CHAPTER FIVE

Applications: Building a Practical Framework for Ecosystem Restoration and Management

One of the greatest challenges of modern resource management is to develop the tools - both conceptual and applied - necessary to enhance the effectiveness of restoration planning at the ecosystem level, including the comparative evaluation of alternate restoration actions, and the evaluation and monitoring of the ecological condition of restored / managed systems. The preceding chapters have provided (1) a narrative overview of natural structure and function of the ecologically different kinds of areas that comprise the aquatic portion of the landscape, (2) a description of the many human activities that have in the past substantially affected these systems' ecology (and in many cases continue to do so), and (3) the net results of these interventions, in terms of the comparative states of fundamental system properties as they existed historically and exist today. This report concludes with suggested applications of that information to the challenges of planning for ecosystem-level restoration and management of the San Francisco Bay-Delta watershed.

I. Developing a Practical and Effective Strategic Approach

Restoration efforts in this highly-developed and populated watershed will necessarily reflect a compromise between conflicting needs. Ensuring the long-term protection of the full range of native biodiversity inhabiting the watershed's ecosystems and habitats requires comprehensive, ecosystem-level efforts. As Noss et al. (1994, p. 3) warned, "*A continually expanding list of endangered species seems inevitable unless trends of habitat destruction are reversed soon through a national commitment to ecosystem protection and restoration*." However, by definition true restoration involves, "*the return of an ecosystem to a close approximation of its condition prior to disturbance*" (NRC 1992). Clearly, the degree of disturbance and, in some cases, irreversible changes in the watershed, along with the extent of the system and current levels of human population and consumptive use, make it quite apparent that the pursuit of true restoration throughout the *entire* geographic range of the watershed is neither feasible nor desirable. It is incompatible with the resource and economic demands of 30 million human inhabitants of the state - demands which *also* must be met. What then might be the strategic solution to this apparent conflict? To address this question, we need to consider two fundamentally different options available, in terms of restoration projects / programs:

(1) **Rehabilitation**. Projects aimed at restoring *some limited number of particularly desirable ecological characteristics,* (e.g., increased population

levels, harvest, or production, etc.) to an area or region. This approach (also called *partial restoration*) may provide substantial "*ecological benefits even though full restoration is not attained*" (NRC 1992).

(2) **Comprehensive Restoration** (or the closest possible approximation thereof). A program designed to restore full *ecological integrity*** to a defined area.

***** (Note: the term "ecological integrity" is used here in the sense of the ability of a defined area to sustainably support essential ecological processes and viable populations of *all* native species, with minimal ongoing human intervention.)

Planning efforts to date suggest that only *a combination of both* approaches - a program that seeks to protect the full range of native biodiversity through comprehensive restoration of representative portions of the region's aquatic ecosystems, along with more broadly dispersed rehabilitative efforts directed at more narrowly focused objectives - will achieve the diverse long and short-term biological conservation / resource enhancement goals encompassed by the CALFED program in a manner compatible with current and projected human population levels and their resource needs. While a species-oriented, rehabilitative approach to restoration / management may address particular economic objectives (e.g., enhanced commercial harvest or recreational opportunities), and also serve as a useful and complementary conservation tool addressing the short-term needs of species in immediate danger, such an approach is, in and of itself, neither efficient or effective as a comprehensive strategy for long-term protection of overall biodiversity (Kohm 1991). Additionally, it must be re-emphasized that simply spreading out species-focused actions over a large portion of the landscape does not constitute a form of "ecosystem"-level restoration or management, which is by definition guided by the states of a comprehensive suite of attributes of a particular **area**, rather than the states of the perceived "limiting factors" of particular species.

The approach recommended above - the concept of complementing such species-focused efforts with a systematic program of comprehensive restoration and / or protection of limited areas that represent the full gamut of native biological communities / assemblages - is a relatively recent development. Called "*ecosystem representation*," the establishment of such a network has recently been called "*one of the most widely accepted goals of conservation*" (Ecological Society of America, 1995). Integrated with other uses of the surrounding landscapes, this approach has the capacity to simultaneously address the needs of entire biological communities as well as ensure the sustainable use of natural resources for the benefit of society. Such a strategy has already been adopted as a proactive national conservation policy in Canada, in the form of the Endangered Spaces Campaign (Hummel 1989), with wide support at the popular level, as well as top levels of government and some 260 environmental organizations. Here, the entire country is being inventoried to identify the diversity of ecosystems that need to be represented, with protection slated to be in place *prior to* the need for species listing. To a large degree, addressing species concerns at these broader levels of communities and ecosystems preempts the need to individually analyze or address the ecological requirements of each and every resident species.

