Restoring, managing and monitoring

Restoration

Plans for Laguna restoration always provoke the question: What ecological condition or time period should the Laguna be restored to? The Laguna watershed—its plants and animals, stream channels, woods and fields—has gone through many changes over time. Each new generation and each different community applies different values: Pomo, Miwok and Wappo; ranchers and farmers; urban and rural dwellers. Each hold their own land ethic. In the present day, the watershed is marked by changed hydrologic patterns, declining native wildlife and plants, invasive species and pollution. While people may differ over what the Laguna should look like, there is wide agreement on the need to restore it to health. Restoration ecology, as a science and practice, has moved away from attempts to recreate historical states, and seeks instead to restore environmental function. The underlying philosophy is pragmatic, as well as aesthetic and ethical. Natural environments provide *ecosystem services*—cleaning the air and water, moderating flooding, and supporting diverse plant and animal communities that naturally control pests and pollinate crops—and bring beauty and meaning to our lives. These services have incalculable value.

Ecosystem services

Although restoration does not seek to recreate historical landscapes, restoration planning is guided by historical ecology. The best evidence for what will form healthy, functional communities in the future, are records of what combinations of plants, animals and hydrologic patterns were successful in the past, together with the examples provided by intact, nearby *reference systems*. From a scientific context, restoration is a process of managed ecological succession. In time, the Laguna will "restore" itself: trees will grow, wetlands will rise or fall to a level of equilibrium, and channels will find their own meandering pathways. However, in degraded systems, natural succession (also known as *passive restoration*) can take much longer to restore a diverse plant and animal community. Often there are few parent plants to provide the seeds for the new generation. Seedlings may

Reference systems

Passive restoration

have difficulty competing with densely growing invasives like perennial pepperweed, *Ludwigia* or *Arundo*, the giant reed. Restoration practitioners seek to accelerate and direct natural succession so that as the plant community matures it supports the greatest number of environmental objectives in the shortest period of time. True restoration is not simply restoring community composition, but restoring natural processes that support the community composition over the long term.

Restoration of the Laguna is thus forward thinking—contributing to a sustainable future within the context of human-structured landscapes, while using knowledge of the Laguna's history to design long-lasting solutions. This restoration is most effective if it takes a watershed approach. For example, restoration plans for each reach of channel or wetland must consider how these areas are affected by conditions upstream, and in turn, how the restoration will influence the environment lower down in the watershed. Restoration does not mean abandoning farms and replanting ballparks, but working steadily and strategically, focusing efforts where they will have the greatest environmental effect. Restoration can often improve the quality of agricultural lands by stabilizing stream banks, topsoil and hillsides; and support a vibrant economy by enhancing the beauty of the landscape, reducing pollution and flood damage.

Restoration can improve agricultural lands

One of the underlying objectives of restoration science is to improve the health of ecosystems in ways that are fully self-sustaining, and that require progressively less maintenance as they mature. This could have been possible in a simpler system, without continuous disturbance from external forces such as high nutrients, weed introductions, and erosion along road-cuts baring new soil. However, the Laguna ecosystem has been very strongly altered and structured to accommodate human needs, and restoration is still a young science. We want many things from our environment—resources, biodiversity, ecosystem services, beauty, health, agriculture and other aspects of a vibrant economy—finding the balance will be an ongoing process and will take long-term commitments to land management.

Resources, biodiversity, ecosystem services, beauty, health, agriculture

Management

It is sometimes difficult to say where restoration leaves off and management begins. If restoration both expedites and directs ecological succession, management keeps succession on track and greases the wheels. According to the Society for Ecological Restoration, "ecological restoration makes ecosystems whole again and ecological management keeps them whole."

Keeping ecosystems whole

In truth, the distinction is somewhat artificial. At what point in time do we say an ecosystem is "made whole?" Restoration activities are intergraded with management activities as joint, ongoing processes. Nurturing oak seedlings for several years after planting is part of the restoration process, but over time, such care is called management. Both restoration and management are expressions of land stewardship—how we care for public and private lands in the watershed.

Land stewardship

Management shapes the landscape. Before Mexican and American settlement, indigenous peoples are thought to have managed the Laguna watershed to increase fruit, nut, seed and root harvests. Wetlands were likely managed for better harvests of basketry and home building materials. Later settlers managed Laguna lands for cattle and sheep ranching and wheat and corn production. Each generation demands new things from the Laguna. The present goal is to bring back wildlife and restored landscapes, along with other environmental values and functions, while supporting the human needs. This requires extensive coordination and cooperation among land managers—in essence, being good neighbors.

Collaborative agreements are an important part of the management program; they seek to ensure that the actions and objectives of different land managers support one another. For example, this is clearly true for wildlife corridors that transect the valley, as animals move from uplands to wetlands with the changing seasons; and also with invasive species, as weeds spread readily across property boundaries. Controlling erosion on hill slopes helps sediment management and flood protection downstream. The Santa Rosa Plain Conservation Strategy for CTS and other listed species will require elaborate planning and management agreements between a variety of public and private landowners. Like restoration, management requires adequate funding, and long-term commitments.

Collaborative agreements support land managers

Adaptive management is a conceptual framework that allows restoration and management efforts to proceed under conditions of uncertainty. It is a formal commitment to continually refine plans and practices in a way that is progressively self-correcting. After establishing objectives and priorities based on the needs and resources of a specific site, a restoration and management plan is developed to reflect site-specific conditions. The plan is put into action along with a monitoring program to evaluate the effectiveness of management activities. As new information comes in, the plan is adapted and fine-tuned to reflect changing conditions and new information. Monitoring informs land managers how the system is changing, and experiments are devised to provide information on why it is changing and suggest new management directions. Whenever possible,

Proceeding under conditions of uncertainty

restoration and management actions should include an experimental or research component, to evaluate the effectiveness of particular actions, look for unintended consequences, and test alternative techniques or hypotheses. This is especially important where management is geared toward only one or a small number of species: for example, CTS recovery or *Ludwigia* control. Normally though, a single-species focus is only appropriate under special circumstances; overall it is best to take a holistic approach to watershed restoration.

Volunteers and citizen groups

Active land management provides eyes-on-the-ground to identify environmental issues as they arise. Volunteer creek stewards and citizen groups can play an important role, adopting creek channels or natural areas and regularly monitoring water quality, bank stability, the presence of weeds and the use of the area by wildlife. Land management also includes stewardship activities like trash pick-up from trails and stream channels, fence repair, and monitoring for illegal activities and camping.

Reauthorization of the SCAPOSD sales tax

Some management activities are much easier to accomplish on public lands. Conservation easements can contain agreements to perform certain management activities, but if the property changes hands, the new owner may be reluctant to honor these agreements. Enforcement in these cases is usually limited to litigation, which can be lengthy and expensive. For this and other reasons, reauthorization of the SCAPOSD sales tax is essential to enable continued public acquisition of open space properties from willing landowners.

Restoration strategies

Certain restoration strategies apply broadly to the Laguna. A focus on native species, the habitats or *plant communities* that they occupy, and the goal of establishing ecosystem stability come first. The preservation of genetic diversity is an important component of this. Connectivity between high quality habitats and the availability of nearby complementary lands supports overall habitat health and viability. Finally, the precautionary principle needs to be applied when faced with uncertainty.

Native species, habitats and ecosystems

High habitat diversity

The Laguna watershed has high species diversity because it has high habitat diversity—grassland habitats, riparian habitats, wetland and aquatic habitats—overlaid by human-structured urban, ex-urban, and agricultural habitats. The term "habitat" usually refers to the physical and biologi-

cal context (often defined by distinct plant communities) that supports characteristic wildlife communities. Thus restoration practices focus on enhancing existing plant populations and supplementing those populations with missing but otherwise naturally occurring native plants and trees. Biological diversity is built on biological diversity. Where there are plant communities with large numbers of native species, there are healthy and diverse populations of animals and insects; likewise having a diverse community of native animal and insect species helps to maintain a diverse plant community. Plants support the animal food web, while herbivorous animals help keep overly dominant plants in check.

Biological diversity is built on biological diversity

Although no ecosystem can be considered truly stable, a bounded range of ecosystem stability is needed for sustaining human needs. Taken separately, many environmental functions are well supported by non-native plants and animals: for example, non-native trees can stabilize stream banks, and non-native grasses protect eroding hillsides. However, these non-natives often have less environmental value overall, because non-native plants tend to support fewer native animals. Stability is based on ecological feedbacks, and these feedbacks are more common among species that have evolved together over time. Without coevolved ecological relationships, non-native species are much more likely to become invasive and throw the ecosystem out of balance.

Ecological feedbacks establish stability

Restoration planning is most successful when designs and lists of species are based on natural reference systems and the historical ecology of the area. Ideally, these reference systems are nearby undisturbed sites that have the species composition and ecosystem functions the restoration project seeks to emulate. To be an appropriate reference, the site must have similar hydrology to the restoration area. In highly-altered systems like the Laguna de Santa Rosa wetlands and waterways it is sometimes a challenge to find good nearby references. Careful historical research may provide the best reference information. Sometimes it may be necessary to search for references in another watershed. In these cases restoration planning becomes as much an art as a science.

Restoration seeks to emulate reference systems

Genetic integrity

Native plant species are highly valued for restoration because they have closely coevolved ecological relationships with other native plants and animals, and because they have become adapted over millennia to the soils, climate, and other physical conditions of an ecosystem. But what is native? To a certain extent, this depends on species mobility and genetic mixing. Plants and animals that do not disperse well become strongly lo-

cally adapted, with their genetic code shaped to local conditions. Through natural selection, individuals that are better suited to the conditions of the Laguna watershed survive to reproduce and pass on their successful genes to offspring. Valley oaks grow throughout northern California, but Valley oaks that are adapted to the climate of the Central Valley may do poorly in comparison to those adapted to the Santa Rosa Plain. As a general rule, restoration projects should use locally derived sources of trees, grasses and other forbs.

Locally derived plant sources

There are caveats to this rule, especially because the conditions in the watershed are changing as a result of direct human influence and climate change. Oaks or other trees that were successfully adapted to historical conditions may not be best adapted to the current rainfall and nutrient regime. Also, restorationists can inadvertently reduce the genetic diversity of local stock if they collect and propagate plants from only a few parent individuals.

There are other exceptions to the rule too. In some cases, locally derived native seed may not be available for rare varieties—this has been a particular concern for restoring endangered vernal pool species. Severely degraded areas may benefit from the use of fast-growing non-native plants for erosion control. Restorationists and conservation biologists must work closely together to develop practices that support genetic integrity while promoting successful restoration projects.

Ideally, seed for restoration projects should be collected from a large number of parent individuals growing at a nearby reference site. If this is not possible, native seed or plants should be purchased from local native seed companies or nurseries. Careful records should be kept on the origin of all plant material used in restoration projects.

