CHAPTER 1: INTRODUCTION TO VOLUME TWO

INTRODUCTION

Coastal habitats provide ecological, cultural, and economic value. They act as critical habitat for thousands of species, including numerous threatened and endangered species, by providing shelter, spawning grounds, and food (Mitsch and Gosselink 2000). They often act as natural buffers, providing ecological, social, and economic benefits by filtering sediment and pollution from upland drainage thereby improving water quality, reducing the effects of floodwaters and storm surges, and preventing erosion. In addition to these ecosystem services, healthy coastal habitats provide many human values including opportunities for:

- Outdoor recreation and tourism
- Education
- Traditional use and subsistence lifestyles
- Healthy fishing communities, and
- Obtaining other marketable goods

Therefore, healthy functioning coastal habitats are not only important ecologically, they also support healthy coastal communities and, more generally, improve the quality of human lives. Despite these benefits, coastal habitats have been modified, degraded, and removed throughout the United States and its protectorates beginning with European colonization (Dahl 1990). Thus, many coastal habitats around the United States are in desperate need of restoration and subsequent monitoring of restoration projects.

WHAT IS RESTORATION MONITORING?

The science of restoration requires two basic tools: the ability to manipulate ecosystems to recreate a desired community and the ability to evaluate whether the manipulation has produced the desired change (Keddy 2000). The latter is often referred to as restoration monitoring.

For this manual, restoration monitoring is defined as follows:

> "*The systematic collection and analysis of data that provides information useful for measuring project performance at a variety of scales (locally, regionally, and nationally), determining when modification of efforts are necessary, and building long-term public support for habitat protection and restoration*."

Restoration monitoring contributes to the understanding of complex ecological systems (Meeker et al. 1996) and is essential in documenting restoration performance and adapting project and program approaches when needs arise. If results of monitoring restored coastal areas are disseminated, they can provide tools for planning management strategies and help improve future restoration practices and projects (Washington et al. 2000). Restoration monitoring can be used to determine whether project goals are being met and if mid-course corrections are necessary. It provides information on whether selected project goals are good measures for future projects and how to perform routine maintenance in restored areas (NOAA et al. 2002). Monitoring also provides the basis for a rigorous review of the pre-construction project planning and engineering.

Restoration monitoring is closely tied to and directly derived from restoration project goals. The monitoring plan (i.e., what is measured, how often, when, and where) should be developed with project goals in mind. If, for example, the goal of a restoration project is to increase the amount of fish utilizing a coastal marsh, then measurements should be selected that can quantify progress toward that goal. A variety of questions about sampling techniques and protocols need to be answered before monitoring can begin. For the fish utilization example, these may include:

- Will active or passive capture techniques be used (e.g., beach seines vs. fyke nets)?
- Where and when will samples be taken?
- Who will conduct the sampling?
- What level of identification will be required?
- What structural characteristics such as water level fluctuation or water chemistry will also be monitored and how?
- Who is responsible for housing and analyzing the data?
- How will results of the monitoring be disseminated?

Each of these questions, as well as many others, will be answered with the goals of the restoration project in mind. These questions need to be addressed before any measurements are taken in the field. In addition, although restoration monitoring is typically thought of as a 'post-restoration' activity, practitioners will find it beneficial to collect some data before and during project implementation. Pre-implementation monitoring provides baseline information to compare with post-implementation data to see if the restoration is having the desired effect. It also allows practitioners to refine sampling procedures if necessary. Monitoring during implementation helps insure that the project is being implemented as planned or if modifications need to be made.

Monitoring is an essential component of all restoration efforts. Without effective monitoring, restoration projects are exposed to several risks. For example, it may not be possible to obtain early warnings indicating that a restoration project is not on track. Without sound scientific monitoring, it is difficult to gauge how well a restoration site is functioning ecologically both before and after implementation. Monitoring is necessary to assess whether specific project goals and objectives (both ecological and human dimensions) are being met, and to determine what measures might need to be taken to better achieve those goals. In addition, the lack of monitoring may lead to poor project coordination and decreased efficiency.

Sharing of data and protocols with others working in the same area is also encouraged. If multiple projects in the same watershed or ecosystem are not designed and evaluated using a complementary set of protocols, a disjointed effort may produce a patchwork of restoration sites with varying degrees of success (Galatowitsch et al. 1998-1999) and no way to assess system-wide progress. This would result in a decreased ability to compare results or approaches among projects.

CONTEXT AND ORGANIZATION OF INFORMATION

In 2000, Congress passed the *Estuary Restoration Act (ERA), Title I of the Estuaries and Clean Waters Act of 2000*. The ERA establishes a goal of one million acres of coastal habitats (including those of the Great Lakes) to be restored by 2010. The ERA also declares that anyone seeking funds for a restoration project needs to have a monitoring plan to show how the progress of the restoration will be tracked over time. The National Oceanic and Atmospheric Administration (NOAA) was tasked with developing monitoring guidance for coastal restoration practitioners whether they be academics, private consultants, members of state, Tribal or local government, non-governmental organizations (NGOs), or private citizens, regardless of their level of expertise.

