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The value of historical information in ecological restoration projects

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**THE VALUE OF HISTORICAL INFORMATION
IN ECOLOGICAL RESTORATION PROJECTS**

A Thesis

Presented to

The Faculty of the Department of Environmental Studies

San Jose State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Science

by

Lisa F. Walsh

December 2001

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ABSTRACT

THE VALUE OF HISTORICAL INFORMATION IN ECOLOGICAL RESTORATION PROJECTS

by Lisa F. Walsh

Researchers agree that to gain a view of the pre-disturbance condition of an ecosystem, a historical perspective regarding restoration may help (Aronson and LeFloc'h 1996; Hobbs and Norton 1996; Dunwiddie 1992).

Very little information exists regarding historical information and its role in restoration. This research identified current methodologies that help reconstruct historical landscapes, analyzed six restoration projects, and surveyed restorationists to determine the value of historical information.

According to the restorationists surveyed, aerial photographs give the greatest insight into earlier conditions of a site and contribute the most toward the development of restoration goals. Baseline data can be generated from historical information (such as aerial photographs and archived maps) and ecological and computer methodologies (sediment coring and GIS) for the purposes of recreating historical landscapes in a restoration project.

Recommendations from this research on how to improve restorations with historical information include gathering a wide variety of information to develop baseline data.

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INTRODUCTION

The Society for Ecological Restoration defines restoration as the intentional alteration of a site to establish a defined, indigenous, historic ecosystem. Henry and Amoros (1995, 892) claim that “the goal of this process is to emulate the structure, functioning, diversity, and dynamics of the specified ecosystem.” Both the National Research Council (1992) and Aronson, et al. (1993) state that restoration means to redirect a disturbed ecosystem to resemble one presumed to have existed prior to the onset of disturbance. To gain a view of the pre-disturbance condition of an ecosystem, a historical perspective regarding restoration may help (Aronson and Le Floch 1996b; Hobbs and Norton 1996; Dunwiddie 1992).

When conducting an ecological restoration project, baseline information on a site prior to disturbance is necessary to develop accurate goals and improve post-project monitoring (Hobbs and Norton 1996; Henry and Amoros 1995; Kondolf 1995; Westman 1991). Historical information, which is an important part of baseline information (Cairns 1991; Henry and Amoros 1995; Kondolf and Micheli 1995; White 1995), is often lacking in current restoration projects (Aronson, Dhillon, and LeFloc’h 1995; Kondolf and Micheli 1995). Determining whether historical data improve restorations and, if so, what type(s) of data might be most useful can advance restoration ecology.

Historical information can be obtained from aerial photographs, historical maps, plant and animal population data, personal interviews, land-use surveys, and additional archival information. Current methodologies such as sediment coring and Geographic Information Systems (GIS) also provide data that help restorationists to reconstruct an ecosystem to its former condition. Data gathered from these sources contribute to the baseline information of a particular site. The National Research Council (1992) pointed out the importance of baseline data for evaluating restoration success or failure. In discussing riparian restoration, Henry and Amoros (1995, 897) claim that "...project design and evaluation must be guided by as much knowledge as possible about *past*... conditions. Documenting the *history*...is essential to provide a temporal context in which to interpret evaluation results" (emphasis added). Kondolf (1995) states that baseline data must encompass as long a pre-project period as possible, which will then contribute to effective evaluation of project success. The idea that historical or baseline information greatly influences the success of the restoration is shared by many in the restoration field (Hobbs and Norton 1996; Henry and Amoros 1995; Kondolf 1995; Westman 1991).

However, such baseline data are often lacking (Aronson, Dhillon, and LeFloc'h 1995; Kondolf and Micheli 1995). Aronson, Dhillon, and LeFloc'h (1995) noted that in many cases no systematic evaluation of results was established and no baseline data were collected. Similarly, Kondolf and Micheli (1995, 2) state that "...the environmental manager who seeks to measure the success of ... restoration is commonly faced with insufficient baseline data, inadequate funds for monitoring, and no guidance on how to proceed with an evaluation." Although historical information is sometimes used to

establish baseline data (Aronson and Le Floc'h 1996a; Henry and Amoros 1995; Kondolf 1995), there is still very little information on whether historical information improves restorations or what types of data might be most useful. By determining the value of historical information in baseline data, recommendations for improving restorations can be made. Understanding the value of current methodologies used to recreate historical landscapes can also benefit restoration projects.

The Context for Restoration

Many of the world's lakes, rivers, streams, estuaries, and wetlands have been dredged, channeled, diked, dammed, diverted, silted in, and contaminated (Berger 1992). More than fifty percent of U.S. wetlands have been destroyed, and the United States is losing over 400,000 acres of wetlands each year. Table 1 from Cairns (1993) presents wetland loss in the past 200 years by state. In California, more than 94 percent of the wetlands in the Central Valley are now gone, as well as approximately 90 percent of San Francisco Bay's salt marshes. In the Northeast, thousands of lakes are dead, as are forests, from acid rain and other pollutants (Berger 1990).

Terrestrial ecosystems have also suffered tremendous destruction and degradation. Billions of tons of topsoil are eroding from abused and pesticide-ridden lands. More than 20,000 toxic waste dumps exist in the United States, with many of these slowly poisoning the groundwater. Measurable quantities of dioxin and DDT can be found in human breast milk and body fat tissues throughout the country (Berger 1990).

Table 1. A Comparison of Wetland Area in the 1780s and 1980s

State	Thousands of Acres in 1780's	Thousands of Acres in 1980's	Percent Loss of Wetland Area
California	5,000	454	90
Ohio	5,000	483	90
Iowa	4,000	422	89
Indiana	5,800	751	87
Missouri	4,844	643	87
Illinois	8,212	1,255	85
Kentucky	1,588	300	81
Connecticut	870	173	74
Maryland	1,850	440	73
Arkansas	9,849	2,784	72
Oklahoma	2,843	950	66
New York	2,582	1,025	60
Mississippi	9,872	4,067	59
Tennessee	1,937	787	59
Pennsylvania	1,127	489	56
Idaho	877	388	56
Delaware	480	223	54
Texas	18,000	7,612	53
Nevada	487	238	51
North Carolina	11,080	5,680	50
North Dakota	4,928	2,499	50
Colorado	2,000	1,000	50
Alabama	7,588	3,784	50
Michigan	11,200	5,583	50
Kansas	841	435	48
Wisconsin	9,800	5,331	46
Florida	20,325	11,038	46
Louisiana	16,195	8,784	46
Virginia	1,849	1,075	42
Minnesota	15,070	8,700	42
Oregon	2,282	1,384	39
New Jersey	1,500	918	39
Rhode Island	103	65	37
Wyoming	2,000	1,250	37
Arizona	931	600	36
Nebraska	2,911	1,908	35
South Dakota	2,735	1,780	35
Vermont	341	220	35
New Mexico	720	482	33
Utah	802	558	30
Washington	1,350	938	30
Massachusetts	818	588	28
Montana	1,147	840	27
South Carolina	6,414	4,659	27
West Virginia	134	102	24
Georgia	6,843	5,298	23
Maine	6,460	5,199	20
Hawaii	59	52	12
New Hampshire	220	200	9
Alaska	170,200	170,000	0

Source: Cairns (1993)

Both aquatic and terrestrial ecosystems are losing native plant and animal species as well as their capacity to perform beneficial functions such as absorbing wastes, purifying water, producing oxygen and providing flood control. Natural habitats also provide aesthetic, recreational, economic, and educational values (Berger 1990,1992; Kusler and Kentula 1990; Jordan, Gilpin, and Aber 1987).

Many factors have contributed to the decline of aquatic and terrestrial ecosystems. Human impacts to many of the earth's ecosystems include pollution, habitat fragmentation and destruction, the addition of invasive species, and the extinction and limitation of native species. Many of these destructive problems are caused by activities such as agriculture, logging, grazing, and urbanization. An example of human impacts to an aquatic system is evident at Green Bay, Wisconsin. The rapid population increase and industrialization of the mid-1800's of the Great Lakes contributed to the degradation of the area, specifically Green Bay (Smith, et al. 1988). The operation of sawmill and paper mills dumped suspended solids and biological oxygen-demanding wastes into the Bay, which robbed the water of oxygen, contributing to numerous fish kills as early as 1920 (Smith, et al. 1988). Land cleared for agriculture in the area also contributed to the decline of Green Bay; the runoff from these farmlands increased the nutrient load, upsetting the natural balance of the aquatic ecosystem. This pattern of pollution, degradation and natural system collapse has been repeated in numerous water bodies.

The overexploitation of the soils of central Chile highlights the type of degradation occurring in many terrestrial ecosystems. The soils are badly eroded due to extensive overuse and other negative land-use practices. In addition, soil microbial activity is practically non-existent in many places (Aronson, et al. 1993b). Aronson, et al. (1993b) characterize the fragile ecosystem of this area as appearing to be an ecologically and economically blocked system showing little or no secondary succession or hope for

increased agricultural or animal husbandry yields in the foreseeable future unless major interventions are undertaken.

Rain in the northeastern United States is 30-40 times more acidic than background levels, billions of tons of topsoil are lost each year; humans are tampering with the world's climate and may even melt the polar ice caps; estuarine and offshore marine ecosystems are breaking down; and a fifth of all the species on earth are in danger of extinction (Berger 1990). Given the UN projected world population of 9 billion within 40 years, the global demand for these precious resources will increase greatly, causing shortages and further damage to aquatic and terrestrial ecosystems (Postel 1985). Berger (1990) and many other ecologists believe that preserving what is left is not enough to preserve and reinstate natural processes. Rather, sites must also be restored, adding to what remains.

Pre-disturbance Condition

It is now clear to scientists, policy-makers and the public that ecological restoration is beneficial and necessary. However, the question of *what* state sites should be restored *to* is an important and difficult one. Falk (1990, 71) states that "...the goal of restoration is to *re-establish the pre-disruption value* of a given parameter." Aronson, et al. (1993a, 9) claim that restoration seeks to "...reorient a disturbed ecosystem's trajectory in a direction resembling its pre-disturbance state." The National Research Council (1992) defines restoration of aquatic ecosystems as the re-establishment of pre-disturbance physical, chemical, and biological characteristics. Most definitions of restoration deal with the assumption that a system was damaged by a human-caused activity (disturbance), and that the site must be restored to a "pre-disturbance" state. The

term “pre-disturbance” in this case refers to human-caused disturbances, not natural disturbance regimes which are processes restorationists often seek to restore.

The pre-human disturbance condition can mean a variety of things to many scientists. Some state that pre-human disturbance in North America signifies environmental conditions at the time of European contact (Reavie, Smol, and Carmichael 1995; Whillans 1996). Other practitioners may choose another point in time for the pre-human disturbance condition. For example, scientists undertaking the Kissimmee River restoration have selected the period prior to the early 1960s as their pre-human disturbance target, which was before the Army Corps of Engineers channelized the Kissimmee.

Most restorationists reject naïve assumptions about a static, pristine, virgin world of unspoiled nature. As a result, restorationists tend to avoid using the “natural” condition as the target restoration goal. Diamond states the obstacle presented when trying to define what is meant by “natural”:

The problem is with the very idea expressed in the word “natural.” What do we mean by this word? Do we mean untouched by human beings? In fact, almost every place on earth, except the polar regions and a few remote islands, has been severely influenced by *Homo sapiens*, directly or indirectly, long before the European colonization of the world took off in 1492. Which condition is the “natural” condition we are trying to create? In America, for example, is it the condition of the landscape at the moment Europeans arrived? Or perhaps three or four centuries later, in 1792, or 1892? (Diamond 1987, 331).