Collecting from different parents

Connectivity and complementary land uses

Habitat function depends on habitat connectivity: continuous riparian buffers protect channel banks and filter pollution; birds and wildlife need protected corridors to travel from the mountains to the floodplains; and fish need free passage in stream channels. A central goal of the Santa Rosa Plain Conservation Strategy for California tiger salamanders and vernal pool plants is to reduce habitat fragmentation and connect wetlands to upland areas. Restoration projects are usually initiated according to both need and opportunity, but whenever possible projects should be designed to form links between existing areas of habitat, thus increasing the size of large, contiguous habitat areas, or forming corridors between habitat patches. Larger preserves are easier to manage, and often provide higher

Forming corridors between habitat patches

quality habitat with less edge effects and lower rates of invasion by invasive species. Some species, like the yellow-billed cuckoo, depend on large blocks of habitat, and will never return to the Laguna until more riparian forest habitat is available. Occasionally, even when disconnected, small sites—like Cunningham Marsh—can be very important and valuable when they contain high quality habitat or very rare species.

The Laguna watershed will always be a patchwork of different land uses. Some lands will be restored to native habitats, some will be actively farmed, and some will be broken into urban and suburban landscapes. Many studies have shown that agricultural areas provide valuable buffers between preserve lands and developed areas. Backyards with ponds, and native landscaping can provide stepping-stone connectivity between habitat patches. Although there is much to be gained by moving forward with large-scale riparian and grassland restoration in natural areas, the value of these areas will be substantially enhanced by protecting the agricultural open space around them, and in educating the community about how to "restore" their own backyards.

Agricultural areas and backyards also connect habitats

Riparian forests and streams are natural corridors with a specially adapted plant community that tolerates flooding and favors wet soil. Animals move along these corridors from the hills to the wetlands and out to the greater Russian River watershed. Hedgerows are an analogous, domesticated version of riparian corridors, traditionally planted along property boundaries, roadsides, fence lines in upland areas. In Europe, hedgerows were planted with nuts and herbs and berries, growing semi-wildly, but harvested every year by rural residents. In recent years, there has been a resurgence of interest in hedgerows for their value to agriculture and wildlife. Planted with a mix of native and non-native (but non-invasive) trees, shrubs and herbaceous plants, hedgerows provide windbreaks, habitat for beneficial insects and birds, pollen and nectar sources. Like riparian buffers, they reduce runoff and non-point source pollution, and provide erosion control. Hedgerows increase the compatibility of land uses, as animals can move along hedgerow corridors through agricultural areas to wildlife preserves. The long-term sustainability of the Laguna ecosystem is enhanced with these kinds of mutually beneficial solutions.

Hedgerows

The precautionary principle

The precautionary principle is meant to be a general appeal to common sense for protecting human health and the environment, but has been variously used to defend both action and inaction in restoration efforts. On one hand, if you do not know the consequences of taking a particu-

lar action, the most precautionary approach is to avoid that action until the outcome is better understood. On the other hand, if inaction itself poses great risks, the most precautionary approach is to take preemptive steps even if the final outcome is unknown. Advocates opposing or supporting the use of herbicides to combat invasive weeds have each used different versions of the precautionary principle; and both can be justified, depending on the underlying philosophy of the advocate and their weighting of relative risks. Both versions have also been used to argue for or against actions relating to global warming. Principle 15 of the 1992 Rio Declaration on Environment and Development adopted by the United Nations Conference on Environment and Development (UNCED), takes a middle-of-the-road approach and affirms that: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." Although the precautionary principle may be too vague and ambiguous to use as a guiding philosophy, common sense, careful deliberation among diverse stakeholders, and application of the best available science can each contribute fundamentally to good restoration decisions.

Common sense

Management strategies

Most management strategies are specific to the habitats being managed, but some apply more broadly. The identification, control and monitoring of invasive species is one of these strategies, perhaps the most important. Another strategy, the development of streamlined permitting, can reduce the time and expense of project planning when many similar projects are in the pipeline. Sharing restoration successes, failures, and works-in-progress with fellow restorationists and the interested public can keep the community on track and energized; one possible way to do is through a *State of the Laguna* conference and report card.

Invasive species

Invasive plants are one of the greatest challenges to restoration success, and this challenge applies, in varying degrees, to all of the different Laguna habitat types. Invasives tend to be opportunistic, strongly-competitive species that have superior abilities for exploiting resources, such as high

nutrients and light, and expand in population to rapidly take up available space. Managing or controlling invasive species consumes valuable restoration time and money. While restoration itself can make an ecosystem less vulnerable to invasion, some invaders can exploit even healthy plant communities, especially those like riparian systems with naturally high disturbance rates. Invasive species control must be systematic and tenacious, with frequent re-treatment of infested areas. See chapter 5 for an in-depth discussion of these issues.

Streamlined permitting

Restoration and management of the greater Laguna de Santa Rosa watershed will require extensive sustained and coordinated efforts, and partnerships between private landowners and public agencies. In other watersheds, streamlined permitting by regulatory agencies has accelerated restoration and recovery efforts for individuals involved in such coordinated partnerships. This can take several forms. Sustainable Conservation, an environmental NGO, has developed a program called *Partners in Restoration*, through which all the regulatory agencies sign on to a set of restoration practices. Essentially, there is a general permit for the set of practices, and specific projects that conform to these practices can apply for coverage under the general permit. This program has been very useful in some watersheds, but can be time-intensive to establish. Another approach is to create large projects with many different implementation sites, and to take these, as a bundle, through a standard permitting process. The projects can be phased, so they do not all need to be funded or implemented simultaneously. CalTrans has taken this approach for permitting many small road improvement projects planned for a five-year period. In planning any restoration project, it is best to contact the regulatory agencies as early as possible. Ideally, NMFS, FWS, CDFG, USACE, and Sonoma County's PRMD will allow a streamlined permitting consultation process for sediment-control and other restoration projects in the watershed.

Partners in Restoration

State of the Laguna watershed conference

Restoration, management, and the research that supports them is strengthened and fed by communication and collaboration. Agencies and groups working separately from one another tend to duplicate efforts and in some cases the activities of one group may undermine the objectives of another. The Laguna is a complex, interlinked ecosystem. Grassland

ecologists should be in close contact with salamander biologists, ranchers, and restorationists working on vernal pools. Riparian restoration should involve water quality regulators, fisheries biologists, flood control engineers and hydrologists. All of this work needs the participation of the general public, and citizens of the watershed (either directly, or through tax dollars). To a large extent, recent advances in Laguna restoration and management have been the result of increased communication between groups. However, there is still a great need to broaden and sustain these communication channels as projects are initiated and completed; and with greater communication among groups it is easier to recognize opportunities for direct collaborations. In this era of tight government funding, collaborations are particularly important for leveraging available grants and funds, and piecing together local, state, federal and private restoration and research dollars.

Sustaining communication channels

The 1988 State of the Laguna Conference brought together researchers, regulators, agencies and naturalists to share concerns and raise local awareness about the Laguna ecosystem and watershed. This conference led to the establishment of the Laguna de Santa Rosa Foundation, and stimulated expansions in land preservation, species conservation, restoration and research on the Laguna ecosystem. Since that time, much has changed in the watershed, and restoration and research projects have accelerated. Reconvening a Laguna conference would provide an excellent platform to bring attention to recent progress, enhance communication, facilitate collaboration, and provoke considerable interest and enthusiasm for further restoration.

It would be appropriate to focus the next conference on the Laguna's many land uses and the need to discover fruitful areas for mutually-beneficial approaches to restoration, conservation, agriculture and development. Conferences might be held every two years: this would reinforce collaborations and keep all interested parties informed and energized.

Keeping interested parties energized

State of the Laguna report card

Nationwide, there has been increasing interest in developing *indicators* to describe the state of the environment. Indicators are common in economics, for example the Dow Jones Industiral Average or the Gross Domestic Product. As pollution-control regulations are implemented and substantial public funding is spent on restoration projects, citizens and policy makers will want to have simple ways to evaluate the success of these efforts. On a small scale, this can be accomplished with structured monitoring

programs, but to evaluate the health of an entire watershed or ecosystem requires more sophisticated indices (Heinz 2002).

Evaluating health through indices

In the past two decades, several large watersheds, including Chesapeake Bay, Santa Monica Bay and the San Francisco Bay, have begun successful large-scale restoration initiatives to improve the water quality in their streams, estuaries and beaches. In order to quantify the progress of these efforts, and inform and educate the public, the respective watershed groups have all developed "report cards," that track improvements in specific water quality and environmental indicators. Done properly, watershed report cards include careful baseline assessments of a range of indicators, and formal compilation of these data to develop indices for high-priority environmental areas. These reports have galvanized public interest and support for healthy watersheds, and paved the way for large public and private restoration grants.

For all these reasons, the Laguna de Santa Rosa watershed would greatly benefit from an annual or biennial *State of the Laguna Report Card*, with indices being developed for wildlife, health habitat, invasive species, water quality, farmlands, stewardship, public access and environmental education. The report could be tied in a number of ways to the State of the Laguna Conference. Interdisciplinary collaborations will be essential for developing many of these indices. Both the report and the conference will be platforms for establishing collaborations and will reinforce a culture of data sharing between participants. Report cards are designed to have real value as a science-based analytical tool, but are published in a format that is easy for the layperson to understand.

Interdisciplinary collaborations

The report card should be developed using many different *indicators* combined in such a way that they evaluate these key indices:

Wildlife: This index accounts for progress made toward conserving and enhancing native species in the Laguna watershed, including listed species of concern. Indicators may include factors such as the number of steelhead observed; number of species and relative abundance of birds observed in the Audubon Christmas Bird Count; and number of CTS in annual larval count.

Healthy Habitat: This index accounts for progress made toward protecting and restoring natural areas in the Laguna. Indicators may include factors such as the funding acquired for Laguna planning, research and restoration; miles of stream channel or riparian forest buffers restored; acres of woodland or wetlands restored; number of trees planted; acres of land protected from

development; as well as indicators measuring progress toward hydrological restoration.

Invasive Species: This index accounts for progress made toward controlling the spread of harmful invasive species in the watershed. Indicators may include factors such as the number of acres of public land kept clear of harmful invasive species; progress toward mapping and monitoring invasive species; increased public awareness of invasive species issues.

Water Quality: This index accounts for progress made toward improving water quality in the Laguna watershed. Indicators should cover multiple water quality parameters (dissolved oxygen, sediment, etc.) and may include factors such as mean water quality in First Flush samples; semi-annual water quality measurements taken at Mirabel; funding acquired for water quality research and restoration; number of water quality restoration projects implemented.

Farmlands: This index accounts for progress made toward improving the sustainability of farming in the watershed. Indicators may include factors such as acres of farmland protected from development; sustainability of local agriculture; funding acquired for implementing environmentally-friendly farming practices; progress toward developing agri-tourism in the watershed.

Stewardship: This index accounts for progress made towards community participation in protecting and restoring the watershed. Indicators may include factors such as the number of volunteers participating in Laguna restoration projects; local environmental policy development; reductions in pesticide use; measures of individual water or resource conservation; bags of trash removed from Laguna waterways.

Public Access and Environmental Education: This index accounts for progress made toward getting the public out into the Laguna for recreation or environmental education. Indicators may include factors such as the number of students or classes visiting natural areas in the Laguna; the number of participants on nature walks; the number of miles of trail improvements or trail easement acquisitions; progress toward developing eco-tourism in the watershed.