To accomplish this task, NOAA has provided guidance to the public in two volumes. The first, *Science-Based Restoration Monitoring of Coastal Habitats, Volume One: A Framework* *for Monitoring Plans Under the Estuaries and Clean Waters Act of 2000 (Public Law 160-457)* was released in 2003. It outlines the steps necessary to develop a monitoring plan for any coastal habitat restoration project. *Volume One* briefly describes each of the habitats covered and provides three matrices to help practitioners choose which habitat characteristics may be most appropriate to monitor for their project. Experienced restoration practitioners, biologists, and ecologists as well as those new to coastal habitat restoration and ecology can benefit from the step-by-step approach to designing a monitoring plan outlined in *Volume One*.

Volume Two, *Tools for Monitoring Coastal Habitats* expands upon the information in *Volume One* and is divided into two sections **Monitoring Progress Toward Goals** (Chapters 2-14) and **Context for Restoration** (Chapters 15-18). The first section, Monitoring Progress Toward Goals includes:

- Detailed information on the structural and functional characteristics of each habitat that may be of use in restoration monitoring
- Annotated bibliographies, by habitat, of restoration-related literature and technical methods manuals, and
- A chapter discussing many of the human dimensions aspects of restoration monitoring

The second section, Context for Restoration includes:

- A review of methods to select reference conditions
- A sample list of costs associated with restoration and restoration monitoring
- An overview of an online, searchable database of coastal monitoring projects from around the United States, and
- A review of federal legislation that supports restoration and restoration monitoring

The Audience

Volumes One and *Two* of *Science-Based Restoration Monitoring of Coastal Habitats* are written for those involved in developing and implementing restoration monitoring plans, both scientists and non-scientists alike. The intended audience includes restoration professionals in academia and private industry, as well as those in Federal, state, local, and Tribal governments. Volunteer groups, non-governmental organizations, environmental advocates, and individuals participating in restoration monitoring planning will also find this information valuable. Whereas *Volume One* is designed to be usable by any restoration practitioner, regardless of their level of expertise, *Volume Two* is designed more for practitioners who do not have extensive experience in coastal ecology. Seasoned veterans in coastal habitat ecology, however, may also benefit from the annotated bibliographies, literature review, and other tools provided.

The information presented in *Volume Two* is not intended as a 'how to' or methods manual: many of these are already available on a regional or habitat-specific basis. *Volume Two* does not provide detailed procedures that practitioners can directly use in the field to monitor habitat characteristics. The tremendous diversity of coastal habitats across the United States, the types and levels of impact to them, the differing scales of restoration activities, and variety of techniques used in restoration and restoration monitoring prevent the development of universal protocols. Thus, the authors have taken the approach of explaining *what one can measure during restoration monitoring, why it is important*, and *what information it provides* about the progress of the restoration effort. The authors of each chapter also believe that monitoring plans must be derived from the goals of the restoration project itself. Thus, each monitoring effort has the potential to be unique. The authors suggest, however, that restoration practitioners seek out the advice of regional experts, share data, and use similar data collection techniques with others in their area to increase the knowledge and understanding of their local and regional habitats. The online database of monitoring projects described in Chapter 17 is intended to facilitate this exchange of information.

The authors do not expect that every characteristic and parameter described herein will be measured, in fact, very few of them will be as part of any particular monitoring effort. A comprehensive discussion of all potential characteristics is, however, necessary so that practitioners may choose those that are most appropriate for their monitoring program. In addition, although the language used in *Volume Two* is geared toward restoration monitoring, the characteristics and parameters discussed could also be used in ecological monitoring and in the selection of reference conditions as well.

MONITORING PROGRESS TOWARDS GOALS

The progress of a restoration project can be monitored through the use of traditional ecological characteristics (Chapters 2 - 13) and/or emerging techniques that incorporate human dimensions (Chapter 14).

THE HABITAT CHAPTERS

Thirteen coastal habitats are discussed in twelve chapters. Each chapter follows a format that allows users to move directly to the information needed, rather than reading the whole text as one would a novel. There is, however, substantial variation in the level of detail among the chapters. The depth of information presented reflects the extent of restoration, monitoring, and general ecological literature associated with that habitat. That is, some habitats such as marshes, SAV, and oyster reefs have been the subject of extensive restoration efforts, while others such as rocky intertidal and rock bottom habitats have not. Even within habitats there can be considerable differences in the amount of information available on various structural and functional characteristics and guidance on selecting parameters to measure them. The information presented for each habitat has been derived from extensive literature reviews of restoration and ecological monitoring studies. Each habitat chapter was then reviewed by experts for content to ensure that the information provided represented the most current scientific understanding of the ecology of these systems as it relates to restoration monitoring.

Habitat characteristics are divided into two types: structural and functional. Structural habitat characteristics define the physical composition of a habitat. Examples of structural characteristics include:

- Sediment grain size
- Water source and velocity
- Depth and timing of flooding, and
- Topography and bathymetry

Structural characteristics such as these are often manipulated during restoration efforts to bring about changes in function. Functional characteristics are the ecological services a habitat provides. Examples include:

- Primary productivity
- Providing spawning, nursery, and feeding grounds
- Nutrient cycling, and
- Floodwater storage

Structural characteristics determine whether or not a particular habitat is able to exist in a given area. They will often be the first ones monitored during a restoration project. Once the proper set of structural characteristics is in place and the biological components of the habitat begin to become established, functional characteristics may be added to the monitoring program. Although structural characteristics have historically been more commonly monitored during restoration efforts, measurements of functional characteristics provide a better estimate of whether or not a restored area is truly performing the economic and ecological services desired. Therefore, incorporating measurements of functional characteristics in restoration monitoring plans is strongly encouraged.