“Pre-human disturbance condition” simply means returning a site to “the way it was” (Cairns 1993, 4).

The archival and ecological methods researched here for reconstructing landscapes will be considered for a range of pre-human disturbance target conditions. It is important to recognize that the reference conditions chosen for restoration targets are not static goals, but starting points for the long-term functioning of the restoration site.

Benefits of Historical Data

Historical data can be beneficial for many phases of restoration projects. These phases include setting goals, developing baseline data, and evaluating restoration success. Goals of restoration projects may include: 1) to recreate a pre-disturbance community; 2) to recreate a self-sustaining ecosystem; 3) to preserve a community in its pre-disturbance state; 4) to model a restoration after an ecosystem of reference; or 5) a combination of the above options (Diamond 1987). Historical data can provide vital baseline information, which guides the development of meaningful and realistic project goals. Historical photographs and/or documents of a particular site prior to disturbance not only aid in setting targets but also in evaluating the success of the restoration.

In order for a restorationist to gain insight into what conditions existed on the site prior to disturbance, baseline data are a necessary component (Hobbs and Norton 1996; Henry and Amoros 1995; Kondolf 1995; Westman 1991). To understand what the useful elements of baseline data are and how historical information fits into restoration, a survey of restorationists was conducted for this study. The following are ways in which this study may benefit others and how the results can be applied to other situations and contexts:

1) Restorationists just beginning a project can find out from other scientists what type of historical source information would aid their restoration efforts. Restorationists may then direct their energies to obtaining one particular type of historical data that will give them the most information to contribute to their baseline data, thus saving time and money during the restoration.

2) Appropriate historical data can be used in developing restoration goals. Dunwiddie (1992, 116) states that “goals defined in the absence of an adequate historical, geographical, or paleoecological perspective can render restored landscapes as mere ‘snapshots’ of a much more complex and dynamic real world.” This research will determine how restorationists are using historical data and what they believe are the best uses for different types of data.

3) It is hoped that restorationists will provide more regular methods of presenting information on the historical data they use to guide their projects.

Determining the types of useful historical data and how they may best be applied can provide guidelines for how restorations should be conducted. This research gathered information on the value of historical data by asking restorationists about its application in their projects. This analysis of historical information in restoration projects will help restoration ecologists in public agencies and private consulting firms, landscape architects, academic scientists/ecologists, non-profit environmental organizations, and private landowners, among others. Increasing the abundance and availability of baseline data can only contribute to increased restoration success. More successful restorations can be very beneficial to society by improving the landscape and environment in which we live. The

National Research Council (1992) has concluded that there is a need for a “national restoration strategy”; improving baseline information is one way to move in that direction.

Research Questions and Methods

The general question this thesis will address is, what is the role and value of historical information in baseline data for ecological restoration projects? Specific questions this study will answer are:

- 1) What types of historical information are restorationists using in their work?
- 2) What types of historical information do they say are most useful as baseline data?
- 3) Do restorationists find the use of historical information influences the success of their restoration projects? If so, how?
- 4) How important is the incorporation of historical information in setting goals for restoration projects?
- 5) What are some current methodologies used to reconstruct historical landscapes and how do they contribute to restoration ecology?

A survey of ecological restorationists was conducted for this thesis to help to answer these questions. The vehicle for generating the survey questions was an analysis of six restoration studies. Insight was gained as to how, why, and what kinds of historical data were currently in use by restorationists. Three case studies that used historical information were compared with three projects that did not use historical data. The objective of the comparison focused on the general goals (for example, to restore to pre-

human disturbance conditions), specific ecosystem level goals (such as increasing native species diversity or abundance), and the types of historical data used to develop the goals (maps, aerial photographs, personal interviews).

The survey questioned practitioners in the field of ecological restoration about the application of historical data in their projects. This survey was cross-sectional in design and consisted of probability sampling in a stratified random fashion. The individuals surveyed were members drawn from the 1994 directory of The Society for Ecological Restoration, and they were selected using a systematic sampling strategy approach. The survey incorporated both questionnaire and interview methods.

A literature review to investigate current methodologies used to reconstruct historical landscapes was also conducted. A discussion of how these approaches are used in restoration ecology follows.

RELATED RESEARCH AND LITERATURE REVIEW

Restoration projects benefit from having as much information as possible about the site's past and current conditions (Hobbs and Norton 1996; Henry and Amoros 1995; Kondolf 1995; Westman 1991). While information about the history of a site is an important component of baseline data (Cairns 1991; Henry and Amoros 1995; Kondolf and Micheli 1995; White 1995), there is very little information in the literature on what types of historical information are useful for baseline data. The related research on this topic reveals how historical data are used and how they may influence goal-setting and post-project evaluations.

Researchers use several approaches to gather baseline data for the design, development of goals, and post-project evaluations of their restoration projects. One method involves using an "ecosystem of reference." This common practice results in obtaining data on important parameters from a similar ecosystem, usually in the vicinity of the site to be restored. Restorationists locate the least disrupted example of the habitat they seek to restore and measure parameters in the field which eventually become ecological targets for the restoration site (Aronson, Dhillon, and LeFloc'h 1995). Habitat restorations that are modeled after an ecosystem of reference will include many of the following ecological criteria: species presence, vegetative cover, and distribution of a plant species; the ability of vegetation to respond to normal ecological disturbances; presence

and abundance of animal species; soil condition and colonization by invertebrates, fungi and bacteria; characteristics of nutrient cycling; and hydrologic regime (Jackson, Lopoukhine, and Hillyard 1995). Ecosystems of reference are useful in cross-checks of methodology, provide data transferable to other areas, and are helpful in comparative studies of related ecosystems (Aronson and Le Floc'h 1996a). Henry and Amoros state that:

Reference data, used from a similar ecosystem carefully chosen considering both its structure and function, should be used for comparisons among ecosystems at the same time and may represent either the ecosystem state before restoration or the desired ecosystem state after restoration. In the former case success or failure of the restoration project will be measured by how far the ecosystem moves from the altered state, whereas in the latter case it will be measured by how the restored ecosystem resembles and functions like the reference one. (Henry and Amoros 1995, 898).

Reference sites are chosen on a case-by-case basis, with each project being unique and requiring individual, specific data from the reference site. Westman (1991, 210) states that "...choosing 100 percent similarity to regional baseline as the acceptable standard for performance is ecologically unrealistic, because it fails to account for regional variation among baseline sites due to habitat variation and stochastic elements influencing disturbance history." Similarity of restored sites to reference sites commonly range from 75 to 95 percent in North American vegetation types, though the figure obviously will vary (Westman 1991).

However, the "reference ecosystem" method is still opposed by some scientists in the restoration field (Pickett and Parker 1994, Erwin 1990). Pickett and Parker (1994) claim that the environment is too dynamic to be able to select just one ecosystem as a

reference for a disturbed site. These scientists state that the assumption of having only one ecologically legitimate or ideal system for a site is a trap.

Pickett and Parker base their argument on a current paradigm for the science of ecology: the “flux of nature.” This paradigm states that dynamics and flux characterize natural systems, as opposed to the “balance of nature” metaphor which claims equilibrium as the dominant state in ecology. Pickett and Parker say that “if a restorationist chooses a reference state, erroneously assuming that it is unchanging or that if disturbed it will return necessarily and readily to a certain equilibrium, then the dynamics of the system will thwart success” (1994, 76).

Erwin (1990) states that an ecosystem of reference is useful for evaluating the structural and functional attributes of a particular habitat or system. However, Westman (1991, 208) warns that there is “room for abuse in selecting the sites for comparison.” He describes an example of a southern California developer who sought to compare the species richness values of proposed development sites of coastal sage scrub to those of a distinct phase in this highly variable vegetation type. Because of the extensive differences in biotic composition of the two vegetation phases, such a comparison was inappropriate.

Using multiple reference sites that capture the range of natural variability for an ecosystem can address many of these problems. But designing a restoration, setting goals, or evaluating the success of a project, using an ecosystem of reference *exclusively* can be limiting (Pickett and Parker 1994, Westman 1991, Erwin 1990). Using data from a reference ecosystem in combination with other forms of baseline information such as

historical data may provide more information helpful to many aspects of restoration (Hobbs and Norton 1996, Henry and Amoros 1995, Kondolf 1995, Westman 1991).

Historical Data Usage

Historical information is recognized as an important part of baseline information in the field of ecological restoration (White 1995, Kondolf and Micheli 1995, Henry and Amoros 1995, Cairns 1991). Primary types of historical information include aerial photographs, historical maps, plant and animal population data, personal interviews, and archival information such as land-use surveys and explorer's notes (Wood 1995, Muhar, Schmutz, and Jungwirth 1995, Kondolf 1995, Henry and Amoros 1995, Grant 1994, Drobney 1994, Aronson, et al. 1993b, Sparks and Sparks 1992, Morlan and Frenkel 1992, Broome 1990, and Packard 1988). Table 2 displays a sampling of how the various forms of historical data are used in different studies.

Table 2. Types and Dates of Historical Data Used in Restoration Projects

Type & Date of Historical Data	Project Location	Citation
Aerial Photographs, 1939, 1972, & 1984	McDonald Basin, OR	Whitall (1995)
Maps (Olmsted's Back Bay Fens), 1879	Boston's Back Bay, MA	Egan (1990)
Plant Data (Herbarium collection), 1882	Morton Aborted, IL	Bowles, Betz, and DeMauro (1993)
Animal Data (Fish Stock Survey), ~1920	River Inn, Austria	Muhar, Schmutz, and Jungwirth (1995)
Personal Interviews (Chilean farmers), early 1900s	Central Chile	Aronson, et al. (1993b)
Land-Use Surveys, 1881	John Day River, OR	Grant (1994)
Archival Data (Stage/Discharge Records), 1929-1960	Kissimmee River, FL	Koebel (1995)
Explorer's Notes (Jones), 1848	Walnut Creek, IA	Drobney (1994)

Aerial photographs, although available only after the late 1920s, can be valuable sources of information and are most useful in determining the boundaries of an ecosystem and the extent of vegetation present at the site. For example, a restoration conducted at McDonald Basin in southwestern Oregon utilized aerial photos taken in 1939, 1972, 1984, and present day. By analyzing the photo series, the restorationists were able to discern that the landscape had been drastically altered (Whiteall 1995). Scientists working on the restoration were then able to determine a pattern of erosion in the basin, and restore the area with dams and appropriate vegetation to eliminate erosion.

Historic maps are usually able to provide more detailed data than aerial photographs. A fine example of the detail of historical maps are those produced by Frederick Law Olmsted, Sr. when he became a consultant for the city of Boston's park system in 1875. Figure 1 shows a map of the Back Bay Fens drawn by Olmsted in 1879. Olmsted restored the area to a tidal marsh for Boston's Park Commission. This extensive map, which outlines in great detail the native vegetation, became useful during a restoration conducted during the 1980s (Egan 1990). For instance, the Agassiz Bridge was reconstructed and replanted with native plants according to Olmsted's plant lists and maps (Egan 1990). Historical maps, specifically the Whitman National Forest Atlas Map of 1912, were used in the restoration of the Middle Fork John Day River in eastern Oregon (Grant 1994). Maps, centuries old, showing parish boundaries and the original river course, were helpful in restoration efforts of the River Neath in Great Britain (Kondolf and Micheli 1995).

