Ecosystem Restoration: Sacramento River Processes

The Middle and Upper Sacramento River Riparian Ecosystem

The Middle and Upper Sacramento riparian zone is created by the river's dynamic geomorphic and hydrologic processes. This unique ecosystem includes water-edge habitat, rich species diversity, and a complex and productive food web. Characteristic habitats include woodlands in various successional stages; gravel bars and shaded riverine habitat for salmon; eroded bank channels for nesting swallows; and sheltered wetlands such as sloughs, side channels, and oxbow lakes for other native species.

Active riverine processes create and maintain these riparian habitats. Such processes include water flow, erosion/deposition, lateral channel migration, and ecological succession. River meandering (i.e., lateral migration of the channel) and avulsion (i.e. channel cut-off) create a mosaic of landscapes and vegetative diversity that is key to the wildlife habitat value of the system. The ability of the river to meander, avulse, and generate new floodplain surfaces is crucial to supporting diverse riparian habitats and healthy populations of riparian-dependent species, and is therefore the basis of many metrics used as indicators of ecosystem health.

Meandering portions of the Sacramento River, particularly through the Red Bluff to Colusa reach, demonstrate the role of such processes in establishing riparian vegetation. On floodplains created by a meandering channel, one plant community typically replaces another over time. This biological process is dependent on sediment erosion and deposition and therefore on sediment mobilization and transport. Ecological succession typically starts where cottonwood and willow seeds germinate on a newly formed sandbar, resulting in a band of young trees. Once the stand is established, growth is rapid as trees develop root systems to withstand the next flood disturbance. Eventually, as this is repeated year after year, the emerging forest develops a gradient in height and age. Typically, older growth riparian habitat (usually dominated by mature cottonwood forest, black walnut, Oregon ash, and/or valley oaks) supports high biodiversity and offers critical habitat for sensitive wildlife species. Recent studies also document backwater slough areas and their associated vegetation communities as ecologically diverse areas.

Threats to the Middle and Upper Sacramento River Riparian Ecosystem

Since the second half of the 19th century, rapid development of the Sacramento Valley and human land uses have changed much of the floodplain. In the last 150 years, agricultural conversion has been the primary factor eliminating riparian habitat. Other land use activities and water development projects have altered the riparian system and contributed to vegetation loss. Such activities include timber and fuel harvesting, channelization, dam and levee construction, bank protection, and streamflow regulation.

Despite historical impacts and on-going urbanization, conversion of habitat to agriculture has slowed, with the result that a number of native species populations (e.g., salmon, nesting bank swallow, yellow-billed cuckoo) still inhabit portions of the Middle and Upper Sacramento River. Although the viability of these habitats and species populations is unknown at this time, current conservation and restoration efforts seek to improve the ecological condition of the floodplain. The future success of complex native forest regeneration, however, appears uncertain and disappointing. Since the development of the Shasta Dam, forest succession and re-growth appear hindered by modified hydrology patterns. Additional information is needed to further identify why the riparian forests may be regenerating less frequently. However, preliminary studies

identify hydrological alterations and bank protection (e.g., levees, armoring) as likely causes, similar to many regulated rivers throughout the west.

Restoration Activities

The Department of Water Resources (DWR), the Sacramento River Conservation Area Forum (SRCAF), the United States Fish and Wildlife Service (USFWS), the Department of Fish and Game (DFG), the Department of Parks and Recreation, the Wildlife Conservation Board (WCB), nonprofit organizations such as The Nature Conservancy and the Sacramento River Partners, and many other stakeholders conduct conservation and restoration activities in the Middle and Upper Sacramento River. The SRCAF developed guidelines for all stakeholders to follow in directing their actions. These guidelines "ensure that riparian habitat management along the river addresses the dynamics of the riparian ecosystem and the reality of the local agricultural economy." SRCAF goals include preserving remaining riparian habitat and reestablishing a continuous riparian ecosystem along the river.

Restoration activities generally fall into one of two categories:

- Actions aimed to protect and maintain existing healthy habitat and natural processes
- Actions aimed to restore and recover lost habitat and disrupted processes.

The SRCAF recommends preserving existing riparian habitat and reestablishing a continuous band of riparian vegetation along the river. Most conservation actions to date further this goal and were initiated to first offset habitat fragmentation as a significant threat to declining populations. The most flood-prone areas, with less productive soils and more rapid bank erosion were restored first. These parcels were where the first willing sellers occurred and the program moves forward only when willing sellers are available. CALFED has funded many of the conservation acquisitions in the last 5 years.