When developing a restoration monitoring plan, practitioners should follow the twelve-step process presented in *Volume One* and refer to the appropriate chapters in *Volume Two* (habitat and human dimensions) to assist them in selecting characteristics to monitor. The information presented in the habitat chapters is derived from and expands upon the *Volume One* matrices (*Volume One* Appendix II).

Organization of Information

Each of the habitat chapters is structured as follows:

1. Introduction
    a. Habitat description and distribution
    b. General ecology
    c. Human impacts to the habitat
2. Structural and functional characteristics
    a. Each structural and functional characteristic identified for the habitat in the *Volume One* matrices is explained in detail. Structural and functional characteristics have generally been discussed in separate sections of each chapter. Occasionally, some functions are so intertwined with structural characteristics that the two are discussed together.
    b. Whenever possible, potential methods to measure, sample, and/or monitor each characteristic are introduced or readers are directed to more thorough sources of information. In some cases, not enough information was found while reviewing the literature to make specific recommendations. In these cases, readers are encouraged to use the primary literature cited within the text for methods and additional information.
3. Matrices of the structural and functional characteristics and parameters suggested for use in restoration monitoring
    a. These two matrices are habitat-specific distillations of the *Volume One* matrices
    b. Habitat characteristics are cross-walked with parameters appropriate for monitoring change in that characteristic. Parameters include both those that are direct measures of a particular characteristic as well as those that are indirectly related and may influence a particular characteristic or related parameter. Tables 1 and 2 can be used to illustrate an example. The parameter of salinity in submerged aquatic vegetation is a direct measure of a structural characteristic (salinity, Table 1). In addition, salinity is related to other structural characteristics such as tides and water source. Salinity is also related to functional characteristics such as biodiversity and nutrient cycling and may be appropriate to include in the monitoring of these functions as well (Table 2). Experienced practitioners will note that many characteristics and parameters may be related to one another but are not shown as such in a particular matrix. The matrices are not intended to be all inclusive of each and every possible interaction. The matrices provided and the linkages illustrated are only intended as starting points in the process of developing lists of parameters that may be useful in measuring particular characteristics and understanding some of their interrelationships.
    c. Some parameters and characteristics are noted as being highly recommended for any and all monitoring efforts as they represent critical components of the habitat while others may or may not be appropriate for use depending on the goals of the individual restoration project.
4. Acknowledgement of reviewers
5. Literature Cited

Three appendices are also provided for each habitat chapter. In the online form of *Volume Two,* these appendices download with the rest of the habitat chapter text. In the printed versions of *Volume Two*, each chapter's appendices are provided on a searchable CD-ROM located inside the back cover. Each appendix is organized as follows:

Appendix I - An Annotated Bibliography
a. Overview of case studies of restoration monitoring and general ecological studies pertinent to restoration monitoring
b. Entries are alphabetized by author

Parameters to Monitor the Structural Characteristics of SAV (excerpt)

Parameters to Monitor	Biological	Habitat created by plants	Physical	Sediment grain size[1]	Topography / Bathymetry	Turbidity	Hydrological	Tides / Hydroperiod	Water sources	Current velocity	Wave energy	Chemical	Nutrient concentration	pH, salinity, toxics, redox, DO[2]
Chemical														
Salinity (in tidal areas)								●	●					●

Table 1. Salinity is a parameter that can be used to directly measure a structural component of submerged aquatic vegetation habitats (Chemical/salinity). It is shown with a closed circle indicating that it highly recommended as part of any restoration monitoring program, regardless of project goals. A circle for salinity is also shown under the **Tides/Hydroperiod** and **Water source** columns as salinity levels are related to these structural characteristics as well. (Entire table can be found on page 9.39.)

Parameters to Monitor the Functional Characteristics of SAV (excerpt)

Parameters to Monitor	Biological	Contributes primary production	Supports biomass production	Provides breeding grounds	Provides nursery areas	Provides feeding grounds	Provides refuge from predation	Supports high biodiversity	Supports a complex trophic structure	Provides substrate for attachment	Chemical	Supports nutrient cycling	Modifies chemical water quality	Modifies dissolved oxygen
Chemical														
Salinity (in tidal areas)								○				○		

Table 2. Salinity is related to the functions of **Supporting high biodiversity** and **Supporting nutrient cycling**. It is shown here with an open circle, denoting that it may be useful to monitor if monitoring of these functions is important to the goals of the restoration project. (Entire table can be found on page 9.40.)

[1] Including organic matter content.
[2] Dissolved oxygen.

Appendix II - Review of Technical and Methods Manuals

These include reviews of:
a. Restoration manuals
b. Volunteer monitoring protocols
c. Lab methods
d. Identification keys, and
e. Sampling methods manuals

Whenever possible, web addresses where these resources can be found free of charge are provided.

