Sacramento River Riparian mapping project.

Mapping of the tributaries of the Sacramento River (part of the 1991 to 1998 shape file):
Although outside of the SRMAP project area, additional nearby mapping has taken place:
Lower Stony Creek to Black butte Dam, 1996, nominal scale RF=1:12000,
Lower Butte Creek from Butte County line, to Butte Sink, 1996, nominal scale RF=1:12000,
Feather River from Verona to Butte County line and Yuba River, 1996, nominal scale RF=1:12000
Feather River from Butte County line to Oroville, 1997, nominal scale RF=1:1200.
Bear River – Feather River to Camp Far West Reservoir, 1996, nominal scale RF=1:12000,
American River – American River to Folsom Lake, 1996, nominal scale RF=1:12000,
Cache Creek – Cache Creek from Capay Valley, 1996, nominal scale RF=1:12000,
Putah Creek – Putah Creek from Montecello Dam to Yolo Bypass, 1998, nominal scale RF =1:12000.

11 Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?
Data for the 2007 shape file was collected from Keswick Dam to Verona and includes; initial field visits, rapid Assessments, field verification and edited shape files. However the data analyzed and presented here are for a subset of the area (Red Bluff to Colusa).

12 What is the source of the current indicator data? Who is the contact person? Provide contact info.

The 2007 edited shape file was created at the GIC in Chico, CA.
Data for the 1999 shape file from Keswick to below Verona was created at the GIC in Chico, CA.
Data for the 1991 – 1998 shape file from Keswick to the Delta (including tributaries in the Sacramento Valley) was created at the GIC in Chico, CA.
Melinda Carlson
GIS Biologist
Geographical Information Center
Chico, California 95929-0327
mcarlson@gic.csuchico.edu
530 898-3212 office
530 898-6317 fax

13 What is the rational for the desired rating?

The desired rating was selected based upon the perceived importance of this indicator in influencing Sacramento River natural resources, and with consideration of what may be possible with a concerted restoration effort.

14 Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc.)

Ludwigia peploides is difficult to see on the aerial photographs when it is under tree or shrub canopy. At times tiny patches of the bright yellow-green color signature for *Ludwigia* may be seen through a canopy but in those instances it would be polygoned to reflect the dominant tree or shrub classification of the canopy.

At times, aerial photos can be difficult to read making vegetation signatures hard to interpret. A few examples that may cause this are glare, shadows, too dark or too light of photo color, or distortion on the edges when there is inadequate overlap from photo to photo. When photos are encountered that are difficult to interpret, it is helpful to look at another source (of same or similar year). Other sources that have been used are Google Earth, Live Search Map and 2005 NAIP Imagery.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Area of Floodplain Reworked

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

1. *How specifically is the indicator defined?*

The area of floodplain reworked per year was measured by measuring the area of the "eroded area polygon" (Figure 1) that is formed when two channel centerlines from two different time periods are intersected. The area that results is then divided by the number of years in the time interval between the two time periods. The area of floodplain reworked measured in this way is an estimate of "new floodplain created."

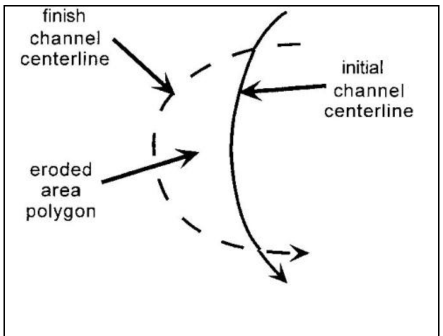


Figure 1 Definition sketch of "eroded area polygon for LWD model

2. *What is the rationale for it being a meaningful indicator?*

For ecosystem processes related to aerial extent of river channel or of riparian habitat related to the river bank, the reworking of land and creation of floodplain is critical for ecosystem functions and processes. For example, Freemont cottonwood development depends on point bars that are created. As cottonwoods mature, they depend on the time-sequence of land reworked or floodplain creation. Other riparian species also require a heterogeneity of floodplain age, which is produced by land being reworked. The "per year" measurement of land reworked is a metric of the rate that such land is being produced.

3. *What references support its use? Provide citations.*

Dixon, M.D., M.G. Turner and C.F. Jin, (2002) Riparian tree seedling distribution on Wisconsin river sandbars: controls at different spatial scales, *Ecol. Monogr.* **72** (2002), pp. 465–485.

Greco, S. E., A. K. Fremier, et al. (2007). "A tool for tracking floodplain age land surface patterns on a large meandering river with applications for ecological planning and restoration design." Landscape and Urban Planning **81**(4): 354-373.

Larsen, E. W., E. H. Girvetz, et al. (2006). "Assessing the Effects of Alternative Setback Channel Constraint Scenarios Employing a River Meander Migration Model." Environmental Management **37(6)**: 880-897.

Malanson, G.P., Riparian Landscapes, Cambridge University Press, New York (1993).

Naiman, R.J., H. Décamps and M.E. McClain, (2005) Riparia: Ecology, Conservation and Management of Streamside Communities, Elsevier, New York (2005).

Steiger, J., E. Tabacchi, S. Dufour, D. Corenblit and J.-L. Peiry, (2005) Hydrogeomorphic processes affecting riparian habitat within alluvial channel–floodplain river systems: a review for the temperate zone, *River Res. Appl.* **21** (2005), pp. 719–737.

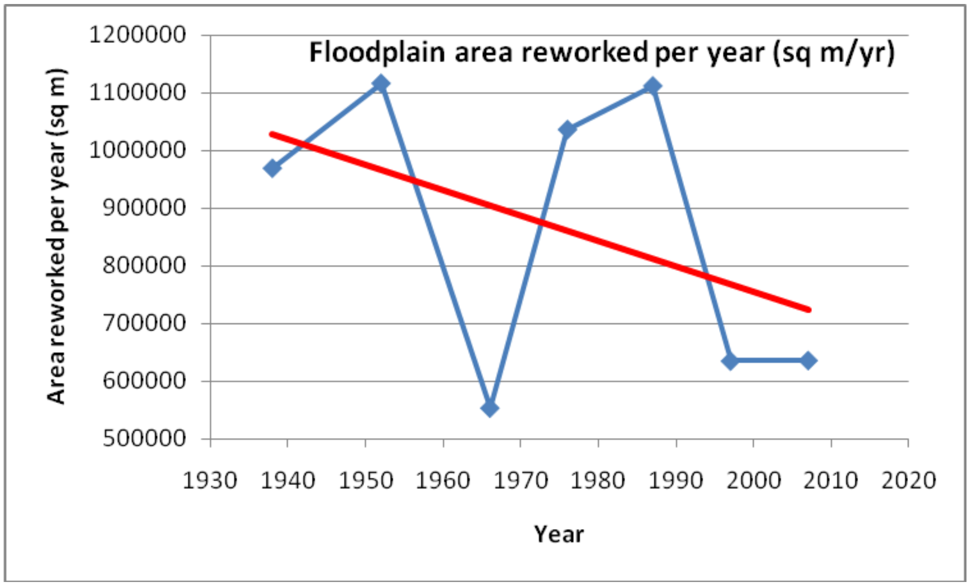
van Coller, A.L., K.H. Rogers and G.L. Heritage, (2000) Riparian vegetation–environment relationships: complimentarily of gradients versus patch hierarchy approaches, *J. Veg. Sci.* **11** (2000), pp. 337–350.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

The area of floodplain reworked per year is by definition a metric that averages rates over a time interval. It is best used to compare different sites during the same time period. It is somewhat duplicative of migration rate, but in this case gives an actual area. It is also a useful metric to compare river reaches. In order to assesses the overall health of the river, the rate of area reworked per year for the whole river can be calculated to see if there is a trend over time (for example, is the rate continuously decreasing?) The same principle may be used for smaller reaches.

5. What cutoffs are appropriate for poor, fair, good and very good?

As with other geomorphic indicators, we might use the original value, in this case of area reworkd, from 1904 to define a “historic” or “very good” condition.



Very Good:	1000000	<	*m²/year*		
Good:	900000	<	*m²/year*	<	1000000
Fair:	700000	<	*m²/year*	<	900000
Poor:			*m²/year*	<	700000

6. *How were the particular rating cutoffs selected?*

Following visual inspection of graphed data from the Sacramento River tracking changes over time.

7. *Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?*

Larsen, E. W., E. H. Girvetz, et al. (2006). "Assessing the Effects of Alternative Setback Channel Constraint Scenarios Employing a River Meander Migration Model." Environmental Management **37(6)**: 880-897.

8. *What is the current indicator value (and status)? What is the month and year that this corresponds to?*

636,451 sq meters, from data that were collected in June, 2007.

9. *What is the desired rating and by when should this be achieved?*

This is a value judgment that needs to be decided in a wider group.

A reasonable target might be the mid-range of the rates over the last century. Taking a somewhat more theoretical and larger scale approach, a good research question is, "What would have to be done to return to the 1904/1938 rate of floodplain reworked?" Even if this were not practically possible, attempting to answer this question might reveal important information about the current state of the river and the possibilities/limitations for restoration.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)?

Year	Channel length (m)	Whole river sinuosity	Bend wave length (m)	Floodplain reworked (sq m/yr)	Entrance Angle (Degrees)	# bends M/L > 2.0
1904	160529	1.31	1038		46	8
1938	160474	1.26	941	969556	47	6
1952	156070	1.26	1042	1116432	42	6
1966	156423	1.25	1085	554168	44	7
1976	157303	1.25	957	1036478	43	7
1987	155528	1.25	1043	1112001	45	5
1997	154221	1.23	1099	635516	40	3
2007	154229	1.24	1106	636451	40	4

11. When were the data collected that yielded these other values? Describe the history of data collection.

The channel centerlines that were analyzed are from 8 time periods (see table) distributed over 104 years. They were plotted by Larsen taken from aerial photos from Greco (1904 to 1997) and Nelson (2007).

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Sacramento River: Colusa to Redbluff.

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

Eric Larsen, Research Scientist
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One Shields Ave
University of California Davis
Davis, CA 95616
UC Davis.

(530) 752-8336
ewlarsen@ucdavis.edu

Another person that is a source of data (channel centerlines) for this indicator:

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Davis, CA 95616-8585
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(530) 754-5983

14. What is the rationale for the desired rating?

The rationale is that there are areas that are constrained that could possibly be allowed to change. Such changes would increase the rate of floodplain reworked, and therefore, an increase in area reworked is conceptually possible. A return to the rate of floodplain reworked of river as it was in a previous time period is not aiming at "a return to pristine," but at least sets a goal that can be used to monitor change.

15. *Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).*

The area reworked will depend on the length scale over which the metric is measured. For example, suppose two sites were chosen to measure the metric: one a mile long and the other 1/10 of a mile long. Obviously, the longer one would tend to have a greater area of floodplain reworked than the smaller one, regardless of the relative dynamism of the areas. This is an important consideration when comparing different sites. A possible way to compare different sites is to choose similar lengths. Another way is to non-dimensionalize by length. This would then be the same as the channel migration rate because area (m^2) per year (yr) divided by length (m) becomes the migration rate in (m/yr).

An additional reference for a related subject – floodplain age – is given below.

Fremier, A. K. (2003). Floodplain age modeling techniques to analyze channel migration and vegetation patch dynamics on the Sacramento River, CA. Environmental Design. Davis, University of California, Davis**:** 97.

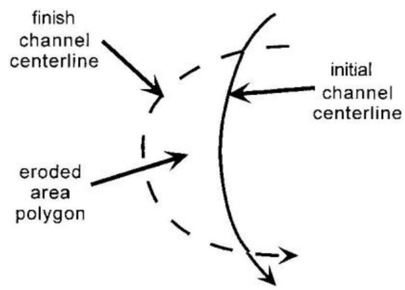
SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Channel Bend Meander Migration Rate

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

1. *How specifically is the indicator defined?*

Channel meander migration rates are calculated by dividing the polygon area of each segment by the average stream length, and then establishing a yearly rate by dividing by the number of years between the initial and final times. It is a simple, reproducible measure of the magnitude of shift in channel location perpendicular to the original channel centerline. Dividing area by length results in a length. When this is divided by time, it results in a rate expressed in length/year.



Channel meander migration, also known as lateral migration, is measured by mapping sequential channel centerlines and by quantifying the change in location of a channel centerline over time using the eroded-area polygon. An eroded-area polygon is created by intersecting two channel centerlines mapped at two different points in time. ArcInfo calculates the area and perimeter of the eroded polygon, from which the average distance migrated perpendicular to the channel centerline is calculated. The lateral migration distance is equal to the polygon area divided by the average stream length for the polygon (with average stream length equal to one-half of the polygon perimeter). Finally the rate is normalized by the number of years of migration so that the final metric is m/yr.

2. *What is the rationale for it being a meaningful indicator?*

The meander migration rate of the entire channel indicates the degree to which the river is dynamic. Another, related measure is the area reworked. The area reworked per year includes information about the patch size under consideration. Taking area reworked per year and “normalizing” by the average length of the patch, gives a dimensionless quantity that can compared across all patch sizes. In the case of whole-river, the graphs for change over time (for floodplain area reworked and for meander migration rate) have precisely the same pattern because the area of the patch in each case is the sum of all the patches in the entire study reach. Meander migration rates are more appropriate measures to compare across river systems. Channel migration rates are the area reworked normalized by the reach length and the number of years in the time interval. The degree to which a bend is dynamic provides a characterization of the river's ability to create new floodplains. Dynamic river processes (e.g., erosion, sediment deposition) revitalize riverine habitats and are beneficial to native flora and fauna. Cottonwood and willow forests naturally regenerate on freshly deposited floodplain surfaces, and salmon and other aquatic species benefit from fresh gravel inputs.

3. What references support its use? Provide citations.

Larsen, E. W. (1995). The Mechanics and Modeling of River Meander Migration, University of California at Berkeley**:** 1-342.

Richards, K. (1982). Rivers: Form and Process in Alluvial Channels. New York, Methuen and Co.

Larsen, E. W., E. Anderson, et al. (2002). The controls on and evolution of channel morphology of the Sacramento River: A case study of River Miles 201-185. Report to The Nature Conservancy.

Micheli, E. R., J. W. Kirchner, et al. (2004). "Quantifying the Effect of Riparian Forest Versus Agricultural Vegetation on River Meander Migration Rate, Central Sacramento River, California, USA." River Research and Applications **20**: 537-548.

Ward, J. V. and J. A. Stanford (1995). Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation, John Wiley & Sons, Ltd. **11:** 105-119.

Ward, J. V., K. Tockner, et al. (2001). Understanding natural patterns and processes in river corridors as the basis for effective river restoration, John Wiley & Sons, Ltd. **17:** 311-323.

Robert J. Naiman and Henri Decamps. The Ecology of Interfaces: Riparian Zones. Annual Review of Ecology and Systematics. Vol. 28, (1997), pp. 621-658

Shankman, D. (1993). "Channel Migration and Vegetation Patterns in the Southeastern Coastal Plain. Migración de canales y patrones de vegetación en el sudeste de la planicie costera." Conservation Biology **7**(1): 176-183.

NAIMAN, R. J., R. E. BILBY, et al. (2000). "Riparian Ecology and Management in the Pacific Coastal Rain Forest." BioScience **50**(11): 996-1011.

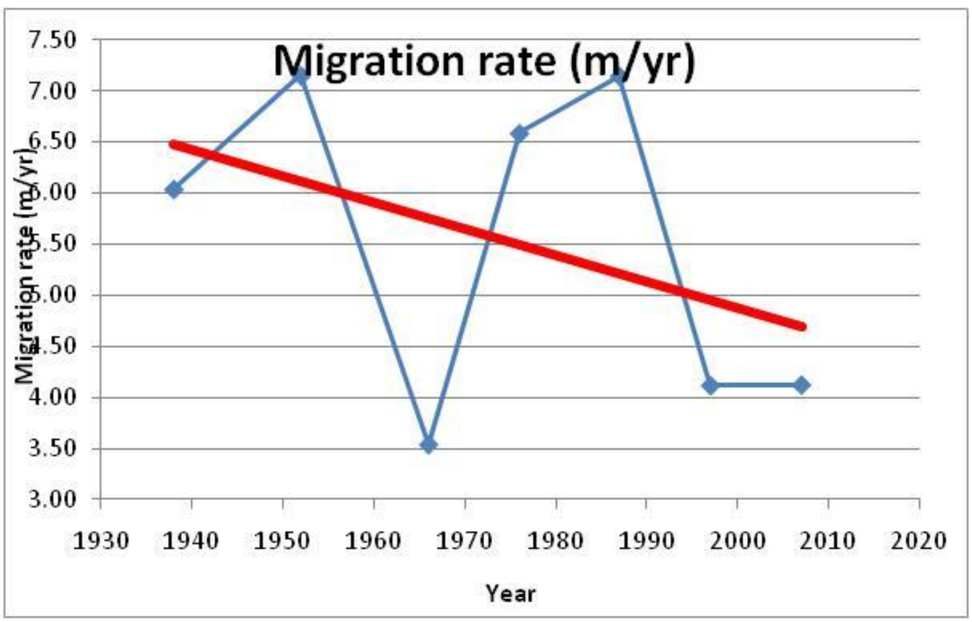
4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

In addition to a whole-river measure, the meander migration rate is an effective site-specific indicator to be used in comparing sites. See, however, the comment made about interpreting values for individual bends in section 15.

The meander migration rate of the whole river, which is a "lumping" needs to be qualified, because it is a complex measure that incorporates many processes such as channel revetment and changing erosion rates due to conversion to agriculture. Given this caveat, it seems to be a useful indicator that reflects the overall dynamism of the river.

A useful procedure, which is beyond the scope of this study, is that the migration rate be computed and then averaged for all non-revetted bends between Red Bluff and Colusa. This would require a significant amount of work that has not yet been done.

5. What cutoffs are appropriate for poor, fair, good and very good?



If the evaluation of the migration rate is considered in terms of floodplain creation, the greater the migration, the better.

Very Good:	*6.5*	< MIG RATE	
Good:	*5.75*	< MIG RATE <	*6.5*
Fair:	*4.5*	< MIG RATE <	*5.75*
Poor:		MIG RATE <	*4.5*

One might also consider using a standard deviation (or plus or minus 25% from the mean) as an increment.

6. How were the particular rating cutoffs selected?

The rating thresholds were selected by eye. The rationale was that historic highs have been 7.15 (m/yr), and very good values were equated to about this level or higher. On the other end of the scale, historic lows have been below 4.5, and this was considered poor. The good and the fair ratings were spaced between these extreme values.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

Larsen, E. W., E. Anderson, et al. (2002). The controls on and evolution of channel morphology of the Sacramento River: A case study of River Miles 201-185. Report to The Nature Conservancy.

Micheli, E. R., J. W. Kirchner, et al. (2004). "Quantifying the Effect of Riparian Forest Versus Agricultural Vegetation on River Meander Migration Rate, Central Sacramento River, California, USA." River Research and Applications **20**: 537-548.

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

The current indicator value is 4.13 m/yr. It was calculated based on comparison of data collected in month 1997 and June 2007.

9. What is the desired rating and by when should this be achieved?

As shown on the figure above, historically, there have been two clusterings of migration rates, the higher ones, and the lower ones. Aiming to restore the rates in the upper zone is a reasonable goal. We therefore defined the rating of “Fair” to “Good” and a meander migration rate that is greater than 5.0 m/yr.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)?

Yes, other values for this indicator were calculated for the same stretch of river, and with the same methods, for all the time periods.

Year	Migration rate (m/yr)
1904	
1938	6.04
1952	7.15
1966	3.54
1976	6.59
1987	7.15
1997	4.12
2007	4.13
Mean	5.52

11. When were the data collected that yielded these other values? Describe the history of data collection.

The channel centerlines that were analyzed are from 8 time periods (1904, 1938, 1952, 1966, 1976, 1987, 1997, 2007) distributed over 104 years. They were taken from photos and banklines prepared by by Greco (1904 to 1997) and Nelson (2007).

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Sacramento River Colusa to Redbluff.

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

Eric Larsen, Research Scientist
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Another person that is a source of data (channel centerlines) for this indicator:

Steve Greco
Dept of Environmental Design
University of California
Davis, CA 95616-8585
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(530) 754-5983

14. What is the rationale for the desired rating?

When assigning values for the desired rating, we want to pick a migration rate (which we correlate with the potential for channel dynamism and creation of floodplain area) that is attainable.

The desired rating value selected was an educated best guess, based on past on-site research. Even so, a thorough investigation of the potential for channel migration in this study reach would have to be performed in order to see if the chosen desired rating is achievable. One good reason to use this desired rating is to set an estimated goal that will encourage research and study to see if it is achievable. One important question to answer would be "what would you have to do to achieve this goal?"

15. *Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).*

If considered for single bends, which was not done here, the definition of good or poor meander migration rates is not a simple question. There are "healthy" sections of the river in all migration rate categories, because migration rate is strongly related to the curvature of the river.