Figure 1. Olmsted's Design of the Back Bay Fens for the City of Boston, 1879
Source: Newton (1971).

Plant and animal population data collected by agencies or researchers prior to a disturbance can be extremely useful when available. During the restoration of the Kissimmee River in central Florida, for example, fish fauna information from the Florida Game and Fresh Water Fish Commission from 1957 provided data on the community composition of the river prior to channelization (Trexler 1995). This helped to determine which species previously thrived in the river and what the velocity of the natural system's flow was. Similarly, fish population surveys from 1920 were used in designing goals for the restoration of the River Inn in Austria (Muhar, Schmutz, and Jungwirth 1995). An example of archival plant data are the historic seed collections that aided in restorations at the Morton Arboretum Rare Plant Program in Illinois (Bowles, Betz, and DeMauro 1993). Seed samples of *Astragalus neglectus* collected from 1882, 1941, and 1961 proved to be successful in providing a garden population that is being developed to maintain genetic material of species native to the prairie.

Personal interviews were used extensively during the restoration of the Middle Fork John Day River in eastern Oregon. Because the goal of the restoration was to "...allow the river to mimic its original, pre-settlement meander geometry and find its own 'equilibrium,'" (Grant 1994, 152) it was important to know as much about the ecosystem prior to ranching and logging activities that took place during the early 1990s. Grant (1994) interviewed E.G. Calhoun, M. Deardorff, and N. Johnson who grew up on the restoration site during the 1910s. Grant claims that the interviews provided valuable information for determining a river's original condition, which was the first step in aiding

the preserve managers in deciding how to go about helping the river find its “natural” state (Grant 1994). Aronson, et al. (1993b) also used personal interviews for gathering baseline data in central Chile; farmers and economists were interviewed regarding agricultural and animal husbandry issues.

One example of the use of archival data are explorer’s notes. Marquette and Jolliet surveyed the plains of central United States, documenting important information on the routes of rivers and species of animals present (Sparks and Sparks 1992). Other accounts of the landscape, such as those from naturalists Jensen, Cowles, Roberts, Rehmann, and Waugh, provide valuable insight as to the types of plants and contours of the land at certain points in the past (Grese 1989). European settlers’ notes on the oak grasslands and tallgrass savannas in the Midwest helped in restorations of that area nearly 200 years later (Packard 1988). Land-use data from 1881 were used during restoration efforts of the Middle Fork John Day River in Oregon (Grant 1994). This information showed the floodplain uses and the multiple active meandering channels, which enabled the people conducting the restoration to classify the river as an interconnecting network of low-gradient channels (Grant 1994).

Current Methodologies Used to Reconstruct Historical Landscapes

Historical data are definitely a means of aiding in the recreation of a pre-disturbance landscape, but are not the only records of past ecological conditions. Two other current and common methodologies used in the field of restoration ecology to

recreate historical landscapes are sediment coring and Geographic Information Systems (GIS). Flower (1997, 37) states that "...any technique that can supply site specific historical data...and baseline conditions is valuable in any long-term pollution/disturbance impact assessment."

Sediment Coring

The importance of long-term perspectives to aid in the understanding of current environmental change and processes is widely recognized among restorationists (Anderson 1995). Baseline data such as photographs or long-term measurements are unavailable for most lake systems, so the natural, predisturbance characteristics of lakes are unknown, as are the trajectories of past environmental change (Reavie, Smol, and Carmichael 1995). However, paleolimnological analysis of lake sediments can be used as "natural archives" of perturbation histories, specifically acidification and eutrophication. A paleoecological study can provide the historical baseline required for assessing lake restoration (Hall and Smol 1993). In order for restoration efforts to be more effective, it is necessary to determine the causes and timing of lake-water quality deterioration (Reavie, Smol, and Carmichael 1995). Using paleolimnological techniques, trophic changes that occurred before conventional monitoring programs were developed can be identified. Sediment records are increasingly being used to provide information about recent (post-1800) rates of change and natural background conditions in lakes (Anderson 1995).

Anderson (1995) outlined a number of factors that have direct relevance to both defining and understanding ecosystem disturbance: 1) a thorough knowledge of baseline conditions; 2) reliable definitions of natural variability; 3) information on when the system began to change; and 4) the range of possible future trajectories. Analyzing properties of sediment cores provide a way to describe the physical, chemical, and biological histories of lake ecosystems.

Many species of algae and zooplankton can be identified by their preserved remains in lake sediments. These microfossil assemblages have been used to infer historical events such as acidification, fires, and eutrophication in many lakes (Findlay, et al. 1998). Histories can be reconstructed by analyzing biological parameters such as presence of diatoms, chrysophytes, non-siliceous algae, zooplankton, and chironomids, as well as chemical parameters such as pH, salinity, and total phosphorus (Anderson 1995). These analyses are often used to develop empirical and statistical models. Reliable dating of lake sediments is fundamental to the success of paleolimnology, and models are most often used to achieve this (Anderson 1995). Sediments generally less than 150 years old are dated using ^{210}Pb . ^{210}Pb is a natural radioisotope derived from the decay of ^{226}Ra . ^{210}Pb is divided into supported and unsupported components that are derived from atmospheric inputs via secondary decay from ^{226}Rn . Surface sediments provide information on more recent samples, generally from 1 to 5 years, depending on the trophic status of the lake as well as the rate of sediment accumulation (Anderson 1995).

These dating methods can be coupled with analyses of biological and chemical components of sediment cores. Diatoms preserved in sediment are sensitive indicators of

nutrient concentration and can be used to infer past water quality (Reavie, Smol, and Carmichael 1995). The remains of diatoms have been considered very useful paleoindicators for several reasons: their siliceous cell walls make them resistant to dissolution and breakage, they occur in most environments where water is present, they are very diverse and often identifiable to the level of species or subspecies, and their taxonomy is generally well described (Dixit, et al. 1992). Paleolimnologists assume the relationship of a taxon to a given environmental variable, and use such relationships to infer that variable from fossil diatom assemblages. These relationships are obtained by assessing the diatom assemblages from the surficial sediments of several lakes and relating the species distributions to modern limnological conditions. Then, several diatom-based transfer functions can be developed to infer environmental characteristics, such as salinity, nutrient, and pH, from nutrient concentrations. Table 3 gives examples in one lake of the dominant diatom taxa present in the sediment cores that correspond to various years and the lake conditions at that time.

Sediment coring methodology can be used in a variety of ways in restoration ecology. For example, Reavie, Smol, and Carmichael (1995) conducted a study of six lakes in British Columbia. Their objective was to infer past trends in total phosphorus concentration to gain a historical perspective on eutrophication in British Columbia. Past changes in total phosphorus were inferred from diatom valves in lake sediment cores from the region.

Table 3: Diatom Stratigraphy of a Sediment Core from Round Loch, Scotland

Core Interval	Period	Dominant Taxa	Lake Condition
0-5 cm	1891-1945	<i>Tabellaria quadrisepitata</i> <i>F. rhomboides v saxonica</i> <i>Eunotia incisa</i> <i>Tabellaria flocculosa</i>	Inferred pH 4.8 - 4.9; Strongly acidified by atmospheric pollution
5-11 cm	1945-1885	<i>Eunotia incisa</i> <i>F. rhomboides v saxonica</i> <i>Tabellaria flocculosa</i> <i>Brachysira vitrea</i>	Inferred pH 5.0 – 5.2; Moderately acidified by atmospheric pollution
11-16 cm	~ 1885	<i>Brachysira vitrea</i> <i>Eunotia incisa</i> <i>F. rhomboides v saxonica</i> <i>Tabellaria flocculosa</i>	Inferred pH 5.2 – 5.3; Mildly acidified by atmospheric pollution
16-40 cm	Pre-1840	<i>Brachysira vitrea</i> <i>F. virescens v exigua</i> <i>F. rhomboides v saxonica</i> <i>Eunotia incisa</i>	Inferred pH 5.3 – 5.6; Possible catchment disturbance, loss of <i>Cyclotella</i> spp.
40-80 cm	Pre-1840	<i>F. virescens v exigua</i> <i>Brachysira vitrea</i> <i>Cyclotella kuekingiana</i> <i>F. rhomboides v saxonica</i> <i>Achnanthes minutissima</i>	Inferred pH 5.6 – 5.8; Pristine softwater lake

Source: Flower (1997).

The objective of the study conducted by Flower (1997) of two lakes in Scotland was to use chemical as well as ecological criteria for developing restoration goals for damaged freshwater habitats. The focus of the study was to identify modern analogue communities for the two lakes which can then serve as biologically defined target ecosystems for acidity mitigation measures. Fossil diatom assemblages of two acidified lakes were compared with modern surface sediments of other lakes in the UK, Norway, and Sweden to initiate a system to identify reference sites for the purpose of developing

restoration goals. Flower (1997, 27) states that "...modern analogue matching can potentially identify whole lake ecosystems that can serve as biological target communities for currently disturbed sites. It is...directly relevant to lake conservation and restoration objectives and offers an alternative method for reconstructing lake paleo-environments."

An Example of a Restoration Project Using Sediment Coring

The work by Findlay, et al. (1998) on the microfossil assemblages of a lake in Germany shows how sediment cores provide important historical information for baseline data. Lake Arendsee is an extremely eutrophic lake in northern Germany, which is being restored by the addition of calcium carbonate (CaCO_3). The surrounding agricultural land contributed to the eutrophic state, causing an imbalance of nitrogen and phosphorus levels. Findlay, et al. (1998, 42) state that "because there is limited limnological information pertaining to Lake Arendsee, we have used the paleolimnological restored to reconstruct past lake trophic status."

The actual coring method was conducted as follows: a 47-cm core was obtained from the area of maximum depth (49.5 m) of Lake Arendsee in September of 1993. The core was frozen, and then cut into 1 cm intervals. Preparations for diatom analysis were performed on 1 gm subsamples from each 1 cm section using hydrogen peroxide digestion. Whole sediment samples were analyzed at 5 cm intervals for remains of algae (akinetes, chlorophytes), protozoa, zooplankton and sponges. Wet and dry sediment weights were measured on subsamples from each section of the core allowing accumulative total dry weights to be calculated. ^{210}Pb , ^{137}Cs , and ^{226}Ra were measured and

a model applied to date the sediment core and estimate the sedimentation rates. Also measured were particulate carbon, nitrogen, phosphorus, iron, calcium, and magnesium (Findlay, et al. 1998).

The analysis revealed two distinguishable peaks in the sediment results: one occurred at the 1962 time interval and the other at the 1986. The first peak may have coincided with increased agricultural practices; the second peak is associated with the Chernobyl event. They concluded that the 45 cm mark of the core dated back to 1800. The sample also revealed various sedimentation rates and dates. Twenty-one genera of diatoms, comprising 75 species, were identified from the sediment core. The diatoms provide clues as to the conductivity, nutrients, light, and eutrophication status of the lake. For example, *Asterionella formosa* Hassall, a species with a preference for high nutrient conditions and low water temperature, was common from 45 cm to 15 cm, and was absent in the upper 14 cm of the core. The algal remains of cyanobacteria and chlorophytes indicated that several compositional changes occurred in the upper sediments of Lake Arendsee. For example, based on the abundance of akinetes (resting cyanobacterial cells), the researchers inferred that Lake Arendsee began to develop a nitrogen deficiency as early as the late 1800s. This nitrogen deficiency appears to be decreasing in the late 1980s, possibly due to the increased nitrogen loading via the fixing cyanobacteria species (Findlay, et al. 1998). The fossil record from 24 cm to 15 cm (1890-1948) indicated that the trophic status of Lake Arendsee was shifting from an oligo-mesotrophic system to a more productive eutrophic system. This is supported by the shift in the diatom assemblages from the dominance of *Cyclotella rossii* to the more eutrophic species

Stephanodiscus binatus and increased abundance of *Fragilaria crotonensis* and *Diatoma elongatum*.