Appendix III - Contact information for experts who have agreed to be contacted with questions from practitioners

As extensive as these resources are, it is inevitable that some examples, articles, reports, and methods manuals have been omitted. Therefore, these chapters should not be used in isolation. Instead, they should be used as a supplement to and extension of:

- The material presented in *Volume One*
- Resources provided in the appendices
- The advice of regional habitat experts, and
- Research on the local habitat to be restored

WHAT ARE THE HABITATS?

The number and type of habitats available in any given estuary is a product of a complex mixture of the local physical and hydrological characteristics of the water body and the organisms living there. The ERA Estuary Habitat Restoration Strategy (Federal Register 2002) dictates that the Cowardin et al. (1979) classification system should be followed in organizing this restoration monitoring information. The Cowardin system is a national standard for wetland mapping, monitoring, and data reporting, and contains 64 different categories of estuarine and tidally influenced habitats. Definitions, terminology, and the list of habitat types continue to increase in number as the system is modified. Discussion of such a large number of habitat types would be unwieldy. The habitat types presented in this document, therefore, needed to be smaller in number, broad in scope, and flexible in definition. The 13 habitats described in this document are, however, generally based on that of Cowardin et al. (1979).

Restoration practitioners should consider local conditions within their project area to select which general habitat types are present and which monitoring measures might apply. In many cases, a project area will contain more than one habitat type. To appropriately determine the habitats within a project area, the practitioner should gather surveys and aerial photographs of the project area. From this information, he or she will be able to break down the project area into a number of smaller areas that share basic structural characteristics. The practitioner should then determine the habitat type for each of these smaller areas. For example, a practitioner working in a riparian area may find a project area contains a *water column, riverine forest, rocky shoreline*, and *rock bottom*. Similarly, someone working to restore an area associated with a tidal creek or stream may find the project area contains *water column, marshes, soft shoreline, soft bottom*, and *oyster beds*. Virtually all estuary restoration projects will incorporate characteristics of the water column. Therefore, all practitioners should read *Chapter 2: Restoration Monitoring of the Water Column* in addition to any additional chapters necessary.

Habitat Decision Tree

A Habitat Decision Tree has been developed to assist in the easy differentiation among the habitats included in this manual. The decision tree allows readers to overcome the restraints of varying habitat related terminology in deciding which habitat definitions best describe those in their project area. Brief definitions of each habitat are provided at the end of the key.

1. a. Habitat consists of open water and does not include substrate (**Water Column**)
   b. Habitat includes substrate (go to 2)
2. a. Habitat is continually submerged under most conditions (go to 3)
   b. Habitat substrate is exposed to air as a regular part of its hydroperiod (go to 8)
3. a. Habitat is largely unvegetated (go to 4)
   b. Habitat is dominated by vegetation (go to 7)
4. a. Substrate is composed primarily of soft materials, such as mud, silt, sand, or clay (**Soft Bottom**)
   b. Substrate is composed primarily of hard materials, either of biological or geological origin (go to 5)
5. a. Substrate is composed of geologic material, such as boulders, bedrock outcrops, gravel, or cobble (**Rock Bottom**)
   b. Substrate is biological in origin (go to 6)
6. a. Substrate was built primarily by oysters, such as *Crassostrea virginica* (**Oyster Reefs**)
   b. Substrate was built primarily by corals (**Coral Reefs**)
7. a. Habitat is dominated by macroalgae (**Kelp and Other Macroalgae**)
   b. Habitat is dominated by rooted vascular plants (**Submerged Aquatic Vegetation - SAV**)
8. a. Habitat is not predominantly vegetated (go to 9)
   b. Habitat is dominated by vegetation (go to 10)
9. a. Substrate is hard, made up materials such as bedrock outcrops, boulders, and cobble (**Rocky Shoreline**)
   b. Substrate is soft, made up of materials such as sand or mud (**Soft Shoreline**)
10. a. Habitat is dominated by herbaceous, emergent, vascular plants. The water table is at or near the soil surface or the area is shallowly flooded (**Marshes**)
    b. Habitat is dominated by woody plants (go to 11)
11. a. The dominant woody plants present are mangroves, including the genera *Avicennia*, *Rhizophora*, and *Laguncularia* (**Mangrove Swamps**)
    b. The dominant woody plants are other than mangroves (go to 12)
12. a. Forested habitat experiencing prolonged flooding, such as in areas along lakes, rivers, and in large coastal wetland complexes. Typical dominant vegetation includes bald cypress (*Taxodium distichum*), black gum (*Nyssa sylvatica*), and water tupelo (*Nyssa aquatica*). (**Deepwater Swamps**)
    b. Forested habitat along streams and in floodplains that do not experience prolonged flooding (**Riverine Forests**)

Water column - A conceptual volume of water extending from the water surface down to, but not including the substrate. It is found in marine, estuarine, river, and lacustrine systems.

Rock bottom - Includes all wetlands and deepwater habitats with substrates having an aerial cover of stones, boulders, or bedrock 75% or greater and vegetative cover of less than 30% (Cowardin et al. 1979). Water regimes are restricted to subtidal, permanently flooded, intermittently exposed, and semi-permanently flooded. The rock bottom habitats addressed in *Volume Two* include bedrock and rubble.