An ecosystem representation approach is particularly appropriate to the goal of protecting overall biodiversity in the Bay-Delta-River watershed, since that goal includes conservation of many species about whose ecology little or nothing is known. The comprehensive restoration and subsequent long-term protection of sizeable areas of any landscape, is in many cases an inherently costly endeavor. Nonetheless, it has been pointed out that such efforts would, "*almost certainly be less costly in terms of time and money than an uncoordinated series of recovery plans and habitat-conservation plans for each individual species*" (Noss et al 1994, p. 8). It has been estimated that comprehensive "community-level" conservation strategies may be able to protect 85-90% of the species in an area without the need for assessment of any particular species requirements (Noss et al. 1994).

It might be argued that such a program is largely unnecessary, since a number of areas that might be considered "representative" of the watershed's aquatic ecosystems are already under some sort of protective management. These include a number of national parks (Yosemite, Kings Canyon, and Sequoia), national forests (Shasta-Trinity, Lassen, Plumas, El Dorado, Tahoe, Stanislaus, Toiyabe, Sierra, and Sequoia), many state and county parks (e.g. Mt. Diablo, Calaveras Big Trees), state recreation areas (e.g. Brannan Island, Kettlemen), national wildlife refuges (e.g. Kern, Pixley, Merced, Kesterson, San Luis), and a number of smaller, less well-known areas. The Wild and Scenic Rivers Act of 1968 provided protection for many rivers across the country. "Wild and Scenic" means that a river must remain undammed and allowed to follow its natural course. In California, these are the only rivers in the state that still have reasonable runs of salmon and steelhead trout (Schoenherr 1992). A number of large-scale restoration projects on former tidal marshes are now in the planning stages, including projects to create managed seasonal wetlands and projects to restore natural tidal wetland processes. The California Department of Fish and Game has recently acquired 7,000 acres slated for future restoration as functional wetlands.

While the current network of protected areas is unquestionably of some conservation value in terms of protecting some relatively rare habitats and species, in general the current network consists of areas that are too small, fragmented, and primarily managed for other purposes (e.g., recreation) to achieve full species protection or system integrity. In this context, Noss (1991, p. 229-230) concluded that "*because parks are generally too small for viable populations of many species and their legal boundaries do not conform to ecological boundaries, disruption of processes (such as fire regimes) and species composition is almost inevitable. Scenery is a hollow virtue when ecological integrity has been lost.*" Unlike national parks and forests, which are primarily managed for other purposes, the ecosystem representation strategy employs protected areas carefully selected on the basis of natural ecological boundaries and features, and managed with the *primary* purpose of ecosystem and species protection.

While the basic concept is relatively simple and straightforward, its practical application is not. The idea that we might just rope off an area, stand aside, and let nature "do her thing" is not a realistic approach to conservation in the 21st century. Today, there are relatively few landscapes left in America that might be considered sufficiently "pristine" to adequately address conservation needs in their present condition. Even activities far distant from a protected area may continue to have substantial effects on local ecology. The situation is even more complicated in the Bay-Delta-River watershed, which has been extensively colonized by exotic species. Thus, to be effective, most protected areas nestled within highly developed landscapes will require active restoration and dedicated management, both of which must be integrated with resource and land use over a much larger geographic scale than the refuge itself. Restored ecosystems may be reasonably expected to *approximate* rather than *duplicate* past conditions, and thus require continual monitoring and flexible, adaptive management provisions to address unexpected or unwanted eventualities.

The basic design of protected areas has received considerable attention in recent years, and substantial progress has been made. The size, shape, and connectivity (with other natural systems) will affect the conservation success of protected areas, and the optimal combination of these must be determined individually for each area, in conjunction with consideration of other societal needs and resource uses within the region. The most widely recognized general approach is to use a centrally located and highly regulated "core area" as the focus of species protection, surrounded by a "buffer zone" which is more open to other compatible uses, but still under active management as part of the refuge. The buffer zone serves several key purposes. It isolates the core area from nearby human activity, provides an area in which to safely "experiment" with adaptive management options (including the effects of different types of human activity), and provides pre-acquired additional area that, if necessary, might be added to the "core" with minimum additional expenditure or disruption of nearby human activity. In complex landscapes (such as the Central Valley watershed) consisting of a number of ecosystem types, protected representations of different systems should be linked by a protected corridor, ensuring adequate connectivity and integrity at the landscape scale.