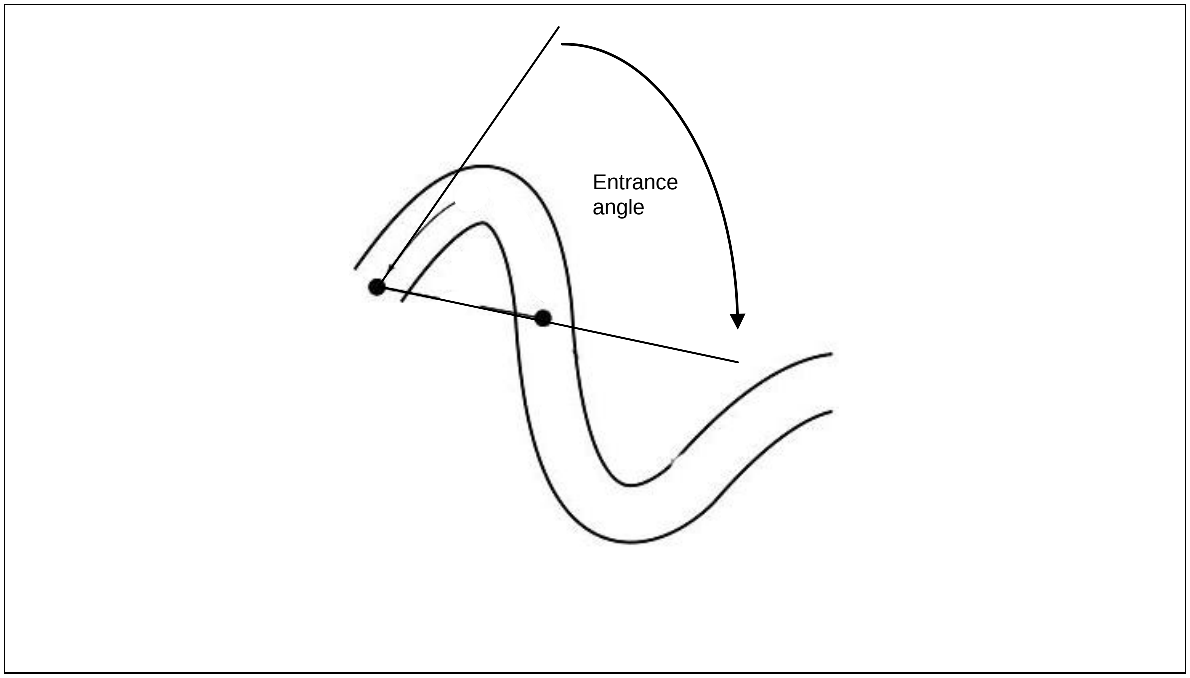
SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Bend Entrance Angle

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

1. *How specifically is the indicator defined?*

   The bend entrance angle (θ) equals the angle between the line connecting bend inflection points and a tangent to the channel centerline at the upstream inflection point. This indicator is an average value for all segments on the river between Red Bluff and Colusa. This includes every mile of river, separated into individual segments by inflection points. There is no lower threshold for entrance angle in this tabulation.



2. *What is the rationale for it being a meaningful indicator?*

The entrance angle represents the upstream curvature of a bend and can be correlated with a tendency to cutoff. Cutoffs can produce oxbow lakes on the Sacramento River, which are important habitats.

The entrance angle of a bend is complementary to other indicator metrics that reflect the shape of the river, particularly the degree of curvature. Therefore, it would be expected that as the sinuosity or curvature (inverse of radius of curvature) *decreases,* there would tend to be a decrease in the entrance angle. The measure of the entrance angle itself is important because it is specifically related to the tendency for cutoff occurrence.

3. What references support its use? Provide citations.

Avery, E. R., E. R. Micheli, et al. (2003). "River Channel Cut-off Dynamics, Sacramento River, California, USA." EOS Transactions, AGU 84 (46)(Fall Meeting Supplement): Abstract H52A-1181.

Morken, I., and Kondolf, M. 2003. *Evolution Assessment and Conservation Strategies for Sacramento River Oxbow Habitats*. Report to The Nature Conservancy, Chico, CA.

Constantine, J. A., S. E. McLean, et al. (2010). "A mechanism of chute cutoff along large meandering rivers with uniform floodplain topography." Geological Society of America Bulletin(doi: 10.1130/B26560.1).

Constantine, J. A., T. Dunne, et al. (2010). "Controls on the alluviation of oxbow lakes by bed-material load along the Sacramento River, California." Sedimentology **57**: 389-407.

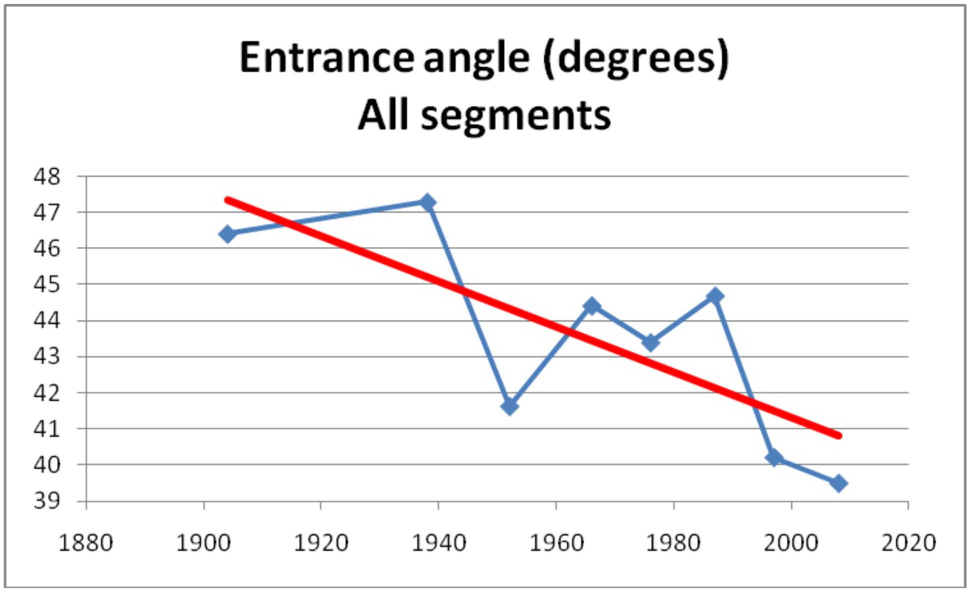
Micheli, E. R. and E. Larsen (2010). "River channel cutoff dynamics, Sacramento River, California, USA " River Research and Applications n/a. doi: 10.1002/rra.1360.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

Like many of the other indicators in this series, the indicator is measured at an individual bend, but the metric that is being used is the average for the entire river. This reflects an overall trend of the whole river, which is a good metric.

It can be used at the single bend scale, and would reflect the site-specific evolution of the bend in question. It would be difficult to assign a rating to that single value.

5. *What cutoffs are appropriate for poor, fair, good and very good?*



Very Good:	*46 degrees*	<	*(theta)*		
Good:	*44 degrees*	<	*(theta)*	<	*46 degrees*
Fair:	*41 degrees*	<	*(theta)*	<	*44 degrees*
Poor:	*41 degrees*	<	*(theta)*		

6. *How were the particular rating cutoffs selected?*

Estimated by graphical inspection.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

Larsen, E. W. (1995). The Mechanics and Modeling of River Meander Migration, University of California at Berkeley**:** 1-342.

Micheli, E. R. and E. Larsen (2010). "River channel cutoff dynamics, Sacramento River, California, USA " River Research and Applications n/a. doi: 10.1002/rra.1360.

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

The current whole river average entrance angle is 39.5 degrees, which is qualitatively rated as poor. The data that were analyzed to produce this value were collected in June 2007.

9. *What is the desired rating and by when should this be achieved?*

It would be reasonable to aim for a “fair” rating by 2020.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)?

There are values for 8 time periods, which include the 2007 data, as shown below.

Year	Entrance Angel (Degrees)
1904	46.4
1938	47.3
1952	41.6
1966	44.4
1976	43.4
1987	44.7
1997	40.2
2007	39.5

11. When were the data collected that yielded these other values? Describe the history of data collection.

The channel centerlines that were analyzed are from 8 time periods (see above table) distributed over 104 years. They were plotted by Larsen taken from aerial photos Greco (1904 to 1997) and Nelson (2007).

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Sacramento River Colusa to Redbluff.

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

Eric Larsen, Research Scientist
Department of Geology
One Shields Ave
University of California Davis
Davis, CA 95616
UC Davis.

(530) 752-8336
ewlarsen@ucdavis.edu

Another person that is a source of data (channel centerlines) for this indicator:

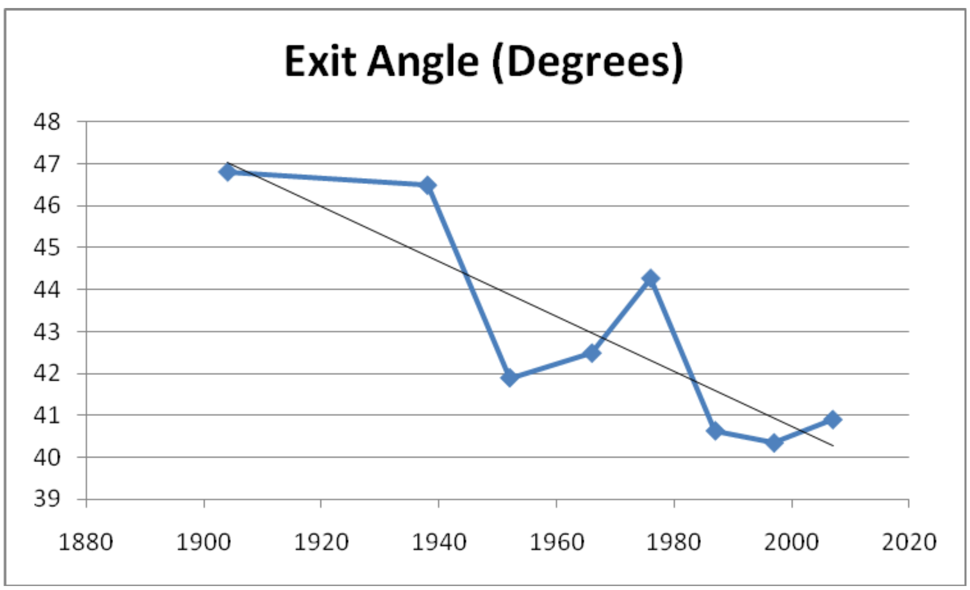
Steve Greco
Dept of Environmental Design
University of California
Davis, CA 95616-8585
segreco@ucdavis.edu
(530) 754-5983

14. What is the rationale for the desired rating?

Qualitatively, we have aimed for a mid-range of return to more complex (more curved) bends. This avoids the extreme of a "return to pristine", and, at the same time, recognizes the need for improved river conditions.

15. *Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).*

There is a similar trend for the exit angle, as shown in the figure below.



SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

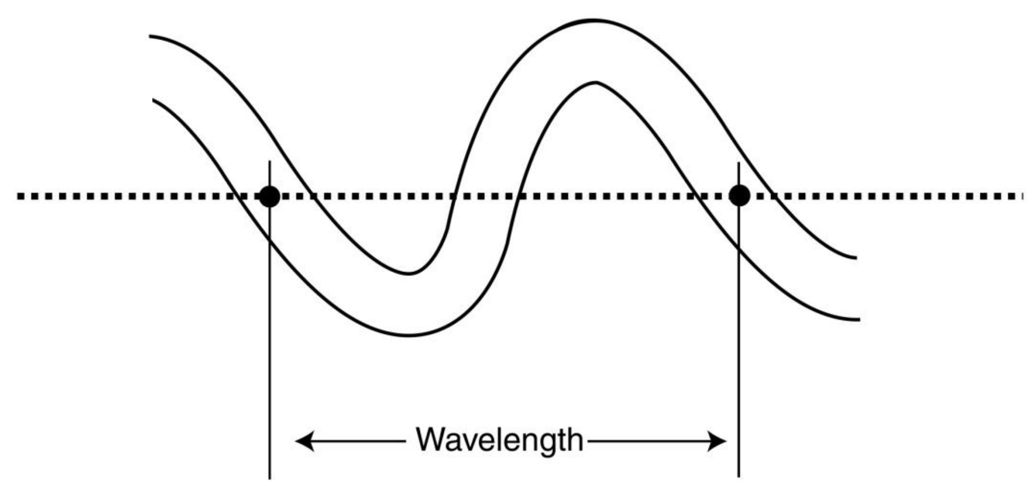
Half-Wavelength

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

1. *How specifically is the indicator defined?*

Average half-wavelength is defined as the average line distance between inflection points summed across all bends between Red Bluff and Colusa. The distance between inflection points is a measure of the wavelength of a meander or a meander bend. In this study "bends" were defined as any segment that had a sinuosity greater than 1.10. The wavelength of a meander is a fundamental measure of the scale or size of a meander. Wavelength is typically measured as twice the straight line distance from one point of inflection to the next immediate point of inflection. The distance between inflection points is a half-wavelength, which we use as an indicator because we are focusing on individual bends, rather than on pairs of bends. The half-wavelength, or distance between inflection points for individual bends, is determined by measuring the straight-line distance between two adjacent inflection points.

Note that most research and literature simply refer to the "wavelength." Our use of half-wavelength is conceptually the same, only numerically half the value of the standard wavelength. Half-wavelength is easier to measure, less open to interpretation, and clearly represents the hydraulic characteristics of a single bend. Many of the general statements that we make about the half-wavelength apply to the wavelength.



The figure shows a complete meander wavelength.

2. What is the rationale for it being a meaningful indicator?

The half-wavelength has been correlated with flow. In what has been called the pivotal first investigation of river morphology, Leopold et al. (1964) show that the dominant discharge ("effective" discharge) and the meander wavelength are empirically related. This is important for river managers who are charged with managing the flow within the river. A team of advisors should decide whether an increase or a decrease in average half-wavelength is beneficial for the given system. Generally, if the characteristic or channel forming flows of the system increases, the average half-wavelength will increase. Since the construction of Shasta Dam, the hydrology of the Sacramento River has been altered. By looking at wavelength we may assess the response of the study reach to hydrologic and geomorphic changes of the Sacramento River. We can look at how half-wavelength changes over time to consider temporal changes, and can look at how half-wavelength changes spatially to understand spatial differences in the geomorphology.

3. What references support its use? Provide citations.

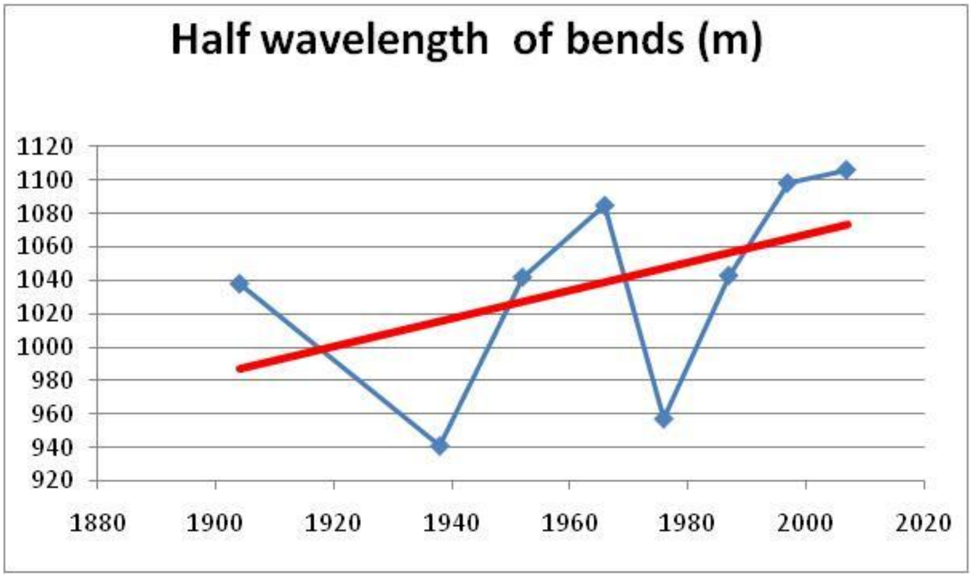
Brooks, A. P., P. C. Gehrke, et al. (2004). Experimental reintroduction of woody debris on the Williams River, NSW: geomorphic and ecological responses, John Wiley & Sons, Ltd. **20:** 513-536.

This is an area where active research would be beneficial.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

Individual half wavelengths can be averaged (over a reach or the whole river) to assess a reach or the whole river.

5. What cutoffs are appropriate for poor, fair, good and very good?



Very Good: 1000 meters < (half wavelength)

Good: 1000 meters < (half wavelength) < 1050 meters

Fair: 1050 meters < (half wavelength) < 1100 meters

Poor: 1100 meters < (half wavelength)

As discussed above, the wavelength is related to the flow rate in a self-forming river. Changing wavelength, particularly if in trends over a number of time increments, indicates a fundamental change in the way a river is self-forming. As with the other geomorphic indicators, we might use the original wavelength (average over all the bends in the river) from 1904 to define a "historic" or "very good" condition. What the data show is that the average wave length of all *segments* in 2007 is roughly the same as it was in 1904. In slight contrast, if the wavelength of only the bends is examined, there is a trend for increasing wavelength. This may – or may not – reflect a change in hydrologic conditions. More research needs to be done to determine what these data can tell us to help inform management decisions on the Sacramento River.

The ratings given above are preliminary estimates, that require further investigation. For the current time, they primarily serve as expedient means to fuel further study.

6. How were the particular rating cutoffs selected?

Visual inspection of graphed historical data.

As with the other geomorphic indicators, we might use the original wavelength (average over all the bends in the river) from 1904 to define a "historic" or "very good" condition, but this is an area where some active research would help us determine how the indicator is related to ecological processes.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

Knighton, D. (1998). Fluvial Forms & Processes A New Perspective. New York, John Wiley & Sons.

Larsen, E. W., E. Anderson, et al. (2002). The controls on and evolution of channel morphology of the Sacramento River: A case study of River Miles 201-185. Report to The Nature Conservancy.

Leopold, L. B., M. G. Wolman, et al. (1964). Fluvial Processes in Geomorphology. San Francisco, W. H. Freeman and Company.

Micheli, E. R., J. W. Kirchner, et al. (2004). "Quantifying the Effect of Riparian Forest Versus Agricultural Vegetation on River Meander Migration Rate, Central Sacramento River, California, USA." River Research and Applications **20**: 537-548.

Richards, K. (1982). Rivers: Form and Process in Alluvial Channels. New York, Methuen and Co.

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

The current indicator value for average half wavelength is 1110 m (bends only). The indicator we report is the one that is computed for bends only. Data that yielded these values were collected in June, 2007.

9. *What is the desired rating and by when should this be achieved?*

Good by June 2030.

This is open to determination pending further research, but the values for 1904, which might be a good estimate 1040 m (bends only).

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)?

Yes, all our other indicators are for the same locations and time increments. Because they are all measurable metrics related to the channel morphology, they are all to some degree interrelated.

Year	Half wave length (m)
1904	1038
1938	941
1952	1042
1966	1085
1976	957
1987	1043
1997	1099
2007	1106
Mean	1039

11. When were the data collected that yielded these other values? Describe the history of data collection.

The channel centerlines that were analyzed are from 8 time periods (see above table) distributed over 104 years. They were plotted by Larsen taken from aerial photos Greco (1904 to 1997) and Nelson (2007).

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Sacramento River Colusa to Redbluff.

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

Eric Larsen, Research Scientist
Department of Geology
One Shields Ave
University of California Davis
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UC Davis.
(530) 752-8336
ewlarsen@ucdavis.edu

Another person that is a source of data (channel centerlines) for this indicator:

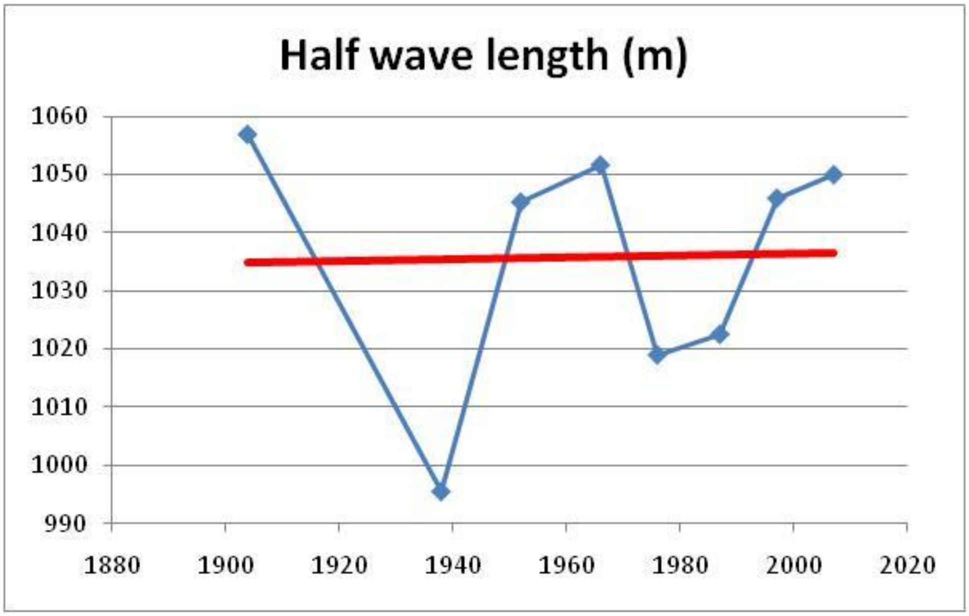
Steve Greco
Dept of Environmental Design
University of California
Davis, CA 95616-8585

segreco@ucdavis.edu
(530) 754-5983

14. What is the rationale for the desired rating?

This appears to be within the natural range of variation of the historical condition.

15. *Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).*



The 2007 indicator value for half wave length of all segments is 1050 m (all segments). This was discussed above. A desired rating for this might be and 1060 m, which is essentially what it is.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Number of In-channel Large Woody Debris Aggregations

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   The number of in-channel large woody debris aggregations is simply the total number of observable aggregations on the main river channel. What is "observable" will vary depending upon the methods employed. See below for details on this.

2. What is the rationale for it being a meaningful indicator?

   Having a multitude of microhabitats within rivers benefits native species and communities with diverse life history needs. LWD provides important habitat for fishes and aquatic inverterates. It reduces predation risk, provides visual isolation that reduces contact between fish, offers a velocity refuge which minimizes energetic costs, provides increased surface area for growth of prey items, provides spatial reference points for riverine species to assist with navigation and orientation to surroundings (Crook and Robertson 1999, Dehaven 2000?). It also plays a role in shaping channel and floodplain morphology by influencing sediment deposition and erosion.

   Riparian, riverbank and flow management strategies all have pronounced influences on wood in streams (Meleason et al. 2003)

3. What references support its use as an indicator of river health? Provide citations.

   Crook D.A. and A.I. Robertson. 1999. Relationship between riverine fish and woody debris: implications for lowland rivers. *Mar. Freshwater Res.* 50: 941-953.