Coral reefs - Highly diverse ecosystems, found in warm, clear, shallow waters of tropical oceans worldwide. They are composed of marine polyps that secrete a hard calcium carbonate skeleton, which serves as a base or substrate for the colony.

Oyster reefs - Dense, highly structured communities of individual oysters growing on the shells of dead oysters.

Soft bottom - Loose, unconsolidated substrate characterized by fine to coarse-grained sediment.

Kelp and other macroalgae - Relatively shallow (less than 50 m deep) subtidal and intertidal algal communities dominated by very large brown algae. Kelp and other macroalgae grow on hard or consolidated substrates forming extensive three-dimensional structures that support numerous plant and animal communities.

Rocky shoreline - Extensive littoral habitats on high-energy coasts (i.e., subject to erosion from waves) characterized by bedrock, stones, or boulders with a cover of 75% or more and less than 30% cover of vegetation. The substrate is, however, stable enough to permit the attachment and growth of sessile or sedentary invertebrates and attached algae or lichens.

Soft shoreline - Unconsolidated shore includes all habitats having three characteristics: (1) unconsolidated substrates with less than 75% aerial cover of stones, boulders, or bedrock; (2) less than 30% aerial cover of vegetation other than pioneering plants; and (3) any of the following water regimes: irregularly exposed, regularly flooded, irregularly flooded, seasonally flooded, temporarily flooded, intermittently flooded, saturated, or artificially flooded (Cowardin et al. 1979). This definition includes cobble-gravel, sand, and mud. However, for the purpose of this document, cobble-gravel is not addressed.

Submerged aquatic vegetation (SAV; includes marine, brackish, and freshwater) - Seagrasses and other rooted aquatic plants growing on soft sediments in sheltered shallow waters of estuaries, bays, lagoons, rivers, and lakes. Freshwater species are adapted to the short- and long-term water level fluctuations typical of freshwater ecosystems.

Marshes (marine, brackish, and freshwater) - Transitional habitats between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water tidally or seasonally. Freshwater species are adapted to the short- and long-term water level fluctuations typical of freshwater ecosystems.

Mangrove swamps - Swamps dominated by shrubs (*Avicenna, Rhizophora*, and *Laguncularia*) that live between the sea and the land in areas that are inundated by tides. Mangroves thrive along protected shores with fine-grained sediments where the mean temperature during the coldest month is greater than 20º C; this limits their northern distribution.

Deepwater swamps - Forested wetlands that develop along edges of lakes, alluvial river swamps, in slow-flowing strands, and in large coastal-wetland complexes. They can be found along the Atlantic and Gulf Coasts and throughout the Mississippi River valley.

They are distinguished from other forested habitats by the tolerance of the dominant vegetation to prolonged flooding.

Riverine forests - Forests found along sluggish streams, drainage depressions, and in large alluvial floodplains. Although associated with deepwater swamps in the southeastern United States, riverine forests are found throughout the United States in areas that do not have prolonged flooding.

THE HUMAN DIMENSIONS CHAPTER

The discussion of human dimensions helps restoration practitioners better understand how to select measurable objectives that allow for the appropriate assessment of the benefits of coastal restoration projects to human communities and economies. Traditionally, consideration of human dimensions issues has not been included as a standard component of most coastal restoration projects. Most restoration programs do not currently integrate social or economic factors into restoration monitoring, and few restoration projects have implemented full-scale human dimensions monitoring. Although some restoration plans are developed in an institutional setting that require more deliberate consideration of human dimensions impacts and goals, this does not generally extend to the monitoring stage. It is becoming increasingly evident, however, that decisions regarding restoration cannot be made solely by using ecological parameters alone but should also involve considerations of impacts on and benefits to human populations, as well. Local communities have a vested interest in coastal restoration and are directly impacted by the outcome of restoration projects in terms of aesthetics, economics, or culture. Human dimensions goals and objectives whether currently available or yet to be developed should reflect societal uses and values of the resource to be restored. Establishing these types of parameters will increase the public's understanding of the potential benefits of a restoration project and will increase public support for restoration activities.

While ecologists work to monitor the restoration of biological, physical, and chemical functional characteristics of coastal ecosystems, human dimensions professionals identify and describe how people value, utilize, and benefit from the restoration of coastal habitats. The monitoring and observation of coastal resource stakeholders allows us to determine who cares about coastal restoration, why coastal restoration is important to them, and how coastal restoration changes people's lives. The human dimensions chapter will help restoration practitioners identify:

1) Human dimensions goals and objectives of a project
2) Measurable parameters that can be monitored to determine if those goals are being met, and
3) Social science research methods, techniques, and data sources available for monitoring these parameters

This chapter includes a discussion of the diverse and dynamic social values that people place on natural resources, and the role these values play in natural resource policy and management. Additionally, some of the general factors to consider in the selection and monitoring of human dimensions goals/objectives of coastal restoration are presented, followed by a discussion of some specific human dimensions goals, objectives, and measurable parameters that may be included in a coastal restoration project. An annotated bibliography of key references and a matrix of human dimensions goals and measurable parameters are provided as appendices at the end of this chapter. Also included, as an appendix, is a list of human dimensions research experts (and their areas of expertise) that you may contact for additional information or advice.