Findlay, et al. (1998) concluded that the paleolimnological study gives a short history of a large freshwater lake, which has undergone major transformations. In the mid to late 1800s, Lake Arendsee was a mesotrophic system dominated by a diverse algal flora represented primarily by chlorophytes, cryptophytes and diatoms. As the demands on the lake and the surrounding watershed increased, the trophic status of Lake Arendsee shifted. The paleolimnological study indicates that the lake became significantly more eutrophic between 1900-1948 due to human impact. Information from the history of Lake Arendsee allows restorationists to develop reasonable targets for improving the nitrogen and phosphorus balance and instituting processes that will move the lake in the direction of those targets. It is therefore conceivable that the addition of calcium carbonate will reduce the nutrient levels of the lake to those levels in existence prior to 1900 (Findlay, et al. 1998).

Limitation and Benefits of Sediment Coring

Some limitations of using sediment coring methodology exist. Lake sediments record little about functional relationships, such as nutrient interaction, in past ecosystems. Restoring lakes to past acidity or nutrient status or to meet subjective anthropogenic values will not necessarily re-establish lost species (Flower 1998). For example, acid mitigation by liming as a restoration measure has not re-established communities present prior to the acidification of the lake. What is accomplished, however, is that the health of

the lake itself is improved so that benthic communities indicative of non-acidified lake systems can flourish and grow. The paleolimnological records can serve as a basis for determining those communities that are present in a healthy lake, but cannot define success or failure of the restoration.

Another limitation, according to Flower (1998), is that sediment cores rarely contain simple and direct high resolution records of paleoclimate change. His work at Lake Baikal in Siberia, for example, showed that the earliest date identified from the sediment cores is 1885. This made the interpretation of long-term paleoclimate variation a considerable challenge (Flower 1998). Flower (1998, 113) adds that "...most sediments are highly modified and contain only subtle records of past lake characteristics." These shortcomings, however, can be partially alleviated by developing a quality assurance system specific to paleolimnology. Flower (1998) states that if it is accepted that understanding recent sedimentary processes is the key to confident interpretation of long-term sediment records, then work on recent sediments has wider significance. An on-going study involving a British, Swiss, and Russian team is geared toward understanding more about the relationships of particle formulation and sediment sinks, and that these research efforts will help to refine interpretation of paleo-environmental records of Lake Baikal (Flower 1998).

Anderson (1995) claims that an assessment of the effects of contemporary lake disturbance is complicated by the lack of background data with which to compare the recent changes, and the possible complicating effects of other, simultaneous changes. A benefit of sediment cores are that they can be used to determine future effects of

environmental scenarios by selecting periods in the fossil record which may serve as a model for future changes. For example, the response of lake biota to disturbances such as ash-falls or outbreaks of pathogens can provide important information about natural recovery rates (Hall and Smol 1993). Another benefit of using sediment cores is the ability to reconstruct water chemical variables using simple weighted models. A combination of simulation models and lake sediment records offers available ways to determine a natural baseline and its variability for a lake (Anderson 1995). In addition, dynamic models are powerful predictive tools, and it is this temporal component that lends itself to greater interaction with paleolimnological factors (Anderson 1995).

Flower (1997, 37) claims that “if a damaged lake ecosystem should be restored, then modern analogue sites, identified by biological matching and preselection criteria, offer the most appropriate way of defining biologically acceptable target communities.” Sediment cores are an integral part of selecting target communities from a reference lake to be used in restoration goals of a disturbed lake. Modern analogue matching techniques based on diatoms and other criteria offer a mechanism by which lake restoration management can be made relevant to past biodiversity and nature conservation objectives. Defining aquatic ecosystem stability and variability using paleolimnological techniques is an essential first stage in evaluating the current status and vulnerability of valued habitats (Flower 1997). For most restoration projects, however, sediment coring analysis is prohibitive because of the cost, expertise and equipment involved.

Geographic Information Systems

Another current methodology applied to the reconstruction of historical landscapes is the geographic information system (GIS). A GIS is an integrated computer hardware and software system designed specifically to manage, manipulate, and interpret spatially referenced databases (Russell, Hawkins, and O'Neill 1997). GIS is rapidly becoming an integral tool in natural resource management due to its sophisticated capability for storing, organizing, and manipulating mapped data (Harris, et al. 1997). GIS use has been increasing at a rate of 25-40% annually; this reflects its increasing importance and utility as an analytical tool (Russell, Hawkins, and O'Neill 1997). GIS is a method by which data generated from archival or ecological sources can be compiled and manipulated to model past landscapes.

GIS was used in initial site selection in the San Luis Rey River watershed in southern California, using watershed level information on basin topography and land cover to rank the potential suitability of sites for restoration. Russell, Hawkins, and O'Neill (1997) relied on two primary data layers as input for identifying sites for riparian preservation and restoration using GIS. One layer was an index of "wetness potential" derived from elevation data obtained in the form of USGS 7.5-minute digital elevation models. The other layer consisted of a land use/land cover map derived from a Landsat Thematic Mapper scene collected during 1992 (Russell, Hawkins, and O'Neill 1997). Eligible restoration sites were then prioritized according to spatial and proximal constraints.

A matrix derived from land cover and a wetness index was developed to predict sites suitable for restoration purposes. Areas with medium or high wetness indices that also had bare, herbaceous, scrub, or agricultural cover classes were regarded as potential sites for riparian wetland restoration (Russell, Hawkins, and O'Neill 1997). The scientists conducting this study decided that they needed to explicitly state the functional values of the riparian wetland environment, because these values would dictate the goals of the potential restoration effort, as well as shape the prioritization process. The functions and values chosen were species habitat and flood attenuation. These two criteria were quantified for use in GIS as: 1) proximity to existing riparian areas of open water, and 2) size of area. Using GIS technology and readily available data, Russell, Hawkins, and O'Neill (1997) were able to identify and prioritize sites for riparian wetland restoration at a regional scale. The methodology employed emphasized watershed-level hydrologic factors and current land use condition as indicators of potential for restoration. The theory behind the study was that greater success in restoration efforts would be achieved if a site's physical and biological potential to support wetland functions is considered early in the site selection process.

GIS, in this instance, helped in the recreation of a historical landscape by determining what sites were eligible for restoration, such as those with high wetness indices, and those that were ineligible for restoration, such as urban areas. In addition, flood attenuation areas were identified using GIS. GIS helps to develop a picture of what existed prior to disturbance and can aid in recreating historical systems.

An Example of a Restoration Project Using GIS

GIS can also be used to measure restoration success, as described in a study by Barrett and Niering (1993). This study used GIS as well as information on tidal marsh vegetation gradients to perform a comparative geographical analysis of the vegetation pattern among different hydrologic states: the original tidal marsh prior to impoundment, the impounded marsh, and the restored tidal marsh condition (Barrett and Niering 1993).

The site of this particular study was in Stonington, Connecticut, adjacent to Little Narragansett Bay. The method of the study involved creating base maps to show the geographical extent of the tidal marsh vegetation prior to dike construction in 1946, 30 years following impoundment in 1976, and 10 years after tidal flow was renewed in 1988. The types of vegetation present in the marsh prior to impoundment were extrapolated from a map created in 1948. Aerial and ground photographs from 1934, 1975, and 1986 were also used as baseline information. For each base map, digital coverage was produced using GIS. Using an overlay function, comparisons from each time frame were calculated against the 1946 reference map. Convergence on or departure from the former salt marsh vegetation pattern was sought to explain important trends during vegetation recovery. These patterns were developed into a crosstabulation matrix. To interpret the outcomes of restoration in a meaningful manner, trends were sought by invoking a gradient approach and grouping together cells of the crosstabulation matrix (Barrett and Niering 1993).

Results of this study indicated that vegetation types present in the restored tidal marsh consisted primarily of *Spartina alterniflora*-stunted, which covered 40% of the

marsh in 1946, and returned as the dominant vegetation type in 1988, occupying 37% of the marsh. Other typical salt marsh vegetation that was present in 1946 failed to achieve a fraction of their former abundance when reestablished in 1988. In general, comparisons between the restored tidal marsh in 1988 and its former, pre-impounded condition in 1946 reveals a wide range of net gains and losses. The geographic similarity between the restored tidal marsh 10 years following re-introduction of the tides in 1988 and the former pre-impounded state of the tidal marsh in 1946 is only slight to moderate, despite the return of most vegetation types present in 1946. In fact, only 28% of the vegetation types are geographically similar to those in 1946 (Barrett and Niering 1993).

Barrett and Niering (1993) concluded that the overall composition of the restored marsh described in 1988 did not match the vegetation pattern as originally described in the 1948 maps. Barrett and Niering (1993) claim that because the salt marsh ecosystem is a dynamic one, replication of the marsh prior to impoundment would be virtually impossible. However, restoration of ecosystem structure also implies restoring ecosystem process, and this may prove to be true in this particular study. Since an exact replica of the 1948 tidal marsh was thought to be unlikely and also unrealistic, is the restoration of Stonington marsh considered a failure? Barrett and Niering (1993) feel it is not. They believe that to effectively measure the success of restoration practices, strict standards of high technical accuracy are needed. GIS played an integral role in providing the historical technical accuracy for this project.

An example of how GIS is used to show historical changes is shown in Figure 2. A GIS image of a river in Indonesia was taken in 1988 and again in 1996 (Nagel 1999).

1988 Satellite Imagery

1996 Satellite Imagery

GIS Change Analysis Layer

River System Change Analysis Study

The dark tone in the GIS layer represents changes from vegetation to water.

The light tone in the GIS layer represents changes from water to vegetation.

The analysis was completed using Thematic Mapper satellite imagery.

Figure 2. GIS Images Showing Changes in a River Ecosystem in Indonesia

Source: Nagel (1999)

The changes depicted include areas of vegetation that changed into water, and water that changed into vegetation. This information can be used in a restoration to outline boundaries of vegetation or water, and can even be used in modeling to predict which areas are suitable for restoration efforts.

Limitations and Benefits of GIS

Few limitations of using GIS in restoration seem to exist, although one is discussed by Harris, et al. (1997). They claim that the use of GIS requires substantial investment in equipment and personnel. In their study, the time and costs involved to generate GIS land cover maps were compared to the time and costs of manually creating the same maps with a planimeter and dot-grid digitizing (Harris, et al. 1997). They discovered that while estimates of land-cover area were similar for the two methods, GIS time-costs were many times higher than manual technique time-costs. Harris, et al. (1997, 112) concluded that "...natural resource managers should carefully evaluate long-term benefits and costs before adopting a GIS for restoration planning."

GIS is an important technology used in the re-creation of historical landscapes (Barrett and Niering 1993), primarily because GIS is such a powerful tool for monitoring and depicting change over time (Johnston 1994). In addition, both archival and ecological data generated on past conditions can be mapped and manipulated with GIS. Other benefits of using GIS in restoration ecology include identifying and prioritizing sites suitable for restoration (Russell, Hawkins, and O'Neill 1997). One advantage of using GIS is that data are permanently stored and may be retrieved automatically. In addition,

GIS is valuable when used in modeling. Harris, et al. (1997) claim that the versatility of GIS is unparalleled in modeling because once land cover is digitized, several modeling efforts can be undertaken with different assumptions and restoration goals.