   DeHaven, Richard USFWS report. 2000?

   Meleason, M.A., S.V. Gregory, and J.P. Bolte. 2003. Implications of riparian management strategies on wood in streams of the Pacific Northwest. *Ecological Applications* 13: 1212-1221.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   This indicator is most useful in characterizing the status of the river at the large scale, as an indicator of the health of reaches or the entire river Project Area (Red Bluff to Colusa).

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

The status indicator ratings are defined as:
Very Good: > 1,000 snag aggregations
Good: 600- 1,000 snag aggregations
Fair: 200 - 600 snag aggregations
Poor: < 200 snag aggregations

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

   Cutoffs were selected based upon review of the existing data. They should be viewed as working hypotheses to be refined as more information becomes available.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

   The methods are not summarized in any documents. Briefly:

   Aerial imagery georectified by CSU-GIC was viewed at a 1:2000 scale on a computer screen. A technician scrolled through the entire mainstem Sacramento River reach from Colusa Bridge to Red Bluff Diversion Dam placing a marker point at each location where large woody debris was visible in the river. Aggregations of woody debris were considered separate if they were at 5 or more meters apart. Submerged woody debris was included if it caused a noticeable disturbance on the surface of the river.

Step 6

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   387 aggregations (fair), as of June 2007.

9. What is the desired rating and by when should this be achieved?

Good by June 2020

Step 7.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

    The 1999 aerials were analyzed in the same manner by the same technician (S Paine) and the value was found to be much higher (738 aggregations)

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    The current indicator data are based upon an analysis of the entire mainstem Sacramento River between the Red Bluff Diversion Dam and the Colusa Bridge. It is representative only of this area. It is worth considering, however, that inputs of woody debris come from both the tributaries and from erosion of the banks along the mainstem.

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

    This indicator information was input by G. Golet following review of relevant materials. Calculations based upon the 1999 and 2007 data were both performed by:

    Seth Paine, TNC Cons Science Tech,
    spaine@tnc.org
    (530) 897-6370 x 214
    Northern Central Valley office
    500 Main Street
    Chico, CA 95928

13. What is the rationale for the desired rating?

Step 8

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

This was listed as a potential indicator by CALFED for their SAC R Processes measure of the ERP.

Unfortunately, only inchannel snags can be mapped, as the color of wood and gravel bars are too similar to distinguish one from the other. Multi-spectral mapping effectively distinguishes wood from gravel, however.

The rate at which wood moves through the system is also important. The middle Sacramento River supplies some of this vital resource to areas south of Colusa where recruitment of wood is virtually nonexistent. Nearly all of the banks are revetted in this section. An important question is how much wood from the middle reach enters the lower reach, and also what is done with wood in this area (i.e. is it actively removed?). A lot of wood is removed from the vicinity of the Colusa Weir.

Adam Henderson (DWR Northern District) did a project looking at movements of radio tagged logs. Are the results of this work written up?

Lee Brenda came to talk to us about wood issues, and the need for the development of a wood budget. It would be valuable to construct a wood budget for the Sacramento River. Methods for doing so are described in Benda and Sias (2003) and Benda et al. (2003).

Benda, L.E., and J.C. Sias. 2003. A quantitative framework for evaluating the mass balance of in-stream organic debris. Forest Ecology and Management 172:1-16.

Benda, L.E., D. Miller, J.C. Sias, D. Martin, R. Bilby, C. Veldhuisen, and T. Dunne. 2003. Wood Recruitment processes and wood budgeting. American Fisheries Society Symposium 37:49-73.

More information on the viability assessment part of the workbook can be found at: http://conserveonline.org/workspaces/cbdgateway/cap/practices/bp_3

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

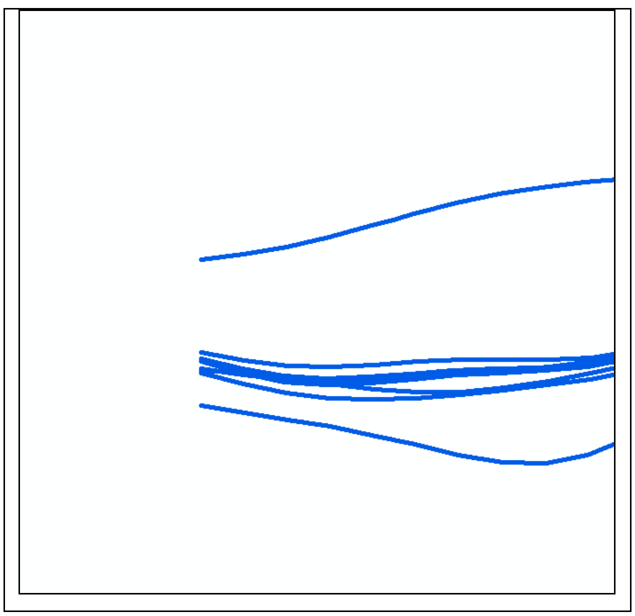
Total River Length

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

1. *How specifically is the indicator defined?*

Total River Length is defined as the distance along the channel centerline drawn from the Red Bluff Diversion Dam to the Colusa Bridge. The total river length was measured by measuring the centerline length of the channel using GIS tools. Because the river tends to be located in different locations through time, it is important to locate the ends of the channel for each year, and to “trim” the ends so that they start and end in the same location. In order to do this, we drew a reference line that “cuts” the end in the same location, as shown in the figure below.

The methodology for drawing a centerline is described below.



2. *What is the rationale for it being a meaningful indicator?*

The total length of river between a starting location and an ending location is a clear and obvious measure of the size of the river. For ecosystem processes related to aerial extent of river channel or of riparian habitat related to the river bank, a greater total length of river (given fixed end locations) will provide more area, and therefore more ecosystem functions and processes. For example, a longer channel allows there to be more potential area for all riparian forest dynamics.

3. What references support its use? Provide citations.

This indicator was used as a metric of river health on the Willamette River in Oregon (IMST 2002).

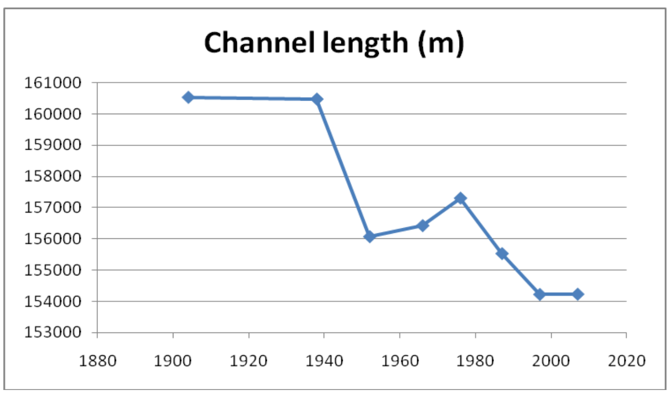
Independent Multidisciplinary Science Team (IMST). 2002. Recovery of Wild Salmonids in Western Oregon Lowlands. Technical Report 2002-1 to the Oregon Plan for Salmon and Watersheds, Governor's Natural Resources Office, Salem, Oregon.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

Total river length is by definition a large scale metric that assesses the overall health of the river, although the exact extent must be specified. The same principle may be used for smaller reaches.

5. What cutoffs are appropriate for poor, fair, good and very good?

As with other geomorphic indicators, we might use the original value, in this case the total length in 1904, to define a "historic" or "very good" condition.



Based on a visual inspection of the graph of length over time (shown above), the following ratings were estimated.

Very Good:	160000	<	*LENGTH*		
Good:	158000	<	*LENGTH*	<	160000
Fair:	156000	<	*LENGTH*	<	158000
Poor:			*LENGTH*	<	156000

6. *How were the particular rating cutoffs selected?*

From the existing data, four evenly spaced categories suggested themselves and were chosen by eye.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

GIS shapefiles were made showing the channel centerline. In order to establish a single-threaded centerline, we defined a protocol for occurrences of mid-channel bars: bars were ignored if their widths were less than the average channel width, but for larger bars the larger of branch of the split channel was assumed dominant. The spatial uncertainty of mapped features using these techniques is limited to a maximum ± 10m (Greco and Alford, 2003).

Greco, S. and C. Alford (2003). Historical Channel Mapping from Maps of the Sacramento River, Colusa to Red Bluff, California: 1937 to 1997. L. A. a. S. R. Laboratory, Department of Environmental Design, University of California, Davis, California.

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

The most recent total river length is 154229 m, from data that were collected in June, 2007.

9. *What is the desired rating and by when should this be achieved?*

This is a value judgment that might best be decided in a wider group.

A reasonable target might be 156000 m, which is the mid-range of the lengths over the last century. Perhaps this could be achieved by 2030.

Taking a somewhat more theoretical and larger scale approach, a good research question is, "What would have to be done to return to the 1904/1938 river length?" Even if this were not practically possible, attempting to answer this question might reveal important information about the current state of the river and the possibilities/limitations for restoration.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)?

Year	Channel length (m)
1904	160529
1938	160474
1952	156070
1966	156423
1976	157303
1987	155528
1997	154221
2007	154229

11. When were the data collected that yielded these other values? Describe the history of data collection.

The channel centerlines that were analyzed are from 8 time periods (see table) distributed over 104 years. They were plotted by Larsen taken from aerial photos Greco (1904 to 1997) and Nelson (2007).

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Sacramento River Colusa to Redbluff.

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

Eric Larsen, Research Scientist
Department of Geology
One Shields Ave
University of California Davis
Davis, CA 95616
UC Davis.
(530) 752-8336
ewlarsen@ucdavis.edu

Another person that is a source of data (channel centerlines) for this indicator:

Steve Greco
Dept of Environmental Design
University of California
Davis, CA 95616-8585
segreco@ucdavis.edu
(530) 754-5983

14. What is the rationale for the desired rating?

The rationale is that there are areas that are constrained that could possibly be allowed to change. Such changes would increase the length, and therefore, an increase in length is conceptually possible. A return to the length of river as it was 30 years ago is not aiming at "a return to pristine," but at least sets a goal that can be used to monitor change.

15. *Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).*

It should be pointed out that there are a couple of restoration projects that are in the planning stages that would actually shorten the length of the river. These are the Kopta Slough project and the Llano Seco / Princeton, Codora, Glenn pumping plant project.

Although these would lead to river shortening they would confer other benefits (e.g. reduction in riprap, revitalization of natural processes of erosion and sediment deposition, creation of off-channel habitat). Thus, as with other management actions, it is desirable to consider their effects from the perspective of multiple indicators.

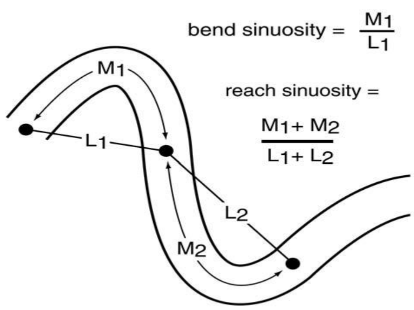
SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Whole River Sinuosity

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

1. *How specifically is the indicator defined?*

The whole river sinuosity (called reach sinuosity in the figure below) is calculated as the sum of the arc lengths (M's) for all bends divided by the sum of the half wave lengths (L's) (see figure). The arc length and half wave length are both measured between successive inflection points of single bends.



2. *What is the rationale for it being a meaningful indicator?*

Whole river sinuosity provides a measure of channel complexity and river dynamism. In alluvial river settings, a sinuous river has more cutbanks and point bars than a straight river. It is also likely to be a more active river in terms of riverine processes of meander migration, erosion and sediment deposition, although such processes may be constrained by the presence of riprap on the river bank. Because sinuous rivers have a greater complexity of habitats and ecological processes associated with them they are more supportive of natural species (e.g., bank swallows, salmon) and communities (cottonwood forests).

3. *What references support its use? Provide citations.*

Brookes, A. (1987). "The distribution and management of channelized streams in Denmark." Regulated Rivers: Research & Management **1**(1): 3-16.

Jungwirth, M., O. Moog, et al. (1993). "Effects of river bed restructuring on fish and benthos of a fifth order stream, melk, Austria." Regulated Rivers: Research & Management **8**(1-2): 195-204.

Brunke, M. and T. Gonser (1997). "The ecological significance of exchange processes between rivers and groundwater." Freshwater Biology **37**(1): 1-33.

James, A. B. W. and I. M. Henderson (2005). "Comparison of coarse particulate organic matter retention in meandering and straightened sections of a third-order New Zealand stream." River Research and Applications **21**(6): 641-650.

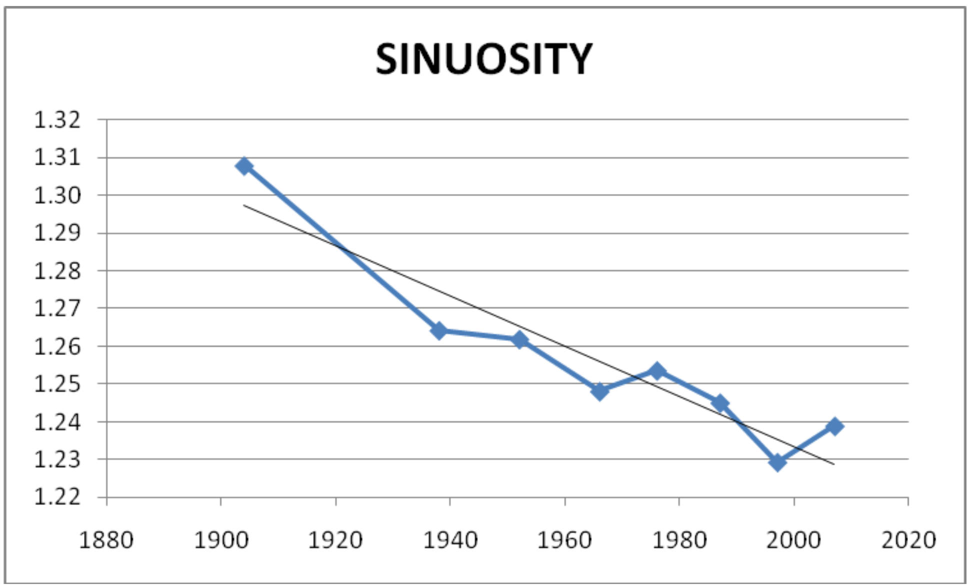
Boano, F., C. Camporeale, et al. (2006). "Sinuosity-driven hyporheic exchange in meandering rivers." Geophys. Res. Lett. **33**(18): L18406.

Constantine, J. A. and T. Dunne (2008). "Meander cutoff and the controls on the production of oxbow lakes." Geology **36**(1): 23-26.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

Because our method utilizes the sinuosity of single bends, single bend sinuosity is an effective site-specific indicator that can be used in comparing sites, at a scale that varies from the entire river to a single bend.

5. What cutoffs are appropriate for poor, fair, good and very good?



For the purposes of developing new floodplain area in the form of pointbars, we can set a preferred range of sinuosities. The following values are estimates of ranges based on an analysis of the data shown above.

Very Good: *1.29* < M/L

Good: *1.27* < M/L < *1.29*

Fair: *1.25* < M/*L* < *1.27*

Poor: M/*L* < *1.25*

6. How were the particular rating cutoffs selected?

Visual estimates based on the available data.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

Descriptions of single bend sinuosity are well documented in almost any text on fluvial geomorphology (e.g. Leopold, Wolman et al. 1964; Dunne and Leopold 1978; Richards 1982). The key distinction to note is that we use a single bend sinuosity as defined above as the basis for a cumulative total river sinuosity.

Leopold, L. B., M. G. Wolman, et al. (1964). Fluvial Processes in Geomorphology. San Francisco, W. H. Freeman and Company.

Dunne, T. and L. B. Leopold (1978). Water in environmental planning. San Francisco, W. H. Freeman.

Richards, K. (1982). Rivers: Form and Process in Alluvial Channels. New York, Methuen and Co.

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

The current whole river sinuosity is 1.24 which is considered “Poor”. The data that were analyzed to produce this value were collected in June 2007.

9. What is the desired rating and by when should this be achieved?

We would want to achieve an overall average sinuosity is in the Fair range (1.25-1.27) by 2020.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)?

There are values for 8 time periods, which include the 2007 data, as shown below.

Year	SINUOSITY
1904	1.31
1938	1.26
1952	1.26
1966	1.25
1976	1.25
1987	1.25
1997	1.23
2007	1.24

11. When were the data collected that yielded these other values? Describe the history of data collection.

The data were collected in 8 distinct time periods (see above table) that span 103 years. They were compiled by Greco (1904 - 1997) and Nelson (2007).

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

The current data were collected in June, 2007. The geographic area is the Sacramento River between Colusa and Red Bluff, and the data are only representative of this area.

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

Eric Larsen, Research Scientist
Department of Geology
One Shields Ave
University of California Davis
Davis, CA 95616
UC Davis.
(530) 752-8336
ewlarsen@ucdavis.edu

Another person that is a source of data (channel centerlines) for this indicator:

Steve Greco
Dept of Environmental Design
University of California
Davis, CA 95616-8585

segreco@ucdavis.edu
(530) 754-5983

14. What is the rationale for the desired rating?

If we use the overall sinuosity of the river (or average of all the bends) as a rating, we want to have a sinuosity (which we correlate with the potential for channel dynamism) that is similar to what was present in the past.

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

Another method of calculating whole river sinuosity is to consider the channel length versus the down-valley length. This was not used because this does not capture the dynamism that is described in #2 below.

It is likely that analysis of small geographic scales (less than 10-20 miles) or short time periods (less than 10 years) would not yield meaningful changes in whole river sinuosity.

Also the changes are "confounding", and may be the result of multiple causes. For example, whole-river sinuosity has decreased due to bank protection; whereas whole-river sinuosity has increased due to replacement of native riparian vegetation with agriculture.

Another metric that is useful for single bend sinuosity monitoring is the "rate of change of sinuosity". Research on single-bend "rate of change of sinuosity" would be useful.

Additional Supporting information, which is not currently available, but could be considered in the future, is the presence or not of bank restraint.

Some of the suite of indicators that we measure are measured at the individual bend scale, and their accumulation or whole-river averages are used as an indicator of total river health.

The indicator values that we are using that are derived from single bend data are:

Sinuosity
Area of floodplain reworked
Entrance angle

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Nest Survival of Black-headed Grosbeak

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

Nest survival for the Black-headed Grosbeak (BHGR-NS) is defined as the probability of a nest surviving from egg laying to fledging (of at least one young) using an analysis method that takes into account the exposure period of the nest (e.g., the Mayfield method or logistic exposure; see below for citations).

2. What is the rationale for it being a meaningful indicator?

Reproductive success is a fundamental demographic component that influences population viability. Reproductive success of birds is a function of the survival of their nests from various elements and thus is strongly influenced by local conditions. Therefore, it may tell us more about the quality of habitats and conditions on the river than other demographic parameters such as adult survival, which may be influenced by habitat conditions in wintering areas or during migration. However, factors on the breeding grounds may influence annual adult survival for this species in the Sacramento Valley (Gardali and Nur 2006).

Birds are high trophic-level species that have specific, diverse, and moderately well understood habitat requirements. Their ability to successfully reproduce requires adequate locally available and safe nesting sites (Martin 1993). Many riparian songbirds, including the Lazuli Bunting, build open cup nests which are more susceptible to predation than cavity nests (Martin and Li 1992).

Predation is a primary cause of nest mortality of open-cup nesting birds (Ricklefs 1969, Martin 1993). Other sources of nest mortality include nest parasitism by the Brown-headed Cowbird (*Molothrus ater*), weather, failure of the nest structure or supporting vegetation, desertion, or human activities. The presence of cowbirds in the nest may also be tied to nest predation (Small et al. 2007), especially if cowbirds are the main nest predators and cowbirds selectively depredate unparasitized nests in order to force re-nesting and have the opportunity to parasitize the next nesting attempt.

Nest survival is commonly measured by researchers and has been estimated at the project sites in the past. By employing a multispecies approach in nest monitoring efforts we can gain multiple perspectives on landbird habitat condition because different bird species select different vegetation strata and substrates to build their nest (Martin 1992). The Black-headed Grosbeak nests in the mid-story at an average of 3-4 meters above the ground.

Riparian habitats are the single most important habitat type for landbirds in the West, so it is important that we assess their performance in these key habitats. Much of our efforts to conserve and restore riparian forests are directed at reversing current local, regional, and continental declines. Finally we have a good understanding of what reproductive success needs to be for individual species of landbirds to have viable populations.

3. What references support its use? Provide citations.

Gardali, T., and N. Nur. 2006. Site-specific survival of Black-headed Grosbeaks and Spotted Towhees at four sites within the Sacramento Valley, California. Wilson Journal of Ornithology 118:178-186.

Martin, T.E. 1992. Breeding productivity considerations: what are the appropriate habitat features for management?, p. 455-473. In Ecology and Conservation of Neotropical Migrant Landbirds (J.M. Hagan III and D.W. Johnston, Eds.). Smithsonian Institution Press, Washington, D.C.

Martin T. E., and P. Li. 1992. Life history traits of open vs. cavity-nesting birds. Ecology 73:579-592.

Martin, T. E. 1993. Nest predation and nest sites. BioScience 43: 523-532.

Ricklefs, R.E. 1973. Fecundity, mortality, and avian demography, p. 366-435. In D.S. Farner [ed.], Breeding biology of birds. National Academy of Sciences, Washington, D.C.

Small, S. L., F. R. Thompson, G. R. Geupel, and J. Faaborg. 2007. Spotted Towhee population dynamics in a riparian restoration context. Condor 109:721-733.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

Nest survival can be used as a site-specific indicator in comparing sites and as an overall indicator. All scales if sample sizes are sufficient.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

Very Good: >60% probability of fledging at least one young.
Good: 40 – 60% probability of fledging at least one young.
Fair: 25 – 40% probability of fledging at least one young.
Poor: <25% probability of fledging at least one young.