The final four chapters of this manual are designed to provide readers with additional information that should enhance their ability to develop and carry out strong restoration monitoring plans. Chapter 15 reviews methods available for choosing areas or conditions to which a restoration site may be compared both for the purpose of setting goals during project planning and for monitoring the development of the restored site over time. Chapter 16 is a listing of generalized costs of personnel, labor, and equipment to assist in the development of planning preliminary cost estimates of restoration monitoring activities. Some of this information will also be pertinent to estimating costs of implementing a restoration project as well. Chapter 17 provides a brief description of the online review of monitoring programs in the United States. The database can be accessed though the NOAA Restoration Portal (http://restoration.noaa.gov/). This database will allow interested parties to search by parameters and methodologies used in monitoring, find and contact responsible persons, and provide examples that could serve as models for establishment or improvement of their own monitoring efforts. Chapter 18 is a summary of the major United States Acts that support restoration monitoring. This information will provide material important in the development of a monitoring plan. A Glossary of many scientific terms is also provided at the end of the document.

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CHAPTER 13: RESTORATION MONITORING OF RIVERINE FORESTS

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INTRODUCTION

A riverine forest is a type of wetland dominated by trees and located along sluggish streams, drainage depressions, and in large alluvial floodplains. Although this habitat occurs throughout the United States, extensive areas of riverine forests are found on the Atlantic and Gulf coasts and throughout the Mississippi river valley from Louisiana to southern Illinois (Figure 1 - Mitsch and Gosselink 2000; Allen et al. 2001). Riverine forests are commonly referred to as bottomland hardwoods, floodplain forests, or riverine swamps. They are referred to as 'palustrine forests' by Cowardin et al. (1979).

Riverine forests are often subdivided into a variety of types or classes based on dominant tree species or the regional landform they are found in. Some examples include deepwater swamps, alluvial floodplains, pondcypress swamps, and wet flatwoods (Mitsch and Gosselink 2000; Allen et al. 2001). Riverine forests can be flooded by up to several feet of water in the winter and spring. By summer, water levels in most cases recede, exposing the soil. Some forests occasionally remain flooded throughout the year (Mitsch and Gosselink 2000; Allen et al. 2001), others have dry-downs early in the growing season nearly every year. All riverine forest habitats need occasional dry periods when the soils are exposed for tree seedlings to germinate. Soils of riverine forests are typically mineral although limited peat accumulation may occur in deeper depressions and wetter areas (Giese et al. 2000).

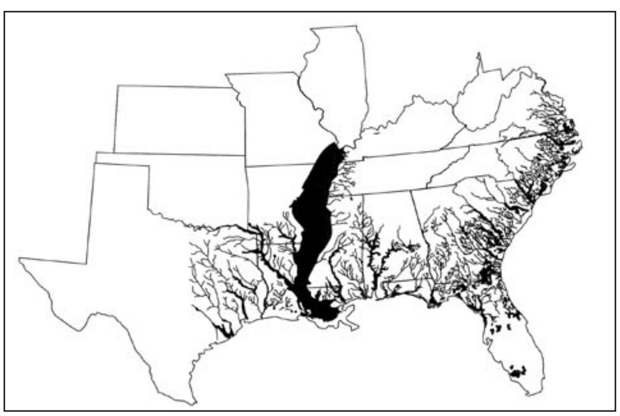

Figure 1. Distribution and extent of riverine forests along rivers and streams in the southeastern United States. Figure Courtesy of USGS, based on a figure modified from Putnam et al. 1960.

The dominant woody vegetation of riverine forests includes softwood as well as hardwood tree species. Some examples include:

Baldcypress (*Taxodium distichum*)
Water tupelo (*Nyssa aquatica*)
Red maple (*Acer rubrum*)
Silver maple (*A. saccharinum*)
Green ash (*Fraxinus pennsylvanica*)

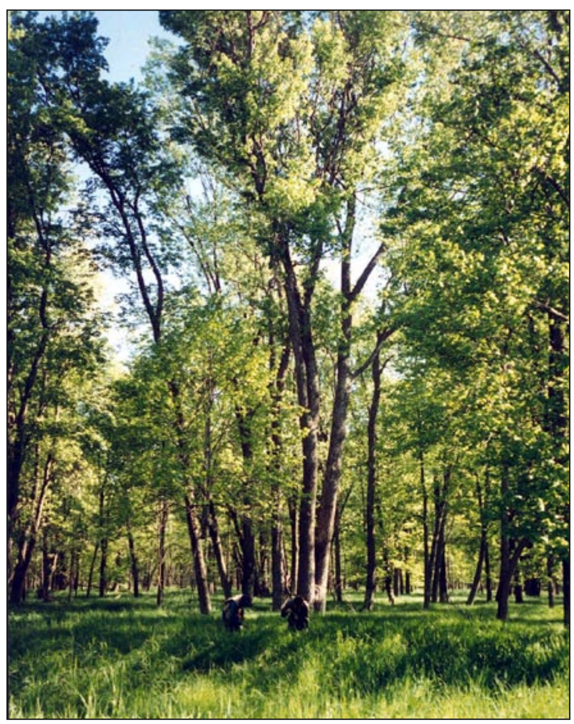

Figure 2. A silver maple dominated riverine forest in northern Lower Michigan. Photo courtesy of Matthew Baker, Smithsonian Institute.