Study Focus

While researchers note the importance of recreating a historical landscape, it is not clear to what extent historical data result in more successful restorations. For example:

1) Do restorations using historical data set more *specific* ecological goals than those not using historic data? 2) Are restoration goals of projects that use historic data more focused toward ecological function versus compliance or other goals than those not using historical data? 3) What recommendations can be made based on these findings to improve the field of restoration ecology in terms of baseline data gathering?

To answer these questions, six restoration projects are analyzed below. Further, a random sample of restorationists were surveyed for their expert opinion on these matters.

Analysis of Six Restoration Projects

Three projects that used historical data and three that did not were analyzed. These case studies were chosen because: 1) they were riparian systems; 2) they contained sufficiently detailed information about the restoration projects; and 3) they were conducted within the past decade. Information collected on each case study included location, setting description, past processes that affected ecosystems, objectives, types of historical data used (if applicable), ecosystem level goals, whether the project was

successful and if so, why. Analyses of these six projects were conducted to gain insight into how historical data are incorporated into their restoration projects and if this affects the success of the restoration.

Project #1 Using Historical Data

Grant, Katherine. (1994). Oregon River Restoration. Restoration and Management Notes, 12: 152-159.

Setting Description:

The Middle Fork John Day River is located in eastern Oregon. The restoration site is a four mile stretch of river about 20 miles downstream from the headwaters. It is described as approximately 330 acres of riparian bottomlands 1/4 to 1/2 mile wide, consisting of wetlands, grasslands, and forest.

Condition Prior to Restoration:

Ranching and timber harvest activities that occurred since the early 1900s are the primary causes of this particular ecosystem degradation. Soils on some open forested and grassland areas have become severely eroded due to sheep grazing. Shallow glides dominate the river, and the few existing pools are associated with boulder rip-rap. Streambanks are exposed and backcut, and the channel receives little shading from the existing riparian vegetation. Without large woody debris to provide channel structure, there is a significant shortage of deep pools important as fish habitat. The increase in water temperature favors the production of non-game fish such as dace, redbreast shiners, and squawfish.

Restoration Goals:

To increase the Chinook salmon population from 200 to approximately 10,000 salmon per season. Specifically, decrease the water temperature from 80 degrees to 68 degrees Fahrenheit, increase habitat quality, and reverse channelization. Goals can be accomplished by removing grazing disturbances, increasing shade on the river by planting trees and lentic vegetation along the banks, and reinstating some relict channels.

Types of Data Used to Derive Goals:

- General Land Survey of 1881
- Whitman National Forest Atlas Map of 1912
- Aerial photos from 1939
- Personal interviews
- Historical accounts (books, Native American reports)
- GIS used to map vegetation from 1939 to 1992
- U.S. Fish and Wildlife Service surveys from 1940s
- Geomorphology and hydraulic reconstruction models

Role of Historical Data:

Numerous forms of historical data were used in the restoration of the Middle Fork John Day River, and considering the goals of the restoration, these sources were highly important. The goals of “allowing the river to mimic its original, pre-settlement meander geometry” (Grant 1994, 152) would not have been possible had the original, pre-settlement conditions not been known. Historical data helped the restorationists “see” what the river was like prior to its degradation.

Project Success:

Grant states that "... historic documents, dendrochronology, geomorphology, and hydraulic reconstruction can provide valuable information for determining a river's original conditions. The history of natural areas management provides a spectrum of management alternatives" (Grant 1994, 159). In the two years since the initial management actions, the composition of the riparian vegetation has responded. Although it may take several more years to make a more definitive statement, it can be said that the restoration of this four-mile stretch is tentatively successful in terms of re-vegetation efforts.

Project #2 Using Historical Data

Muhar, S., Schmutz, S., and Jungwirth, M. (1995). River Restoration Concepts - Goals and Perspectives. Hydrobiologia, 303: 183-194.

Setting Description:

The River Inn is in the Tyrol region of Austria. The River Inn is a 6th-order mountain stream with glacial influences. The restoration project includes both local and large-scale watershed sites. No further description is available.

Condition Prior to Restoration:

Enormous expansion of urban areas, extension of industrial sites, highways and railway construction, power plants located along the river, and dredging activities all adversely affected this ecosystem. The river course has been straightened and stabilized.

Restoration Goals:

Goals are to reestablish the braided stretches of the river (including oxbows), alter wetland dynamics to allow flooding to occur, increase the species richness to a range of more than 24 fish species, and increase the river's capacity to transport its original bedload.

Types of Data Used to Derive Goals:

- Historical maps from the 18th century
- Fisheries surveys from 1920s
- Historical literature from 19th century
- Archived material (land use forms, local history records)
- Vegetation studies (early 20th century)
- An expert on river morphology and flood dynamics

Role of Historical Data:

Numerous forms of historical information were utilized in this restoration. The premise for this work was the development of the term "guiding view" ("Leitbild" in German) instead of using an ecosystem of reference. The restorationists thought it crucial to understand and fully comprehend the original, pre-disturbance nature of the ecosystem, and use this "guiding view" as the basis for the development of restoration goals. They believe that the goals should originate before extensive alterations to the river ecosystem were made; for example, in the form of systematic course straightening, bed stabilization measures or hydro-electric power plants, and before fundamental changes in the essential characteristics of rivers such as channel pattern, and flooding dynamics occurred.

Project Success:

Muhar, Schmutz, and Jungwirth (1995) state that historical reports, old surveys, and records of old fishing rights, etc. have helped to reconstruct individual criteria or ecological targets, which permitted them to generate an overall view of the unmodified situation. Small scale restoration efforts on the River Inn have been successful. For example, design measures aimed at habitat improvements such as profile enlargements, structuring of the bank line, the creation of pools and riffles, and flow control by means of transverse structures have been taken to restore regulated river sections.

Project #3 Using Historical Data

Koebel, Joseph W. Jr. (1995). An Historical Perspective on the Kissimmee River Restoration Project. Restoration Ecology, 1: 149-159.

Setting Description:

The Kissimmee River is located in central Florida between the city of Orlando and Lake Okeechobee. The setting for this restoration is one hundred four square kilometers of land, including 70 km of river channel and 11,000 ha of floodplain wetlands.

Condition Prior to Restoration:

Between 1962 and 1971, the Kissimmee River was channelized into a canal 90 km long and 9 meters deep and 64-105 meters wide. A series of impounded reservoirs was also formed. These actions, which transformed the river-floodplain ecosystem into a series of deep impoundments, drained much of the floodplain and eliminated historical water-level fluctuations, and greatly modified flow characteristics.

Restoration Goals:

The general goals for this project are to restore pre-channelized, natural, seasonal water-level fluctuation. More specific goals include: establish species similar to those which existed in the historical Kissimmee; create conditions where the floodplain can be inundated 50% of the time, and when inundated, water depths measure 0.3 to 0.7 meters; decrease the number of mesophytic and xerophytic species such as coinwort, sour paspalum, elderberry and increase the number of historic hydrophytic species such as maidencane, smartweed, and alligator weed.

Types of Data Used to Derive Goals:

- Stage and discharge records from 1929 to 1960
- Literature from the mid-1920s
- Fisheries records and historical studies from the Florida Game and Fresh Water Fish Commission from the 1950s
- Bird records from the Audubon Society 1936-1959
- Archived maps

Role of Historical Data:

Numerous types of historic data were utilized in the Kissimmee River restoration project. A scientific advisory panel commissioned by the South Florida Water Management District stated that: "Reference conditions define realistic expectations for restoration and will include those factors that most likely contributed to the establishment, interaction, and persistence of the biological communities prior to channelization. Reference conditions can be established in three ways: 1) by establishing an unaffected reference site with similar chemical, physical, and land-use conditions as the pre-channelized system; 2) by

using pre-channelization data; and 3) by using theoretical approaches" (Koebel 1995, 158). All three methods were employed in this restoration and special attention was paid to pre-channelization data, especially fisheries.

Project Success:

Because the scale of this project is so large, it will be many years (or decades) for evidence of success or failure to become known. However, a demonstration project with similar goals was critical in determining what factors may indicate success of the restoration. The demonstration project ran from 1984 to 1990, and primarily included plans to alter the hydrology of a test site. In terms of success of the demonstration project, several factors are to be noted. First, reintroduction of flow through remnant river channels was a major feature. Plant communities responded during the project and indicated that reestablishment of appropriate hydrologic conditions led to rapid restoration of historic vegetation characteristics in river and floodplain habitats. Shifting sand substrate in the remnant channels was also restored to historic conditions. A return of fish species represented 58.5% of total biomass and a 39.3% return of species in areas with increased flow. Lastly, wading bird densities were two times higher at the end of the demonstration project than during the 1978-1980 survey. Results of the demonstration project confirmed the feasibility of restoring the structure and function of the Kissimmee River ecosystem.

Project #1 Not Using Historical Data

Baird, Kathryn. (1989). High Quality Restoration of Riparian Ecosystems. Restoration and Management Notes, 7: 60-64.

Setting Description:

The San Luis Rey River is a riparian area in San Diego County, California, densely covered with trees, shrubs, herbs, and open space. The topography consists of gentle hills with a surface elevation of 0.9m to 1.2m above the average low water table.

Condition Prior to Restoration:

Intensified developmental pressure and mitigation due to highway construction has adversely affected this habitat by reducing native plant species necessary for the nesting and propagation of the least Bell's vireo. The river was overgrown with exotics, and no least Bell's vireos were present at the site prior to restoration activities.

Restoration Goals:

Goals for this project are to create a framework within which natural selective forces can operate to create a self-sustaining, functioning riparian habitat. This habitat should not only provide habitat for a complete assemblage of riparian species, including the least Bell's vireo, but should also be capable of long-term regeneration and recovery following natural disturbances. In addition, specific goals included providing 47% coverage of trees with 1000 trees per acre, 33% coverage of shrubs with 3966 shrubs per acre, 8% coverage of herbs with 2655 herbs per acre, and 12% open space present in the restoration area.

Data Used to Derive Goals:

Analysis of biological data from 30 active vireo nest sites and 10 non-nesting riparian sites. These included plant density, percent cover, species composition, and community structure and arrangement in the landscape.

Role of Historical Data:

Very little historical data were used in this restoration project. Baird was fortunate to have comparable reference sites from which to pattern the restoration.

Project Success:

Baird states that "Our San Luis River site will be considered successful when a pair of least Bell's vireos has nested successfully on the site, or when the vegetation on the site matches that on active breeding sites within specified limits. Within the first season of restoration work, a variety of passerine birds have been spotted foraging within the site, among them pairs of least Bell's vireos, yellow-breasted chats, black grosbeaks, warbling vireos and common yellow-throats with young, yellow and orange-crowned warblers and western flycatchers" (Baird 1989, 63). In summary, Baird claims that "...the most important thing we have learned from our experience so far is the value of imitating the natural habitat closely in designing a restoration site" (Baird 1989, 64).

Project #2 Not Using Historical Data

Jensen, Sherman E., and William S. Platts. (1990). Restoration of Degraded Riverine/Riparian Habitat in the Great Basin and Snake River Regions. In Wetland Creation and Restoration: The Status of the Science, J.A. Kusler and M.E. Kentula (Eds.) (pp. 367-404). Washington, D.C.: Island Press.