Habitat recommendations

The first step in watershed restoration is to bring back healthy physical processes: the natural flows of water and sediment moving down from the upper tributaries through the main channel and floodplains. Some of this water and sediment are retained in the system. Rainwater penetrates the soil and slowly enters the aquifer. Winter floods carry sediment onto the floodplain, where it forms new topsoil. Some is deposited in the channels, and over time sedimentation and erosion processes cause the channel to move and meander across the floodplain or to pond and form lakes in local depressions. Most riparian trees and shrubs are well-adapted to these processes, and some, like cottonwoods, depend on the formation of new gravel bars for regeneration. Riparian vegetation has a moderating influence on the movement of water, sediment and stream channels: deep roots anchor and stabilize channel banks, and large woody debris creates pools and riffles, slowing water flows.

Human development interferes with natural processes

Modern patterns of human development interfere with these natural processes: we like streams to stay within their banks (no flooding), and to maintain a stable course (no channel movement). In the past, public agencies have invested heavily in channelization and reinforced stream banks, building dams and otherwise constraining flows. Sediment was dredged, and trees were cut away to allow water to move "efficiently" away from developed areas. Based on these protections, houses and businesses were built in otherwise vulnerable areas, such as behind levees or next to creeks. However, development is in itself destabilizing: impermeable surfaces—paving and rooftops—accelerate the flow of water, increase the flashiness of floods, and the fast-moving water carries more sediment. Over the long term, it will be increasingly difficult to constrain natural forces, and the community will need to find a balance between human needs and ecosystem processes.

Ameliorating development

In the Laguna, it is very unlikely we will be able to fully restore natural hydrologic conditions, especially because global climate change is rapidly altering weather conditions. Instead, the best strategy is to study existing patterns of topography, urbanization, rainfall and water flow, and find ways to ameliorate the destabilizing elements of development, while restoring beneficial processes. In short, since the cities of Cotati, Rohnert Park, Santa Rosa, Sebastopol and Windsor are unlikely to be relocated, we need to find better ways to reduce sediment inputs, stormwater flows, and urban flooding, while facilitating natural water filtration and recharge, stabilizing banks and restoring wildlife habitat. At this time, most stud-

ies of Laguna hydrology have focused on specific issues, such as channel capacity in Santa Rosa or Rohnert Park. But as detailed in chapter 7, our ability to restore the Laguna depends on having an integrated and comprehensive baseline analysis of Laguna hydrology and hydraulics. This analysis will create a foundation for large-scale restoration projects, and give some measure of predictability to urban planners.

Stream habitats

Left alone and given plenty of time, the Laguna tributaries and waterways will come to their own equilibrium, reestablishing meanders, marshes and lakes, and a dense riparian corridor. But in the long intervening years, while awaiting this natural equilibrium, certain fish and wildlife species may be lost from the system. To preserve this biological richness, restorationists must move forward with restoring naturalistic stream contours, and with replanting riparian vegetation. Stream setbacks are as little as thirty feet in some urban areas: setbacks this narrow provide little room for restoring natural meanders, and give little protection from flooding or bank failure. Where possible, the cities and the Open Space District should acquire land and easements along creeks, to permit stream channel restoration. These lands can be used as linear parks with trails, bike paths and wheelchair access on maintenance roads.

The risk of waiting for natural equilibrium

One of the most important conservation reasons for stream channel restoration is to improve fish passage for anadromous steelhead trout and coho salmon looking for spawning areas in the higher-elevations of the Laguna tributaries. Culverts, dams and other in-stream structures can block the movement of adults swimming upstream in Fall, and young salmon moving toward the ocean in late Spring (see chapter 6). Many other less-migratory fish species (see appendix B) can also be hampered by channel obstructions. Systematic surveys are needed to evaluate the status of fish passage in the Laguna tributaries, especially where they pass through private land. Restorationists and fisheries biologists must form partnerships with public and private landowners to improve migratory and habitat conditions in stream channels.

Fish passage

At this time, many of the Laguna's flood control channels have simple *trapezoidal* cross-sections, with relatively steep banks and little surrounding tree cover. Shallow water ponds along the bottom of these channels during the summer months, and they fill with dense cattails, *Ludwigia* and other aquatic plants. These provide marginal habitat even for warm water fish, and present a problem for mosquito control. Installing *low-flow channels* is a good alternative stream restoration/enhancement in these cases where le-

Trapezoidal channels promote only marginal habitat

vees and property ownership boundaries constrain larger-scale restoration projects. Water can then collect in a deep, narrow ribbon within the bank-full channel. Deeper water provides better fish habitat. Densely-growing aquatic plants will be constrained to the low-flow channel, requiring less management for mosquitoes and flood control maintenance. Sedges and other upper-wetland plants can be planted higher up the bank, and trees can be planted near the toe, shading the narrow low-flow channel.

The natural condition of the Laguna watershed is to deposit large quantities of sediment in the alluvial fans of Sonoma Mountain and the Mayacamas, in the geographic areas of present-day Cotati, Rohnert Park, Santa Rosa and Windsor. As a consequence, and given their constrained configuration—unable to deliver sediments to the surrounding floodplain—flood control channels in these cities will inevitably fill with sediment. Besides source control (reducing erosion in the upper watershed) there are two general solutions to sedimentation problems: building catchment basins on the eastern edge of the plain, and designing channel restoration projects that incorporate and anticipate some level of channel maintenance that includes sediment removal. Regulatory agencies and watershed groups have been rightly protective of the Laguna's streams and tributaries. Past practices have given channel maintenance a poor reputation, as channels were denuded of vegetation and dredged, with little attempt to retain environmental values. With good planning it is possible to strike a balance between flood control and habitat protection: this balance is essential to maintain public support for environmental restoration.

Catchment basins versus ongoing sediment removal

Wetland habitats

Protecting and restoring wetland habitat diversity is one of the most important actions for protecting and restoring the health and biological diversity of the Laguna ecosystem. The Laguna's vernal pools and swales are widely recognized as a key and characteristic habitat, supporting many rare and endangered plants and animals. Floodplains are not always recognized as a seasonal wetland habitat, but like vernal pools, they are defined by annual periods of inundation followed by summer desiccation, and support many of the same plant species. Perennial wetlands include the standing tule marshes of the Laguna main channel, and the year-round ponds distributed throughout the watershed. The most rare wetland habitats in the Laguna watershed are the upland marshes. Only a scant handful remains in the hills around Sebastopol. Maintaining this

Floodplains as seasonal wetlands

mosaic of wetland habitats depends on maintaining and restoring wetland hydrologic function.

Before Spanish and Mexican settlement, the location and distribution of riparian forests, open floodplains and perennial marshes likely fluctuated through time with changing hydrological conditions and accidental or intentional wildfires. Even now, the relative occurrence of these habitat types is mostly determined by subtle differences in elevation and drainage, together with the history of natural or man-made disturbances at a site. In the last century, there was a substantial loss in wetland diversity, as forests were cleared and wetlands were drained and filled for agricultural use and for urban development, creating a more homogeneous landscape.

Subtle differences in elevation

Wetlands function as the "kidneys" of the watershed, by filtering sediment and nutrients from the water. These nutrients support large food webs of plants, invertebrates, small animals and many species of birds. However, different wetland types host different plant and animal communities, and function in different ways. For example, vernal pools support rare and endemic plant species, but as they are strictly rain fed, they do not play the same role in nutrient reduction as large perennial wetlands that receive upland runoff. Flood plains, in particular, are effective at collecting sediments and storing floodwaters.

Wetlands filter sediment and nutrients

Wetlands are protected from development under the Federal Clean Water Act and the Porter-Cologne Act; however, developers can mitigate losses by creating new replacement wetlands. Mitigation wetlands are usually designed for specific functions, or to provide habitat for specific species. The success of constructed wetlands often depends on the wetland type, and whether "naturalistic" hydrological conditions can be reproduced. The Kelly Farm demonstration wetlands—which are located just east of Sebasopol—were built to clean and dispose of treated wastewater, and have been extremely successful, providing high-quality wildlife habitat as well as *water polishing*—through plant uptake of pollutants. In contrast, many artificially created vernal pools have failed to provide adequate hydrologic conditions to support the requirements of endemic vernal pool plant species.

Wetland mitigation and constructed wetlands

At this time, wetland restoration is not given the same mitigation value, by law, as wetland creation (under the "no net loss of wetlands rules"), despite the fact that restored wetlands often have greater environmental potential due to their geographic position and underlying soil conditions or hydrology. Wherever possible, regulators should require that wetlands be replaced in kind, and restored wetlands should be given equal value to created wetlands in mitigation settlements. Some wetlands

Wetland restoration versus wetland creation

ecologists have called for policy changes that promote experimental efforts to improve techniques for wetland creation and restoration, such as awarding extra mitigation credits for projects designed as experiments, and allowing longer evaluation times.

Seasonal wetlands

Aerial photos of the Santa Rosa Plain show traces of a vast network of vernal pools and swales, although many of these have been plowed and filled over the years and become overgrown with non-native grasses. It is estimated that less than 10% of the historical extent of this habitat type remains. For a detailed description of the vernal pool habitats please see the *Santa Rosa Plain Vernal Pool Ecosystem Preservation Plan*. The unique hydrology of these pools—holding water long past the rainy season—comes from thick underlying clay layers that in the summer are cracked and dry. This harsh environment has favored the evolution of unique and specially adapted communities of plants and animals. There are at least four federally endangered plant species that are associated with seasonal wetlands on the Santa Rosa Plain, as well as endangered California tiger salamanders. In 1995, the Santa Rosa Plain Vernal Pool Task Force developed a protection plan and prioritization scheme for wetland preservation. As most of this land has remained in private hands, conservation has been slow and patchy, and inconsistent management has degraded the quality of many legally protected pools.

Vernal pool hydrology

Specially adapted communities

Both CTS and the listed plant species have been heavily impacted by habitat loss and fragmentation. In the past several decades, the vernal pool/grassland complex has seen extensive agricultural, residential and commercial development, with more development projected for the near future. For breeding, CTS need rain-fed seasonal wetlands, where larvae spend 3–6 months prior to metamorphosis. If the pool dries too rapidly, larvae will die. Adults spend most of the year in rodent burrows in grassy uplands, traveling as much as 1000 meters to breeding pools on rainy winter nights. CTS use of uplands is compatible with hay production and livestock grazing, but man-made obstructions such as curbs and wide roadways interfere with annual migrations between uplands and breeding pools. CTS share many habitat requirements with the listed plant species. Among the endangered plants, there are some variations in environmental preferences for soils and water-depths, but in general, these species prefer shallower pools than do salamanders, and are sometimes found in floodplain seasonal wetlands as well as rain-fed vernal pools.

CTS life cycle needs

The federal and state governments operate under a policy of "no net loss of wetlands." This means that when a wetland is destroyed in the course

of development, regulations favor wetland creation over wetland restoration. Since the function of vernal pools—their ability to hold water, host vernal pool plants and discourage the growth of non-native species—is dependent on their underlying soil characteristics and hydrologic integrity, created wetlands may have much lower habitat value than the wetlands they are intended to replace. However, there are a great many opportunities for restoration or enhancement of historic vernal pools and swales, and an increasing number of examples of successful restoration projects of this type. The connectedness of vernal pools and swales is also critical for their ecological function because seeds, soil and small invertebrates are carried between pools during periods of high rainfall. Asymmetric pools with both shallow and deep portions can provide good habitat for both plants and salamanders. For all these reasons, wetland restoration is a complicated art and science, and needs careful site-specific planning and coordination between both experienced engineers and biologists.