[1] 2205 Commonwealth Boulevard, Ann Arbor, MI 48105.
[2] 700 Cajundome Boulevard, Lafayette, LA 70506.

Sugarberry/hackberry (*Celtis laevigata*)
Elm (*Ulmus* spp.)
Cottonwood (*Populus deltoids*)
Swamp cottonwood (*P. herophylla*)
Willow (*Salix* spp.), and

a variety of oaks such as:

Overcup (*Quercus lyrata*)
Willow (*Q. phellos*)
Nuttall (*Q. texana*)
Water (*Q. nigra*), and
Cherrybark (*Q. pagoda*) (Putnam et al. 1960; Hosner and Minckler 1963; Barnes and Wagner 1981; Allen et al. 2001)

Pond cypress (*Taxodium distichum* var. *nutans*) and Atlantic white cedar (*Chamaecyparis thyoides*) also occur in isolated locations in the southeastern United States.

Riverine forests support a diversity of animal populations, including commercially important wildlife species. Many species of macroinvertebrates such as crayfish, shrimp, insects, clams, snails, and worms are also commonly found in riverine forests (Wharton et al. 1982). Fish make extensive use of flooded riverine forests for temporary feeding, spawning, and nursery areas. Deepwater, backwater, and main river channel areas provide refuge for fish when floodwaters subside (Wharton et al. 1982; Killgore and Hoover 1992). Forests that are inundated for longer periods of the growing season provide greater habitat benefits for invertebrates and fish than those that dry down in the summer (Bowers et al. 2000). The American alligator, cottonmouth snakes, and several species of frogs and salamanders all use riverine habitats for foraging, cover, and reproduction (Bowers et al. 2000). White-tailed deer, nutria, rabbits, beaver, mink, migrating songbirds, waterfowl, and wading birds are all typical residents of riverine forest habitats (Wharton et al. 1982; O'Neal et al. 1992; Guilfoyle 2001).

Riverine forests are essential to the health and function of downstream areas. Alluvial forests temporarily store floodwaters, reduce downstream flood peaks, and retain sediments that would otherwise be transported downstream. They absorb and transform nutrients, preventing eutrophication of downstream water bodies and export organic matter that can be used as food by fish (Conner and Day 1982; Giese et al. 2000; Stanturf et al. 2000). The floodplain forest of the Apalachicola River in the Florida panhandle, for example, is a primary mechanism influencing the chemistry and biology of Apalachicola Bay. River flow is influenced by local rainfall patterns, watershed drainage, flood water storage in the floodplain, and plant cover (Wharton et al. 1982). Thus the salinity level of the Bay (and its associated effects on plants and animals of the Bay) is partly under the influence of the riverine forests through which floodwaters flow. The productivity of the Bay also depends on the annual pulses of organic material and silt from riverine forests but also on longer-term (5 to 7 year) flood pulses originating in the mountains of Georgia. These larger flows flush accumulated organic material, nutrients, and sediments that have been stored within the riverine forest out to the Bay and have been linked to peaks in commercial fish catches nearshore. Similar processes have also been noted in the Chesapeake Bay and in Barataria Bay in Louisiana (Wharton et al. 1982).

HUMAN IMPACTS TO RIVERINE FORESTS

Although the total area of riverine forest cover prior to European settlement for the entire United States is not known, estimates for some areas do exist. The Mississippi Alluvial Valley had the largest extent of riverine forest (Figure 1) at 25 million acres (Hefner and Brown 1985), approximately 20% of that remains today (MacDonald et al. 1979). In Texas and Illinois, only 34% and 2% respectively of the original riverine forest remain (Frye 1987; Allen et al.

2001). Losses in these and other areas once dominated by riverine forests continue. The majority of losses have primarily been due to conversion to agriculture although flood control structures, reservoirs, drainage and conversion to pine forests, surface mining, petroleum extraction, and urban development have also impacted forest area (Allen et al. 2001). In addition, conversion to tree-farm monoculture for wood production, construction of impoundments, diversion canals, channelization, dredging, shortening of channels, and urban development also diminish the health and acreage of riverine forests (Wharton 1982). Highway construction projects impact riverine hardwood forests beyond the footprint of the highway because water often ponds or drains more slowly from the upstream or uphill side of the highway causing extensive mortality of species not capable of surviving the increased flooding or soil saturation. Although these alternative land uses contain obvious value, so too, do the functions provided by healthy, intact riverine forests.

Need for Restoration

Functions such as floodwater storage and nutrient cycling have only recently begun to be understood and valued by society. When floodplain ecosystems are connected to their associated rivers and allowed to flood, they filter nutrients, store sediments, retain floodwater and otherwise help preserve downstream water quality. In addition, riverine forests also provide important habitat for migratory and resident birds, fish, and a variety of other wildlife. As the public has become more aware of the environmental and economic benefits of riverine forests, the desire to preserve and restore them has increased. Conservation and preservation of remaining riverine forests is important but considering the extent of loses, restoration of these habitats is also required (Allen et al. 2001).