Setting Description:

The Snake River originates in glaciated lands in the vicinity of Yellowstone and Grand Teton National Parks. The setting of this project is Pigeon Cove, part of the Snake River Canyon located near Twin Falls, Idaho.

Condition Prior to Restoration:

During road construction, a rock slide was initiated which blocked much of the river, causing increased streamflow velocities that eroded streambanks. Wetland habitats supported by seeps along the canyon walls were destroyed. A total of about 7.6 hectares of wetland/riparian habitat was impacted.

Restoration Goals:

General goals for this project are a "less impaired state." Also, enhancement of fish and wildlife habitats are additional goals. Jensen and Platts state that restoration goals are commonly generic and related to regional and local values and bias. Common goals may include additional values and functions such as aesthetics, recreation, flood storage and flood desynchronization, streambank stabilization, and water quality. Specific goals include revegetate the an area of 3.8 hectares, based on guidance from Habitat Evaluation Procedures (HEP) from the U.S. Fish and Wildlife Service (Jensen and Platts 1990).

Types of Data Used to Derive Goals:

- **Baseline assessments from engineers, hydrologists, soil scientists, botanists and wildlife specialists regarding current hydrology, soil, botanical, and fish and wildlife measures.**
- **Topographic surveys.**
- **Assessment of impacts influencing the existing state and the achievable state of the site.**
- **HEP guidelines were also used to derive goals.**

Role of Historical Data:

Very little, if any, historical data were used during the restoration of Pigeon Cove. There may be several reasons for this: the restored area was relatively small, only 3.8 hectares; re-vegetation was the primary ecological goal, and planting such a small area required assessment pertaining to feasibility only; problems were the result of a single recent event; and guidelines for the restoration were primarily contained in the HEP, so the "leg work" required by the restorationists concerning the goals of this restoration was relatively little.

Project Success:

Planting for Pigeon Cove was conducted in 1987. Abnormally low runoff in 1987 and 1988 resulted in peak river flow levels well below the elevation of the bench, resulting in minimally successful revegetation. The coarse nature of substrates used to construct the bench limited its water retention and its capacity for establishment and sustenance of vegetation. Seeps from the canyon walls rapidly percolated through the porous substrate and were thus unavailable to plants. It is anticipated that future flooding will deposit fine sediments on the bench and improve conditions for revegetation. It was concluded that

revegetation of riparian areas were only 30 to 50 percent successful. Transplanted xeric shrubs were mostly unsuccessful due to drought conditions. However, shrub/tree plantings were 80 percent successful in seep areas along the canyon wall. Although monitoring of this site can conclude that the restoration was initially unsuccessful, that does not mean that the site will remain in this sub-optimum condition. Several important lessons were learned, and new techniques are being employed to increase the vegetation of the affected area and positive outcomes are expected.

Project #3 Not Using Historical Data

Briggs, Mark K., Bruce A. Roundy, and William W. Shaw (1994). Trial and Error: Assessing the Effectiveness of Riparian Revegetation in Arizona. Restoration and Management Notes, 12: 160-167.

Setting Description:

The location for this project is Goose Flats, which is located on the Colorado River near Blythe, Arizona. Goose Flats is located on a portion of the Colorado River that is 220 feet above sea level and receives an average of only 4 inches of precipitation per year.

Condition Prior to Restoration:

The manipulation of natural river flow by impoundment structures, accumulation of sodium and other salts in the soils of the floodplain, and competition from saltcedar (*Tamarix chinensis*) were the past processes that affected this project site. The condition of this site prior to restoration activities included severe loss of riparian habitat invasion by saltcedar and other non-native species was prevalent, notable damage caused by beaver and off-road vehicles to existing vegetation.

Restoration Goals:

General goals of this project were to stabilize deteriorating conditions by slowing or preventing streambank erosion, which can initiate recovery of the riparian area. An additional goal for this project was to re-vegetate the area to improve wildlife habitat. A ten-year survival rate of planted vegetation is expected to be around 70 percent.

Types of Data Used to Derive Goals:

- Recent plant inventory information (1993)
- Assessment from botanists and hydrologists concerning the plantings and necessary watering feasibility.

Role of Historic Data:

Very little, if any, historical data were used in this restoration project. Because of the very arid quality of the site, special concern was paid to the plantings and their survivability (for example, their access to water). Only species expected to survive these harsh conditions were selected to be planted on this site.

Project Success:

Although the restoration efforts for this site were quite expensive for the area re-vegetated, the efforts paid off. As of the site visit in 1991, a total of 4,172 trees and shrubs (seven species) had been established. This represents over 20 percent of planted vegetation, and is considered very successful for two growing seasons in this area. As previously mentioned, the 10-year survival rate is predicted to be around 70 percent. There is no reason to assume that this will not occur.

Discussion of Literature Review Cases

Based on the analysis of the six case studies, a primary difference between the projects that incorporated historical data and those that did not lies in the goals of the restoration. Specifically, the projects that used historic data had *qualitative* and more general goals, and the projects that did not use historic data had *quantitative* and more specific goals. This is shown in Table 4.

Table 4. Summary of Restoration Goals of Six Case Studies

Project	Used Historical Data?	Goals	Qualitative	Quantitative	Successful?
Oregon River	Yes	To restore to natural conditions & functions.	To increase the Chinook salmon population to pre-settlement levels.	-	Yes
River Inn	Yes	To re-establish original river characteristics.	To reconstruct the braided stretches of the river.	-	Yes
Kissimmee River	Yes	To restore pre-channelized water-level fluctuations; re-establish floodplain; improve groundwater recharge; increase native species.	To establish fish & plant communities similar to historic levels.	-	Yes
San Luis Rey River	No	To create a self-sustaining, functioning habitat capable of supporting riparian species including the least Bell's vireo.	-	To develop a habitat capable of supporting at least 1 pair of Bell's vireo with 47% coverage of trees; 33% coverage of shrubs; 8% coverage of herbs; & 12% open space.	Yes
Snake River	No	To create a "less-impaired state." To enhance fish & wildlife habitats.	-	To revegetate an area of 3.8 hectares.	50% successful
Goose Flats on the Colorado River	No	To stabilize deteriorating conditions.	-	To revegetate an area using approximately 20,000 trees and shrubs.	20% successful

Historical data are more general and may show a range of conditions, some of which can no longer be recreated. They may not lend themselves to the development of specific targets, but rather provide a broader view of different target conditions and

ecological variability. Data collected in the field, on the other hand, are very specific and tend to represent one ecosystem at one point in time. Variability may not be well represented.

The projects that did not use historical data used reference sites and current baseline or inventory information to set their goals (Briggs, Roundy, and Shaw 1994; Jensen and Platts 1990; Baird 1989). Information from reference sites and historical data provide two important perspectives about the restoration site.

When using historical information, scientists realize that the restoration of an ecosystem to a pre-human disturbance condition is not always possible (Cairns 1991; Westman 1991). Defining the historical condition of a habitat is sometimes possible only in general terms, because of lack of quantitative data on the historical condition (Westman 1991). In addition, the restoration to pre-settlement conditions may be impractical or even impossible for a number of reasons (Cairns 1988). Ecological problems include: 1) inadequate sources of species for re-colonization because of uniqueness of the damaged community; 2) the inability to halt some of the factors causing damage to the restoration site; 3) the original ecosystem may have developed as a result of a sequence of meteorological events that are unlikely to be repeated; and 4) the sheer complexity of duplicating the sequencing of species introductions of the original ecosystem (Cairns 1988). Current conditions provide perspective on what is now possible. Historical data give information on change and potential future conditions.

The literature gives some information on how restorationists use historical data. A survey was conducted for this thesis to gain a more in-depth understanding of what *types*

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of historical information restorationists believe comprise useful baseline. The analysis of the six case studies aided in the development of the questions used in the survey. The forms of historical data were compiled using those methods specified in the case studies. The analysis of the case studies was particularly helpful in the formation of the survey questions regarding goals and success criteria.

METHODS

Survey methodology was used in this thesis to determine what types of historical data restorationists believe are most useful in baseline information and if historical data can help in improving restoration projects. The questions asked in this survey were qualitative in nature, focusing on forms of historical information currently used, the importance of historical data, and success criteria of restoration projects. Others who have used surveys in their restoration research include Briggs, Roundy, and Shaw (1994) and Henry and Amoros (1995). Briggs, Roundy, and Shaw (1994) collected data regarding riparian revegetation projects using a mail questionnaire-type survey. This survey was also qualitative and focused on four general areas: background information, project methodology, post-mitigation work, and revegetation results. Henry and Amoros (1995) claim that monitoring and interpreting ecosystem changes following restoration can be enhanced by conducting a pre-restoration survey and a post-restoration survey of restorationists.

The literature review was conducted as a basis for survey questions and to identify the most popular techniques used in the reconstruction of historical landscapes.

Study Design and Data Collection

The sample pool for the survey was members of The Society for Ecological Restoration (SER) listed in the 1994 SER directory. The survey was cross-sectional in design and consisted of probability sampling in a systematic fashion. The total number of members listed in this directory is 2,445. In order to sample 10% of the members of SER and assuming a 50% response rate (Fink and Kosecoff 1992), 490 total surveys were mailed. Fink and Kosecoff (1992) state that the desired response rate tends to be entirely subjective and the general rule is "higher is better." In addition, the size of the sample should be large enough to yield useful data (Fink and Kosecoff 1992). A systematic sample was obtained by using every 5th name listed in the directory.

The one-page survey incorporated questionnaire and interview methods. Questions were nominal, ordinal, or interval (questionnaire-type) with one "open-ended" (interview-type) question. Figure 3 on the following page shows the survey sheet.

The survey was accompanied by a cover letter stating the researcher's name and affiliation, address, subject of the survey, length of time anticipated to complete the survey, and when completed survey forms would like to be received. A self-addressed, stamped envelope was included for the completed survey form.

As part of the study design, 20 pilot surveys were mailed out prior to the actual survey. The population sample for the pilot survey was obtained in the same manner as the actual survey, although individuals involved in the pilot test were not be asked to take part in the actual survey. The purpose for this pilot study was to ensure that the logistics

- 1) Your name: _____ Title: _____ Affiliation: _____
 Number of years you have been involved with ecological restoration: _____ years.
- 2) The type of restoration you are most familiar with and base your experiences on for this survey are: (circle one)

Estuarine	Saltwater Wetland	Freshwater Wetland	-	Riparian	Dune
Lake/Pond/Reservoir	Vernal Pool	Prairie	Forest	Other	_____
- 3) Is the baseline data currently used in your restoration projects adequate? (circle one) Yes No Don't know
- 4) The forms of historical data when available and relative usage encountered in your restoration projects:
 (circle usage for each)

A) Aerial photographs:	Often used	Rarely used	Never used
B) Historical maps:	Often used	Rarely used	Never used
C) Plant/animal population data:	Often used	Rarely used	Never used
D) Personal interviews:	Often used	Rarely used	Never used
E) Other _____:	Often used	Rarely used	Never used
- 5) In your experience, the *primary* role of historical data when used in restoration projects is: (check one)

A) _____ In the sole design of the restoration project
B) _____ In the development of the restoration goals
C) _____ For comparative interest only in the end product
D) _____ Other (specify) _____
- 6) What criteria do you most often use to evaluate the success of your restoration projects? (check all that apply)

A) _____ Soils (movement, quality)	G) _____ Historical/Archaeological
B) _____ Vegetation (composition, height, coverage, biomass)	H) _____ Recreational
C) _____ Water (quantity, quality, flow)	I) _____ Educational/Scientific
D) _____ Consistency with government plans	J) _____ Aesthetic
E) _____ Invertebrate/Vertebrate (presence, abundance, distribution, migration)	K) _____ Health/Safety
F) _____ Other (please specify): _____	
- 7) How important is the incorporation of available historical data when developing goals for a restoration project? (circle one)

Very important	Moderately important	Unimportant
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- 8) Do you feel that projects that incorporate historical data have more specific ecosystem-level goals than projects that do not use historical data? (circle one) Yes No Don't know
- 9) Generally, how successful are the majority of your projects that use historical data? (check one)

_____ 0-25%	_____ 25-50%	_____ 50-75%	_____ 75-100%
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- 10) What forms of historical data, if available, do you believe would contribute the most to improving the success rates of restoration projects if used on a regular basis? (circle one)

Aerial photographs	Historical maps	Plant/animal population data
Personal interviews	Other (specify) _____	
- 11) Please write any comments, suggestions, or recommendations about the use of historical data and restoration:

Figure 3. Survey Sheet

of the survey would flow smoothly and that the survey questions were targeted toward the topic (Fink and Kosecoff 1992).