Soil characteristics and hydrologic integrity

Asymmetric pools

The success of species recovery depends on the quality of the wetlands, so ongoing wetland preserve management is almost as important as protection. Thatch removal through mowing, grazing, or burning appears to be critical for the success of wetland wildflowers that cannot easily germinate when dense mats of dead grass are present. Non-native grasses growing in vernal pools increase the rate of transpiration and water loss, reducing the inundation period sometimes causing pools to dry out before salamander larvae have time to complete metamorphosis. There is active research underway to develop better vegetation management strategies for seasonal wetlands. Controlled burns may be effective in some situations. Orphan preserves, with no management plan, funding or responsible entity, become quickly degraded: consistency and long-term commitment are essential to preserve management.

Thatch removal

Vernal pools and swales exist in the matrix of uplands, and to be successful, vernal pool restoration must be accompanied by grassland restoration. Without restoring the matrix, vernal pool communities will most likely experience wave after wave of invasion by non-native grasses and problem species like perennial pepperweed. The basic toolbox of management techniques is the same for both habitat types, although specific management objectives may call for different treatments, depending on conditions; for example, using different species of grazing animals on grasslands and wetlands to target different non-native weeds. See chapter 6 for more about adaptive management and restoration issues related to the seasonal wetland communities on the Santa Rosa Plain.

Vernal pool restoration and nearby grassland restoration

Floodplains

The Laguna annual floodplain is a somewhat-neglected wetland type. At lower elevations it grades into perennial wetlands, and at higher elevations it is dominated by seasonal wetland plants, including sedges, spike rush and curly dock, transitioning into water-loving grasses. Much of the higher floodplain—especially areas extending out from the main Laguna channel—should be restored to riparian forest. Northern harriers, white-tailed kites, egrets, and many perching birds hunt or forage on the floodplain, and in the winter these areas form large shallow lakes favored by ducks and other waterfowl. Floodwaters drop their sediment as flows slow and spread out across the floodplain, producing rich fertile soil; a number of farms along the Laguna still grow hay or graze livestock on these fields.

Floodplains and wildflowers

The Laguna floodplain is an alternate habitat for many of the annual wildflowers that are associated with vernal pools and swales. For example, one of the few remaining patches of Sebastopol meadowfoam occurs on the annual floodplain immediately north of the City of Sebastopol's Meadowlark Field. As in other seasonal wetland habitats, wildflower abundance has declined sharply since grazing was removed from the property in the late 1990s. This wetland is scheduled for restoration, and there are plans to create public access with ADA-compliant boardwalks to allow up-close viewing of the wildflower displays. It is important to preserve open floodplains or riparian meadows to retain this diversity of wetland habitat types.

Invasive plants threaten floodplains

Without restoration and management, the Laguna's annual floodplains are at serious risk of being overtaken by invasive species. The greatest threats now present in the Laguna are perennial pepperweed, purple loosestrife, and several perennial bunchgrasses, including Harding grass and reed canary grass. There are many other non-native species growing in this habitat, including curly dock and pennyroyal, but these do not seem to be growing in dense monocultures, to the exclusion of all native species, and are thus less of a concern. Management options are relatively limited, and restricted to the dry season. Although more research is needed to explore alternatives, it is likely that livestock grazing will be the most sustainable alternative for those riparian meadows not slated for restoration to perennial wetland or riparian forest. A number of best management practices have been developed to keep livestock from disturbing and damaging channel banks. Landowners can often obtain funding for temporary electric fences and alternate watering sources through the NRCS and the RCDs; however, these and similar efforts should be supported by other conservation organizations and public funders as well.

Open-water wetlands

Historically, the Laguna had several lakes, both large and small, including a few very small ones near what is now Llano Road, one very large one just north of Sebastopol (originally called *Livantulihyume* and later renamed Lake Jonive), and one medium sized one between Guerneville and River Road (sometimes called Lake Ballard). Lake Jonive was popular for boating and fishing, and resorts were built along its shores. The size and location of the lakes varies somewhat in the historical record. In part this may be due to the seasonality of Laguna wetlands—the lakes spreading out over the floodplain in the winter—and in part because of the dynamic nature of the Laguna, as it has been reconfigured by sediment, floodwaters, and human intervention. The Laguna's lakes were drained and filled during the 20th century, and this habitat type is now nearly lost.

Livantulihyume (Lake Jonive)

Lost lakes

In the present day, there are a few small, permanently ponded stretches of the Laguna channel—one near Alpha Farm, one in Sebastopol, and one near Occidental Road—these areas were "cleaned out", by dredging, in the 1960s. There are other man-made ponds throughout the watershed: farm ponds, backyard ponds, and reservoirs. Sebastopol's Laguna Wetlands Preserve has several ponds that are remnants of the old sewage treatment plant at that site. These vary in depth—the shallower ones are now mostly dominated by marsh plants—and support a diverse ecological community of birds and other wildlife. The City of Santa Rosa maintains several large wastewater holding-ponds along the Laguna that provide irrigation water to the City Farms and other agricultural operators in the area. These are frequented in the winter by large numbers of waterfowl. Although the City's ponds are lake-like in size, they are not lake-like in function, because (with the exception of the Kelly Farm Demonstration Wetlands, and the Joint Wetlands at the Laguna Treatment Plant) the edges are kept clear of vegetation and they do not support a diverse fish and wildlife community.

Many man-made ponds do not function in lake-like ways

The best opportunity for bringing back one of the lost Laguna lakes may be to restore Lake Jonive on the CDFG's Laguna Wildlife area, just north of Occidental Road. This property contains a severely degraded wetland, dominated by invasive *Ludwigia*. In addition to the benefits of replicating historical conditions and increasing flood-storage capacity, restoration of Lake Jonive would benefit fish and wildlife, and would enhance the ability to control aquatic weeds and mosquito populations. Restoration of deep-water areas is also an accepted technique for improving water quality. A restored Lake Jonive would be a tremendous public resource for recreational boating and wildlife observation.

Restoring Lake Jonive

There is another opportunity for restoring open water habitat, just north of Sebastopol. When the Sebastopol and Occidental ponds were dredged in the 1960s, the connecting stretch of channel was left untouched at the request of the landowner. If this half mile reach were opened up, it would be an ideal opportunity for public access to the Laguna channel, making it possible to kayak in the summer from Highway 12 to Guerneville Road. This reach of the channel passes through a large ongoing restoration site, and parallels new trail alignments being established by the SCAPOSD. Both of these large-scale sediment removal projects require feasibility studies to evaluate their effects on nearby hydraulic dynamics, but both would likely increase flood protection in Sebastopol. See chapter 7 for more about these issues.

Aquatic weed control

Although *Ludwigia*, the Laguna's most problematic invasive weed, does not grow in deeper open water, there are a number of submerged or floating aquatic weeds that pose a threat to this wetland type. Parrotfeather is present in small patches in the Laguna, and land managers should develop control programs while the infestations are still manageable in size. Water hyacinth is at high risk of being introduced by well-meaning gardeners who appreciate its attractive purple flowers. *Hydrilla* may also be introduced, on boats or fishing equipment from infested lakes and reservoirs. Education is essential for limiting both intentional and accidental introductions. Reducing nutrient loading is also likely to limit the growth of invasive floating or submerged aquatic weeds.

Perennial marshes

Tule marshes were a signature California habitat throughout the Central Valley as well as in coastal freshwater wetlands. Now they are almost entirely gone—drained and filled—converted first to farmland and then to subdivisions. These marshes were extremely significant for the Pomo and Miwok of the Laguna watershed, who used tule for house construction and for building reed boats. Tule seeds are an important food for many waterfowl. Muskrats and otter forage in the marshes for fish, frogs and freshwater invertebrates.

Highest priority restoration sites

Wetland ecologists have proposed that the highest priority sites for wetland restoration are "hotspots" where needs for habitat, water quality improvement, and flood control all overlap. From a statewide perspective, the Laguna geophysical region (see Appendix F) is one of these hotspots. Within the Laguna, the presence of perennial marshes is determined by topography: occurring in areas that are low enough for water to be pres-

ent year-round, but high enough so that emergent marsh vegetation can be rooted on the bottom and still reach the sun for most of the year.

Loss of wetlands

A study of historical survey maps reveals a significant loss of Laguna wetlands over the past 91 years. In the most significant area, between Occidental Road and River Road, the extent of the wetlands as shown on the surveys has diminished measurably over this timeframe: in 1915 there were approximately 540 acres of shallow emergent wetlands; by 1942, there were 351 acres; by 1954, 254 acres; by 1980, 240 acres; and at the present time, 2006, only 160 acres of shallow emergent wetlands remain in this reach. Similar, though smaller, wetland losses have occurred during this period in the reach from Stony Point to Todd Road. The former extent of the Cotati Marsh has not been determined, but today there are no remaining remnants, the city of Rohnert Park occupying most of its former extent, and the flood conveyance channels effectively draining the area.

Former Cotati Marsh

Constructed wetlands for treating runoff

Restored and constructed wetlands, of a variety of types, are emerging as an important class of sustainable techniques for treating agricultural runoff and urban stormwater. These can be built on a variety of scales and shapes to meet specific needs and opportunities, on the edges of farms or cities. Where catchment areas are specifically designed to trap sediment, annual maintenance for sediment removal must be built into the design and permitting. There is also potential for re-establishing hydrologic connections between the channel and the floodplain, bringing back more perennial wetlands and increasing flood storage capacity. This will require extensive baseline modeling and analyses of floodplain topography, as described in chapter 7.

Research at the Kelly Farm demonstration wetlands has shown that these emergent marshes remove nutrients and other impurities from the water, and provide excellent wildlife habitat. One drawback to using these constructed wetlands more extensively for wastewater treatment and disposal, is that their discharges are warmer than the receiving water. Since elevated temperature itself is considered a form of impairment, there is a conflict in management objectives. Another drawback is that if constructed wetlands are designed for wastewater treatment, they must be located above the 100–year flood elevation, to avoid pollution discharges during winter storm events. Potential sites would likely displace either agricultural land or grasslands, both of which will be targeted for CTS/vernal pool conservation preserves. For these reasons, it is preferable to focus on wetland restoration at lower elevations in the floodplain for

Focus on wetland restoration rather than wetland creation

habitat, stormwater treatment and flood storage, rather than on wetland creation in uplands for the purposes of wastewater treatment.

One of the greatest unresolved questions for perennial wetland restoration in the Laguna is the long-term management of *Ludwigia*. This extremely invasive aquatic plant shares habitat with tule and cattails and other emergent marsh species. Where *Ludwigia* has become established, it forms a dense monoculture, excluding all but very dense and mature stands of tule. There are several large infestations, described in the *Ludwigia Management Plan* (appendix D), as well as numerous small patches, spread throughout the watershed, including many of the area's agricultural ponds. *Ludwigia* appears to be limited by water depth: the water must be shallow enough to allow plants to root on the bottom, but low enough in the floodplain that the soil remains saturated throughout most of the year. One of the suggestions for *Ludwigia* management is to manage water levels; that is, flooding or draining *Ludwigia* areas. The drawback to this plan is that it also eliminates large sections of tule marsh. In some cases, such as infested flood control channels, it may be appropriate to excavate a low-flow channel, restricting *Ludwigia*'s habitat area. Other management options—ranging from nutrient reductions to biological control, and selective herbicides—must be explored to preserve open marshes while controlling this weed.