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

These indicator values are based on past knowledge of nest survival (Small and Gardali 2004) and adult survival (Gardali and Nur 2006) in the project areas. These indicator values are based on past knowledge of nest survival in the project area, a literature review of nest survival estimates by Martin (1992), and online estimates of adult survival (Michel et al. 2006).

Michel, N., DeSante, D.F., Kaschube, D.R., and Nott, M.P. 2006. The Monitoring Avian Productivity and Survivorship (MAPS) Program Annual Reports, 1989-2003. NBII/MAPS Avian Demographics Query Interface. http://www.birdpop.org/nbii/NBIIHome.asp (December 2006).

Our best estimate of lambda from the Sacramento Valley was below one, indicating a potential population sink. At current levels of productivity, populations will require high adult survival rates to remain stable. Total nest survival (0.525, n = 140 nests from Small and Gardali 2004) was low compared to a population in Arizona (0.743, n = 13; Martin 1992).

Gardali, T., and N. Nur. 2006. Site-specific survival of Black-headed Grosbeaks and Spotted Towhees at four sites within the Sacramento Valley, California. Wilson Journal of Ornithology 118:178-186.

Golet, G.H., T. Gardali, C.A. Howell, J. Hunt, R.A. Luster, 2008. Wildlife response to riparian restoration on the Sacramento River. San Francisco Estuary & Watershed Science 6(2):1.

Small, S.L., and T. Gardali. 2004. Regional population growth rates of Black-headed Grosbeaks nesting in California riparian Forests. *In* Gardali, T., S.L. Small, N. Nur, G.R. Geupel, G. Ballard, and A.L. Holmes. 2004. Monitoring songbirds in the Sacramento Valley (1993 – 2003): population health, management information, and restoration evaluation. PRBO unpublished report, contribution # 1233.

7. <u>Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?</u>

Johnson, D.H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96:651-661.

Jones, S. L., and G. R. Guepel. 2007. Beyond Mayfield: measurements of nest-survival data. Studies in Avian Biology Number 34. Cooper Ornithological Society, Camarillo, California, USA.

Manolis, J. D., D. E. Anderson, and F. J. Cuthbert. 2000. Uncertain nest fates in songbird studies and variation in Mayfield estimation. Auk 117:615-626.

Mayfield, H.F. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255-261.

Mayfield, H.F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456-466.

Miller, H.W., and D.H. Johnson. 1978. Interpreting the results of nesting studies. Journal of Wildlife Management 42:471-476.

Step 6

8. <u>What is the current indicator status? What is the month and year that this corresponds to?</u>
   Fair: In June 2010 Howell recalculated Mayfield estimates for 330 nests studied from 1994-2003 for the Sacramento River. There were 169 losses and 3907 observer days which yield a nest survival estimate of 33% (PRBO unpublished data).

9. <u>What is the desired rating and by when should this be achieved?</u>
   The desired rating is good and this should be achieved by 2015.

Step 7

10. <u>Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)?</u>

Black-headed Grosbeak nest survival was 52% from 1993 to 2000 (n = 140 nests from multiple sites along the Sacramento River (Small and Gardali 2004).
In a separate analysis comparing restored and remnant sites, nest survival was 40% in restored sites (n=39 nests) and 44% in remnant sites (n=156 nests) from 3 sites along the Sacramento River sites studied in 1998-2003 (Golet et al. 2008); these 3 sites were a subset of the sites reported in Small and Gardali (2004).

11. <u>When were the data collected that yielded these other values? Describe the history of data collection.</u>

Data from Small and Gardali (2004) were from the same locations as data re-analyzed by Howell. Nests used in Golet et al. (2008) analysis were from a subset of sites and years.

12. <u>Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?</u>

Nests were located in restored and remnant riparian sites on the Sacramento River NWR in Butte, Colusa, Glenn, and Tehama counties. This indicator is representative of the Sacramento River from Red Bluff to Colusa.

13. <u>What is the source of the current indicator data? Who is the contact person? Provide contact info.</u>

Chrissy Howell PhD, Senior Conservation Scientist
Thomas Gardali, Associate Division Director
Terrestrial Ecology Division, PRBO Conservation Science
3820 Cypress Drive #11
Petaluma, CA 94954
TG: (415) 868-0655 ext. 381 CH: (707) 781-2555 ext. 315
tgardali@prbo.org   chowell@prbo.org

14. <u>What is the rationale for the desired rating?</u>

While nest success appears good or fair (depending on time period), this population was apparently still a sink and nest survival might be the most easily managed parameter. Indicator ratings may seem high but this species does not have a large clutch, does not appear to double brood, and does not attempt many re-nests following nest failure.

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

Further analysis should be conducted to determine a definitive value for Black-headed Grosbeak nest survival and the corresponding values for lambda, as well as the sensitivity of lambda to variance in nest survival estimates. Differences among nest survival estimates for this species may stem from which nests were included in analyses, which nests were considered successful, and how the number of observer days were calculated.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Nest Survival of Lazuli Bunting

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

Nest survival for the Lazuli Bunting (LAZB-NS) is defined as the probability of a nest surviving from egg laying to fledging (of at least one young) using an analysis method that takes into account the exposure period of the nest (e.g., the Mayfield method or logistic exposure; see below for citations).

2. What is the rationale for it being a meaningful indicator?

Reproductive success is a fundamental demographic component that influences population viability. Reproductive success of birds is a function of the survival of their nests from various elements and thus is strongly influenced by local conditions. Therefore, it may tell us more about the quality of habitats and conditions on the river than other demographic parameters such as adult survival, which may be influenced by habitat conditions in wintering areas or during migration.

Birds are high trophic-level species that have specific, diverse, and moderately well understood habitat requirements. Their ability to successfully reproduce requires adequate locally available and safe nesting sites (Martin 1993). Many riparian songbirds, including the Lazuli Bunting, build open cup nests which are more suspectible to predation than cavity nests (Martin and Li 1992).

Predation is a primary cause of nest mortality of open-cup nesting birds (Ricklefs 1969, Martin 1993). Other sources of nest mortality include nest parasitism by the Brown-headed Cowbird (*Molothrus ater*), weather, failure of the nest structure or supporting vegetation, desertion, or human activities. For the Lazuli Bunting, parasitism by the Brown-headed Cowbird is very high in the Sacramento Valley (Gardali et al. 1998). The presence of cowbirds in the nest may also be tied to nest predation (Small et al. 2007), especially if cowbirds are the main nest predators and cowbirds selectively depredate unparasitized nests in order to force re-nesting and have the opportunity to parasitize the next nesting attempt.

Nest survival is commonly measured by researchers and has been estimated at the project sites in the past. By employing a multispecies approach in nest monitoring efforts we can gain multiple perspectives on landbird habitat condition because different bird species select different vegetation strata and substrates to build their nest (Martin 1992). The Lazuli Bunting, for example, nests low in shrubs and herbs.

Riparian habitats are the single most important habitat type for landbirds in the West, so it is important that we assess their performance in these key habitats. Much of our efforts to conserve and restore riparian forests are directed at reversing current local, regional, and continental declines. Finally we have a good understanding of what reproductive success needs to be for individual species of landbirds to have viable populations.

3. What references support its use? Provide citations.

Gardali, T., A. M. King, and G. R. Geupel. 1998. Cowbird parasitism and nest success of the Lazuli Bunting in the Sacramento Valley. Western Birds 29:174-179.

Martin, T.E. 1992. Breeding productivity considerations: what are the appropriate habitat features for management?, p. 455-473. In Ecology and Conservation of Neotropical Migrant Landbirds (J.M. Hagan III and D.W. Johnston, Eds.). Smithsonian Institution Press, Washington, D.C.

Martin T. E., and P. Li. 1992. Life history traits of open vs. cavity-nesting birds. Ecology 73:579-592.

Martin, T. E. 1993. Nest predation and nest sites. BioScience 43:523-532.

Ricklefs, R.E. 1973. Fecundity, mortality, and avian demography, p. 366-435. In D.S. Farner [ed.], Breeding biology of birds. National Academy of Sciences, Washington, D.C.

Small, S. L., F. R. Thompson, G. R. Geupel, and J. Faaborg. 2007. Spotted Towhee population dynamics in a riparian restoration context. Condor 109:721-733.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

Nest survival can be used as a site-specific indicator in comparing sites and as an overall indicator. All scales if sample sizes are sufficient.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

Very Good: >40% probability of fledging at least one young.
Good: 30 – 40% probability of fledging at least one young.
Fair: 20 – 30% probability of fledging at least one young.
Poor: <20% probability of fledging at least one young.

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

These indicator values are based on past knowledge of nest survival in the project area, unpublished population growth models, a literature review of nest survival estimates by Martin (1992), and online estimates of adult survival (Michel et al. 2006).

Michel, N., DeSante, D.F., Kaschube, D.R., and Nott, M.P. 2006. The Monitoring Avian Productivity and Survivorship (MAPS) Program Annual Reports, 1989-2003.

NBII/MAPS Avian Demographics Query Interface. http://www.birdpop.org/nbii/NBIIHome.asp (December 2006).

Martin, T.E. 1992. Breeding productivity considerations: what are the appropriate habitat features for management?, p. 455-473. In Ecology and Conservation of Neotropical Migrant Landbirds (J.M. Hagan III and D.W. Johnston, Eds.). Smithsonian Institution Press, Washington, D.C.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

Johnson, D.H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96:651-661.

Jones, S. L., and G. R. Geupel. 2007. Beyond Mayfield: measurements of nest-survival data. Studies in Avian Biology Number 34. Cooper Ornithological Society, Camarillo, California, USA.

Manolis, J. D., D. E. Anderson, and F. J. Cuthbert. 2000. Uncertain nest fates in songbird studies and variation in Mayfield estimation. Auk 117:615-626.

Mayfield, H.F. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255-261.

Mayfield, H.F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456-466.

Miller, H.W., and D.H. Johnson. 1978. Interpreting the results of nesting studies. Journal of Wildlife Management 42:471-476.

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to?
   Lazuli Bunting nest survival was 6 % in riparian remnants and 6% in restored riparian from 1993 to 1999 (Small et al. 2000) as of August 1999.

9. What is the desired rating and by when should this be achieved?

The desired rating is good and this should be achieved by 2015.

Small, S.L., N. Nur, A. Black, G. R. Geupel, D. Humple, and G. Ballard. 2000. Riparian bird populations of the Sacramento River system: Results from the 1993-1999 field seasons. Report to The Nature Conservancy and U.S. Fish & Wildlife Service.

Step 7

10. Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)?

Lazuli Bunting nest survival was 11% from 1993 to 1997 (Gardali et al. 1998) as of August 1997.

11. When were the data collected that yielded these other values? Describe the history of data collection.

Data reported in Gardali et al. 1998 are a subset of data reported in Small et al. 2000.

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Data were collected along the Sacramento River at Kopta Slough, Stony Creek (Phelan Island), River Vista, LaBaranca, Ohm, and Flynn.

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

Chrissy Howell PhD, Senior Conservation Scientist
Thomas Gardali, Associate Division Director
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tgardali@prbo.org chowell@prbo.org

14. What is the rationale for the desired rating?

Lazuli Bunting is apparently in trouble in the Sacramento Valley. Hence, there is a need to improve nest survival as soon as possible.

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

Simple population growth models (lambda) need to be constructed for the Lazuli Bunting to determine desired ratings for nest survival estimates, as well as the sensitivity of lambda to variance in nest survival estimates. Regardless, the Lazuli Bunting is in trouble in the Sacramento Valley and nest survival estimates need to be improved as soon as possible (even though no population growth models have been done it is clear that nest survival is extremely low).

From 2000-2003 nest monitoring efforts on the Sacramento River focused on other avian species and less than ten Lazuli Bunting nests were found during this time, so these data have not been analyzed for nest survival estimates.

The negative effects of cowbirds on their hosts can be reduced indirectly by managing factors in the landscape or by directly controlling the cowbirds. Direct methods of cowbird control include the trapping 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. Addling will not help if cowbirds are also major nest predators.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Nest Survival of Spotted Towhee

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

Nest survival for the Spotted Towhee (SPTO-NS) is defined as the probability of a nest surviving from egg laying to fledging (of at least one young) using an analysis method that takes into account the exposure period of the nest (e.g. the Mayfield method or logistic exposure; see below for citations).

2. What is the rationale for it being a meaningful indicator?

Reproductive success is a fundamental demographic component that influences population viability. Reproductive success of breeding songbirds is a function of the survival of their nests from various elements and thus is strongly influenced by local conditions. Therefore, it may tell us more about the quality of habitats and conditions on the river than other demographic parameters such as adult survival, which may be influenced by habitat conditions in wintering areas or during migration. However, the Spotted Towhee is a year round resident whose survival is tied to conditions at the project site.

Birds are high trophic-level species that have specific, diverse, and moderately well understood habitat requirements. Their ability to successfully reproduce requires adequate locally available and safe nesting sites (Martin 1993). Many riparian songbirds, including the Lazuli Bunting, build open cup nests which are more suspectible to predation than cavity nests (Martin and Li 1992).

Predation is a primary cause of nest mortality of open-cup nesting birds (Ricklefs 1969, Martin 1993). Other sources of nest mortality include nest parasitism by the Brown-headed Cowbird (*Molothrus ater*), weather, failure of the nest structure or supporting vegetation, desertion, or human activities. For the Lazuli Bunting, parasitism by the Brown-headed Cowbird is very high in the Sacramento Valley (Gardali et al. 1998). The presence of cowbirds in the nest may also be tied to nest predation (Small et al. 2007), especially if cowbirds are the main nest predators and cowbirds selectively depredate unparasitized nests in order to force re-nesting and have the opportunity to parasitize the next nesting attempt.

Nest survival is commonly measured by researchers and has been estimated at the project sites in the past. By employing a multispecies approach in nest monitoring efforts we can gain multiple perspectives on landbird habitat condition because different bird species select different vegetation strata and substrates to build their nest (Martin 1992). The Spotted Towhee nests on the ground or very low in shrubs and herbs.

Riparian habitats are the single most important habitat type for landbirds in the West, so it is important that we assess their performance in these key habitats. Much of our efforts to conserve and restore riparian forests are directed at reversing current local, regional, and continental declines. Finally we have a good understanding of what reproductive success needs to be for individual species of landbirds to have viable populations.

3. What references support its use? Provide citations.

Martin, T.E. 1992. Breeding productivity considerations: what are the appropriate habitat features for management?, p. 455-473. In Ecology and Conservation of Neotropical Migrant Landbirds (J.M. Hagan III and D.W. Johnston, Eds.). Smithsonian Institution Press, Washington, D.C.

Martin T. E., and P. Li. 1992. Life history traits of open vs. cavity-nesting birds. *Ecology* 73:579-592.

Martin, T. E. 1993. Nest predation and nest sites. BioScience 43: 523-532.

Ricklefs, R.E. 1973. Fecundity, mortality, and avian demography, p. 366-435. In D.S. Farner [ed.], Breeding biology of birds. National Academy of Sciences, Washington, D.C.

Small, S. L., F. R. Thompson, G. R. Geupel, and J. Faaborg. 2007. Spotted Towhee population dynamics in a riparian restoration context. Condor 109:721-733.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

Nest survival can be used as a site-specific indicator in comparing sites and as an overall indicator. All scales if sample sizes are sufficient.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

Very Good: >35% probability of fledging at least one young.
Good: 25 – 35% probability of fledging at least one young.
Fair: 15 – 25% probability of fledging at least one young.
Poor: <15% probability of fledging at least one young.

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

These indicator values are based on current knowledge of nest survival (Small et al. 2007) and adult survival (Gardali and Nur 2006) in the project area and a simple population growth rate model (Small et al. 2007). Additionally we consulted a literature review of nest survival estimates by Martin (1992) and online estimates of adult survival (Michel et al. 2006).

Michel, N., DeSante, D.F., Kaschube, D.R., and Nott, M.P. 2006. The Monitoring Avian Productivity and Survivorship (MAPS) Program Annual Reports, 1989-2003. NBII/MAPS Avian Demographics Query Interface. http://www.birdpop.org/nbii/NBIIHome.asp (December 2006).

From Small et al. (2007): The finite rate of population growth (l), ranged from 0.25 to 0.33 based on period nest success rates of unparasitized (0.05) and parasitized nests (0.76), an observed cowbird parasitism rate of 38% during the period 1994–2003 (Small 2005), female young fledged per successful nest from unparasitized (1.30) and parasitized (0.37) nests (assuming half of fledglings are female), apparent adult survival (0.25 ± 0.11) for the period of 1995–2000 in the Sacramento River Valley (Gardali and Nur 2006), and a range of juvenile survival values calculated as percentages (0%–100%) of adult survival.

Gardali, T., and N. Nur. 2006. Site-specific survival of Black-headed Grosbeaks and Spotted Towhees at four sites within the Sacramento Valley, California. Wilson Journal of Ornithology 118:178-186.

Golet, G.H., T. Gardali, C.A. Howell, J. Hunt, R.A. Luster, 2008. Wildlife response to riparian restoration on the Sacramento River. San Francisco Estuary & Watershed Science 6(2):1.

Small, S. L., F. R. Thompson, G. R. Geupel, and J. Faaborg. 2007. Spotted Towhee population dynamics in a riparian restoration context. Condor 109:721-733.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

Johnson, D.H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96:651-661.

Jones, S. L., and G. R. Guepel. 2007. Beyond Mayfield: measurements of nest-survival data. Studies in Avian Biology Number 34. Cooper Ornithological Society, Camarillo, California, USA.

Manolis, J. D., D. E. Anderson, and F. J. Cuthbert. 2000. Uncertain nest fates in songbird studies and variation in Mayfield estimation. Auk 117:615-626.

Mayfield, H.F. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255-261.

Mayfield, H.F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456-466.

Miller, H.W., and D.H. Johnson. 1978. Interpreting the results of nesting studies. Journal of Wildlife Management 42:471-476.

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to?
   Fair: In June 2010 Howell recalculated Mayfield estimates for 224 Spotted Towhee nests studied from 1993-2003 for the Sacramento River. There were 133 losses and 1936 observer days which yield a daily survival rate of 0.9313. The daily survival rate is raised to the power of the length of the nest cycle. Small et al. (2007) used 22 days as the length which would yield a nest survival rate of 21% in the re-analysis (PRBO unpublished data).

9. What is the desired rating and by when should this be achieved?

The desired rating is very good and this should be achieved by 2015. While nest success appears good, this population may still be a sink.

Step 7

10. Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)?

Small et al. 2007) reported that Spotted Towhee nest survival was 26% from 1994 to 2003.

In a separate analysis comparing restored and remnant sites, nest survival was 18% in restored sites (n=43 nests) and 9.6% in remnant sites (n=172 nests) from 3 sites along the Sacramento River sites studied in 1998-2003 (Golet et al. 2008).

11. When were the data collected that yielded these other values? Describe the history of data collection.

Data from Small et al. (2007) were from the same locations as data re-analyzed by Howell. Nests used in Golet et al. (2008) analysis were from a subset of sites and years.

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Nests were located in restored and remnant riparian sites on the Sacramento River NWR in Butte, Colusa, Glenn, and Tehama counties. This indicator is representative of the Sacramento River from Red Bluff to Colusa.

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

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14. What is the rationale for the desired rating?

While nest success appears fair or good (depending on time period), nest survival might be the most easily managed parameter to increase the population growth rate.

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

Further analysis should be conducted to determine a definitive value for Spotted Towhee nest survival and the corresponding values for lambda, as well as sensitivity of lambda to variation in nest survival. Differences among nest survival estimates for this species may stem from which nests were included in analyses, which nests were considered successful, and how the number of observer days were calculated. Additional calculations of the length of the nest cycle would also be useful.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Adult Survival of Black-headed Grosbeak

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

Apparent adult survival for the Black-headed Grosbeak (BHGR-AS) is defined as the probability that an adult will survive from one year to the next using mark-recapture studies.

2. What is the rationale for it being a meaningful indicator?

Apparent adult survival for landbirds is an important demographic component in understanding population dynamics/viability. Adult survival is influenced by habitat conditions at the project areas and indirect evidence for this species suggests that events during the breeding season may have consequences on annual survival (Gardali and Nur 2006). Hence, adult survival can tell us about habitat quality in the same way that nest survival does. Additionally, estimating both adult survival and nest survival will provide a better/complimentary picture of population viability as both are required to calculate lambda.

Adult survival is influenced by abundance and richness of the predator community, habitat structure (ability to take cover from predators), food availability, and reproductive effort (cost of reproduction). For migratory species like the Black-headed Grosbeak, conditions during migration and on the wintering grounds may also influence survival.

Adult survival is commonly measured by researchers and it has been estimated at the project sites in the past for Black-headed Grosbeaks (i.e., we have baseline data).

In general, birds are high trophic-level species that have specific, diverse, and moderately well understood habitat requirements. The probability of survival depends on variables such has habitat cover from predators, food availability, and perhaps reproductive effort (i.e., cost of reproduction). By employing a multispecies approach to estimate adult survival we can gain multiple perspectives on landbird habitat condition. Also, riparian habitats are the single most important habitat type for landbirds in the West, so it is important that we assess their performance in these key habitats/areas. Much of our efforts to conserve and restore riparian forests are directed at reversing local, regional, and continental declines. Finally, we are beginning to get a good understanding of what adult survival needs to be for individual species to have viable populations.

3. What references support its use? Provide citations.

Gardali, T., and N. Nur. 2006. Site-specific survival of Black-headed Grosbeaks and Spotted Towhees at four sites within the Sacramento Valley, California. Wilson Journal of Ornithology 118:178-186.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

Nest survival can be used as a site-specific indicator in comparing sites and as an overall indicator. All scales if sample sizes are sufficient.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

Very Good: >70% probability of surviving from one year to the next.
Good: 60 – 70% probability of surviving from one year to the next.
Fair: 40 – 60% probability of surviving from one year to the next.
Poor: <40% probability of surviving from one year to the next.

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

These indicator values are based on current knowledge of nest survival (Small and Gardali 2004) and adult survival (Gardali and Nur 2006) in the project areas.