The total exclusion of people from conservation areas is *not* a necessary pre-requisite to successful conservation, but strict control of the amount and types of activity unquestionably is. It is an undeniable fact that indigenous peoples throughout the world have lived amidst, and been sustained by, native plants and animals for many millennia without destruction of species or habitats. Here, the magnitude and nature of resource exploitation were compatible with ecological integrity of these natural systems. Reasonable levels of hunting, fishing or other uses of the natural resources of protected areas are not necessarily inherently harmful; many ecosystems thrive on regular "disturbances" - floods, fire, etc. - that periodically kill, injure, or displace thousands of resident animals and plants. Adaptive management and the use of the core / buffer zone concept provides a means to empirically determine the levels and types of human activities that are compatible with conservation objectives within protected areas.

II. Developing Practical Tools for Restoration and Management at the Ecosystem Level

This report does not, and was never intended to, provide a detailed blueprint for restoration in this watershed. Rather, it was designed to provide a coherent and defensible *ecological framework* for restoration, defining appropriate management units and essential ecosystem characteristics that comprise the most useful and practical focus of restoration actions and planning. Development of a comprehensive and detailed restoration plan for the watershed will require considerable additional effort. Below, the translation of the information base developed in this report into practical restoration / management tools is demonstrated.

Among the most useful and essential of tools needed by ecosystem restoration / management programs are *ecological indicators* - practical measures of system characteristics that provide a direct means to objectively evaluate and monitor the status and "health" of the system as a whole, or of individual aspects of the system of particular interest. Essentially, indicators are the means by which restoration / management success may be objectively measured, or alternate restoration management options evaluated. Because of these pivotal roles, the development of ecological indicators has received a great deal of attention in recent years, although there remains little consensus on just how to best go about developing such tools. To illustrate how the kind of historical information base developed here might be applied to such tasks, the narrative overview of Delta ecology presented above was used to develop a provisional suite of indicators that could be used to practically plan, evaluate and monitor a conservation program seeking to restore and sustainably protect a representative portion of the historical Delta ecosystem.

A large number of broadly stated ecological attributes, such as "variable flows" or "complex topography," might be identified as ecologically influential. Each of these may in turn have numerous aspects warranting consideration, and each aspect might be measured in a number of ways. Thus, the process of selecting indicators involves choosing, from a far larger number of variables that might be measured, a manageable and appropriate set. A rational approach to the problem of selecting indicators was illustrated by Keddy and Drummond (1996), who focused upon (p. 748-749) "*essential properties*" that "*indicate higher levels of health or integrity*" and are additionally, "*(1) easy to measure and monitor and (2) compare macro-rather than micro-scale properties.*"

To illustrate these applications of the developed historical data base, the above criteria were applied to the conceptual framework of ecological structure and function of both the Delta and upland river-floodplain ecosystems developed in Chapter 2 to derive a suite of system attributes (Tables V-A and V-B) that reflect each of the major categories used to analyze these systems: habitat structure, biological community composition, and essential hydrogeomorphic and ecological processes. The attributes selected are believed essential to biodiversity support and ecological integrity in this system; thus, they might well serve as a basis for evaluating and monitoring overall system integrity. Based upon the understanding of natural system structure, function, and organization developed here, it would seem reasonable to conclude that if all these attributes were intact, the system could be judged as doing "well." Conversely, serious biological/ ecological repercussions might reasonably be expected to accompany the finding that any one or combination of these attributes was not intact. The next task was to select, for each attribute, a tentative list of indicators (practical measures) that could be used to quantitatively evaluate and monitor the attribute (Tables V-A and V-B).