Ludwigia and water depth

Upland marshes

Cunningham Marsh represents the most rare and unusual habitat type in the Laguna watershed, a wetland perched in the hills to the west of the Laguna channel, with year-round water supplies supporting many endangered bog plants not found in the more common tule-dominated marshes. Along with Pitkin Marsh, it is considered to be a remnant, low nutrient wetland—or *oligotrophic wetland*—in contrast to the lowland eutrophic tule marshes associated with the Laguna main channel. These are the only remaining natural localities of the endangered Pitkin Marsh lily, *Lilium pardalinum* ssp. *pitkinense*. Although Cunningham marsh has historically supported many other rare plants, over the years most have become extirpated, first by overgrazing and anthropogenically increased sediment deposition, and then by overgrowth of invasive species. The current plant species composition, that includes more generalists, suggests a shift toward higher nutrient availability.

Low nutrient wetlands

The California Dept. of Fish and Game holds a conservation easement over a portion of the historic Cunningham Marsh, and with the permission of the landowners, is working with the Milo Baker Chapter of the California Native Plant Society to manage vegetation at the site. The ob-

jectives of the current Cunningham Marsh Vegetation Management Plan are, in brief, to promote the recovery of Pitkin Marsh lily populations, as well as other populations of local endemic rare wetland plants; and to establish management practices that gradually reduce the need for intensive maintenance, by reducing the spread of non-native plants and improving the condition of native upland and riparian vegetation. The plan specifies a need both for better baseline characterization of the habitat, and for more research on techniques facilitating rare plant establishment. See the Cunningham Marsh Plan for more details (Baye 2005).

Recovery of the Pitkin Marsh lily

Because of their high habitat value and extreme rarity, protection of Cunningham Marsh and other remnants of this habitat type should be given very high priority for protection and restoration. If possible, these lands should be acquired in fee and transferred to a conservation organization that is committed to long-term management and protection of the environmental values of these marshlands.

High priority protection of Cunningham Marsh

Mosquitoes

There is much to be said about the overlapping concerns of mosquito control and wetland restoration in the Laguna. We need healthy, restored wetlands in the Laguna to support wildlife and purify the water. However, wetlands inevitably breed mosquitoes. Tests of birds and mosquitoes show that West Nile virus is now endemic here, along with viral encephalitis; and global warming is predicted to increase the incidence of other mosquito-borne diseases, including malaria, which was once common in California. Beyond disease concerns, public support for wetland restoration will grow thin when met with large clouds of biting insects.

West Nile virus

The good news is that, properly done, restored wetlands have fewer mosquitoes than degraded wetlands. Controlling nutrient levels will reduce the abundance of bacteria and algae that the mosquito larvae use for food. Lower nutrients help reduce the density of aquatic plants where larvae hide from natural predators like small fish and frogs. Controlling wetland weed infestations—through harvesting, biological control, herbicides or other methods—may be necessary as a temporary measure for creating open water conditions. Record-high adult mosquito numbers dropped sharply following *Ludwigia* control efforts in Rohnert Park carried out in 2005. Vernal pools that have been overgrown with grasses and other non-native vegetation can also be a substantial source of mosquitoes. Vegetation management—grazing or mowing pools—supports healthy vernal pool communities, and reduces mosquito abundance.

Mosquito numbers and *Ludwigia* control

Restoring riparian and upland habitats also reduces mosquito problems because swallows and other insectivorous birds need healthy forests

to nest and perch. Bats also eat mosquitoes, but rely on larger insects—like moths and flying beetles—for the bulk of their diets. To maintain healthy bat populations to reduce mosquito numbers, requires healthy habitat—such as riparian forest and native wetland areas or even multi-species hedgerows—to boost the numbers of alternative insect prey. Many birds and bats nest in holes or crevasses of mature trees, and their numbers are consequently limited in the Laguna. Establishing bat and bird boxes can help restore their populations.

Boosting alternative insect prey

Some excellent restoration practices, if not well designed, can actually increase mosquito numbers. For example, constructed basins and swales designed to slow or trap stormwater can improve water quality by filtering out nutrients, trash and sediment; they can also reduce flooding, and increase groundwater recharge. However, because these basins don't support natural mosquito predators, they swiftly become mosquito sources unless the water can rapidly drain out. While the Mosquito District uses natural control products in the Laguna, the long-term goal is to manage wetlands in such a way that mosquito control is unnecessary. Finding the most environmentally-appropriate long-term management strategies will be an ongoing research and restoration challenge.

Constructed basins are an ongoing challenge

Riparian habitats

Riparian restoration integrates across almost all watershed-level restoration objectives in the Laguna: habitat connectivity, biodiversity, water quality, and flood protection. Healthy riparian areas are essential for fish and wildlife. Riparian forests provide movement corridors and habitat structure along the banks and within stream channels. Trees, shrubs and understory plants of different ages, sizes and species provide a range of different food sources, hiding places and nesting areas for birds and terrestrial animals. Within streams, submerged roots and fallen trees diversify the structure of aquatic habitats, supporting a greater variety of fish and invertebrates. Narrow riparian buffers can provide valuable stream canopy, but broader riparian forests support larger wildlife communities because they have less "edge" habitat.

Narrow buffers versus broader forests

Riparian plantings improve water quality by trapping sediment and pollution: plants take nitrogen directly out of the water and use it for fertilizer. Denitrifying bacteria in the soil around riparian plants also convert aqueous nitrogen compounds to nitrogen gas. Plants take up phosphorus both from the water and from phosphorus-rich sediment trapped by the vegetation. Vegetation also traps pesticides and other organic compounds, which are broken down by soil microbes. Shading from the riparian

Phosphorus and nitrogen uptake

canopy prevents the streamflow from heating, and reduces aquatic plant growth and decomposition, thus increasing oxygen levels in the water. Riparian forest buffers provide additional sediment control by reducing bank erosion: tree roots hold soil in place. During floods, trees and shrubs provide "roughness" slowing water flows and diffusing the water's energy. The space provided by riparian setbacks protects the flood storage capacity of the system, even if some of this water is displaced by vegetation.

There is a tremendous need for riparian restoration in the Laguna watershed. Using satellite imagery from 2001, we found that 51% of the channels in the Laguna watershed lacked stream canopy (see Plate 2). This analysis does not take into account areas where riparian trees and shrubs have already been planted, but are still immature; however, it is a conservative estimate, because even very sparse canopy was counted as coverage. Viewed from the air, the Laguna's riparian canopy is a narrow intermittent fringe skirting the stream channels. However, studies have shown that riparian ecosystems can be highly resilient with great potential for regeneration, because riparian plant species are well adapted to high levels of disturbance.

Narrow fringe of riparian canopy

Over time, natural processes will restore the riparian forest, as animals and floodwaters disperse seeds and reproductive plant fragments. Michael Lennox, a graduate student at Sonoma State University, has compared over 90 local sites that have either been actively restored or protected from grazing (passive restoration). According to initial results, sites with only passive restoration have equivalent numbers of woody native trees and shrubs, but fewer distinct species of plants. A recent review of research in the Columbia basin, found that passive restoration (via riparian fencing) was very effective in systems that were not highly degraded and did not suffer extensive weed infestations. Given these findings, greater grazing control in riparian areas should be an essential starting point, followed up by active plantings.

Passive restoration and distinct species

Species diversity depends on the presence of parent plants to provide seeds and other propagules, and can be important for long-term restoration success and ecological value. Researchers conducting riparian restoration along the Sacramento River found that, unless they planted understory species, like sedges and shrubs, the willows and other trees quickly became surrounded by weedy non-native competitors. Now their restoration projects include thirty different varieties of woody plants, grasses, sedges, and shrubs, restoring entire plant communities. These sites are more resilient to invasion, and provide greater habitat value in a shorter period of

Restoring entire plant communities

time. Sites with greater plant species diversity also have greater structural diversity, supporting a greater variety of birds and other animals.

Passive management

Passive management can have mixed results. Every year, public agencies invest thousands of dollars in riparian restoration, planting native trees and shrubs to restore the habitat and ecosystem services they provide. Under the best possible circumstances and optimal conditions, these trees and shrubs would be self-sustaining and rapidly grow to replace lost canopy. But in practice, areas that most need restoration have relatively harsh conditions: sunny, dry, and occupied by water-hungry non-native grasses. As a consequence, most plantings need follow-up maintenance to increase their chance of survival, including mowing, invasive species control, and in many cases, irrigation.

Plantings need follow-up maintenance

An alternative approach, similar to commercial forestry practices, is to over-plant, with little or no follow-up. This approach anticipates relatively high mortality but assumes that surviving individuals will be stronger and better adapted to the site. There are greater up-front costs and planting efforts, but (in theory) no management costs. The difference between these approaches is the time required for the plantings to mature and the degree of certainty for plant survival. Some trees and shrubs are more tolerant of neglect, and withholding irrigation and other maintenance activities may skew species distributions at restoration sites, favoring types that are more drought-tolerant as juveniles. Many restoration projects are in public areas, and are planted by students and volunteers. Trading off high mortality for low maintenance costs is likely to be demoralizing for the public, even if they are warned of the strategy in advance. Whenever possible, restoration plantings should be nurtured and maintained, to increase survival rates and accelerate plant growth. Because it is often difficult to obtain grant funding for ongoing maintenance or management of natural areas, grants should include at least three years of follow-up into their budgets. Cities restoring riparian corridors as parks or bikeways need to include maintenance in their public works budgets.

High mortality versus low maintenance

Natural succession involves progressive colonization by different species that are each adapted to a different disturbance frequency or intensity. Early successional species colonize bare soil where there are few competitors. They are gradually replaced by later successional species that may need shade or deeper soils provided by the first colonists. The most diverse plant communities, supporting the greatest variety of wildlife, are mosaics of different successional stages. To mimic these natural processes, restoration projects should ideally be phased, for example, first planting

Mosaics of successional stages

trees and shrubs that tolerate harsher conditions, then following-up with more shade-loving understory plants after the first plantings have begun to fill in.

Riparian maintenance

Although there are great benefits to restoring riparian trees and shrubs, vegetation management is also important for maintaining the flood management capabilities of these somewhat-artificial systems. Trees and other woody plants can contribute to flooding when they grow into streams that pass through urban and residential districts. Multi-trunked willows, *Arundo donax* (giant reed), and Himalayan blackberry, are particularly problematic, becuase they fill channels, trap debris and form dams. Although "large woody debris" is beneficial for steelhead and salmon, especially in the upper watershed, debris piles are less appropriate for developed areas on the Santa Rosa Plain. Many non-native riparian species, including Himalayan blackberry and periwinkle, are hosts for blue-green sharpshooter bugs that carry Pierce's disease, weakening or killing grapevines. Removing these host plants, and replacing them with natives less favored by these bugs, reduces the need for pesticides. Densely-growing aquatic plants contribute to flood-control problems by accreting sediments and displacing large volumes of water. The key is to maintain healthy vegetation at the edges of channels, but to discourage woody plants within low-flow channel banks. Without good flood protection, it will be difficult to sustain public support for riparian restoration, especially in urban areas.