Our best estimate of lambda from the Sacramento Valley was below one, indicating a potential population sink. At current levels of productivity and survival, populations will require high adult survival rates to remain stable.

Gardali, T., and N. Nur. 2006. Site-specific survival of Black-headed Grosbeaks and Spotted Towhees at four sites within the Sacramento Valley, California. Wilson Journal of Ornithology 118:178-186.

Small, S.L., and T. Gardali. 2004. Regional population growth rates of Black-headed Grosbeaks nesting in California riparian Forests. *In* Gardali, T., S.L. Small, N. Nur, G.R. Geupel, G. Ballard, and A.L. Holmes. 2004. Monitoring songbirds in the Sacramento Valley (1993 – 2003): population health, management information, and restoration evaluation. PRBO unpublished report, contribution # 1233.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

Gardali, T., and N. Nur. 2006. Site-specific survival of Black-headed Grosbeaks and Spotted Towhees at four sites within the Sacramento Valley, California. Wilson Journal of Ornithology 118:178-186.

Lebreton, J.-D., K. P. Burnham, J. Clobert, and D. D. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecological Monographs 62:67-118.

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to?

Good: The estimates for Black-headed Grosbeak range from poor (e.g., ~16%) to very good (e.g., ~80%) depending on site and time series (Gardali and Nur 2006) based on breeding season data collected between 1995 to 2000. Best estimate from 1995 to 2000 was 62%.

9. What is the desired rating and by when should this be achieved?
   The desired rating is good and this should be achieved by 2015.

Step 7

10. Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)?

The most recent estimates (1995 to 2000) were considerably lower than earlier estimates (1993 to 1995); the best estimate from 1993 to 1995 was 81%.

11. When were the data collected that yielded these other values? Describe the history of data collection.

Data were collected using mark-recapture analyses applied to mist-netting data collected between 1993 and 1995.

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Data were collected at Flynn, Sul Norte, Ohm, and Phelan Island and are representative of the Sacramento River between Red Bluff and Colusa.

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13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

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14. What is the rationale for the desired rating?
    The desired indicator rating may seem high but this species does not have a large clutch, does not appear to double brood, and does not attempt many re-nests following nest failure. Hence, we are recommending that this indicator rating be very good.

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).
    Adult survival could be limited at any stage of the annual cycle and for a migratory species like the Black-headed Grosbeak that includes areas away from the

Sacramento River. Gardali and Nur (2006) suggested that adult survival along the Sacramento River might be influenced by conditions on the breeding grounds however. Hence, improving nest survival might improve adult survival (i.e., cost of reproduction) as would increasing post-breeding/pre-migration food sources, increasing dense vegetative cover in general, and continuing to increase the overall amount of habitat on the river. A report or publication that reviews literature on this subject and then makes specific recommendations and associated justification statements would be useful.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Adult Survival of Spotted Towhee

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

Apparent adult survival for the Spotted Towhee (SPTO-AS) is defined as the probability that an adult will survive from one year to the next using mark-recapture studies.

2. What is the rationale for it being a meaningful indicator?

Apparent adult survival for landbirds is an important demographic component in understanding population dynamics/viability. For year-round resident species such as the Spotted Towhee, adult survival is influenced by habitat conditions at the project areas (Gardali and Nur 2006). This may also be true for migratory species during the breeding season. Hence, adult survival can tell us about habitat quality in the same way that nest survival does. Additionally, estimating both adult survival and nest survival will provide a better/complimentary picture of population viability as both are required to calculate lambda.

Adult survival is influenced by abundance and richness of the predator community, habitat structure (ability to take cover from predators), food availability, and reproductive effort (cost of reproduction).

Adult survival is commonly measured by researchers and it has been estimated at the project sites in the past for Spotted Towhees (i.e., we have baseline data).

In general, birds are high trophic-level species that have specific, diverse, and moderately well understood habitat requirements. The probability of survival depends on variables such has habitat cover from predators, food availability, and perhaps reproductive effort (i.e., cost of reproduction). By employing a multispecies approach to estimate adult survival we can gain multiple perspectives on landbird habitat condition. Also riparian habitats are the single most important habitat type for landbirds in the West, so it is important that we assess their performance in these key habitats. Much of our efforts to conserve and restore riparian forests are directed at reversing local, regional, and continental declines. Finally, we are beginning to get a good understanding of what adult survival needs to be for individual species of landbirds to have viable populations.

3. What references support its use? Provide citations.

Gardali, T., and N. Nur. 2006. Site-specific survival of Black-headed Grosbeaks and Spotted Towhees at four sites within the Sacramento Valley, California. Wilson Journal of Ornithology 118:178-186.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

Nest survival can be used as a site-specific indicator in comparing sites and as an overall indicator. All scales if sample sizes are sufficient.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

Very Good: >60% probability of surviving from one year to the next.
Good: 50 – 60% probability of surviving from one year to the next.
Fair: 40 – 50% probability of surviving from one year to the next.
Poor: <40% probability of surviving from one year to the next.

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

These indicator values are based on current knowledge of nest survival (Small et al. 2007) and adult survival (Gardali and Nur 2006) in the project area and a simple population growth rate model (Small et al. 2007).

From Small et al. (2007): The finite rate of population growth (lambda), ranged from 0.25 to 0.33 based on period nest success rates of unparasitized (0.05) and parasitized nests (0.76), an observed cowbird parasitism rate of 38% during the period 1994–2003 (Small 2005), female young fledged per successful nest from unparasitized (1.30) and parasitized (0.37) nests (assuming half of fledglings are female), apparent adult survival (0.25 $\pm$ 0.11) for the period of 1995–2000 in the Sacramento River Valley (Gardali and Nur 2006), and a range of juvenile survival values calculated as percentages (0%–100%) of adult survival.

Gardali, T., and N. Nur. 2006. Site-specific survival of Black-headed Grosbeaks and Spotted Towhees at four sites within the Sacramento Valley, California. Wilson Journal of Ornithology 118:178-186.

Small, S. L., F. R. Thompson, G. R. Geupel, and J. Faaborg. 2007. Spotted Towhee population dynamics in a riparian restoration context. Condor 109:721-733.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

Gardali, T., and N. Nur. 2006. Site-specific survival of Black-headed Grosbeaks and Spotted Towhees at four sites within the Sacramento Valley, California. Wilson Journal of Ornithology 118:178-186.

Lebreton, J.-D., K. P. Burnham, J. Clobert, and D. D. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecological Monographs 62:67-118.

Step 6

8. <u>What is the current indicator status? What is the month and year that this corresponds to?</u>

Fair: The estimates for Spotted Towhee range from poor (e.g., ~21%) to very good (e.g., ~75%) depending on site and time series (Gardali and Nur 2006). The most recent estimate (1995 to 2000) was 25% from 1995 to 2000. Hence the "fair" rating.

9. <u>What is the desired rating and by when should this be achieved?</u>
   The desired rating is good and this should be achieved by 2015.

Step 7

10. <u>Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)?</u>

Data from 1993 to 1995 yielded best estimates of 60%.

11. <u>When were the data collected that yielded these other values? Describe the history of data collection.</u>

Mark-recapture analyses applied to mist-netting data collected between 1993 and 1995.

12. <u>Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?</u>

Data were collected at Flynn, Sul Norte, Ohm, and Phelan Island and are representative of the Sacramento River between Red Bluff and Colusa.

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13. <u>What is the source of the current indicator data? Who is the contact person? Provide contact info.</u>

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14. <u>What is the rationale for the desired rating?</u>
    Small et al. (2007) suggested that the populations they studied along the Sacramento River were sinks. Hence the rational to improve adult survival is simply to increase the population growth rate for this species.

Step 8

15. <u>Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).</u>

Adult survival could be limited at any stage of the annual cycle. Gardali and Nur (2006) suggested that adult survival along the Sacramento River might be influenced by conditions on the breeding grounds however. Hence, improving nest survival might improve adult survival (i.e., cost of reproduction) as would increasing post-breeding/pre-migration food sources, increasing dense vegetative cover in general, and continuing to increase the overall amount of habitat on the river. A report or publication that reviews literature on this subject and then makes specific recommendations and associated justification statements would be useful.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Bird Species Richness

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

Bird Species Richness is defined as the number of bird species detected from approximately May – mid-July along a survey route with 14 or 15 survey points. See below for list of potential species used in calculating richness.

2. What is the rationale for it being a meaningful indicator?

Species richness is an indication of the avian biodiversity at a site. Knowing how many and which species are present in the project area is fundamental to understanding if the wide spectrums of needs (for species with diverse requirements) are being met during the breeding season. For example, some species require more mature forests while others prefer forests in early seral stages. Hence, species richness may be a valuable measure of habitat suitability for a broad range of taxa.

3. What references support its use? Provide citations.

Gardali, T., A. L. Holmes, S. L. Small, N. Nur, G. R. Geupel, & G. H. Golet. 2006. Abundance patterns of landbirds in restored and remnant riparian forests on the Sacramento River, California, USA. Restoration Ecology 14: 391-403.

Golet, G.H., T. Gardali, C.A. Howell, J. Hunt, R.A. Luster, 2008. Wildlife response to riparian restoration on the Sacramento River. San Francisco Estuary & Watershed Science 6(2):1.

Reaka-Kudla, M.L., Wilson, D.E. & Wilson, E.O. (Editors). 1997. Biodiversity II. Understanding and protecting our natural resources. Joseph Henry Press, Washington, D.C. 551 pp.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

This indicator is useful for the overall health of the river at a given survey transect where there are 14-15 survey points. Each survey point must be greater than or equal to 200m apart from each other. Transect data may be compared among different locations along the river.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

Very Good: > 45 species

Good: 35 – 45 species
Fair: 25 – 35 species
Poor: < 25 species

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

The list of species used to set an upper limit for the Very Good ranking (see list in "Other Comments" section) was based on RHJV (2003); the rationale for their inclusion is detailed in Chase and Geupel (2005). Besides RHJV (2003) focal species, Sacramento Valley breeding species were included based on PRBO unpublished data. The breaks in the ratings are arbitrary. Data used to guide this however were from Small et al. (2001) and Gilchrist et al (2002).

Chase, M.K., and G.R. Geupel. 2005. The use of avian focal species for conservation planning in California. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191.

Gilchrist, J., P. Pintz, and S. L. Small. 2002. Riparian bird communities in the Sacramento Valley: a report of the 2001 field season. PRBO unpublished report.

RHJV (Riparian Habitat Joint Venture). 2003. The riparian bird conservation plan: a strategy for reversing the decline of riparian associated birds in California. California Partners in Flight. http://www.prbo.org/calpif/pdfs/riparian.v-2.pdf.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

The method is to count the total number of unique species observed along 14-15 survey points of a single transect during a 5 minute survey period. Transects were visited 2 or 3 times during the breeding season (generally May through June). All species observed flying over the survey point were included, as well as all birds detected at any distance from the point.

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to? What is the desired rating and by when should this be achieved?

Very Good: 48.7 species. An average for each of 5 sites (listed below) was derived for 2000-2001, and the mean of these 5 averages is reported.
Data collected at 15 points at Kopta Slough indicated 52, 47, 42, and 44 birds respectively for the years 2000-2003. Data collected at 15 points at Rio Vista indicated 48, 42, 47, and 36 birds respectively for the years 2000-2003. Data collected at 15 points at La Barranca indicated 58 and 50 birds respectively for the years 2000-2001. Data

collected at 14 points at Packer Island indicated 47 and 48 birds respectively for the years 2000-2001. Data collected at 14 points at Ryan indicated 47 and 48 birds respectively for the years 2000-2001. All data were collected during May through June. These values were tabulated by Chrissy Howell in August 2010.

The desired rating is to maintain a very good rating.

Step 7

9. Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)?

Species richness has been calculated previously using different methods such as restricting observations to birds seen within 50 m of the point, excluding flyovers, or based on transects in which the number of points varied. I do not have specific citations for this, and frankly, every report has done it a little bit differently. I decided to take the "widest" approach by including all distances and all species observed (even those flying over).

10. When were the data collected that yielded these other values? Describe the history of data collection.

Data were collected at the transects listed below which are located along the Sacramento River between Red Bluff and Colusa. Transects vary in the number of points within them. Due to logistical and financial considerations, not all transects, or all points within each transect, were surveyed in all years.

Transect Name	Years surveyed
Beehive	1999-2003
Bidwell-Sacramento River Park	2000-2002
Codora	1994-2001
Colusa	2000-2002
Flynn	1993-2003
Haleakala	1993-2001
Jacinto	2001-2003
Kaiser	1999-2003
Kopta Slough	1996-2003
La Baranca	1993-2001
Llano Seco	1999-2003
Millar	1999
Mooney	2002
Ohm	1993-2003
Ord Bend	2000-2003
Packer Island	1999-2001
Pine Creek	1998-2003
Pine Creek II	2003
Princeton	2001-2003
River Vista	1993-2003
Ryan	1993-2001

Stony Creek	1994-2003
Sul Norte	1993-2003
Thomas	1999-2002
Vermet	2003
Woodson Bridge State Park	2000-2002

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Data were collected at the following sites: Kopta Slough, Rio Vista, La Baranca, Packer Island, and Ryan. These sites are considered representative examples of the Sacramento River riparian habitats between Red Bluff and Colusa. They were selected for analysis because they had a similar number of points.

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

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13. What is the rationale for the desired rating?

Knowing how many and which species are present in the project area is fundamental to understanding if the wide spectrums of needs (for species with diverse requirements) are being met during the breeding season. It is desirable that species richness remain high.

Step 8

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

There are different methods to calculating species richness including restricting observations to birds seen within 50 m of the point and excluding flyovers. It would be worthwhile to compare the results for species richness using these more restrictive criteria to the more expansive approach taken in Step 6. Yet another approach would be to calculate the average richness per point since the number of points within a transect is variable.

Other comment: Data used to guide this were from Small et al. (2001) and Gilchrist et al (2002); relevant species are listed below.

1. Acorn Woodpecker
2. American Goldfinch

3. American Kestrel
4. American Robin
5. Ash-throated Flycatcher
6. Bank Swallow
7. Bell's Vireo
8. Black-chinned Hummingbird
9. Belted Kingfisher
10. Bewick's Wren
11. Brown-headed Cowbird
12. Black-headed Grosbeak
13. Blue Grosbeak
14. Black Phoebe
15. Bullock's Oriole
16. Bushtit
17. California Towhee
18. California Quail
19. Cooper's Hawk
20. Common Yellowthroat
21. Downy Woodpecker
22. House Wren
23. Killdeer
24. Lark Sparrow
25. Lazuli Bunting
26. Lesser Goldfinch
27. Lesser Nighthawk
28. Marsh Wren
29. Mourning Dove
30. Northern Rough-winged Swallow
31. Oak Titmouse
32. Osprey
33. Red-shafted Flicker
34. Red-shouldered Hawk
35. Red-tailed Hawk
36. Red-winged Blackbird
37. Song Sparrow
38. Spotted Sandpiper
39. Spotted Towhee
40. Sharp-shinned Hawk
41. Swainson's Hawk
42. Tricolored Blackbird
43. Tree Swallow
44. Turkey Vulture
45. Violet-green Swallow
46. White-breasted Nuthatch
47. Western Bluebird
48. Western Kingbird
49. Western Scrub-jay
50. Western Wood-pewee
51. Wrentit
52. White-tailed Kite
53. Yellow-breasted Chat
54. Yellow-billed Cuckoo
55. Yellow-billed Magpie
56. Yellow Warbler
57. Willow Flycatcher

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Abundance of Black-headed Grosbeak

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

Abundance for the Black-headed Grosbeak (BHGR-AB) is defined as birds per hectare.

2. What is the rationale for it being a meaningful indicator?

Abundance or density is a fundamental component of population health. An effective monitoring program must be able to provide reliable estimates of trends in abundance.

As a priority, these data should be collected during the breeding season. Birds may not attempt to nest unless their basic resource needs are met: e.g., appropriate structure for nesting, safety from predators and parasites, and adequate food.

Doing general surveys such as these at multiple times of the year would be ideal as some species use the project area for purposes other than breeding (as migratory stop over sites, as wintering areas, etc.). The Black-headed Grosbeak is a migratory species that breeds in the Central Valley so surveys should correspond to migratory and breeding phases.

3. What references support its use? Provide citations.

Bock, C.E. and Z.F. Jones. 2004. Avian habitat evaluation: should counting birds count? Frontiers in Ecology and the Environment 2:403-410.

Central Valley Joint Venture. 2006. Central Valley Joint Venture Implementation Plan – Conserving Bird Habitat. U.S. Fish and Wildlife Service, Sacramento, CA.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

This indicator is currently useful at the sub-watershed level as defined by the CVJV (2006) as well as the whole river. It may be possible to scale it down to the level of the site if the site has the appropriate habitat characteristics used by the species.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

Very Good: >1.34 birds/ha.
Good: 0.89 - 1.34 birds/ha.
Fair: 0.44 - 0.89 birds/ha.
Poor: 0 - 0.44 birds/ha.

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

The target abundance density was calculated using the method described in #7. We then used cut-offs of 0-25% (poor), 26-50% (fair), 51-75% (good), and 76-100% (very good) to calculate rankings.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

PRBO point count data were used to estimate grosbeak density for the Sacramento Valley. Current densities (individuals per hectare) were estimated by dividing the number of detections within 50 m by the area of the 50-m radius circle (0.785 hectares), then multiplying by a detectability coefficient derived from spot maps. To compute detectability coefficients, point count data collected on transects that wholly or partially overlapped spot map plots were compared with their respective spot map data; the ratio of the two resulting density estimates approximated the difference between point count-derived densities and 'true' densities. All point count-derived densities were then multiplied by this ratio to adjust for species-specific detectability. Point count-derived densities were averaged across years at each point, and across points within each basin.

Central Valley Joint Venture. 2006. Central Valley Joint Venture Implementation Plan – Conserving Bird Habitat. U.S. Fish and Wildlife Service, Sacramento, CA.

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to?

Fair: Current estimate for Sacramento Valley is 0.5956 (± 0.0395) birds/ha based on 365 point count stations surveyed by PRBO from 1993 to 2003 during the breeding season at sites along the Sacramento River. This estimate refers to the 1993 to 2003 time period.

9. What is the desired rating and by when should this be achieved?
   The desired rating is good and should be achieved by 2015.

Step 7

10. Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)?

Gardali et al. (2006) estimated linear trends in abundance based on PRBO point count data which indicated a 6.00% increase which was statistically significant.

Gardali, T., A. L. Holmes, S. L. Small, N. Nur, G. R. Geupel and G. H. Golet. 2006. Abundance patterns of landbirds in restored and remnant riparian forests on the Sacramento River, California, U.S.A. Restoration Ecology 14: 391-403.

11. When were the data collected that yielded these other values? Describe the history of data collection.

Data were collected in the same locations as in #8 and during the same time period (1993-2003).

Central Valley Joint Venture. 2006. Central Valley Joint Venture Implementation Plan – Conserving Bird Habitat. U.S. Fish and Wildlife Service, Sacramento, CA.

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Data were collected at the sites listed below which are located along the Sacramento River between Red Bluff and Colusa. Due to logistical and financial considerations, not all transects were surveyed in all years.

Transect Name	Years surveyed
Beehive	1999-2003
Bidwell-Sacramento River Park	2000-2002
Codora	1994-2001
Colusa	2000-2002
Flynn	1993-2003
Haleakala	1993-2001
Jacinto	2001-2003
Kaiser	1999-2003
Kopta Slough	1996-2003
La Baranca	1993-2001
Llano Seco	1999-2003
Millar	1999
Mooney	2002
Ohm	1993-2003
Ord Bend	2000-2003
Packer Island	1999-2001
Pine Creek	1998-2003
Pine Creek II	2003
Princeton	2001-2003
River Vista	1993-2003
Ryan	1993-2001
Stony Creek	1994-2003
Sul Norte	1993-2003
Thomas	1999-2002
Vermet	2003
Woodson Bridge State Park	2000-2002

13. <u>What is the source of the current indicator data? Who is the contact person? Provide contact info.</u>

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14. <u>What is the rationale for the desired rating?</u>

The target density was based on the 75th percentile value of all point counts in the Sacramento Valley (365 survey points), adjusted by a detectability coefficient. This density is **1.34** birds per hectare which was calculated by multiplying the target density per ha for this species in the Sacramento Valley (Table 9-8 in CVJV 2006) by 2.47 (1 ha = 2.47 ha). An arbitrary breakdown of the target density of 1.34 was used (simply divided by 3).

Step 8

15. <u>Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).</u>

Abundance may increase if additional riparian habitat is restored or enhanced, or if nest survival increases. Abundance estimates for other migratory birds (e.g., raptors, waterbirds, etc.), and especially the Yellow-Billed Cuckoo and Bank Swallow should complement the estimates derived from landbird point count data if possible. These species require special survey methods.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Abundance of Common Yellowthroat

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

Abundance for the Common Yellowthroat (COYE-AB) is defined as birds per hectare.

2. What is the rationale for it being a meaningful indicator?

Abundance or density are fundamental components of population health. An effective monitoring program must be able to provide reliable estimates of trends in abundance.

As a priority, these data should be collected during the breeding season. Birds may not attempt to nest unless their basic resource needs are met: e.g., appropriate structure for nesting, safety from predators and parasites, and adequate food.

3. What references support its use? Provide citations.

Bock, C.E. and Z.F. Jones. 2004. Avian habitat evaluation: should counting birds count? Frontiers in Ecology and the Environment 2:403-410.

Central Valley Joint Venture. 2006. Central Valley Joint Venture Implementation Plan – Conserving Bird Habitat. U.S. Fish and Wildlife Service, Sacramento, CA.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

This indicator is currently useful at the sub-watershed level as defined by the CVJV (2006) as well as the whole river but cannot be scaled down. It may be possible to scale it down to the level of the site if the site has the appropriate habitat characteristics used by the species.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

Very Good: >0.25 birds/ha
Good: 0.17 - 0.25 birds/ha
Fair: 0.09 - 0.17 birds/ ha
Poor: 0 - 0.09 birds/ha

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents

(e.g., recovery plans for endangered species), in which case complete citations should be provided.