Finally, it is clear that practical application of ecological indicators requires the development of "reference values" - a quantitative framework with which to evaluate measured values and/or establish target values for indicators. Keddy and Drummond (1996) used empirical measurements from a number of modern representative temperate deciduous forest ecosystems to establish high-to-low ranges for indicators. Such an approach is not an option in the present case, because comparable modern systems are not available. However, historical conditions may also be used to establish an analogous quantitative framework that, while not particularly precise, may nonetheless provide an invaluable guide to emulation of a suite of environmental conditions that approximate "natural" conditions closely enough to achieve desired restoration goals and objectives. For example, the natural topography, proportionate extent of major habitat types, typical organic content of soils, etc. all are reasonably quantified through the historical analysis provided, and might be compared with current values for the same parameters to provide a quantitative framework for the selected indicators (Table V-C). While attempting precise definition of "healthy" or "unhealthy" values for these indicators may not particularly productive, the range provided (natural versus current) nonetheless quantitatively defines and compares conditions known to have at one time sustainably supported "desirable" biological assemblages with conditions deemed "unacceptable" from that same standpoint.

It is emphasized that the preliminary tools presented in V-A to V-C are intended as "demonstration" products. The choice of attributes is admittedly somewhat arbitrary - perhaps others should be added, or perhaps all are not necessary. Nonetheless, the list provided would appear to represent a rational starting point in this regard. These suggestions are unquestionably in need of further refinement, and will continue to be modified according to the results of a planned adaptive management approach to watershed restoration. It is also emphasized that application of attributes (and indicators) will require careful consideration of the unique properties and environmental conditions found at particular restoration sites, as well as the specific goals and objectives of the particular projects / programs. Nonetheless, it is clear that restoration / management efforts at *any and all scales* at least require consideration of a comprehensive suite of essential attributes; interactions among seemingly "irrelevant" factors (from the standpoint of more narrowly focused management programs) may in fact eventually prohibit or inhibit project success.

III. Concluding Recommendations

This report has examined the ecological history of the Bay-Delta-River watershed, and considered practical alternative strategic approaches to ecological restoration that might lead to long-term protection of the system's native species and ecological structure and function. Based upon these analyses, we make the following broad recommendations:

> (1) An ecosystem approach to natural resource restoration and management is the most efficient and effective available means to meet the need for long-term protection of ecological integrity and biodiversity within the watershed. This must be complemented by more focused efforts that address the immediate needs of threatened and endangered species. The granting of protected status and preparation of recovery plans for individual species must remain a viable tool in our comprehensive species protection strategies.
>
> (2) A guiding and overarching long-term restoration strategy should be clearly articulated and adopted that seeks to achieve and integrate a geographically broad program of ecological rehabilitation with a focused, ecosystem representation program aimed at full restoration of ecological

structure and function of a connected network of representative areas of each of the ecosystem and habitat types defined herein.

(3) In general, ecosystems should replace populations and species as the fundamental planning units of long-term, comprehensive restoration efforts. Specific long-term restoration actions should be primarily, although not exclusively, aimed at the enhancement and protection of essential ecosystem processes and structural features, rather than particular taxa or species. Although protection of individual species, biodiversity or ecological integrity may not be the primary goal of resource use in non-protected areas, such considerations should be accommodated to the full extent compatible with other (higher priority) resource use objectives.

(4) Hydrogeophysical support (flows and sediments) must be adequate to support essential ecosystem functions and restore and maintain essential structural attributes within designated restoration sites, and to provide sufficient connectivity among restored sites to allow the natural migration and movement of wide-ranging species.

(5) In all cases, care must be taken to ensure that program elements - "new" restoration / management actions - do not inadvertently displace or threaten surviving remnant populations of native species now restricted to locations likely to be highly altered by such actions, or create conditions that favor exotic species rather than natives.

Adopting the recommendations of this report will not resurrect the rich, complex, undisturbed ecosystems of the San Francisco Bay-Delta-River system of 150 years ago. Nonetheless, applying an understanding of "natural" watershed ecology will serve as an invaluable guide to comprehensive restoration in particular representative segments of the watershed, and to a general program of rehabilitation throughout much of the region. Initiating a restoration program based on good intentions alone is not sufficient. The most successful restoration program for this watershed will ultimately be that which most effectively and efficiently applies the precepts of modern restoration ecology within the practical limits of resources available and within the practical constraints set by other legitimate societal needs. Such efforts - properly designed and executed - have the capacity to protect, restore and sustain native ecosystems, and the full range of remaining native plants and animals that depend on them; reduce conflicts over protection of endangered species; provide for more economically and environmentally sound flood management; enhance recreational opportunities; ensure high water quality for urban and industrial uses; and create an aesthetically more pleasing environment. It is our best opportunity to preserve the unique ecological heritage of California's Bay-Delta-River watershed for ourselves and future generations.