Healthy vegetation at the edges of channels

Urban creek restoration is enjoying a renaissance in America, with many small watershed groups adopting sections of creeks or streams, and participating in plantings, weed removal, and trash clean up. These cared-for creeks become linear parks and bike routes, and are a source of civic pride. In this way, restoration is an important restorative process for communities as well as the landscape. Individuals and community groups gain a restored connection to the earth, and greater appreciation for natural areas and the ecological services—like clean air and water—that they provide. Restoration projects can bring together neighbors, reduce stress, and create hope for a better environment for generations to come. If individuals have a personal investment in a restoration project, they are likely to be advocates for the care and protection of the newly-planted habitat, and others like it. Restoration projects can be an ideal classroom for teaching ecological principles about water quality, biodiversity and ecosystem services provided by wetlands and waterways. Many public agencies and environmental organizations build education programs around restoration, and such programs should be strongly supported.

Advocates for care and protection

Riparian buffer widths

Riparian buffers are the vegetated strips of land alongside channels and waterways. Depending on physical conditions, riparian buffers may be forested, or they may support other forms of vegetation, such as the seasonal wetland plants and wet meadows that grow in the annual floodplain. The appropriate width for riparian buffers depends on both the function and the physical context of the riparian corridor. Where streams pass through urban areas, narrow setbacks do not allow wide buffer areas. The need for flood protection constrains the choice of trees and understory plants, and requires ongoing maintenance to keep channels clear. Although wider riparian buffers allow a greater range of environmental benefits, even narrow strips of trees in urban areas are an ecological improvement over bare channels in full sun.

Narrow riparian buffers versus channels in full sun

There is an emerging science around how wide riparian buffers must be to perform ecosystem functions. Analyses focus on particular waterways (currently, researchers are evaluating the riparian buffer width needed for the long-term health of the Russian River channel) or on the average width-range needed to perform specific functions. According to the US Forest Service, buffers should be 35-100 ft to remove nitrogen, but for sediment and erosion they must be 50-100 ft and up to 200 ft for flood protection. Wildlife often need much greater riparian corridors, with widths up to 1600 ft. Areas with steeper slopes, active channel areas and unstable soils need wider buffers for greater protection to homes and roads. The current zoning code for the City of Santa Rosa calls for 50 ft setbacks for new construction, but in many developed areas, the setback is only 30 ft. The Draft Sonoma County General Plan 2020 calls for 100 ft riparian setbacks—measured from the top of the high bank on either side of the stream—on land outside of urban jurisdictions. In practice, the width of riparian buffers is often constrained by existing development. However, if the Laguna's floodplain elevations change as predicted by the Army Corps study, the most environmentally and economically sound alternative may be to relocate some residences away from stream areas and convert land to riparian corridors.

Analyzing buffer widths

Certain species, like the yellow-billed cuckoo, need large blocks of forest. Historical ecology and hydrological analyses of the floodplain must be used to identify which parcels are likely to support extensive riparian plantings, given current and projected future conditions. Portions of the Laguna floodplain north of Occidental Road used to support a dense riparian forest, but hydrologic changes in this area have caused floodwaters to be retained much longer into the summer months, and as a

consequence, the forest has reverted to emergent perennial wetland. Based on this evidence, it is not likely that riparian tree plantings will survive in areas with long periods of inundation. Restoration options include either adapting to changing circumstances and restoring riparian areas with wetland plants, or managing water levels by dredging, draining or otherwise reconfiguring the landscape to "correct" the hydraulic function and support riparian vegetation. This is a complex issue: extensive dredging or reconfiguration of wetlands represents a great disturbance to the system, is very expensive, and should not to be taken lightly. If the root cause of the hydrological changes is not addressed (such as excess sedimentation or man-made blockages), the system may continue to change, undermining restoration efforts.

Riparian trees and long periods of inundation

The NCRWQCB is developing a stream and wetland protection policy that recognizes the need to protect and restore the hydraulics and vegetation of riparian areas, in order to improve water quality and protect beneficial uses. The process is still in its initial stages, and policy alternatives will be shaped by public and stakeholder input. However, the process will likely result in much stronger regulation for setbacks and development along waterways.

Stronger regulation for setbacks

Given competing land uses in the Laguna, and the need to support a diversity of habitats as well as agricultural uses, not all areas that could potentially support riparian vegetation will be restored to riparian vegetation. Some riparian areas are emergent wetlands, grading to wet meadows and floodplain seasonal wetlands, and these areas should be protected for their distinct habitat value. For the foreseeable future, restoration efforts should be focused on planting existing creek setbacks in urban and rural areas, and in restoring specially-designated wetlands. This will require public and private collaborations for planning, funding, implementation and ongoing management, as well as outreach and education programs.

Riparian vegetation versus seasonal wetlands

Riparian reforestation project

Full riparian restoration requires community mobilization. Communities in the Chesapeake Bay watershed restored 2010 miles of riparian forest buffers in 6 years. Their new goal—set in 2003—is 10,000 more miles by 2010, with a long-term goal of 70% riparian forest cover in the watershed. In the Laguna, preliminary GIS analyses indicate that approximately 350 out of 711 miles of perennial and seasonal streams in the watershed lack riparian canopy (see Plate 2). Conservatively assuming that 30% of stream corridors are either unfeasible for restoration or should be left as open wetlands, 150 miles of stream channel (300 miles of channel banks)—for

300 miles of channel banks targeted for restoration

a total of 70% coverage—is an appropriate target for riparian restoration in the Laguna.

Fast-growing riparian trees can shade the channel in as little as ten years, depending on plant size and whether they have been tended and irrigated. Other ecosystem functions, like trapping sediment and nutrients, accrue more rapidly. The width and density of the riparian restoration along each reach of channel depends on site-specific conditions. Target widths are based on channel size. The highest-priority areas are nearest to stream channels; buffer widths can be increased in later restoration phases.

This ambitious goal requires the participation of watershed groups, restoration organizations, local jurisdictions, and public landowners and managers in the watershed. With community participation, we can meet this goal by 2016, greatly enhancing aquatic and riparian ecosystem integrity, controlling erosion and sedimentation; and promoting water quality. Many riparian restoration projects are already underway: including efforts by cities, school groups, and organizations like the Cotati Creek Critters, who are restoring two miles of Laguna channel banks in Cotati and Rohnert Park.

Grassland and oak savannah habitats

Restoration and management plans for grasslands, oak savannah, and to a certain extent seasonal wetlands, must be developed in concert, because these habitats grade into one another. Before Spanish and Mexican settlement, the distribution of oak woodlands and grasslands likely shifted over time according to natural and artificial fire regimes. Grasslands are an important habitat for birds, burrowing mammals, lizards and snakes. Historically, Laguna grasslands hosted elk and pronghorn antelope. Throughout the Santa Rosa Plain, grasslands and oak savannah are dotted with vernal pools and swales that host a specialized suite of plants and animals, including California tiger salamander. These salamanders spend most of their lives in rodent burrows in surrounding uplands, returning to the pools to breed. Like CTS, many animals move between different parts of the habitat, and it is this variation in habitat that supports the Laguna's great variation in species diversity.

Working landscapes

Most Laguna grasslands are working landscapes, grazed by dairy cows, horses and other livestock. Many are irrigated with treated wastewater, which has the joint benefit of allowing several hay crops per year, and efficiently disposing of the wastewater. Conversion from non-native perennial grassland to native annual grassland has inhibited their envi-

ronmental function: increasing runoff, erosion and weed invasion, and reducing water retention and their ability to filter and retain nutrients and sediment in surface water. The deep roots of perennial grasses are much more effective at stabilizing soils, and for this reason restoration of the hills in the southern regions of the Laguna, with perennial grasses, may decrease the risk of land slumps, erosion and sedimentation in stream channels. Along with a decline in their environmental function, grasslands are also physically disappearing, converting to other land uses with still less environmental value. As cities gradually expand to fill their urban growth boundaries, grassland areas above the floodplain are being eliminated at the edges; and in rural areas many grasslands are being converted to grapes and other crops. Only recently have we come to recognize the importance of this matrix to the rest of the landscape.

Multiple-use landscapes

Over the next decade, citizens in the Laguna watershed will be challenged to find ways to support an economically viable ranch and dairy economy, while restoring the environmental function of grasslands. In the Central Valley, there is a major effort to form partnerships between ranchers and scientists, not only to restore water quality and other ecosystem services, but also to stay profitable. Keeping agricultural land at work is insurance against sprawl; it also provides food security. In the coming years, there are plans to establish several large conservation areas to protect endangered species associated with vernal pool habitats. Many of these preserves will need to share space with ranch or dairy operations, in part because much of the land is in private ownership, but also because without management through grazing, burning or haying, the health of grasslands and seasonal wetlands will swiftly decline. The Sonoma County Agricultural Preservation and Open Space District (SCAPOSD) participates in ranchland protection by purchasing conservation easements that compensate ranchers for keeping the land in pasture: for this reason, and many others, taxpayer reauthorization of SCAPOSD is important for protecting the Laguna's natural resources.

Sharing space with ranch and dairy operations

The restoration goals for grassland and oak savannah habitat are shaped by the many uses of these landscapes. Different properties will have different specific management objectives, but all property owners have a mutual interest in reducing weed invasions, improving soil conditions, retaining topsoil, reducing runoff and protecting water quality. On publicly owned preserves the objectives should include oak regeneration and substantial restoration of native grassland flora, thus shifting the species composition from predominantly non-native, to predominantly native

species, and enhancing the diversity of both the native grass and the native wildflower communities, and thus supporting greater animal diversity. As an added bonus, these lands can then become source areas for seed and wildlife. Native perennial grasses are also beautiful to look at, drought tolerant, and provide erosion control. At one experimental site in Yolo County, researchers have increased rangeland forage by restoring native bunch grasses. However, much more research is needed to determine how to best manage grazing land in order to be cost-effective for agricultural producers while providing optimal environmental benefits.

Shifting species composition toward natives

Irrigation with treated wastewater is an important human use of Laguna grasslands and oak savannah. The soil community in these habitats works very effectively to remove pollutants from the water; farmers have access to several hay crops a year; and excess water is transpired into the atmosphere safely providing a system of treated wastewater discharge. But for a number of reasons, grassland irrigation favors exotic grasses over native California perennials, so grassland restoration efforts will be most successful in areas that have been removed from irrigation, such as CTS preserves.

Grassland irrigation favors exotics

Grassland restoration

Although parts of the Laguna grasslands still have healthy stands of native grasses, many are completely dominated by non-native species, so restoration practices may vary from site to site in preserve areas, depending on the natural regeneration potential and the extent of seed limitation. In most cases, some level of planting—either seeds or plugs—will be necessary. Management is essential for all grassland restoration. California grasslands evolved under relatively intense burning and grazing regimes. Indigenous Californians burned grasslands to increase root and tuber productivity and to improve seed harvests. Present-day management efforts are mostly concerned with discouraging the growth of non-natives. Mark Stromberg and Paul Kephart of the Hastings Natural History Preserve provide the following rule of thumb: "If you do nothing with your native grassland, you will grow mostly weeds. If you graze it or mow it, you will have mostly grasses, but well-timed mowing or fire will promote wildflowers."