The target abundance density was calculated using the method described in #7. We then used cut-offs of 0-25% (poor), 26-50% (fair), 51-75% (good), and 76-100% (very good) to calculate rankings.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

PRBO point count data were used to estimate yellowthroat density for the Sacramento Valley. Current densities (individuals per hectare) were estimated by dividing the number of detections within 50 m by the area of the 50-m radius circle (0.785 hectares), then multiplying by a detectability coefficient derived from spot maps. To compute detectability coefficients, point count data collected on transects that wholly or partially overlapped spot map plots were compared with their respective spot map data; the ratio of the two resulting density estimates approximated the difference between point count-derived densities and 'true' densities. All point count-derived densities were then multiplied by this ratio to adjust for species-specific detectability. Point count-derived densities were averaged across years at each point, and across points within each basin.

Central Valley Joint Venture. 2006. Central Valley Joint Venture Implementation Plan – Conserving Bird Habitat. U.S. Fish and Wildlife Service, Sacramento, CA.

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to?

Fair: Current estimate for Sacramento Valley is 0.1338 (± 0.0173) birds/ha based on 365 point count stations surveyed by PRBO from 1993 to 2003 during the breeding season at sites along the Sacramento River. This estimate refers to the 1993 to 2003 time period.

9. What is the desired rating and by when should this be achieved?
   The desired rating is good and this should be achieved by 2015.

Step 7

10. Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)?

Gardali et al. (2006) estimated linear trends in abundance based on PRBO point count data that indicated a 3.99% increase and was statistically significant.

Gardali, T., A. L. Holmes, S. L. Small, N. Nur, G. R. Geupel and G. H. Golet. 2006. Abundance patterns of landbirds in restored and remnant riparian forests on the Sacramento River, California, U.S.A. Restoration Ecology 14: 391-403.

11. When were the data collected that yielded these other values? Describe the history of data collection.

Data were collected in the same locations as in #8 and during the same time period (1993-2003).

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Data were collected at the transects listed below which are located along the Sacramento River between Red Bluff and Colusa. Due to logistical and financial considerations, not all transects were surveyed in all years.

Transect Name	**Years surveyed**
Beehive	1999-2003
Bidwell-Sacramento River Park	2000-2002
Codora	1994-2001
Colusa	2000-2002
Flynn	1993-2003
Haleakala	1993-2001
Jacinto	2001-2003
Kaiser	1999-2003
Kopta Slough	1996-2003
La Baranca	1993-2001
Llano Seco	1999-2003
Millar	1999
Mooney	2002
Ohm	1993-2003
Ord Bend	2000-2003
Packer Island	1999-2001
Pine Creek	1998-2003
Pine Creek II	2003
Princeton	2001-2003
River Vista	1993-2003
Ryan	1993-2001
Stony Creek	1994-2003
Sul Norte	1993-2003
Thomas	1999-2002
Vermet	2003
Woodson Bridge State Park	2000-2002

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

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14. What is the rationale for the desired rating?

The target density was based on the 75th percentile value of all point counts in the Sacramento Valley (365 survey points), adjusted by a detectability coefficient. This density is **0.25** birds per hectare which was calculated by multiplying the target density per *acre* for this species in the Sacramento Valley (Table 9-9 in CVJV 2006) by 2.47 (1 ha = 2.47 ac). An arbitrary breakdown of the target density of 0.25 was used (simply divided by 3).

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

Abundance may increase if additional riparian habitat is restored or enhanced, or if nest survival increases. Abundance estimates for other migratory birds (e.g., raptors, waterbirds, etc.), and especially the Yellow-Billed Cuckoo and Bank Swallow should complement the estimates derived from landbird point count data if possible. These species require special survey methods.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Abundance of Spotted Towhee

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

Abundance for the Spotted Towhee (SPTO-AB) is defined as birds per hectare.

2. What is the rationale for it being a meaningful indicator?

Population size (abundance) is a fundamental component of population health. An effective monitoring program must be able to provide reliable estimates of trends in abundance.

As a priority, these data should be collected during the breeding season. Birds may not attempt to nest unless their basic resource needs are met: e.g., appropriate structure for nesting, safety from predators and parasites, and adequate food.

3. What references support its use? Provide citations.

Bock, C.E. and Z.F. Jones. 2004. Avian habitat evaluation: should counting birds count? Frontiers in Ecology and the Environment 2:403-410.

Central Valley Joint Venture. 2006. Central Valley Joint Venture Implementation Plan – Conserving Bird Habitat. U.S. Fish and Wildlife Service, Sacramento, CA.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

This indicator is currently useful at the sub-watershed level as defined by the CVJV (2006) as well as the whole river but cannot be scaled down. It may be possible to scale it down to the level of the site if the site has the appropriate habitat characteristics used by the species.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

Very Good: >1.92 birds/ha
Good: 1.28 - 1.92 birds/ha
Fair: 0.64 - 1.28 birds/ha
Poor: 0 - 0.64 birds/ha

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents

(e.g., recovery plans for endangered species), in which case complete citations should be provided.

The target abundance density was calculated using the method described in #7. We then used cut-offs of 0-25% (poor), 26-50% (fair), 51-75% (good), and 76-100% (very good) to calculate rankings.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

PRBO point count data were used to estimate towhee density for the Sacramento Valley. Current densities (individuals per hectare) were estimated by dividing the number of detections within 50 m by the area of the 50-m radius circle (0.785 hectares), then multiplying by a detectability coefficient derived from spot maps. To compute detectability coefficients, point count data collected on transects that wholly or partially overlapped spot map plots were compared with their respective spot map data; the ratio of the two resulting density estimates approximated the difference between point count-derived densities and 'true' densities. All point count-derived densities were then multiplied by this ratio to adjust for species-specific detectability. Point count-derived densities were averaged across years at each point, and across points within each basin.

Central Valley Joint Venture. 2006. Central Valley Joint Venture Implementation Plan – Conserving Bird Habitat. U.S. Fish and Wildlife Service, Sacramento, CA.

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to?

Fair: Current estimate for Sacramento Valley is 0.7999 (± 0.0342) birds/ha based on 365 point count stations surveyed by PRBO from 1993 to 2003 during the breeding season at sites along the Sacramento River. This estimate refers to the 1993 to 2003 time period.

9. What is the desired rating and by when should this be achieved?
   The desired rating is good and this should be achieved by 2015.

Step 7

10. Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)?

Gardali et al. (2006) estimated linear trends in abundance based on PRBO point count data that indicated a 8.52% increase and was statistically significant.

Gardali, T., A. L. Holmes, S. L. Small, N. Nur, G. R. Geupel and G. H. Golet. 2006. Abundance patterns of landbirds in restored and remnant riparian forests on the Sacramento River, California, U.S.A. Restoration Ecology 14: 391-403.

11. When were the data collected that yielded these other values? Describe the history of data collection.

Data were collected in the same locations as in #8 and during the same time period (1993-2003).

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Data were collected at the transects listed below which are located along the Sacramento River between Red Bluff and Colusa. Due to logistical and financial considerations, not all transects were surveyed in all years.

Transect Name	**Years surveyed**
Beehive	1999-2003
Bidwell-Sacramento River Park	2000-2002
Codora	1994-2001
Colusa	2000-2002
Flynn	1993-2003
Haleakala	1993-2001
Jacinto	2001-2003
Kaiser	1999-2003
Kopta Slough	1996-2003
La Baranca	1993-2001
Llano Seco	1999-2003
Millar	1999
Mooney	2002
Ohm	1993-2003
Ord Bend	2000-2003
Packer Island	1999-2001
Pine Creek	1998-2003
Pine Creek II	2003
Princeton	2001-2003
River Vista	1993-2003
Ryan	1993-2001
Stony Creek	1994-2003
Sul Norte	1993-2003
Thomas	1999-2002
Vermet	2003
Woodson Bridge State Park	2000-2002

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

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14. What is the rationale for the desired rating?

The target density was based on the 75th percentile value of all point counts in the Sacramento Valley (365 survey points), adjusted by a detectability coefficient. This density is **1.92** birds per hectare which was calculated by multiplying the target density per *acre* for this species in the Sacramento Valley (Table 9-11 in CVJV 2006) by 2.47 (1 ha = 2.47 ac). An arbitrary breakdown of the target density of 1.92 was used (simply divided by 3).

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

Abundance may increase if additional riparian habitat is restored or enhanced, or if nest survival increases.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Abundance of Yellow Warbler

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

Abundance for the Yellow Warbler (YWAR-AB) is defined as birds per hectare.

2. What is the rationale for it being a meaningful indicator?

Population size (abundance) is a fundamental component of population health. An effective monitoring program must be able to provide reliable estimates of trends in abundance.

As a priority, these data should be collected during the breeding season. Birds may not attempt to nest unless their basic resource needs are met: e.g., appropriate structure for nesting, safety from predators and parasites, and adequate food.

Doing general surveys such as these at multiple times of the year would be ideal as some species use the project area for purposes other than breeding (as migratory stop over sites, as wintering areas, etc.).

The Yellow Warbler has been designated as a Bird Species of Special Concern by the California Department of Fish and Game.

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3. What references support its use? Provide citations.

Bock, C.E. and Z.F. Jones. 2004. Avian habitat evaluation: should counting birds count? Frontiers in Ecology and the Environment 2:403-410.

Central Valley Joint Venture. 2006. Central Valley Joint Venture Implementation Plan – Conserving Bird Habitat. U.S. Fish and Wildlife Service, Sacramento, CA.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

This indicator is currently useful at the sub-watershed level as defined by the CVJV (2006) as well as the whole river but cannot be scaled down. It may be possible to scale it down to the level of the site if the site has the appropriate habitat characteristics used by the species.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

Very Good: >0.32 birds/ha

Good: 0.21 – 0.32 birds/ha
Fair: 0.10 – 0.21 birds/ha
Poor: 0 – 0.10 birds/ha

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

The target abundance density was calculated using the method described in #7. We then used cut-offs of 0-25% (poor), 26-50% (fair), 51-75% (good), and 76-100% (very good) to calculate rankings.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

PRBO point count data were used to estimate warbler density for the Sacramento Valley. Current densities (individuals per hectare) were estimated by dividing the number of detections within 50 m by the area of the 50-m radius circle (0.785 hectares), then multiplying by a detectability coefficient derived from spot maps. To compute detectability coefficients, point count data collected on transects that wholly or partially overlapped spot map plots were compared with their respective spot map data; the ratio of the two resulting density estimates approximated the difference between point count-derived densities and 'true' densities. All point count-derived densities were then multiplied by this ratio to adjust for species-specific detectability. Point count-derived densities were averaged across years at each point, and across points within each basin.

Central Valley Joint Venture. 2006. Central Valley Joint Venture Implementation Plan – Conserving Bird Habitat. U.S. Fish and Wildlife Service, Sacramento, CA.

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to?

Poor: Current estimate for Sacramento Valley is 0.0208 (± 0.0103) birds/ha based on 365 point count stations surveyed by PRBO from 1993 to 2003 during the breeding season at sites along the Sacramento River. This estimate refers to the 1993 to 2003 time period.

9. What is the desired rating and by when should this be achieved?

The desired rating is fair and this should be achieved by 2015.

Step 7

10. Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)?

Gardali et al. (2006) did not estimate linear trends in abundance based on PRBO point count data for this species due to low samples sizes.

Gardali, T., A. L. Holmes, S. L. Small, N. Nur, G. R. Geupel and G. H. Golet. 2006. Abundance patterns of landbirds in restored and remnant riparian forests on the Sacramento River, California, U.S.A. Restoration Ecology 14: 391-403.

11. When were the data collected that yielded these other values? Describe the history of data collection.

N/A

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Data were collected at the transects listed below which are located along the Sacramento River between Red Bluff and Colusa. Due to logistical and financial considerations, not all transects were surveyed in all years.

Transect Name	**Years surveyed**
Beehive	1999-2003
Bidwell-Sacramento River Park	2000-2002
Codora	1994-2001
Colusa	2000-2002
Flynn	1993-2003
Haleakala	1993-2001
Jacinto	2001-2003
Kaiser	1999-2003
Kopta Slough	1996-2003
La Baranca	1993-2001
Llano Seco	1999-2003
Millar	1999
Mooney	2002
Ohm	1993-2003
Ord Bend	2000-2003
Packer Island	1999-2001
Pine Creek	1998-2003
Pine Creek II	2003
Princeton	2001-2003
River Vista	1993-2003
Ryan	1993-2001
Stony Creek	1994-2003
Sul Norte	1993-2003
Thomas	1999-2002
Vermet	2003
Woodson Bridge State Park	2000-2002

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

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14. <u>What is the rationale for the desired rating?</u>

The target density was based on the 75th percentile value of all point counts in the Sacramento Valley (365 survey points), adjusted by a detectability coefficient. This density is **0.32** birds per hectare which was calculated by multiplying the target density per *acre* for this species in the Sacramento Valley (Table 9-10 in CVJV 2006) by 2.47 (1 ha = 2.47 ac). An arbitrary breakdown of the target density of 0.32 was used (simply divided by 3).

Step 8

15. <u>Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).</u>

Abundance may increase if additional riparian habitat is restored or enhanced, if nest survival increases, or as the current vegetation ages because Yellow Warblers prefer older successional stage riparian. The use of conspecific attraction experimental methods (such as broadcasting Yellow Warbler songs) may also increase abundance.

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Abundance of Yellow-breasted Chat

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

Abundance for the Yellow-breasted Chat (YBCH-AB) is defined as birds per hectare.

2. What is the rationale for it being a meaningful indicator?

Population size (abundance) is a fundamental component of population health. An effective monitoring program must be able to provide reliable estimates of trends in abundance.

As a priority, these data should be collected during the breeding season. Birds may not attempt to nest unless their basic resource needs are met: e.g., appropriate structure for nesting, safety from predators and parasites, and adequate food. Knowing what species are setting up territories and exhibiting behaviors indicative of breeding provides an important (although incomplete) measure of whether or not bird's needs are being met during the breeding season.

Doing general surveys such as these at multiple times of the year would be ideal as some species use the project area for purposes other than breeding (as migratory stop over sites, as wintering areas, etc.).

3. What references support its use? Provide citations.

Bock, C.E. and Z.F. Jones. 2004. Avian habitat evaluation: should counting birds count? Frontiers in Ecology and the Environment 2:403-410.

Central Valley Joint Venture. 2006. Central Valley Joint Venture Implementation Plan – Conserving Bird Habitat. U.S. Fish and Wildlife Service, Sacramento, CA.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

This indicator is currently useful at the sub-watershed level as defined by the CVJV (2006) as well as the whole river but cannot be scaled down. It may be possible to scale it down to the level of the site if the site has the appropriate habitat characteristics used by the species.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

Very Good: > 0.93 birds/ha
Good: 0.62 - 0.93 birds/ha

Fair: 0.31 – 0.62 birds/ha
Poor: 0 – 0.31 birds/ha

6. <u>How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.</u>

The target abundance density was calculated using the method described in #7. We then used cut-offs of 0-25% (poor), 26-50% (fair), 51-75% (good), and 76-100% (very good) to calculate rankings.

7. <u>Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?</u>

PRBO point count data were used to estimate chat density for the Sacramento Valley. Current densities (individuals per hectare) were estimated by dividing the number of detections within 50 m by the area of the 50-m radius circle (0.785 hectares), then multiplying by a detectability coefficient derived from spot maps. To compute detectability coefficients, point count data collected on transects that wholly or partially overlapped spot map plots were compared with their respective spot map data; the ratio of the two resulting density estimates approximated the difference between point count-derived densities and 'true' densities. All point count-derived densities were then multiplied by this ratio to adjust for species-specific detectability. Point count-derived densities were averaged across years at each point, and across points within each basin.

Central Valley Joint Venture. 2006. Central Valley Joint Venture Implementation Plan – Conserving Bird Habitat. U.S. Fish and Wildlife Service, Sacramento, CA.

Step 6

8. <u>What is the current indicator status? What is the month and year that this corresponds to?</u>

Poor: Current estimate for Sacramento Valley is 0.1377 (± 0.0096) birds/ha based on 365 point count stations surveyed by PRBO from 1993 to 2003 during the breeding season at sites along the Sacramento River. This estimate refers to the 1993 to 2003 time period.

9. <u>What is the desired rating and by when should this be achieved?</u>
   The desired rating is fair and this should be achieved by 2015.

Step 7

10. <u>Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)?</u>

Gardali et al. (2006) did not estimate linear trends in abundance based on PRBO point count data for this species due to low samples sizes.

Gardali, T., A. L. Holmes, S. L. Small, N. Nur, G. R. Geupel and G. H. Golet. 2006. Abundance patterns of landbirds in restored and remnant riparian forests on the Sacramento River, California, U.S.A. Restoration Ecology 14: 391-403.

11. When were the data collected that yielded these other values? Describe the history of data collection.

N/A

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

Data were collected at the transects listed below which are located along the Sacramento River between Red Bluff and Colusa. Due to logistical and financial considerations, not all transects were surveyed in all years.

Transect Name	Years surveyed
Beehive	1999-2003
Bidwell-Sacramento River Park	2000-2002
Codora	1994-2001
Colusa	2000-2002
Flynn	1993-2003
Haleakala	1993-2001
Jacinto	2001-2003
Kaiser	1999-2003
Kopta Slough	1996-2003
La Baranca	1993-2001
Llano Seco	1999-2003
Millar	1999
Mooney	2002
Ohm	1993-2003
Ord Bend	2000-2003
Packer Island	1999-2001
Pine Creek	1998-2003
Pine Creek II	2003
Princeton	2001-2003
River Vista	1993-2003
Ryan	1993-2001
Stony Creek	1994-2003
Sul Norte	1993-2003
Thomas	1999-2002
Vermet	2003
Woodson Bridge State Park	2000-2002

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

Geoff Geupel, Division Director
Chrissy Howell PhD, Senior Conservation Scientist
Terrestrial Ecology Division, PRBO Conservation Science
3820 Cypress Drive #11

Petaluma, CA 94954
GG: (415) 868-0655 ext. 301 CH: (707) 781-2555 ext. 315
ggeupel@prbo.org chowell@prbo.org

14. What is the rationale for the desired rating?

The target density was based on the 75th percentile value of all point counts in the Sacramento Valley (365 survey points), adjusted by a detectability coefficient. This density is **0.93** birds per hectare which was calculated by multiplying the target density per *acre* for this species in the Sacramento Valley (Table 9-7 in CVJV 2006) by 2.47 (1 ha = 2.47 ac). An arbitrary breakdown of the target density of 0.93 was used (simply divided by 3).

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

Abundance may increase if additional riparian habitat is restored or enhanced, or if nest survival increases.

SACRAMENTO RIVER
ECOLOGICAL INDICATOR INFORMATION
Aerial Extent of Colonial Waterbird Rookeries

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

The indicator is the Aerial Extent of Colonial Waterbird Rookeries between Red Bluff and Colusa. It is defined as the sum of the mapped polygons of rookeries in square meters. The main species in these colonies are Great Egret (GREG), Great Blue Heron (GBHE), and Double-crested Cormorant (DCCO). Additional species that may be present at the colonies include Snowy Egret (SNEG) and Cattle Egret (CAEG). Night Herons are also possible, although they more typically nest in marshes. Great Blue Herons may sometimes nest in very small colonies.

2. What is the rationale for it being a meaningful indicator?

The presence of a breeding colonial waterbird colony suggests that there are adequate nearby food resources and breeding habitat. Large colonies are often found in the same location year after year, although smaller colonies may shift around. Great Egrets and Great Blue Herons require large trees for breeding. Structure appears to matter more than tree species in breeding site selection. Sycamores are often used by cormorants which don't fly well. Sycamores are open and don't leaf out until late in the season. Oaks and cottonwoods may also be used.

Rivers are clearly important for these species. A statewide inventory of colonial waterbirds had recently been initiated. It is called the Western Colonial Waterbird Survey, and more information on it can be found at: www.fws.gov/mountain-prairie/species/birds/western_colonial/index.html. PRBO Conservation Science (D. Shuford, K. Strom) has been coordinating this survey with USFWS, Region 8 (Rob Doster and Marie Strassburger), and CDFG (Lyann Comrack). All the major rivers of the state will be inventoried as part of this effort. The results of the survey will provide a state-wide context for what is observed on the Sacramento River.

3. What references support its use as an indicator of river health?

These documents speak more to the importance of monitoring waterbirds than to their utility as indicators of river health.

Kelly, J. P., K. Etienne, C. Strong, M. McCaustland, and M. Parkes. 2006. Annotated atlas and implications for the conservation of heron and egret nesting colonies in the San Francisco Bay area. ACR Tech. Rep. 90-3-17. Available from Audubon Canyon Ranch, 4990 Shoreline Hwy. 1, Stinson Beach, CA 94970 or at www.egret.org/atlas.html.

Kelly, J. P., D. Stralberg, K. Etienne, and M. McCaustland. 2008. Landscape influence on the quality of heron and egret colony sites. Wetlands 28:257-275.

Kushlan, J. A., M. J. Steinkamp, K. C. Parsons, J. Capp, M. Acosta Cruz, M. Coulter, I. Davidson, L. Dickson, N. Edelson, R. Elliot, R. M. Erwin, S. Hatch, S. Kress, R. Milko, S. Miller, K. Mills, R. Paul, R. Phillips, J. E. Saliva, B. Sydeman, J. Trapp, J. Wheeler, and K. Wohl. 2002. Waterbird Conservation for the Americas: The North American Waterbird Conservation Plan, version 1. Waterbird Conservation for the Americas, Washington, DC.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

This indicator is most useful when considered over the entire alluvial portion of the river. Tracking changes over time in different reaches may help elucidate factors that influence waterbird abundance.