Now, many of the stakeholders involved see habitat restoration as a viable conservation strategy. Recent studies, funded by CALFED, now document listed species utilizing these restored habitats, and increases in ecosystem diversity as restoration sites mature. Although measuring success of these sites is a complex challenge, a number of ecosystem components are utilized to do so. So far, these include bird populations, indicators of soil development, terrestrial invertebrate populations, and bat populations.

A significant shift is now underway to focus more on protection and restoration of the processes that create and maintain the mosaic of riparian habitat. Additional studies, also funded by CALFED, have been initiated to direct this focus. These studies are geared towards generating information about river process and in-channel habitats. These include an evaluation of juvenile salmonid use of different habitat types, oxbow slough evolution, isotope tracing for anthropogenic sources of nutrients, macroinvertebrate population dynamics, studies of meander migration and forest evolution, and riparian community dynamics (rates of change, and successional trajectories). Recent conservation efforts have also increased in scale and scope to restore flooplain and channel connectivity. Extensive meetings and discussion with stakeholders, advanced hydraulic modeling, and geo-technical investigations are used to evaluate projects that can be implemented over many miles along the river and encompass the floofplain as a management unit. These projects include setback levees, and levee removal, in conjunction with revegetation efforts, to develop conservation strategies that are in line with flood damage reduction concerns.

Potential Indicators

California researchers do not yet endorse standard metrics or data collection methodology to assess Middle and Upper Sacramento riparian habitat health, but several initiatives are underway. Multiple institutions, some with restoration projects supported by CALFED funding, monitor the Middle and Upper Sacramento River. Some institutions have submitted 2002 CALFED proposals to further assess how river meandering affects habitat, species, and other ecological indicators. Researchers at the University of California and Point Reyes Bird Observatory have developed innovative models to directly and indirectly predict Sacramento River health (see Technical Notes for additional information). In addition, another proposal seeks to evaluate linkages between the flow regime and ecosystem function to inform management decisions in the future. Information generated from a series of field studies would be captured in a decision analysis framework to initiate a comprehensive evaluation of river system function.

Two research groups, DWR and the Service, lead indicator initiatives by measuring habitat health with mapping efforts and geographical information systems (GIS) analysis. For example, within the next few months, SRCA and DWR anticipate publishing rocked bank inventories, an initiative to quantitatively measure and monitor bank characteristics and river health. DWR and the Service both measure the amount of Middle and Upper Sacramento River bank that is free to meander, but their data collection and reporting processes lack standardization. In other words, quantitative information about Middle and Upper Sacramento River habitats exist in raw GIS format, but deciphering what "big-picture" habitat ecological indicators reveal about the ecosystem requires additional data analysis, consolidation, and interpretation.

An additional challenge is to see these studies incorporated into management actions. In early 2003, the Nature Conservancy, USFWS, DF&G, and the WCB expect to release a joint report summarizing a wide range of recent studies conducted between Red Bluff and Colusa. Studies summarized include hydraulic modeling, a geo-technical investigation, a public use and access study, a cultural resources study, a study evaluating riparian forest recruitment mechanisms, a meander migration study, and a study evaluating potential indicators of ecosystem function. These studies were undertaken to inform management decisions of all of the conservation stewards in the area. The report will be integrated, and has already informed other planning efforts among the partner agencies such as the DF&G planning process, the USFWS Comprehensive Conservation Planning process, and the Army Corps of Engineers Sacramento and San Joaquin River Basin Comprehensive Study.

Monitoring and data integration have not yet progressed enough to quantitatively track trends in Middle and Upper Sacramento River habitat. It is clear, however, that a spatial and temporal assessment of ecosystem characteristics and habitat health requires a suite of ecological indicators, rather than one metric. Characteristic metrics with potential for further development as quantitative indicators include:

Potential Indicator	Process Targeted	Status/ Notes
Ecosystem Scorecard	water flow, erosion/deposition, lateral channel migration, and ecological succession	Currently under development by the Nature Conservancy at their Cosumnes and Sacramento River projects. Measures ecosystem responses to restoration measures.
Fluvial geomorphic	water flow, erosion/deposition,	Difficult to measure. Generally, the more complex the river hydraulic diversity, the