Well-timed mowing

One obstacle to grassland restoration in the Laguna is that there are no local sources with sufficiently abundant supplies of native grass seed. For optimum success of restoration efforts, and to preserve the genetic integrity of local ecotypes, it would be very valuable if a Laguna agricultural producer could grow local, native perennial grasses for seed. If this were done, grass seed could be sold to restorationists and public and private

Native grass seed sources

landowners throughout the watershed. If demand fell, the perennial plants themselves could be divided into plugs and transplanted into restoration sites, or the farmed area could be converted to grassland. Another ongoing challenge to grassland restoration will be to develop techniques for establishing native perennial grasses while discouraging both annual and perennial non-native grasses now widespread in the Laguna. This is an area that is ripe for a restoration research program.

In practice, the species targeted for restoration and the specific management techniques depend strongly on site characteristics, constraints, and particular management objectives. For this reason, grassland restoration must begin with site-specific baseline assessments (including repeated seasonal surveys) of the vegetation to evaluate which native and non-native species are present, and their relative abundance. Traditional range management assessments of standing dry matter and turf conditions provide other tools for restoration and management planning. Restoration and management techniques include different methods for seeding and planting, as well as grazing, mowing, haying, burning, and where necessary, selective herbicide applications. Each method has strengths and weaknesses, and in many cases the best choice may be a combination of approaches.

Baseline assessments

Grazing

Livestock grazing, along with burning, closely reproduces a natural ecological process. In the Laguna, like elsewhere in the world, grasses have co-evolved with grazing animals and can be very productive while retaining their habitat quality. For this reason, rangeland is considered to be one of the most sustainable agricultural systems, benefiting humans as well as the environment. Few other range management practices are suitable for use on large spatial scales, and these, like burning, mowing, haying or herbicide use, have their own environmental impacts. Grazers have both positive and negative effects on the grassland ecosystem by removing plant biomass, trampling the soil, and adding nutrients through defecation. One of the central goals for grazing management in the Laguna is to control non-native species, especially in and around vernal pools.

Rangeland as a sustainable system

Using grazing for grassland restoration is controversial because, without proper safeguards, animals can denude vegetation, destabilize channel banks and increase bacteria levels and nutrients in the waterways. Year-round grazing can exhaust the vigor of perennial species, so that they cease producing seeds and gradually diminish. Past grazing practices have contributed to the replacement of native species by non-native annual grasses and rangeland weeds. Livestock eat oak seedlings, and heavily

Grazing can be controversial

grazed savannah often has only mature oaks, gradually succumbing to old age. In riparian areas, livestock browse on trees and shrubs and contribute to erosion and loss of riparian forest buffers. Grazing animals can also be a vector of invasive species, spreading seeds in fur, hoofs and feces; lands that have already been disturbed by high grazing intensity are particularly vulnerable to these introductions. Grazing animals are not always compatible with public access, especially in parks where dogs are allowed. However, with proper management, these problems can be avoided, and under the right conditions, the benefits of grazing far outweigh the risks.

Grazing can support seasonal wetland health

According to a recent review, many land managers now believe that grazing at appropriate levels supports the health of seasonal wetlands, by reducing the biomass of non-native plants through grazing and trampling. This eliminates competition from actively growing weeds, and the suppression of wildflower germination by dead, matted thatch. Jaymee Marty, a scientist with The Nature Conservancy working in the Central Valley, found that cattle-grazed pools had 20%-50% more native annuals than ungrazed pools, and less exotic grasses. This supports observations in the Laguna, where the complete removal of grazing on some sites (including the CDFG's preserve on Todd Road) has been followed by a sharp decline in native species diversity. Grazed pools also retained their water up to 2 months longer, which is very important for protecting the habitat value of pools for CTS. Joan Schwann, a graduate student at Sonoma State University, is currently studying the effects of sheep grazing on vernal pools at the City of Santa Rosa's Alpha Farm.

Lack of grazing and the decline of native species

Cow, horses, sheep, goats

Different animals are appropriate for different management objectives: cows and horses mostly prefer grasses, while sheep and goats mostly prefer broadleaf plants. They also have different eating habits. Goats are browsers, eating trees and shrubs as well as low plants. The weight of the animal can be a factor, especially before the soil has dried and firmed. Cows and horses are much heavier than goats and sheep, and can compact the soil or make deep indentations. On the positive side, cows need less monitoring because they are more selective than goats or sheep, with less tendency to denude the landscape. Larger animals are sometimes preferred because they are less vulnerable to predators, like dogs, coyotes, and mountain lions. Some wildlife enthusiasts have suggested re-introducing tule elk to the Laguna grasslands, as they have at Point Reyes in Marin County. Bringing back this native grazer would generate much excitement and boost tourism, as well as providing a historically appropriate way to manage grasslands.

Development of grazing plans

To develop grazing plans, restorationists should work closely with local agricultural producers and the UC Extension range management advisor, who are familiar with local conditions and issues. Only certified rangeland managers licensed by the state are permitted to create formal grazing plans. Like other restoration tools, grazing plans work in an adaptive management framework, depending on conditions and the outcome of previous management efforts. Key factors include the variety and characteristics of non-natives targeted for control, and the ecology of species that are targeted for recovery. Certain species (both native and invasive) are more sensitive than others to grazing. Key elements of a grazing plan include the abundance and type of forage (grasses or broadleaf plants), the number and species of animals, and the duration and season of grazing. Grazing plans are designed to adapt to annual fluctuations in rainfall, which control the quantity of plant material, and the field conditions. One technique is to sample the residual dry matter present after a period of grazing, and use that information, along with other environmental indicators to determine future stocking rates. The CDFG has funded development of a grazing management plan for the Todd Road and Wright Preserve properties in the Laguna, and grazing will likely be an important management tool for CTS/vernal pool conservation areas on the Santa Rosa Plain. As a consequence, existing fences that are still in serviceable condition should be retained on restoration project sites to allow greater flexibility for management options.

Grazing regimes need to be flexible

Economics are a major factor controlling the number of grazing animals in the Laguna. Local dairy farmers compete with large producers in the Central Valley, and have increasing regulatory restrictions related to nutrient and sediment inputs. Grazing regimes have to be somewhat flexible to support financially viable dairies and other forms of livestock production, as well as grassland or vernal pool conservation goals. If regulatory requirements become too great, without financial assistance farmers may be forced to give up ranching or dairying operations, and there will be fewer animals available for land management purposes; instead, there may be financial pressure for farmers to convert to other land uses. CTS are somewhat of a balancing economic factor. Much of the grassland above the annual floodplain will increase sharply in value to reflect the mitigation needs for development on the Santa Rosa Plain. With conservation easements or other compensation mechanisms, farmers may have a strong enough economic incentive to maintain family-based ranching or dairying operations.

Using grazing for grassland restoration is essentially performing biological weed control on a landscape scale. Once the grasslands have been restored, grazing becomes an ongoing management technique to maintain grassland health. Grazing animals can also provide weed control in other habitat types. There are a number of commercial operations that hire out sheep and goats to provide intense, targeted treatment for invasive species infestations. While the general goals are the same (restoring native plant communities), the techniques can be somewhat different. If the goal is to completely denude a patch of invasive plants, such as Himalayan blackberry, livestock managers often erect small (10 m^2) temporary fenced enclosures to reduce the number of feeding options for the animals, and target grazing pressure. Animals are sometimes given nutritional supplements, or rotated as necessary to maintain their health. The enclosures can be moved around to cover larger infestations.

Grazing for weed control

Burning

Controlled burns are the most traditional and perhaps the most effective grassland management technique in the Laguna and throughout California. By one estimate, any given patch of grassland in the state was burned on average every 2-5 years by humans or natural causes, before Spanish and Mexican settlement. Controlled burns clear the landscape of invading shrubs and weeds, reduce the thatch layer, and reduce the fuel load, thus potentially limiting fire danger. Correctly timed, low-intensity grass fires are effective for promoting native grasses and wildflowers.

Nonetheless, grassfires are very bad for air quality, and are only allowed—by permit from the Agricultural Commissioner—under particular environmental conditions: days with low fire danger and proper air circulation. In some cases, land managers seeking to use fire as a management tool, have worked with local fire districts to conduct controlled burns as training exercises. In general, however, it is unlikely that the use of fire will be a widespread grassland management tool in the Laguna.

Low-intensity grass fires promote wildflowers

Mowing

Mowing and haying are the two other active management techniques suitable for large-scale grassland restoration efforts in the Laguna. To control annual weeds, mowing must be timed to cut the plants just before the seeds become mature enough to germinate; perennial grasses usually set seed slightly later in the season. After a few years of mowing to exhaust the seed bank, annual grasses will become less abundant than perennials. Mowing is probably the best choice for tight areas around houses, around young plantings or particularly sensitive native species that cannot easily

Mowing to control weeds must be well timed

be protected from grazing animals. Mowing must also be timed to allow wildflowers to set seed—especially in good wildflower years—so that flowers can stock up their seed banks. The drawback to mowing is that it is fuel and labor-intensive, and thus ultimately less sustainable.

Herbicides

Although herbicides are sometimes essential for controlling certain particularly tenacious weeds, they have too many non-target impacts and are too expensive for general use. Herbicides are sometimes recommended for preparing the planting area prior to large-scale grassland restoration.

Oak restoration

Valley oaks (*Quercus lobata*) are emblematic of the Santa Rosa Plain and provide exceptional habitat for many species of birds, animals and insects. Garry oaks (*Quercus garryana*), California black oaks (*Quercus kelloggii*) and coast live oaks (*Quercus agrifolia*) are also found on the plain, and a number of other species occur in the oak woodlands of surrounding hillsides (see chapter 6). Even dead and dying oaks are important animal habitat; they provide cavities and crevasses for nesting birds and roosting bats, and perch sites for raptors hunting gophers in the grass. Some of the larger oaks are thought to be 300-400 years old. These mature oaks provide the highest quality habitat, with vigorously growing shoots, abundant acorns, and generous nesting and roosting sites. The greatest concerns for this habitat type are the need for oak recruitment, the early demise of mature oaks, and the loss of oak woodland and savannah to housing and agricultural development. Wherever possible, mature trees should be preserved in the Laguna landscape.

Concern for oak recruitment

Throughout California, few young oaks are found among the aging groves, and in many places the oak savannah has grown thin. There are many different factors that are likely acting in combination to limit oak recruitment. Reduced fire frequencies, especially in the absence of grazing, can lead to thatch build-up, which inhibits germination. Rodents, deer, and livestock graze on seedlings and saplings reducing survival rates. But regular disturbance through mowing and disking is likely the most limiting factor, destroying otherwise viable recruits.