<u>Step 5</u>

5. What cutoffs are appropriate for poor, fair, good and very good?

> <u>The status indicator ratings are defined as:</u>
> *Very Good: > 50,000 square meters*
> *Good: 30,000 – 50,000 square meters*
> *Fair: 20,000 – 30,000 square meters*
> *Poor: < 20,000 square meters*

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

These cutoffs were selected simply by considering expert opinion. This opinion states that the status of the main species occupying these colonies is quite good. Thus the rating category for "Good" was defined to include the most recently quantified value.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

Melinda Carlson at the Chico State University Chico Geographic Information Center located the cormorant and egret rookeries on the 2007 Sacramento River aerial photos and created a GIS shapefile with one point corresponding to each colony. Using ArcMap, Seth Paine, a TNC GIS technician, zoomed in at each point, and created a polygon encompassing the approximate extent of each colony. He then made calculated the area of the polygon in acres and square meters.

Mapping of the mainstem Sacramento River was done by analyzing aerial photos that were taken 6-26-07, and amended with photos from a second flight on 6-17-08. Methods for the overall mapping effort, with an emphasis on landcover mapping are described in Nelson et al. (2008).

An important consideration is the timing of aerial mapping relative to that of colonial nesters. June is probably acceptable for multi-species colonies, but one composed of just Great Blue Herons may not be occupied at that time as that species starts early and may have fledged young by mid-June. Early May is likely a better time for this species (D. Shuford, *personal communication*).

Nelson, C., M. Carlson, R. Funes. 2008. Rapid Assessment Mapping in the Sacramento River Ecological Management Zone – Colusa to Red Bluff. Report to the CALFED Ecosystem Restoration Program, Sacramento, CA.

<u>Step 6</u>

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

In June, 2007, there were 35,009 square meters of visible colonial waterbird nesting area at 14 distinct colonies located between Red Bluff and Colusa. The corresponding status is “Good”.

See the below table for individual colony sizes and locations. The composition of these colonies is uncertain, but best guesses were made (by M. Carlson) from available imagery.

OBJECTID	Colony type	River Mile	Bank	Acres	Sq Meters
1	Egret/Heron	272	Left	0.566	2,289
2	Egret/Heron	259	Left	0.091	370
3	Egret/Heron	236	Right	0.525	2,126
4	Egret/Heron	233	Left	0.164	662
5	Egret/Heron	219	Right	0.241	977
6	Egret/Heron	214	Left	0.350	1,416
7	Egret/Heron	209	Right	0.366	1,482
8	Cormorant	188	Left	0.428	1,731
9	Cormorant	180	Left	0.454	1,838
10	Egret/Heron	180	Right	1.520	6,152
11	Egret/Heron	173	Right	1.248	5,051
12	Egret/Heron	162	Left	0.140	568
14	Egret/Heron	157	Mid	2.557	10,347
			total:	8.651	35,009

Regarding species composition at the colonies, J. Silveira, FWS biologist, reports:

“The rookeries I've encountered on the river (Flynn, Llano Seco) have been occupied by GBHE, GREG, and DCCO; the Angel Slough rookery has been occupied by GBHE and GREG. Rookeries at Sacramento NWR have been occupied by GBHE, GREG and SNEG; and we have had a BCNH rookery at Delevan NWR in the past.”

9. What is the desired rating and by when should this be achieved?

   “Very Good” by July 2020.

Step 7.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

Similar data to what is presented below for 2007 could be derived from analysis of the 1999 Sacramento River riparian aerial photos. These were flown May 21, 1999, and the riparian shape file was created in 2001 to 2002. The shapefile is of landcover and vegetation classess. However this imagery could be reinspected for waterbird colonies.

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

The current data were collected over the entire stretch of the river from Red Bluff to Colusa during a comprehensive survey. They are representative of this area. Three additional colonies were mapped south of Colusa. The data for these is provided below, although they were not included in the calculations for this indicator.

OBJECTID	Colony type	River Mile	Bank	Acres	Sq Meters
15	Egret	138	Right	1.833	7,416
16	Egret	120	Right	1.832	7,414
17	Cormorant	102	Right	1.043	4,220

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

The locations of these colonies were identified during the mapping of the vegetation by:

Melinda Carlson
GIS Biologist
Geographical Information Center
Chico, California 95929-0327
mcarlson@gic.csuchico.edu
530 898-3212 office

An expert on waterbirds that I consulted with when writing this is:

W. David Shuford
PRBO Conservation Science
Wetlands Center
P.O. Box 69
Bolinas, CA 94924
ph: 415-868-0371, ext. 310
email: dshuford@prbo.org

Another biologist with good local knowledge is:

Joseph Silveira
Wildlife Biologist
U.S. Fish & Wildlife Service
Sacramento National Wildlife Refuge Complex
752 County Road 99 W
Willows, CA 95988
(530) 934-2801 tel
joe_silveira@fws.gov

13. What is the rationale for the desired rating?

The desired rating would be an improvement over the current condition and would make the populations more resilient to future impacts.

Step 8

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

John Kelly Audubon Canyon Ranch has an atlas of SF Bay area. Looked at landscape issues influences on RS and species composition.

Should more detailed surveys of waterbird colonies be initiated, the following document should be consulted: WESTERN COLONIAL WATERBIRD SURVEY PROTOCOLS by Jones (2008). It is available at: http://www.fws.gov/mountain-prairie/species/birds/western_colonial/Phase%20I%20western%20waterbird%20protocols%2025%20Sept.pdf. The primary author and contact for this document is Stephanie L. Jones, USFWS, Nongame Migratory Bird Coordinator, Region 6, P.O. Box 25486 DFC, Denver, CO 80225, email: stephanie_jones@fws.gov, phone: 303-236-4409.

The protocols compiled in Jones (2008) are directly derived from the recommendations for counts of all species made by the Colonial Waterbird Monitoring Partnership's *Breeding Season Population Census Techniques for Seabirds and Colonial Waterbirds throughout North America* (Steinkamp et al. 2003) and *South Dakota Breeding Waterbird Colony Monitoring. Part I: Breeding Bird Count Protocols* (Drilling, N. 2007).

Drilling, N. 2007. South Dakota breeding waterbird colony monitoring. Part I: breeding bird count protocols. Unpublished report, RMBO, Fort Collins, CO.

Steinkamp, M., B. Peterjohn, V. Byrd, H. Carter, and R. Lowe. 2003. Breeding season survey techniques for seabirds and colonial waterbirds throughout North America. Waterbird Monitoring Partnership of the Waterbirds for Americas Initiative. Available at: http://www.waterbirdconservation.org/pubs/PSGManual03.PDF

More information on the viability assessment part of the workbook can be found at: http://conserveonline.org/workspaces/cbdgateway/cap/practices/bp_3

SACRAMENTO RIVER

ECOLOGICAL INDICATOR INFORMATION

Number of Bank Swallow Burrows

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

<u>Step 4</u>

1. How specifically is the indicator defined?

   The indicator is the number of Bank Swallow (*Riparia riparia*) burrows between Red Bluff and Colusa.

2. What is the rationale for it being a meaningful indicator?

   Bank swallows can tell us a lot about the degree to which certain natural riverine processes (especially erosion) are functional in alluvial systems.

   They only nest on steep (typically near vertical) cutbanks that have suitable soils. This nesting habitat is sensitive to how the flow regime (timing, magnitude, duration and ramping rates), sediment transport, and the lateral migration of the river are managed. Active river meander is not only important for swallows. It is a fundamental riverine process that shapes the habitat for a broad suite of terrestrial and aquatic biota.

   The Bank Swallow was listed as threatened under the California Endangered Species Act in 1989 in response to a sharp decline in the distribution and abundance of the species across the state. Currently, ~70% of California's bank swallows nest on the Sacramento River, and most are on the ~100 river mile stretch between the towns of Red Bluff and Colusa.

   Human activities and modifications of the ecosystem have had significant effects on bank swallow breeding populations and habitat. Indications from recent research, for example, suggest that bank swallows have been affected by conversion of native grasslands and forests to orchards and row crops, which may provide fewer insects on average for foraging (Moffatt et al. 2005). More significantly, bank armoring activities have had both immediate and long-term adverse effects on bank swallow populations and habitat including: (1) coverage of steep, fresh surfaces that are suitable for bank swallow nesting, (2) destruction of individual birds (and in extreme cases entire colonies) when construction occurs during breeding season, (3) localized reductions in the river's ability to create the steep, fresh bank surfaces required by nesting bank swallows, and (4) reduction in riparian habitat forming processes which may influence foraging opportunities and food supply. The river's ability to create nesting habitat for bank swallows has also been affected by human modifications to rates and patterns of sediment transport and flow, which together regulate the geomorphic processes that set the rate, type, and timing of bank erosion (Stillwater Sciences 2007).

Bank swallow sometimes refurbish holes used in previous years for breeding. But this can lead to problems as parasites (including a mite and a louse) increase their populations over the winter time and then infect and can kill the chicks. For this reason bank swallows likely have higher reproductive success when they build cutbanks in freshly eroded banks. So erosion is generally favorable for this species, although high rates of erosion during the breeding season can be problematic if they cause excessive bank sloughing.

3. What references support its use as an indicator of river health? Provide citations.

Buechner, M. 1992. Preliminary population viability analysis for bank swallows (*Riparia riparia*) on the Sacramento River, California: a computer simulation analysis incorporating environmental stochasticity. California Department of Fish and Game, Nongame Bird and Mammal Section.

CDFG (California Department of Fish and Game). 1992. Recovery plan: bank swallow. Report No. 93.02. CDFG, Nongame Bird and Mammal Section, Wildlife Management Division, Sacramento.

Garcia, D. 2009. Spatial and temporal patterns of the Bank Swallow on the Sacramento River. Masters Thesis, California State University, Chico.

Garcia, D., R. Schlorff, and J. Silveira. 2008. Bank swallows on the Sacramento River, a 10-year update on populations and conservation status. Central Valley Bird Club Bulletin 11:1-12.

Garrison, B. A. 1998. Bank swallow (*Riparia riparia*). In California Partners in Flight Riparian Bird Conservation Plan: a strategy for reversing the decline of riparian-associated birds in California. California Partners in Flight, Point Reyes Bird Observatory, Stinson Beach, California. http://www.prbo.org/calpif/htmldocs/species/riparian/bank_swallow_acct2.html

Garrison, B. A. 1999. Bank swallow (*Riparia riparia*). No. 414. *In* A. Poole and F. Gill, editors. The birds of North America. The Academy of Natural Sciences, Philadelphia, Pennsylvania and The American Ornithologists' Union, Washington, D. C.

Garrison, B. A., J. M. Humphrey, and S. A. Laymon. 1987. Bank swallow distribution and nesting ecology on the Sacramento River, California. Western Birds 18: 71-76.

Girvetz, E.H. 2010. Removing erosion control projects increases bank swallow (Riparia riparia) population viability modeled along the Sacramento River, California, USA Biological Conservation 143: 828–838

Moffatt, K. C., E. E. Crone, K. D. Holl, R. W. Schlorff, and B. A. Garrison. 2005. Importance of hydrologic and landscape heterogeneity for restoring bank swallow (*Riparia riparia*) colonies along the Sacramento River, California. Restoration Ecology 13: 391-402.

Schlorff, R.W. 1997. Monitoring bank swallow populations on the Sacramento River: A decade of decline. Transactions of the western section of the wildlife society 33:40-48.

Stillwater Sciences. 2007. Linking biological responses to river processes: Implications for conservation and management of the Sacramento River—a focal species approach. Final Report. Prepared by Stillwater Sciences, Berkeley for The Nature Conservancy, Chico, California.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   This indicator is most useful when considered over the entire alluvial portion of the river. Tracking changes over time in different reaches may help elucidate factors that influence swallow abundance.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

   The status indicator ratings are defined as:
   Very Good: > 40,000 burrows
   Good: 30,000 - 40,000 burrows
   Fair: 20,000 - 30,000 burrows
   Poor: <20,000 burrows

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

   The rating cutoffs were assigned following reviews of the 1992 DFG bank swallow recovery plan, Buechner (1992) and Girvetz (2010). Citations are listed above.

   The current (2010) population size is estimated to be:

   10,662 burrows x 0.45 occupancy rate x 2 birds per pair = 9,596 birds (<5,000 pairs)

   This is approximately half of what the population size was when the Buechner's (1992) PVA was done. In that document, Buechner calculated that a population of 10,000 breeding pairs has a 20% or greater risk of falling below 1000 pairs, and 33% risk of disappearing entirely within 50 years.

   The 1992 Recovery plan states that a population of 100,000 breeding pairs would be necessary to ensure a less than 50% chance of falling below 5,000 breeding pairs within 50 years. Note that the 2010 population was below this threshold.

Analyses conducted by Girvetz (2010) suggested that under current conditions the probability of dropping below the quasi-extinction threshold (2000 pairs) in 50 years is 21%.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

   The Bank Swallow working group has produced a draft methods paper that describes how surveys are conducted on the Sacramento and Feather Rivers. Adam Henderson (DWR), Ryan Martin (DWR), Joe Silveira (FWS) and David Wright (DFG) have collaborated on this. Ron Schlorff (DFG retired) provided input to help document methods followed in the earlier years of survey work when he was the lead on the surveys. Although not yet finalized, this paper has most all of the necessary information for how to collect the data to represent this indicator.

<u>Step 6</u>

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   In July 2010 there were 10,662 burrows counted between Red Bluff and Colusa.

9. What is the desired rating and by when should this be achieved?

   Fair, by July 2020.

<u>Step 7</u>.

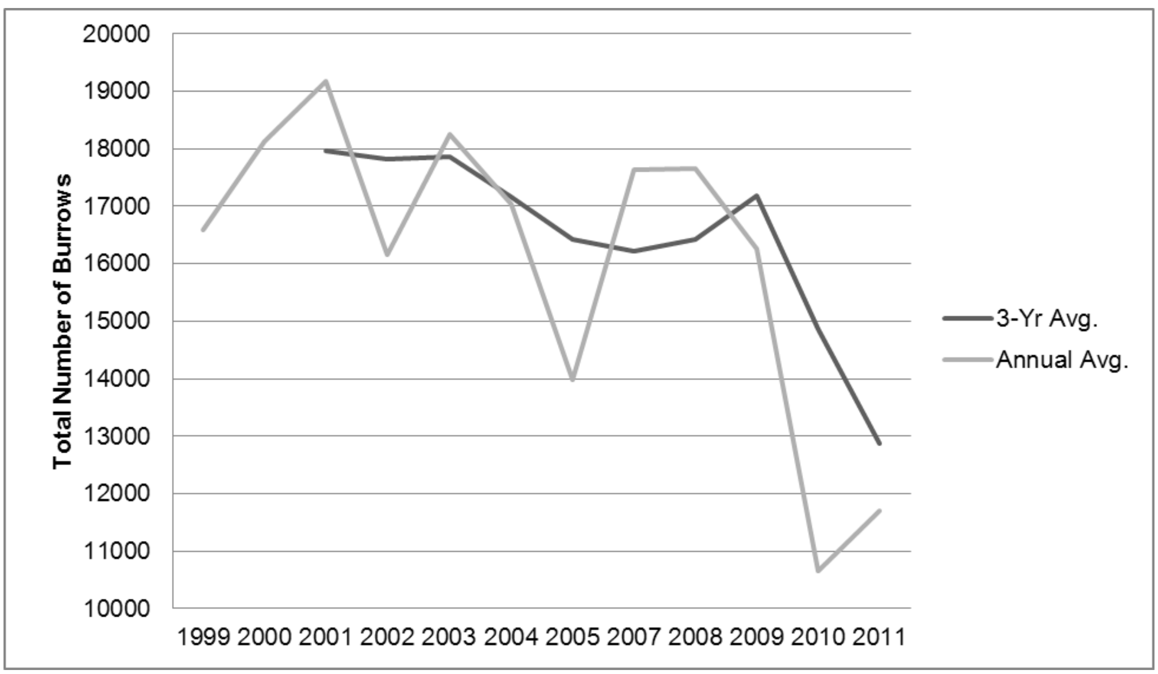
10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

    Colony and burrow counts have been conducted nearly every year from 1986 to the present. Three years were missed.

    The 2010 burrow counts represent a 34.4 % decrease from 2009, or a 13.5 % decrease from the 3-year running average. Comparisons with other years are drawn in the below table which was taken from the 2010 draft summary report by J. Silveira.

Bank Swallow Burrow Counts, Sacramento River, Red Bluff to Colusa (RM 243 to RM 143): 1999 through 2010. Data from J. Silveira, USFWS (unpublished).

Year	Total Burrows	Percent Change from Previous Year	3-Year Average of Total Burrows	Percent Change from 3-Year Average
2011	11,710	9.8	12,877	-13.3
2010	10,662	-34.4	14,860	-13.5
2009	16,259	-7.9	17,186	4.6
2008	17,660	0.1	16,430	1.3
2007	17,640	26.1	16,223	-1.3
2005	13,990	-17.9	16,430	-4.2
2004	17,040	-6.7	17,153	-4.0
2003	18,260	13.0	17,863	0.2
2002	16,160	-15.7	17,820	-0.8
2001	19,170	5.7	17,963	
2000	18,130	9.3		
1999	16,590			



11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    The current data were collected over the entire stretch of the river from Red Bluff to Colusa during a comprehensive survey. They are representative of this area.

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

    This indicator information was input by G. Golet following review of relevant materials. Experts on this subject matter as it pertains to application on the Sacramento River are:

    Joseph G. Silveira
    Wildlife Biologist
    U.S. Fish & Wildlife Service
    Sacramento National Wildlife Refuge Complex
    752 County Road 99 W
    Willows, CA 95988
    (530) 934-2801 tel (530) 934-7814 fax
    joe_silveira@fws.gov

13. What is the rationale for the desired rating?

    The rationale for the desired rating was derived from reviews of the 1992 DFG bank swallow recovery plan, Buechner (1992), Girvetz (2010), and with consideration of what is realistically possible in 10 years.

Step 8

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

    Girvetz (2010) found that the spatial structure of the habitat patches was not important to the viability of this population. Rather the total area seemed to be driving the population.

    Importantly restoration of riverbank habitat (removal of riprap) reduced extinction probability to less than 10%. This is a 57% reduction in the probability of the population dropping below the quasi-extinction threshold compared to the current condition.

    Joe Silveira (USFWS) made the good suggestion that it may be useful to have ratings and goals broken down by subreaches. This would be useful in that it would help prioritize areas for rock removal.

More information on the viability assessment part of the workbook can be found at: http://conserveonline.org/workspaces/cbdgateway/cap/practices/bp_3

SACRAMENTO RIVER

ECOLOGICAL INDICATOR INFORMATION

Number of Bank Swallow Colonies

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

   The indicator is the number of Bank Swallow (*Riparia riparia*) colonies between Red Bluff and Colusa.

2. What is the rationale for it being a meaningful indicator?

   Bank swallows can tell us a lot about the degree to which certain natural riverine processes (especially erosion) are functional in alluvial systems.

   They only nest on steep (typically near vertical) cutbanks that have suitable soils. This nesting habitat is sensitive to how the flow regime (timing, magnitude, duration and ramping rates), sediment transport, and the lateral migration of the river are managed. Active river meander is not only important for swallows. It is a fundamental riverine process that shapes the habitat for a broad suite of terrestrial and aquatic biota.

   The Bank Swallow was listed as threatened under the California Endangered Species Act in 1989 in response to a sharp decline in the distribution and abundance of the species across the state. Currently, ~70% of California's bank swallows nest on the Sacramento River, and most are on the ~100 river mile stretch between the towns of Red Bluff and Colusa.

   Human activities and modifications of the ecosystem have had significant effects on bank swallow breeding populations and habitat. Indications from recent research, for example, suggest that bank swallows have been affected by conversion of native grasslands and forests to orchards and row crops, which may provide fewer insects on average for foraging (Moffatt et al. 2005). More significantly, bank armoring activities have had both immediate and long-term adverse effects on bank swallow populations and habitat including: (1) coverage of steep, fresh surfaces that are suitable for bank swallow nesting, (2) destruction of individual birds (and in extreme cases entire colonies) when construction occurs during breeding season, (3) localized reductions in the river's ability to create the steep, fresh bank surfaces required by nesting bank swallows, and (4) reduction in riparian habitat forming processes which may influence foraging opportunities and food supply. The river's ability to create nesting habitat for bank swallows has also been affected by human modifications to rates and patterns of sediment transport and flow, which together regulate the geomorphic processes that set the rate, type, and timing of bank erosion (Stillwater Sciences 2007).

Bank swallow sometimes refurbish holes used in previous years for breeding. But this can lead to problems as parasites (including a mite and a louse) increase their populations over the winter time and then infect and can kill the chicks. For this reason bank swallows likely have higher reproductive success when they build cutbanks in freshly eroded banks. So erosion is generally favorable for this species, although high rates of erosion during the breeding season can be problematic if they cause excessive bank sloughing.

The number of colonies is an important component of bank swallow population health. Having more colonies may help buffer the population from impacts (e.g., predation, disturbance, etc) that are location specific. It is beneficial to spread the risk among numerous geographic areas.

3. What references support its use as an indicator of river health? Provide citations.

Buechner, M. 1992. Preliminary population viability analysis for bank swallows (*Riparia riparia*) on the Sacramento River, California: a computer simulation analysis incorporating environmental stochasticity. California Department of Fish and Game, Nongame Bird and Mammal Section.

CDFG (California Department of Fish and Game). 1992. Recovery plan: bank swallow. Report No. 93.02. CDFG, Nongame Bird and Mammal Section, Wildlife Management Division, Sacramento.

Garcia, D. 2009. Spatial and temporal patterns of the Bank Swallow on the Sacramento River. Masters Thesis, California State University, Chico.

Garcia, D., R. Schlorff, and J. Silveira. 2008. Bank swallows on the Sacramento River, a 10-year update on populations and conservation status. Central Valley Bird Club Bulletin 11:1-12.