characteristics	lateral channel migration	healthier the ecosystem.
Forest regeneration and rates and trajectories of succession	water flow, erosion/deposition, lateral channel migration, and ecological succession	Appears in decline. More data are needed, but may be correlated with anthropogenic hydrologic changes and bank protection.
Large woody debris (LWD) habitat	water flow, erosion/deposition, lateral channel migration, and ecological succession	Important habitat to adult and juvenile salmon. Difficult to measure (requires manual ground visits for verification). Standardized inter-agency methodologies do not yet exist.
Linear feet of retired non-critical bank stabilization relative to total channel area	water flow, erosion/deposition, lateral channel migration	DWR measures bank features, including man-made "rocked bank." Quantitative numbers should be available in a soon-to-be-published DWR report.
Neotropical bird populations and habitat	erosion/deposition, lateral channel migration	Nesting bank swallow and yellow-billed cuckoo populations rely on specific riverine habitat types to support nesting activities.
Recruitment of gravel	water flow, erosion/deposition, lateral channel migration	Important spawning habitat for salmon. Correlated with bank erosion and the potential for channel meandering.
Shaded riverine aquatic (SRA) habitat	water flow, erosion/deposition	Important habitat for juvenile salmon and ecosystem health.

Technical Note: Sacramento River Processes

The metrics

Ecosystem Scorecard: A Nature Conservancy project on the Cosumnes River currently serves as a test site for developing an ecosystem scorecard. Ideally, this scorecard will measure habitat and species responses to restoration measures. The Nature Conservancy does have pilot parameters, metrics, and targets. Moreover, concrete goals have been identified with measurable indicators of "good," "medium," or "high" success (based on actual numbers and their relationships to restoration targets).

The Nature Conservancy is developing a similar scorecard evaluation framework for the Sacramento River, but additional challenges exist. Relative to the Cosumnes River, the Sacramento River system is larger with more complex upstream influences. A table of goals, parameters, metrics, and targets do not yet exist for the Sacramento River.

Fluvial Geomorphic Characteristics: Fluvial geomorphic characteristics reveal information about river hydraulic diversity and complexity, but are difficult to measure. Bathymetric surveys offer the most practical methodology to collect fluvial geomorphic information. Typically, the greater the river diversity and complexity, the healthier the ecosystem.

Several standard and non-standard geomorphic measurements also hold promise as meaningful indicators of ecosystem health. Baseline measurements for sinuosity, average depth, width, and slope by reach already exist. The tracking of these parameters over time should allow for the detection of specific fluvial geomorphic trends. Additionally, area of land re-worked (new surfaces created by river meandering) and point bar characteristics such as area, slope, and texture have been added to the standard suite of geomorphic measurements on the Sacramento River.

Hydrologic Characteristics: Many methodologies and unlimited parameters exist to measure and present flow spatial and temporal changes. In 2001, DWR initiated the use of Indicators of Hydraulic Alteration (IHA) as a standardized methodology for this purpose on the Sacramento River. IHA offers a statistical analysis methodology that provides numerical and graphical outputs to generate a suite of standard hydrologic statistics that measure spatial and temporal hydraulic changes.

Flow requirements based on ecosystem needs may offer specific ecological indicator for fisheries and habitat health. Typically, the greater the flow, the healthier the environment and salmon escapement. With increased water flows, migrating salmon are more likely to survive and reproduce due to the benefits of lower water temperatures, reduced predation, and improved health. More challenging questions arise, however, when assessing how flow regimes allow for the regeneration of riparian forest. Researchers may look towards flow as an ecosystem indictor, but this remains an area of active research on the Sacramento River.

Forest Regeneration and Succession: Ecological indicators must assess more than historical and present conditions by also addressing forest succession. This is also important because current river restoration activities and meandering conditions do not generate a lot of new habitat area. Rather, the habitat areas undergo continuous dynamic cycling. Therefore, the successional nature of forest regeneration becomes especially important.

Unfortunately, the Middle and Upper Sacramento River riparian appears in decline. Some sensitive plant communities associated with the Sacramento River have declined in acreage and are considered rare, including the rose mallow (California hibiscus) and the silky cryptantha. The system fails to regenerate its native and complex forest habitats. Many old trees continue to grow in the Middle and Upper Sacramento River area, but new trees fail to establish themselves. More data are needed, but it appears that the failure of forest regeneration is linked to hydrologic changes. Noticeable successional failures in the riparian forests appeared after Shasta Dam development. Hypotheses speculate that the successional ecological changes are related to hydrologic changes, but the relationship is not yet understood. DWR's IHA initiative offers the first potential standardized suite to relate the hydrology, biology, and ecology using standardized metrics. If successful, IHA should integrate hydraulic parameters and ecosystem function into one comprehensive framework that generates a suite of standard statistics.