Table V-A. Delta Ecosystem: Proposed Essential Attributes and Their Indicators

	Ecosystem Attribute	Corresponding Indicator
1.	Flat topography, near sea level	% of area within ± 5 ft MHHW
2.	High organic content of wetland soils	% organic content (wet weight)
3.	Variable wetland water levels (daily / seasonally)	(a) difference in % area awash at MHHW versus MLLW (b) mean flood frequency / year
4.	Natural water movement patterns (river channels only)	days of bi-directional flows: *Sacramento channels* Winter (December-March) Spring (April-July) Summer / Fall (August-November) *San Joaquin channels* Winter (December-March) Spring (April-July) Summer / Fall (August-November)
5.	Characteristic salinity distribution	mean monthly salinity *western Delta* December-July August-October *central Delta* December-July August-October *eastern Delta* December-July August-October
6.	Natural habitat mosaic	Proportionate extent of: intertidal wetlands subtidal waterways supratidal landforms other (urban, ag)

Table V-A. Delta Ecosystem: Proposed Essential Attributes and Their Indicators

	Ecosystem Attribute	Corresponding Indicator
7.	Good water/soil/sediment quality	toxicity measure water soils benthic sediments
8.	Naturalistic plant assemblages	(a) Marshplains # native species present % native biomass (b) Willow fern swamps # native species present % native biomass (c) Riparian # native species present % native biomass
9.	Naturalistic animal assemblages	For <u>each</u> of the following: fishes, birds, insects, mammals -- # native species/genera present # exotics established last 3 years % biomass native species
10.	Sources of Primary Production	% ecosystem primary production by: native emergent plants riparian plants phytoplankton benthic macrophytes

Table V-B. Upland River-Floodplain Ecosystem: Proposed Essential Attributes and Their Indicators

(Indicator reference values will predictably differ at different sites, and in different geomorphic zones)

	Ecosystem Attribute	Corresponding Indicator
1.	Balanced sediment budget	net change in depth of unconsolidated sediments
2.	Dynamic channel substrates	inter-annual comparison of sand-bar distribution
3.	Continuous channels	# of barriers blocking / diverting flows and / or movement of fishes
4.	Seasonal shifts in stream level	mean % change in depth (cm): February vs. September
5.	Periodic flooding	mean frequency overbank flows
6.	Naturalistic hydrograph	mean monthly flows
7.	Continuous riparian corridor	mean length unbroken riparian zone / 10 km
8.	Instream habitat complexity	(a) pool / riffle ratio / linear mile (b) frequency of LWD
9.	Good water / soil / sediment quality	toxicity measure water soils benthic sediments
10.	Naturalistic plant assemblages	(a) Riparian # native species present % native biomass (b) Phytoplankton # native species present % native biomass (c) benthic macrophytes # native species present % native biomass
11.	Naturalistic animal assemblages	For <u>each</u> of the following: fishes, birds, insects, mammals -- # native species / genera present # exotics established last 3 years % biomass native species

Table V-B. Upland River-Floodplain Ecosystem: Proposed Essential Attributes and Their Indicators

(Indicator reference values will predictably differ at different sites, and in different geomorphic zones)

	Ecosystem Attribute	Corresponding Indicator
12.	Nutrient / energy sources	(a) Primary production / unit stream length by: riparian plants phytoplankton benthic macrophytes (b) Annual weight of returning salmon (natural spawning streams only)

Table V-C. Delta Ecosystem: Sample Reference Values for Selected Indicators[1]

	Ecosystem Attribute	Corresponding Indicator	Reference Values: Natural[2]	Reference Values: Current
1.	Topography	% of area within ± 5 ft MHHW	>85%	<25%
2.	Soil composition	% organic content (wet weight)	>80%	<20%
3.	Habitat mosaic	Proportionate extent of:		
		intertidal wetlands	85%	<5%
		subtidal waterways	7.5%	7.5%
		riparian vegetation (supratidal)	7.5%	<1%
		other (urban, agriculture)	0%	>90%

1 These reference values are presented primarily for demonstration purposes. Values given represent best estimates.

2 "Natural" values are derived from historic reconstruction and refer to estimated values circa 1850.