Garrison, B. A. 1998. Bank swallow (*Riparia riparia*). In California Partners in Flight Riparian Bird Conservation Plan: a strategy for reversing the decline of riparian-associated birds in California. California Partners in Flight, Point Reyes Bird Observatory, Stinson Beach, California. http://www.prbo.org/calpif/htmldocs/species/riparian/bank_swallow_acct2.html

Garrison, B. A. 1999. Bank swallow (*Riparia riparia*). No. 414. *In* A. Poole and F. Gill, editors. The birds of North America. The Academy of Natural Sciences, Philadelphia, Pennsylvania and The American Ornithologists' Union, Washington, D. C.

Garrison, B. A., J. M. Humphrey, and S. A. Laymon. 1987. Bank swallow distribution and nesting ecology on the Sacramento River, California. Western Birds 18: 71-76.

Girvetz, E.H. 2010. Removing erosion control projects increases bank swallow (Riparia riparia) population viability modeled along the Sacramento River, California, USA Biological Conservation 143: 828–838

Moffatt, K. C., E. E. Crone, K. D. Holl, R. W. Schlorff, and B. A. Garrison. 2005. Importance of hydrologic and landscape heterogeneity for restoring bank swallow (*Riparia riparia*) colonies along the Sacramento River, California. Restoration Ecology 13: 391-402.

Schlorff, R.W. 1997. Monitoring bank swallow populations on the Sacramento River: A decade of decline. Transactions of the western section of the wildlife society 33:40-48.

Stillwater Sciences. 2007. Linking biological responses to river processes: Implications for conservation and management of the Sacramento River—a focal species approach. Final Report. Prepared by Stillwater Sciences, Berkeley for The Nature Conservancy, Chico, California.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

   This indicator is most useful when considered over the entire alluvial portion of the river. Tracking changes over time in different reaches may help elucidate factors that influence swallow abundance.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

   The status indicator ratings are defined as:
   Very Good: > 100 colonies
   Good: 75 - 100 colonies
   Fair: 50 - 75 colonies
   Poor: < 50 colonies

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

   The rating cutoffs were assigned following reviews of the data. Also considered were the 1992 DFG bank swallow recovery plan, Buechner (1992) and Girvetz (2010). Citations are listed above.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, then briefly summarize the methods here, or identify the best person(s) to write these up?

   The Bank Swallow working group has produced a draft methods paper that describes how surveys are conducted on the Sacramento and Feather Rivers. Adam Henderson (DWR), Ryan Martin (DWR), Joe Silveira (FWS) and David Wright (DFG) have collaborated on this. Ron Schlorff (DFG retired) provided input to help document methods followed in the earlier years of survey work when he was the lead on the surveys. Although not yet finalized, this paper has most all of the necessary information for how to collect the data to represent this indicator. There is a concern that the way in which colonies have been distinguished from one another may not have been consistent from year to year. Obviously the methods report must be clear about this. At issue is how much of a gap there must be between burrows.

Step 6

8. What is the current indicator value (and status)? What is the month and year that this corresponds to?

   In July 2010 there were 38 colonies counted between Red Bluff and Colusa. This corresponds to a "Poor" rating.

9. What is the desired rating and by when should this be achieved?

   Fair, by July 2020.

Step 7.

10. Are there additional values for this indicator that have been calculated that correspond to this same scale of reporting (parcel, reach, etc.)? If so what when were they collected and what were the values? Describe the history of data collection.

    Colony (and burrow) counts have been conducted nearly every year from 1986 to the present. Three years were missed.

    This represents a 21% decrease in the number of colonies from 2009 (there were 48).

11. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

    The current data were collected over the entire stretch of the river from Red Bluff to Colusa during a comprehensive survey. They are representative of this area.

12. What is the source of the current indicator data? Who is the contact person? Provide contact info.

    Currently Joe Silveira summarizes the data from each year's survey.

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13. What is the rationale for the desired rating?

    The rationale for the desired rating was derived from reviews of the 1992 DFG bank swallow recovery plan, Buechner (1992), Girvetz (2010), and with consideration of what is realistically possible in 10 years.

Step 8

14. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

    Girvetz (2010) found that the spatial structure of the habitat patches was not important to the viability of this population. Rather the total area seemed to be driving the population.

    Importantly restoration of riverbank habitat (removal of riprap) reduced extinction probability to less than 10%. This is a 57% reduction in the probability of the population dropping below the quasi-extinction threshold compared to the current condition.

    Joe Silveira (USFWS) made the good suggestion that it may be useful to have ratings and goals broken down by subreaches. This would be useful in that it would help prioritize areas for rock removal.

More information on the viability assessment part of the workbook can be found at: http://conserveonline.org/workspaces/cbdgateway/cap/practices/bp_3

SACRAMENTO RIVER ECOLOGICAL INDICATOR INFORMATION

Number of Occupied Yellow-billed Cuckoo Territories

This document contains indicator information to be captured in the Sacramento River Ecological Scorecard. Steps refer to locations in the MS Excel workbook viability wizard.

Step 4

1. How specifically is the indicator defined?

Number of Yellow-billed Cuckoo territories occupied between Red Bluff and Colusa.

2. What is the rationale for it being a meaningful indicator?

The Yellow-billed Cuckoo is a riparian obligate, Neotropical migrant, and a state endangered species that has been proposed for federal listing. Federal listing was warranted but precluded by other higher priority efforts to revise the Federal List of Threatened and Endangered Species in 2008. The Sacramento River is thought to be one of the major populations of Yellow-billed Cuckoos in California. Yellow-billed Cuckoos are very secretive and must be surveyed using tape playback methods (Halterman et al. 2010). Using playback methods it is possible to determine the number of territories occupied by Yellow-billed Cuckoos during the breeding season (roughly mid-June through mid-August).

3. What references support its use? Provide citations.

Gaines, D.A. and S.A. Laymon. 1984. Decline, status and preservation of the Yellow-billed Cuckoo in California. Western Birds 15:49-80.

Girvetz, E.H. and S.E. Greco. 2009**.** Multi-scale predictive habitat suitability modeling based on hierarchically delineated patches: an example for yellow-billed cuckoos nesting in riparian forests, California, USA. *Landscape Ecology* 24: 1315-1329.

Girvetz, E.H**.** and S.E. Greco. 2007**.** How to define a patch: a spatial model for hierarchically delineating organism-specific habitat patches. *Landscape Ecology* 22: 1131-1142

Halterman, M.D., D.S. Gilmer, S.A. Laymon, and G.A. Falxa. 2001. Status of the Yellow-billed Cuckoo in California: 1999-2000. Report to the USGS-BRD Dixon Field Station, 6924 Tremont Rd, Dixon, CA 95620.

Halterman, M.D., M.J. Johnson, and J.A. Holmes. 2010. Western Yellow-billed Cuckoo Natural History Summary and Survey Methodology. http://www.southernsierraresearch.org/cuckoo_methodology_May2010[1].pdf (accessed on Sept 3, 2010).

Hughes, J.M. 1999. Yellow-billed Cuckoo (*Coccyzus americanus*). *In* The Birds of North America, No. 148 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

4. Can it be a site-specific indicator to be used in comparing sites, or is it an indicator of the overall health of the river? At what scale is the indicator useful (e.g., site, reach, parcel, patch, whole river)?

This indicator is applicable at the stretch of Sacramento River between Red Bluff and Colusa.

Step 5

5. What cutoffs are appropriate for poor, fair, good and very good?

Very Good: >76 territories occupied
Good: 52-76 territories occupied
Fair: 25-51 territories occupied
Poor: <25 territories occupied

6. How were the particular rating cutoffs selected? Usually this is through consultation with experts (expert opinion), in which case the expert(s) should be listed. Other times cutoffs may come from quantitative goals listed in documents (e.g., recovery plans for endangered species), in which case complete citations should be provided.

Based on available survey data collected over multiple years on the Sacramento River between Red Bluff and Colusa, Girvetz and Greco (2009) developed a multi-scale hierarchical patch delineation method. They used this method to measure landscape patch characteristics at two distinct spatial scales ("super-patch" and "sub-patch") and statistically relate them to the presence of Yellow-billed Cuckoos occupying forest patches along the Sacramento River. For sub-patches they assumed that Cuckoos would not cross non-riparian gaps greater than 100 m because they had rarely been observed making larger crossings than that. For super-patches they assumed that Cuckoos would not cross gaps greater than 300 m because there had been a few limited observations of nesting cuckoos moving across ~250 m gaps to reach a nest site and 300 m was thought to be a potential upper limit. The sub-patch scale was more important than the super-patch scale; and based on delineating the habitat by sub-patches they determined that there were 102 suitable riparian sub-patches for Yellow-billed Cuckoos.

Based on a maximum of 102 sub-patches as potential Yellow-billed Cuckoo territories, we used cut-offs of 0-25% (poor), 26-50% (fair), 51-75% (good), and 76-100% (very good) to calculate rankings.

7. Are the methods for calculating the indicator described in published documents or reports? Provide citations. If not, who would be the best person to write these up?

Information on how 102 was identified as the maximum number of potential territories on the Sacramento River from Red Bluff to Colusa can be found in Girvetz and Greco (2009).

Girvetz, E.H. and S.E. Greco. 2009. Multi-scale predictive habitat suitability modeling based on hierarchically delineated patches: an example for yellow-billed cuckoos nesting in riparian forests, California, USA. *Landscape Ecology* 24: 1315-1329.

Step 6

8. What is the current indicator status? What is the month and year that this corresponds to?

The current indicator status is poor. PRBO has not yet analyzed data from the 2010 field season to provide the exact number of occupied territories in 2010, but we have determined that it will be less than 25.

9. What is the desired rating and by when should this be achieved?

The desired rating is good by 2015.

Step 7

10. Are there additional indicator values that have been calculated that correspond to the scale of reporting (parcel, reach, etc.)?

Girvetz and Greco (2009) reported that of the 102 sub-patches identified as suitable, 13-18 were occupied per year in 1987-1990, 23 were occupied in 1999, and 28 were occupied in 2000. Although this appears to indicate an increase, survey effort, survey methods, and survey interpretation varied considerably among years so no conclusions should be drawn at this time. Data from other sites (Colorado River) show that YBCU occupancy can be highly variable from year to year.

11. When were the data collected that yielded these other values? Describe the history of data collection.

Data were collected during 1987-1990 and 1999-2000.

12. Where were the current indicator data collected? And over what geographic area is the indicator presumed to be representative of?

The current indicator data were collected by PRBO at ~1500 survey locations in riparian habitat between Red Bluff and Colusa within 2km of the Sacramento River.

13. What is the source of the current indicator data? Who is the contact person? Provide contact info.

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14. What is the rationale for the desired rating?

Given that additional riparian areas have been restored in the past, that past restorations have matured, and that additional areas continued to be restored, it is desirable to aim for >52 occupied territories.

Step 8

15. Provide any other useful comments (to do items, unresolved issues, alternative indicators, etc).

Dr. Murrelet Halterman collected the Yellow-billed Cuckoo data in 1987-1990 and 1999-2000 along the Sacramento River; she is currently the Cuckoo Project Director for the Southern Sierra Research Station. She was contacted in developing this scorecard indicator and concurs with the ranking and rationale.

From Girvetz and Greco (2009):
For the Yellow-billed Cuckoo, the area of cottonwood forest measured at the sub-patch scale was found to be the most important factor determining the presence of nesting in forest patches. The average size of Yellow-billed Cuckoo occupied sub-patches was 59 ha, ranging from 6 to 269 ha. These patches contained an average of 31 ha (range of 1–142 ha) of mixed riparian forest, 15 ha (range of 0–72 ha) of cottonwood forest, 2 ha (range of 0–15 ha) of open water, and had an average thickness of 233 m (range of 84–517 m). The sub-patches were allowed to include gaps of riparian habitat that were less than 100 m wide so the width or thickness of the sub-patch could include non-riparian areas that were less than 100 m wide.

The number of sub-patches calculated by Girvetz and Greco (2009) was based on aerial imagery collected in 1997 and 1999. It would be good to update the calculation of potential sub-patches based on more recent imagery data.

Appendix 3. Summary of indicator results partitioned into six topical categories. The trend column indicates whether or not the observed results suggest a favorable change over time. A "+" indicates positive result, a "-" indicates a negative result, and a "0" indicates no difference. Multiple symbols are used to indicate strong or mixed results. Information on each indicator, including *definition, rationale, methods, results* and *interpretations* is provided in Appendix 1.

RIPARIAN HABITATS

Ecological Indicators	Geographic Study Area	Temporal Horizon	Results	Data Source & Citation(s)	Trend
Forest Edge Contrast	Riparian zone between Red Bluff and Colusa	1997 and 2007	48% increase	Schott and Shilling (unpublished)	-
Forest Patch Proximity	Riparian zone between Red Bluff and Colusa	1997 and 2007	1,215% increase	Schott and Shilling (unpublished)	+
Forest Patch Core Size	Riparian zone between Red Bluff and Colusa	1997 and 2007	610% increase	Schott and Shilling (unpublished)	++
Percent of Historical Riparian Zone Currently in Conservation Ownership	Riparian zone between Red Bluff and Colusa	1999 and 2007	35-43% increase	Golet and Paine (unpublished)	++
Percent of Historical Riparian Zone Currently in Natural Habitat	Riparian zone between Red Bluff and Colusa	1999 and 2007	11% increase	Golet and Paine (unpublished)	+
Percent of Riparian Shoreline Bordered by >500 Meters of Natural Habitat	Shoreline between Red Bluff and Colusa	1999 and 2007	43% increase	Golet and Paine (unpublished)	++
Number of In-channel Large Woody Debris Aggregations	Main river channel between Red Bluff and Colusa	1999 and 2007	48% decrease*	Golet and Paine (unpublished)	- -
Soil Organic Carbon	Restoration and remnant sites of varying ages	All four seasons 2000 - 2001	Increasing with age since restoration	Brown and Wood (2002)	+
Overall					**+**

**Large amount of LWD in the river in 1999 may be a consequence of the high flows in 1997.*

NATIVE PLANT SPECIES AND COMMUNITIES

Ecological Indicators	Geographic Study Area	Temporal Horizon	Results	Data Source & Citation(s)	Trend
Amount of Vegetation in Various Categories	Riparian zone between Red Bluff and Colusa	1999 and 2007	Natural vegetation cover increased by ≥16%	Nelson et al. 2008	+
			Non-native cover increased (giant reed by 11%, water primrose by 14%, and Himalayan Blackberry by 37%)		-
Basal Area of Woody Species	Restoration and remnant sites of varying ages	2003 and 2008	95% increase over 5 yrs	Wood (unpublished)	++
Frequency of Woody Species in Various Size Classes	Restoration and remnant sites of varying ages	2002, 2003, 2006 and 2008	Distributions among size classes are becoming similar between restoration sites and remnant habitats	Wood (unpublished)	+
Importance Value of Woody Species	Restoration and remnant sites of varying ages	2003 and 2008	At restoration sites: Increases in coyote brush (198%), box elder (47%), valley oak (12%), and Gooddings black willow (7%)	Wood (unpublished)	+
			Decreases in arroyo willow (6%), blue elderberry (21%), Fremont cottonwood (4%) and western sycamore (20%)		-
Native Understory Frequency of Occurrence	Restoration and remnant sites of varying ages	2001 and 2007	8% increase at restoration sites	Holl and Crone 2004, McClain et al. 2011	+
			Values still far below remnant		0
Native Understory Species Richness	Restoration and remnant sites of varying ages	2001 and 2007	2 species increase at restoration sites	Holl and Crone 2004, McClain et al. 2011	+
			Values still far below remnant		0
Overall					**+**

INVASIVE RIPARIAN AND MARSH PLANTS

Ecological Indicators	Geographic Study Area	Temporal Horizon	Results	Data Source & Citation(s)	Trend
Area of Giant Reed	Riparian zone between Red Bluff and Colusa	1999 and 2007	11% increase	Nelson et al. 2008	-
Area of Himalayan Blackberry	Riparian zone between Red Bluff and Colusa	1999 and 2007	37% increase	Nelson et al. 2008	- -
Area of Water Primrose	Riparian zone between Red Bluff and Colusa	1999 and 2007	14% increase	Nelson et al. 2008	-
Importance Value of Black Walnut	Restoration and remnant sites of varying ages	2003 and 2008	50% increase at restoration sites, but value still very low	Wood (unpublished)	-
Relative Native Understory Cover	Restoration and remnant sites of varying ages	2001 and 2007	12% increase at restoration sites Values still far below remnant	Holl and Crone 2004, McClain et al. 2011	+
Overall					**-**

BIRDS AND OTHER WILDLIFE

Ecological Indicators	Geographic Study Area	Temporal Horizon	Results	Data Source & Citation(s)	Trend
Nest Survival of Black-headed Grosbeak, Lazuli Bunting and Spotted Towhee	Restoration and remnant sites of varying ages	1993 - 1999 for Lazuli Bunting; 1994 - 2003 for other species	Similar for all species at restored and remnant sites, but relatively low overall, especially for Lazuli Bunting (6%)	PRBO Conservation Science, Golet et al. 2008	+
Adult Survival of Black-headed Grosbeak and Spotted Towhee	Restoration and remnant sites of varying ages	1995 - 2000	Somewhat lower for both species at restoration sites than remnant sites	Gardali and Nur 2006	-
Landbird Species Richness	Restoration and remnant sites of varying ages	1993 - 2003	Species richness increased dramatically as restoration sites matured, approaching levels at remnant sites	PRBO Conservation Science, Golet et al. 2008	++

Abundance of Black-headed Grosbeak, Common Yellowthroat, Spotted Towhee, Yellow Warbler, and Yellow-breasted Chat	Restoration and remnant sites of varying ages	1993 - 2003	Abundance increased dramatically as restoration sites matured, approaching levels at remnant sites	Gardali et al. 2006	++
Number of Occupied Yellow-billed Cuckoo Territories	Suitable breeding sites between Red Bluff and Colusa	2000 and 2011	Population appears to have declined	Dettling and Howell 2011	-
Number of Bank Swallow Burrows	Mainstem river between Red Bluff and Colusa	1999 - 2010, excluding 2006	34% decrease from 2009, 14 % decrease from 3-yr running average, pronounced decline over period of record	Silveira et al. 2011	- -
Number of Bank Swallow Colonies	Mainstem river between Red Bluff and Colusa	1999 - 2010, excluding 2006	21% decrease from 2009, variable overall	Silveira et al. 2011	0/-
Number of VELB Exit Holes per Shrub	Restoration sites of varying ages	2003	Older restoration sites had higher levels of VELB occupancy than younger sites	River Partners 2003	++
Bee Species Richness	8-yr old restoration sites and remnant habitats	February - August 2003	Restoration sites had similar (7% lower) richness to remnant riparian sites	Williams 2010	+
Bee Abundance	8-yr old restoration sites and remnant habitats	February - August 2003	Restoration sites had similar (26% higher) abundance to remnant riparian sites	Williams 2010	+
Beetle Species Richness	Young restoration, older restoration and remnant habitat	December 2000 - November 2001	Remnant habitats had the most species and were more similar to older restoration sites than young sites	Hunt 2004; Golet et al. 2008	+
Bat Abundance	Orchards, young and older restoration sites, and remnant habitats	September - October 2002	Older restoration site had more bats than the newly planted site	Stillwater Sciences et al. 2003, Golet et al. 2008	+
Overall					**0/+**

STREAMFLOWS AND FLOOD PROCESSES

Ecological Indicators	Geographic Study Area	Temporal Horizon	Results	Data Source & Citation(s)	Trend
Average Number of Days per Year with Bed Mobilizing Flows	Middle Sacramento River	1892 - 2010	Reduced by 9% relative to pre-dam conditions	Kondolf (unpublished)	-
Average Number of Years when Flows were Insufficient to Mobilize the Bed	Middle Sacramento River	1892 - 2010	Increased by 133% relative to pre-dam conditions	Kondolf (unpublished)	- -
Average Number of Days per Year with Floodplain Inundation	Middle Sacramento River	1892 - 2010	Reduced by 41% relative to pre-dam conditions	Kondolf (unpublished)	- -
Average Number of Years when Flows were Insufficient to Inundate the Floodplain	Middle Sacramento River	1892 - 2010	Increased by 129% relative to pre-dam conditions	Kondolf (unpublished)	- -
Average Number of Days with Flows Sufficient to Connect the Highest Elevation Side Channels	Middle Sacramento River	1892 - 2010	Reduced relative to pre-dam conditions	Kondolf (unpublished)	-
Average Number of Days with Flows Sufficient to Connect the Middle Elevation Side Channels	Middle Sacramento River	1892 - 2010	Reduced relative to pre-dam conditions	Kondolf (unpublished)	-
Average Number of Days with Flows Sufficient to Connect the Lowest Elevation Side Channels	Middle Sacramento River	1892 - 2010	Greatly increased relative to pre-dam conditions	Kondolf (unpublished)	- -
Overall					**- -**

RIVER PLANFORM AND GEOMORPHIC PROCESSES

Ecological Indicators	Geographic Study Area	Temporal Horizon	Results	Data Source & Citation(s)	Trend
Area of Floodplain Reworked	Riparian zone between Red Bluff and Colusa	1906 - 2007	Highly variable, but declining	Larsen (unpublished)	-
Length of Bank with Riprap	Main river channel between Red Bluff and Colusa	1936 - 2002	Dramatic increase over time especially since the 1960s	Henderson (unpublished)	- -
Length of River with Conservation Ownership on Both Banks	Main river channel between Red Bluff and Colusa	1999 and 2007	>71% increase	Golet and Paine (unpublished)	+
Whole River Sinuosity	Main river channel between Red Bluff and Colusa	1906 - 2007	Relatively slight, but steady decrease over time	Larsen (unpublished)	-
Average Bend Entrance Angle	Main river channel between Red Bluff and Colusa	1906 - 2007	Variable, but declining	Larsen (unpublished)	-
Total Channel Length	Main river channel between Red Bluff and Colusa	1906 - 2007	Progressive decrease over time	Larsen (unpublished)	-
Overall					**- -**