Data Analysis

Information from the survey was tallied and collated into tables. The results of this survey were analyzed using descriptive statistics such as tallies, frequencies, rankings, and percentages. The majority of the questions asked in this survey were qualitative.

Limitations

Limitations encountered by conducting a survey include: 1) logistics of the survey not flowing smoothly; 2) a low response rate of completed surveys; and 3) regional and/or international differences in interpretation of survey questions. The problem of ensuring smooth flowing logistics was dealt with by mailing a pilot survey prior to sending out the actual survey. By anticipating a lower response rate than average for a mail survey, more surveys were mailed out (Fink and Kosecoff 1992). The question regarding project success assumes that most projects were successful. In retrospect, perhaps an option of “unsuccessful” should have been included. Very little could be done regarding the differences in the interpretation of survey questions; by having an “other” category (in which the respondent can fill in a blank) and a “comments” section as part of the survey allowed the respondents some individuality in their responses.

RESULTS

A total of 489 surveys were mailed out to members of The Society for Ecological Restoration. Figure 4 indicates a 44% response rate, although 5% of those were incomplete responses. For example, an incomplete response may have been from an SER member who maintained membership solely as a hobby, and who does not conduct actual restoration projects. Fourteen percent of the surveys mailed out were classified as “undeliverable,” and these responses were returned unopened. Thirty-nine percent of the survey responses were completed, and comprised the data used in the following summaries. Forty-two percent of the survey responses were not returned.

Figure 4. Total Survey Response Distribution

Figure 5 shows the distribution of survey responses by area: international, northwestern United States, southwestern United States, southeastern United States, and northeastern United States.

Figure 5. Response Distribution by Area

Figure 6 shows the distribution of survey responses by type of ecosystem restoration conducted. Ecosystem types listed in the survey were estuarine, saltwater wetland, freshwater wetland, riparian, dune, lake/pond/reservoir, vernal pool, prairie, and forest. It is clear that the largest percentage of responses belonged to those conducting restorations on riparian systems. This result was expected based on the literature reviews. Some examples of the "other" category provided by respondents were mined lands, pine barrens, semiarid grasslands, suburban lots, and subalpine areas.

Distribution of Survey Responses by Ecosystem

Figure 6. Distribution of Survey Responses by Ecosystem

Figure 7 clearly indicates that a majority of those who conduct restorations believe that their baseline data were not adequate. Examples of baseline data are models, ecosystems of reference, expert consultation, and historical information.

Figure 7. Adequacy of Baseline Data Currently Used in Restoration Projects

Survey question 4 asked respondents to rate how often they use various types of historical data. Table 5 shows which types of historical data are most often used. The most often used types of historical information are aerial photographs, followed by plant and animal population data, historical maps, and lastly, personal interviews.

**Table 5. Forms of Historical Data and Percent "Often Used" in
All Ecosystems and Riparian Systems**

Form of Historical Data	All Ecosystems	Riparian
Aerial Photographs	77%	86%
Historical Maps	48%	56%
Plant/Animal Population Data	64%	74%
Personal Interviews	38%	44%

Table 6 shows how the surveyed restorationists use historical data in their restoration projects: as the sole design of the project; in the development of restoration goals; for comparative interest in the end product; or other roles. For those restorationists that used historical data in the sole design of the project, historical data provided the only means of outlining how the restoration should be conducted. Those that used historical data in goal development may have incorporated other methods in the development of goals as well. Restorationists who were interested in the comparative interest in the end product simply used historical data as a means of comparison, a “before” and “after” comparison to determine the impact of their restoration.

An overwhelming majority of survey respondents indicated that historical data were used primarily in goal development of their restoration projects. The next most popular role for historical data was in the sole design of the restoration project, meaning no additional factors other than historical data were involved in the design of the project. Relatively few respondents used historical data for comparative interest in the end product, meaning that the data were not involved in the evaluation phase. Still fewer responses indicated that restorationists used historical data in the “Other” category, which included federal compliance, and species compatibility.

Because riparian systems comprise a large area of restoration, the responses from restorationists who conduct their work in riparian systems was also evaluated separately from the other ecosystems. The responses from people conducting riparian restorations very closely match those from all ecosystems.

Table 6. The Primary Role of Historical Data in Restoration

	Sole Design	Goal Development	Comparative Interest in End Product	Other
All Ecosystems	16%	71%	7%	6%
Riparian	24%	68%	4%	4%

Respondents were asked what parameters they use to determine whether the goals of the project have been met. Goals are determined in the planning phase of the project, and they are evaluated through monitoring of the project at prescribed intervals following completion of the project. Criteria used to evaluate success in meeting the goals are shown in Figure 8.

The most common criterion by far is vegetation (including composition, height, percent coverage, and biomass), followed by water (water quality, quantity, flow, and patterns) and animal population data (presence, abundance, distribution, migration, and species richness). The next most popular groups of criteria are soils (composition, movement, quality), aesthetic value, and educational importance. The responses for riparian systems closely pattern that of all ecosystems, with only animal population data and soils reversed.

Figure 8. Rank Ordering of Criteria Used to Evaluate Success

Table 7 shows percentages regarding the importance of historical data in the goal development process. Most respondents feel that historical data, when available, play a very important role in goal development.

Table 7. The Importance of Incorporating Historical Data in Restoration Goal Development

	Very Important	Moderately Important	Unimportant
All Ecosystems	54%	45%	1%
Riparian	53%	45%	2%

In answer to the question on the specificity of goals, most respondents claim that their projects in which historical data are used do have more specific, or quantitative, ecosystem-level goals. This is reflected in Table 8 below. Examples of ecosystem-level goals are nutrient cycling, trophic level interactions, and biodiversity.

Table 8. Project Goals, With and Without Historical Data

	More Specific	Less Specific	Don't Know
All Ecosystems	61%	16%	23%
Riparian	60%	19%	21%

Table 9 shows that the majority of respondents believe that their projects that use historical data are 50-75% successful in meeting goals, closely followed by 75-100% successful. Several limitations exist for this general question. First, each person has a slightly different idea of what success is, although it is assumed that a successful project is one that meets its restoration goals. Second, the range for success rates provided is broad. Third, the success of the project may be independent of whether historical data

was used or not. Finally, bias may exist because most people tend to claim their projects as successful. The survey did not ask respondents why they thought their projects were successful.

Table 9. Success Rates for Projects that Use Historical Data

	0-25% Successful	25-50% Successful	50-75% Successful	75-100% Successful
All Ecosystems	5%	14%	42%	39%
Riparian	3%	25%	36%	36%

Figure 9 reports what types of historical data respondents believed would contribute the most to restoration success. Aerial photographs were the most common form, plant/animal population data were next, followed by historical maps.

Figure 9. Rank Ordering of Historical Data Forms that Contribute to Restoration Success

DISCUSSION

The term “restoration” is generally defined as “seeking a complete or near-complete return of a site to a pre-existing state” (Aronson, et al. 1993b, 168). Similarly, restoration generally includes a return to an ecosystem condition that resembled those before alteration (Trexler 1995; Bradshaw 1987; Gore 1985). Information on the pre-disturbance condition of a site may contribute to baseline data (Henry and Amoros 1995; Kondolf and Micheli 1995; White 1995; Cairns 1991). Because baseline information is currently lacking in many restoration projects (Aronson, Dhillon, and Le Floc’h 1995; Kondolf and Micheli 1995), knowledge of how to improve baseline data gathering can be helpful. This study focused on determining: 1) what types of historical information are used in baseline data, 2) whether use of historical information improves restoration goal-setting, evaluation and success of projects, and 3) what methodologies are currently used to reconstruct historical landscapes.

Fifty-four percent of the respondents of the survey felt that the amount of baseline data available for their projects was inadequate. This mirrors views expressed by Aronson, Dhillon, and Le Floc’h (1995) and Kondolf and Micheli (1995), who claim that very often no baseline data are collected, and if they are collected, they are often inadequate. In addition, Zedler and Weller (1990, 407) state that “the restoration planning process does not include baseline studies of wetland ecosystem functioning, i.e. the

dynamics of the wetland.” The reasons for inadequate baseline data may be poor inventory records or unavailability of data altogether, lack of active research on the part of the restorationists to locate baseline data, or prohibitive costs of the restoration project (Henry and Amoros 1995; Kondolf 1995; Kondolf and Micheli 1995; Cairns 1989).

Using historical information in baseline data can contribute to the overall success of a restoration project. More information gathered about a restoration site can enable more accurate project design, goals, and evaluation methods to be developed (Hobbs and Norton 1996; Henry and Amoros 1995; Kondolf 1995; Westman 1991). Aerial photographs, historical maps, or archival documents allow past conditions at particular points in time to be known. These data are not likely to provide information on ecosystem processes unless numerous views of a site were recorded over time. Thus, it is important to combine historical data with other ecological data to reveal the ecological processes on a site.

Objective #1: What types of historical information are most useful in baseline data?

According to the restorationists polled, aerial photographs probably give the greatest insight into a site’s physical and vegetative components and contribute the most toward the development of restoration goals (Whiteall 1995). Henry and Amoros (1995, 897) say that “...ecosystem state prior to perturbation could be approached using old aerial photographs.” Determining what types of vegetation were present at a site using aerial photographs prior to disturbance can help in selecting the type, coverage and boundaries of vegetation (Whiteall 1995).

Aerial photographs, along with other types of historical data, can aid restoration efforts in three major ways: by allowing identification of the underlying problems, in establishing realistic restoration objectives, and by facilitating selection of appropriate strategies to achieve those objectives (Kondolf and Larson 1995). For example, when conducting a restoration of a riparian system, aerial photographs can provide the following: an evaluation of influences of a river channel; an examination of river changes and features in sequential aerial photographs (when available); identification of changes in land use in surrounding areas; evidence of channelization or reservoir construction; and identification of major sources of sediment supply.