The California State University, Chico – Geographic Information Center has completed riparian vegetation surveys and GIS coverages of vegetation communities along the Sacramento River over the past decade. The continuation of this work coupled with forest demographic surveys would provide much of the data needed to assess forest health.

Large Woody Debris (LWD) Habitat: LWD is also important habitat to adult and juvenile salmon. The Service maps and quantifies LWD in the Middle and Upper Sacramento River by examining debris contents, debris potential, and how debris moves within the river. The Service and DWR also quantify the number of snags and their locations in the river, but lack standard acceptable methodologies. Typically, the agencies take aerial photographs and then verify the information through manual ground visits.

Linear Feet of Retired Non-Critical Bank Stabilization: Over the past several years, DWR has conducted several inventories of "rocked bank." These findings and results from the rocked bank inventories are not yet available. DWR should publish its report in the next few months. A standardized methodology developed by USFWS and DWR has been distributed. In parts of the Sacramento River, one half of the outsides of bends have been rocked.

Neotropical Bird Populations and Habitat: Neotropical bird populations and nesting habitat perhaps offer the best ecological measure to reveal habitat health in the Middle and Upper Sacramento River. Two species of particular importance, the nesting bank swallow and yellow-billed cuckoo, have unique ties to the riparian system. Monitoring institutions conducting nesting bank swallow and yellow-billed cuckoo assessments include DFG, the Service, Nature Conservancy, and PRBO. Standardized bird population monitoring methodology does exist, so comparative population studies can help to draw conclusions about habitat types, acreage area, and the adequacy of existing habitat to support nesting activities.

Bank swallows require eroded bank to nest and, therefore, may serve as an indicator species for river habitat. Therefore, the availability of bank swallow nesting habitat reflects the river's ability to meander and create new surfaces. DFG surveys bank swallow populations, inventories habitat, maps habitat, and identifies potential habitat for future swallow nesting locations. The bank swallow metric can be interpreted to indicate high-priority conservation areas and restoration habitat targets.

Yellow-billed cuckoos need a mixed mosaic of old growth and edge forest habitat, and are therefore closely tied to ecosystem dynamics. Yellow-billed cuckoos and other medium to small-bodied land birds are often associated with the great valley cottonwood riparian forest community

during the spring and summer. UC Davis graduate students developed a quantified yellow-billed cuckoo model to quantify Sacramento River populations.

Recruitment of Gravel: Gravel recruitment and suitability as salmon-spawning substrate serves as a potential indicator of ecosystem health. Because 85% if gravel in the Middle Sacramento River comes from bank erosion, measuring gravel directly can indicate the availability of eroded bank and a healthy meandering river system. Gravel measuring includes sampling for coarseness, distribution, and other geological traits. Gravel recruitment indicators do not offer spatial references, so a complementary study with additional visual mapping potential may involve the mapping of salmon redds. In the future, the California Department of Fish and Game (DFG) could use aerial photography surveys north of the Red Bluff diversion dam to quantify and locate salmon spawning habitat in the Middle and Upper Sacramento River. This potential indicator would likely serve as an ecological indicator for salmon populations.

Shaded Riverine Aquatic (SRA) Habitat: SRA acts as ecological indicator habitat that, by legal definition, serves a specific function for juvenile salmon and ecosystem health. Unlike some other habitat types, however, SRA has a functional definition that spans numerous ecosystem types. This makes SRA difficult to identify and measure with traditional mapping techniques, such as GPS images. Identifying and quantifying SRA requires technical knowledge and expert judgment. Because of these complexities involved, DWR does not actively measure SRA but will note SRA locations and area sizes, if known. The Service currently conducts site-by-site assessments of SRA.

Longer-term science needs and recommendations

Current restoration recommendations include:

- Standardizing data collection and reporting methodologies.
- Establishing baseline information about ecosystem processes and habitat.
- Restoring physical and successional processes.
- Conduct reforestation activities.
- Allowing riparian forests to reach maturity.
- Develop quantifiable models of ecosystem processes and function.

To maximize their effectiveness, ecological indicators require standardizing methodology, integrated research results, and a framework for assessment. To understand habitat dynamics, researchers must identify and agree on comprehensive, integrated, and standardized quantitative baseline information for historical riparian habitat in the Upper Sacramento River. With such standardized methodologies and baseline data, researchers may then have sufficient information to use ecological indicators and physical processes to prioritize habitat restoration activities and to create or maintain richness, diversity, and continuity of the riparian forest ecosystem.