Oak recruitment limiting factors

Mature oaks, approaching the end of their natural life spans, suffer other stresses. California black oaks and coast live oaks are susceptible to Sudden Oak Death (SOD), a plant disease caused by the pathogen *Phytophthora ramorum*. Valley oaks and Garry oaks have natural immunities to SOD. Many of the local universities—including U.C. Davis, U.C. Berkeley and Sonoma State—have substantial SOD research programs, to

Sudden Oak Death

better understand the physical and biological factors leading to its spread and virulence (see the California Oak Mortality Task Force website: http://nature.berkeley.edu/comtf/). Spores are spread over short distances by water, air and insects; and over long distances by people moving firewood and nursery plants. Hikers and bikers can also spread SOD on their shoes and bike tires. Stresses are different for oaks that grow on the plain and the hill slopes surrounding the Laguna basin. Many savannah areas on the plain are irrigated to dispose of treated wastewater and to produce hay crops. This nutrient-rich water stimulates the growth of non-native grasses, and may increase the vulnerability of oaks to fungal diseases. However, even dead and dying oaks have very high habitat value, and care should be taken to preserve these snags whenever possible. Where trees must be taken down for safety reasons, the trunks and limbs should be retained on site to decay naturally on the ground and to provide a final habitat for underground cavity dwellers.

Clearing the oak woodlands

In the middle of the 20th century, many oak woodlands in hill areas of northern California were cleared for rangeland. These clearings were associated with dramatic increases in erosion (Pitt 1978). Recent GIS analysis suggests that regeneration may be favored by the presence of other trees, and that cleared, south-facing hillsides may have particularly poor natural regeneration (Brooks and Merenlender 2001). Many of the upland oak species are susceptible to SOD, and many upland areas are well suited to grape growing, making them targets for vineyard conversion. Restoration of oaks and perennial bunch grasses on hill slopes around the Santa Rosa Plain could have substantial benefits for reducing slumping, erosion and subsequent sedimentation in stream channels.

Current favored oak restoration practices

Despite recent population declines, there is real promise for oak restoration in the Laguna watershed. Where seedlings are cared for, they have high survival and grow rapidly. Current favored restoration practices include local collection of acorns that are planted into duff or leaf-mulch piles and that are protected from seedling herbivory with wire mesh. Oaks planted as acorns appear to have a similar survival and growth rate as oaks planted by seedling, and the actual planting is easier (D. Cadman, pers. com.). Livestock grazing is both good and bad for oak restoration. Grazing animals help support healthy rangelands by reducing thatch. However, oak seedlings are themselves hard-hit by browsing cows, sheep and deer. Recommendations from a recent review include limiting summer grazing in oak restoration areas, stocking at moderate densities to reduce thatch, and protect seedlings (both natural and planted) until they are 6 ½ feet in height. Watering helps juvenile oaks become established, but irrigation

should be kept away from the drip-line of mature trees. Where mature oaks are present, land managers often plant acorns and seedlings under the canopy. In cleared areas, oaks are planted in clusters to produce small groves that will eventually become thinned by one or two dominant individuals.

Oak recruitment is the most limiting factor for oak population recovery in the Laguna watershed. The overall objectives for oak savannah should be to plant replacements for oaks nearing the end of their natural life spans, and promote oak re-colonization of grasslands where feasible, increasing oak density. As oaks take many years to reach maturity, it is important to begin restoration efforts as soon as possible.

Evaluation

The adaptive management life cycle encompasses an iterative approach that includes continual evaluation and adjustment. Baseline assessments provide a yardstick for measuring future restoration and management success. Ongoing monitoring provides comparison data for checking how recent efforts measure up. Both of these require an organizational tool, such as a computerized database, to retain and provide easy access to the collected data.

Baseline assessments

Baseline assessments are essential for restoration and management planning. Ecosystems within the greater Laguna watershed have undergone very rapid change in the last half-century, straining the ability of natural processes to provide essential services like flood attenuation, water purification and recharge, and wildlife habitat. While restoration will enable these services to continue with greater effectiveness, more information is needed to properly design and implement projects. The situation is analogous to a patient presenting serious and debilitating symptoms to their doctor. Although the symptoms indicate the nature of the underlying problem, the doctor must thoroughly evaluate the patient's vital signs and health history before undertaking expensive and difficult surgery. This caution is aimed at allowing the operation to have maximum success and to avoid unintended consequences.

For the most rigorous restoration planning, baseline assessments are needed at multiple nested scales, for example: the scale of the individual site, the scale of the property or preserve area, and the scale of the entire

watershed. For restoration at individual project sites, baseline assessments are used to evaluate specific features needing restoration—like eroding banks and invasive species, and the special features needing protection—like native plants or nesting birds. These assessments, along with ongoing monitoring, form a basis for adaptive management analyses. Where restoration projects require extensive permitting, baseline analyses are required by law as part of the EIR/EIS development.

Assessment of individual sites and assessment of the entire watershed

Baseline assessments at larger spatial scales are needed for evaluating the potential effects of processes taking place upstream or on neighboring properties. In particular, watershed-scale assessments are needed to understand the basic physical processes shaping the ecological system: how the movement of water and the underlying soils and geography affect plants and animals and ecosystem services. In particular, coordinated, watershed-scale studies and modeling are needed to develop a baseline characterization of the watershed and predict future changes in year-round water dynamics. Such a study is described in more detail in chapter 7; at a minimum it will require analysis of topography, meteorology, stream surveys and flow monitoring, soils and land use, and infiltration rates. Currently, researchers are working on a fluvial geomorphology analysis of the Russian River, to evaluate the optimal width of riparian forest buffers needed for healthy stream conditions. The Laguna channel and its tributaries on the Santa Rosa Plain are much more confined than the Russian; however, having a baseline assessment of optimal riparian buffer width—based on stream dynamics—would be valuable for urban and restoration planning.

Developing a baseline characterization

We are only just beginning to understand how the Laguna's physical processes enable its rich biological diversity, how species interact with one another, whether wildlife populations are growing or shrinking, and what should best be done to restore the ecosystem to health. All of these baseline questions will require sustained research and monitoring. These efforts should be organized and retained in a centralized database; however, at the present time there is no central, organized place for storing current and historic data, information from baseline assessments, and ongoing research results. For Laguna research to blossom, we need a comprehensive data management system with easy access for engineers, planners, students and scientists.

Sustained research and monitoring

Monitoring

Ongoing management requires ongoing monitoring. This is essential for a formalized adaptive management process, and builds on the initial baseline

assessments of environmental characteristics and resources. Monitoring is a way of following-up and documenting the results of experiments, and tracking changes in the landscape and ecological community through time. For example, some bird species are excellent indicators of habitat condition. Different bird species prefer different habitat attributes—tree height, shrub density or insect abundance—which improve as restoration projects mature. In this way, birds integrate many components of a complex ecosystem, and allow quality comparisons among different sites. For these reasons, structured bird monitoring is a respected method for quantifying the success of restoration projects. There are many different levels and forms of monitoring, from the strictly quantitative—with randomly placed quadrants and standard operating procedures—to simple field surveys, or elaborate monitoring blitzes like the Audubon Christmas Bird Count. Surveys put boots-on-the-ground: finding barriers to fish passage, sites of bank erosion, and other opportunities for restoration.

Birds as indicators of habitat condition

Like maintenance, monitoring has been chronically under-funded in restoration projects. Ideally, each preserve or parcel should have an established monitoring program. The scope of the program depends on the parcel, and the land manager's objectives. CTS preserves, for example, will need fairly elaborate monitoring over a number of years to track population fluctuations and vernal pool habitat quality. Other preserves may only need annual observational surveys for invasive species or flood damage. In the Cunningham Marsh Plan, biologist Peter Baye recommends that land managers place emphasis on sustained monitoring over long periods of time, with simple data collection methods that are robust to changes in scientific methodology, rather than more complex and detailed efforts. Photo documentation from fixed photo-monitoring coordinates is very useful, as are basic descriptions and dates of management actions. Using GPS, it is possible to fairly accurately map the location of individual plants to help track survival rates or the success of invasive species control efforts.

Monitoring has been chronically under-funded

Some monitoring programs, such as CTS larval surveys or invasive species monitoring, need to be collaborative efforts at a large geographic scale. These monitoring programs seek to track population dynamics across the landscape; these monitoring programs are needed because information from individual preserves does not provide an adequate picture. CTS is believed to have metapopulation dynamics, with extirpation and re-colonization occurring regularly at different breeding pools. As another example of a landscape level monitoring program, wild turkeys are undergoing a population explosion in Sonoma County, and coordinated

Landscape level monitoring programs

monitoring is needed to evaluate their abundance, ecological impacts and potential control success.

Like baseline assessments, monitoring generates large amounts of data. This information must be gathered together, standardized, and organized, for it to be useful to future land managers. Ideally, it should be stored in a digital form, with geographic coordinates. As Peter Baye observes, having a central database to collect and store monitoring information also helps to buffer the variability associated with funding cycles and fluctuations in volunteer interest.

Laguna ecosystem database

A Laguna-centric ecosystem database is essential. Because the Laguna watershed is large and complex, researchers who are focused on one component of the ecosystem must reference work on other components. For example, a fluvial geomorphologist recently needed information on the distribution of tree species in the Laguna, because she was attempting to use dendrochronology to estimate rates of sediment deposition. This information could have been readily retrieved if a data repository had been in place. Over the past decades, many studies have been conducted in the Laguna, and the data was collected in "hard copies" and filed away by individual organizations. Very frequently, data files were not accompanied by detailed explanations of why the study was conducted, or maps and explanatory diagrams. As a consequence, much of this information, if not lost, has remained inaccessible. Research is hampered when it is difficult to determine what data is available and where it is held.

Data management has developed into a discipline in its own right. Digital databases can organize and store vast amounts of information; these data can be searched and retrieved, and can be referenced to geographic coordinates. Over the next several years, federal agencies and international environmental organizations like The Nature Conservancy will be spearheading web-based information systems, where local groups can upload data sets, which can then be accessed by researchers around the world. Invasive species management, for example, will greatly benefit from this distributed, shared format, and will help to document the geographic spread of particular species.

The Nature Conservancy's web-based information system

The value of a database depends on the quality of the information it contains, and in having an estimate of the confidence we place in any given value. Data collected by high school students may be as valuable as that collected by museum curators. This may or may not be readily apparent to outside users, thus it is essential to include the conditions under

which data was gathered. Confidence intervals have been necessary for historical ecology studies, reconstructing landscape contours from old and sometimes conflicting maps and documents, by overlaying sources with different levels of certainty. The analysis gives a "consensus" on the likely location of a landscape feature, along with a confidence estimate. All classes of data benefit from this treatment. Backyard bird count data can be combined with formal surveys by ornithologists, and citizen-gathered water quality data can be combined with studies by RWQCB staff. Ideally, standard operating procedures (SOPs) should be developed for each class of data. The Nature Conservancy has been developing these for weed mapping; PRBO Conservation Science and Audubon have developed SOPs for certain types of bird monitoring. Other monitoring efforts in the Laguna are still working toward a set of standard protocols.

Confidence intervals

Having a stable, comprehensive repository of data will also be essential for creating a Laguna Report Card (described below). Other watersheds, including San Francisco Bay and Chesapeake Bay, use current and historical information to track improvement and decline in environmental indices, in categories like pollution, habitat, and fisheries or wildlife. This way of measuring progress, depends on adopting a standardized set of monitoring procedures. The database will provide a stable platform on which to establish the report card framework, with an agreed upon set of indices and standards of analysis. Developing a biodiversity database was a primary objective of the Santa Rosa Plain Vernal Pool Ecosystem Preservation Plan, and is a recommendation of the Draft 2020 Sonoma County General Plan.

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