A high-quality original photograph can be enlarged by 200–400% to provide detailed information about a site. Another technique to improve the value of aerial photographs is a zoom transfer stereoscope, which can be used to compensate for radial distortion on older photos and to map changes onto a common scale (Kondolf and Larson 1995). High resolution photogrammetry can also enhance aerial photographs. This method enables the heights of features such as terraces or high gravel bars and cut banks to be measured by comparing them with adjacent trees, bridges, or boulders of known dimensions (Madej 1992). Aerial photography is perhaps most ideal for documenting changes in riparian forest cover, especially the encroachment of riparian vegetation into formerly active channels downstream of reservoirs (Kondolf and Larson 1995). These methods can help in aquatic and riparian restoration by providing a means of recreating the physical conditions needed to maintain natural communities, including substrate, water

depth and velocity, inundation frequency, and temperature (Gore 1985; National Research Council 1992).

Aerial photographs are available for many areas; the first photos are often dated between the late 1920s and the 1940s. The U.S. Geological Survey Earth Science Information Center maintains a database of aerial photographs at scales of 1:24000; state and local agencies commonly contain archives of photos with higher resolution (Kondolf and Larson 1995). Commercial aerial photograph firms often have stock photos and can also take custom photos as required by a researcher's specifications.

The primary limitation of using photographs is that they are literally "snapshots" of the ecosystem and they provide very little information on the ecological processes of the site. Ecological variability cannot be determined from photos. Another major limitation of using aerial photographs is that the first photograph of a site may well be taken after the disturbance has already occurred. In this case the photo provides information on the post-disturbance condition, but does not give insight on the pre-disturbance state. Another limitation is that dense bank vegetation may obscure the channel from aerial photos of smaller streams (Kondolf and Larson 1995). This problem, however, can be partially mitigated by photos taken during the winter. It may also be difficult, even with enlargements and other means used to improve detail, to obtain information such as depth of water or sediment, type and richness of species present, and to identify subtle changes that affect ecosystem structure or function. Another limitation of using aerial photographs is that they do not photocopy well.

Aerial photographs still remain an immensely valuable method of reconstructing historical landscapes, and should be located and used during restoration efforts. An example of a project currently using aerial photographs is the San Francisco Bay ECO-ATLAS project in California. ECOATLAS maps wetlands for monitoring and research. Scientists involved in restoration today rely on aerial photographs more than any other form of historical data. It is expected that aerial photographs will continue to play a dominant role in restoration ecology.

Augmenting the use of photographs with other methods can enhance restoration success. For example, sediment cores can provide information on ecological variability over time. Studies of reference sites should be included to provide data on ecosystem variability. The combination of these methods allows restorationists to set realistic ecological goals.

Objective #2: How important is the incorporation of historical information in setting goals and in evaluation procedures for restoration projects?

Over one-half of the survey respondents claimed that historical data were very important in restoration goal development. Hobbs and Norton (1996, 95) focus on restoration goals in saying “key processes in restoration ecology that we consider essential are...to determine *realistic goals for reestablishing species and functional ecosystems* (emphasis added).” Because the implicit goal of restoration should be a return to pre-disturbance condition if at all possible (Cairns 1989), data regarding the pre-disturbance condition is immensely useful (Aronson and Le Floch 1996a; Hobbs and Norton 1996;

Dunwiddie 1992. Grant (1994) used a land survey from 1881, a National Forest Atlas Map from 1912, and aerial photographs from 1939 to set goals for the restoration project she conducted in Oregon. These historical sources showed multiple active channels meandering across the center of the floodplain, and were important in setting goals for restoring the relict channels as water courses additional to the current channels. Similarly, Koebel (1995) incorporated the use of archived maps for the restoration of the Kissimmee River. These were integral in setting goals regarding the reconstruction of the original channel, depicting where construction and excavation activities were to occur. Muhar, Schmutz, and Jungwirth (1995) used fisheries surveys from the 1920s in setting goals for the restoration of the River Inn in Austria. Specifically, the goal of increasing species richness to more than 24 fish species was directly influenced by information contained in the historical fisheries survey.

Restorationists that use historical data when setting goals for their projects often use this information when developing evaluation procedures (Grant 1994, Koebel 1995, Muhar, Schmutz, and Jungwirth 1995). For example, data regarding historical river channels are constantly referred to when constructing and evaluating channels during a restoration (Grant 1994, Koebel 1995). In addition, historical fisheries surveys are used in evaluating the fisheries population after restoration activities are completed (Muhar, Schmutz, and Jungwirth 1995). Aronson and Le Floch (1996a) state that establishing a clear historical perspective is essential to restoration and rehabilitation ecology. Using archived data to develop goals and evaluation procedures are important in establishing the historical perspective of a restoration site.

Objective #3: Does the use of historical information influence the success of restoration projects?

The majority of respondents in the survey stated that their projects that used historical data were successful. In particular, aerial photographs contribute the most to improving restoration success. However, historical data may be best for setting qualitative goals, which are not as easy to evaluate as quantitative targets. The respondents of the survey stated historical data were useful in setting quantitative versus qualitative goals; this view differed from the results found in the case studies. The case studies indicated that projects which did not use historical data had more quantitative goals than projects that used historical data. This discrepancy may be attributed to the nature of the particular case studies selected or the manner in which the survey question was written and interpreted.

If pre-disturbance aerial photos were used to delineate the extent and type of vegetation used in a project, those same photos can be used to compare the revegetation growth after the project is complete, much like the work conducted at McDonald Basin in Oregon (Whitall 1995). Native species were planted in the McDonald Basin based on information gained from aerial photos taken in 1939, 1972, and 1984; preliminary results two years after restoration began indicated a twenty percent survival rate of species present in the aerial photos (Whitall 1995). This indicates a return of the predisturbance condition, and although still fairly early, can be classified as successful (Whitall 1995). Restoration of a gravel mining area in northern Colorado also incorporated the use of aerial photographs from 1939 and 1950 (Manci 1999). Wetland boundaries bordering the

Poudre River were recreated using the historical photographs, and success was noted when wetland vegetation grew in those areas. The use of historical information in this project played an important role in the determination of success.

Recognizing that change is present in all ecosystems (Pickett and Parker 1994), past information may provide important clues into how the change takes place, how species react to the change, and the extent of change of the ecosystem. Aronson and Le Floch (1996a, 327) state that “a historical overview can indicate ecological transformations.”

Objective 4: How can current methodologies best be used to reconstruct historical landscapes?

Baseline data can be generated from *both* historical data (aerial photographs, archived maps, etc.) and ecological and computer methodologies (sediment coring and GIS) for the purposes of recreating historical landscapes in a restoration project. The use of both historical and current methods of restoration is evident in Barrett and Niering's (1993, 18) research: “...in the restoration of Barn Island marsh, evaluating the success of tidal marsh restoration varies from anecdotal assessments to more quantitative, goal-oriented approaches, including historical comparison of the previous marsh condition.”

An example of a restoration project that uses both historical data and current techniques is the study by O'Sullivan (1992) which used a range of methods to model phosphorus levels in shallow lakes. O'Sullivan (1992) incorporated historical data on land use, fertilizer applications, and abundance of livestock from 1905-1985 and sediment

coring methodology. His source of these historical records was parish returns and fertilizer records. O'Sullivan (1992) investigated the water quality, ecology, and trophic status of the lakes, and developed a model of the eutrophication based on analysis of the lake sediments. The models evaluate the current nutrient loads, the likely effects on the lakes of historical agricultural changes, and possible restoration management strategies. The models predicted an increase in nitrogen levels from 1905 to 1945, and then a steeper rise to a peak in 1985 (O'Sullivan 1992). Information about nitrogen and phosphorus from Vollenweider's model for lakes (1975) shows how the lake in O'Sullivan's (1992) study would have become increasingly eutrophic. Data from the sediment cores and parish records corroborate these findings. The models, sediment cores, and parish records all show that phosphorus loads reached dangerous levels by 1945, and have gradually increased until they are now about ten times the acceptable limit (O'Sullivan 1992).

Another example of a study incorporating both archived information and current methods to reconstruct a historical landscape is in the work by Whillans (1996). Whillans (1996) uses aerial photographs, historic maps, commercial fishing records, and personal recollections along with sediment cores to detect changes in Cootes Paradise, a marsh adjacent to Lake Ontario. The aerial photographs date from 1934 to 1985, historic maps are from the early 1800s, the fishing records from 1860, and personal recollections are from 1893. Based on the data provided by these sources, Whillans (1996) identified the need to re-introduce vegetation, reduce fetch, exclude common carp, anchor the marsh sediments, and reduce the influx from agricultural land affecting the marsh.

Archival and current methods were also used in restorations of the Willamette Valley of Oregon and in Vancouver, Canada (Buchanan 1999). An example of historical data usage is shown in Figure 10, which is an artist's rendition of the Willamette area in the 1880s. Figure 11 displays how GIS is used in depicting the expansion of the urban landscape through time in Vancouver.

A recommendation regarding historical information and current methodologies is to use them to validate data about a restoration site. Whillans (1996) concluded that the knowledge base of past retrospection will continue to be important for reference when verifying rehabilitation. In fact, validation of data may be the key advantage when combining historic and current methodologies in restoration. For example, Harris, et al. (1997) validated modeling results using historical data on riparian tree cover. They determined from the model results the increase and/or decrease of riparian tree cover over time, and verified results with aerial photographs and archived data. Restoration may be improved when quantitative verification using current methodologies validates historical data pertaining to a site. Validation with historical data is a necessary component of any real-life restoration modeling exercise (Harris, et al. 1997; Whillans 1996; Barrett and Niering 1993; O'Sullivan 1992).

Whenever possible, restorationists should gather as much historical information about a site as well as attempt to learn more about the historic landscape by analyzing data provided by current methodologies. Bedford (1990) argued that the assessment of pre-disruption values depends heavily upon the understanding of geographic and historical

Willamette Valley 1847

Willamette Valley 1888

Figure 10. Paul Kane's rendition of the Willamette Valley in 1847 and an unknown artist's depiction of the same area in 1888. Source: Boag (1992).

Figure 11. GIS images of Vancouver showing urban expansion over time.
Source: Buchanan (1999).

factors. By incorporating available historic and current methodologies about a restoration site, baseline data can be improved. Improving baseline data of a project site can only help in improving restoration objectives, goals, and success.

RECOMMENDATIONS

This research found that the restorationists surveyed believed that baseline data currently used in their projects were inadequate; this idea is also supported by the literature search (Aronson, Dhillon, and Le Floch 1995; Kondolf and Micheli 1995, among others). Recommendations from this research on how to improve restorations with historical and current information include:

- 1) Gather a variety of information, historical and current, to develop baseline data.**
- 2) Locate pre-disturbance photographs, if available, of a site prior to restoration efforts.**
- 3) Improve inventory methods by taking aerial photographs of existing ecosystems, including potential reference ecosystems, which may become future restoration sites.**
- 4) Incorporate available historical data to the maximum extent possible when setting restoration goals and evaluation procedures.**
- 5) Use historical data on vegetation, if available, to evaluate project success.**
- 6) Use both historical and ecological data to validate our understanding of historical landscapes.**

As Falk (1990, 71) states, "restoration...uses the past not as a goal but as a reference point for the future. If we seek to recreate the temperate forests, tallgrass savannas, or desert communities of centuries past, it is not to turn back the evolutionary clock but to set it ticking again." In order to accomplish this, restoration must be conducted by relying on as complete a profile as possible of what the ecosystem was like in the past, as well as what is realistic in the future. Baseline information gathered in the forms of historical data and current methodologies help to provide this profile, and can greatly influence restoration ecology in a positive manner.

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