Originally when riverine forests were harvested for lumber, cutover areas were converted to agriculture and no reforestation or restoration was attempted. Eventually large-scale logging operations were developed in areas unsuitable for agricultural production. These required that bottomlands be managed for forest production over long periods of time. Early efforts at replanting cutover riverine forest areas were focused on planting pines or other fast growing tree species for repeated harvest. There was little concern or need for ecological monitoring in these situations. The only thought was to assess how fast the trees were growing and when they would be ready for harvest.

Ecosystem-based restoration of riverine forest ecosystems is a relatively new practice. Only since the early 1980s have any serious, large-scale, ecological restorations been attempted. Considering the amount of this habitat type that has been lost, the need for restoration is great. Unfortunately it is also expensive if it is to be done properly and/or on any large scale. Hydrologic restoration projects need to be carefully monitored to ensure that hydroperiods and water flows are developing as planned and that excessive erosion or flooding in unintended areas is not occurring. If planting is also part of the restoration project, monitoring of which planting schemes offer the best survivorship of planted material can increase the efficiency of future restoration efforts. Without monitoring, it will be impossible to determine if money spent on site acquisition, site preparation, and plant materials were well spent or wasted.

STRUCTURAL CHARACTERISTICS OF RIVERINE FORESTS

When planning a restoration and monitoring project, practitioners should be mindful that it may take several decades before a riverine forest is able to fully perform all ecological functions. Therefore, it is important to state early on in the restoration planning process what the particular goals of the restoration project are and how the project will be monitored over time to see if those goals have been achieved. A few examples to illustrate this point may be helpful:

- If the goal of a restoration project is to allow fish access to a forested floodplain for feeding and breeding purposes by removing a dike or levee, evidence of fish usage in the area might be seen within a year or two.
- If the goal of the project is to restore plant diversity to levels similar to a reference condition[3], this might be achieved in a relatively short time period as well (5 to 10 years).
- The goal of restoring native fish or bird species, on the other hand, may require the presence of woody debris in the stream channel for cover, a closed canopy to shade the water and keep day-time temperatures low, or old trees with cavities in which to build nests. If large trees to supply these habitat needs are not available, trees will need to be grown from seedlings or saplings. Thus monitoring may take a human lifetime or more as trees grow to the proper size.

Understanding project goals and how they are to be monitored also helps determine what management actions may be required later to ensure that goals are achieved.

As with many of the other habitats described in *Volume Two*, the monitoring of restoration efforts in riverine forests should focus first on the primary structural characteristics of the habitat and then shift toward functional characteristics over time. The primary structural characteristics of riverine forests have been broken down into four categories.

Biological

- Habitat created by plants

Physical

- Sediment grain size
- Topography/Bathymetry

Hydrological

- Hydroperiod and water source

These structural characteristics were identified as being fundamental to the development of a healthy riverine forest habitat. Each of these dictates whether or not a forest can develop in an area, which particular tree species will become established, and the degree to which the habitat can perform characteristic biological and physical functions. Much of the information presented here has been derived from studies in the southeastern United States, as this is where riverine forests are most extensively found[4]. The same general characteristics and parameters, however, may apply to riverine forests throughout the United States.

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[3] See Chapter 15 for a discussion of methods to select proper reference conditions for restoration monitoring.

[4] This document and its associates were created to address monitoring requirements of the Estuary Restoration Act of 2000 (ERA), Title I of the Estuaries and Clean Waters Act of 2000. The Act places a head of tide inland boundary on habitats to be addressed by these documents. Therefore, inland riverine forests, often called 'riparian forests', are not specifically described in this text. Two publicly available resources, however, provide extensive technical assistance toward the restoration and monitoring of these systems and can be found at: http://www.usda.gov/stream_restoration/ and http://www.npwrc.usgs.gov/resource/literatr/ripareco/ripareco.htm#contents

Figure 3. Small-scale changes in topography can also influence the abundance of understory vegetation. Lower, wetter areas (left) are often devoid of groundcover while slightly higher and dryer areas (right) have abundant vegetation. Photo courtesy of Matthew Baker, Smithsonian Institute.

BIOLOGICAL

Habitat Created by Plants

Riverine forests can be extremely diverse communities, exhibiting a variety of canopy/ ground cover combinations (Eyre 1980). The presence and abundance of understory vegetation depends upon hydrology, soil type and pH, and to a large extent the amount of light that penetrates the canopy (Hosner and Minckler 1963; Dunn and Stearns 1987). Some areas with open canopies and moderate flooding may have a diverse shrub and herbaceous ground flora (Figure 3). Others, with closed canopies or longer flooding times may be devoid of any ground layer vegetation (Mitsch and Gosselink 2000). The relationship of these plant community characteristics to the physical, hydrological, and chemical structural characteristics of riverine forests are explained in the various sections below.

Most wildlife have particular ranges of attributes within which they are best adapted. Forestry attributes such as stem density, % canopy closure, tree height, diameter at breast height (DBH), amount of woody debris on the forest floor, forested area, presence of gaps, seed (mast) production, amount of litter fall, frequency of fire, and tree species composition can all have a positive or negative impact on wildlife habitat depending on the particular animal species or community in question. A comprehensive description of how riverine forests provide habitat is beyond the scope of this document. Although a few examples are used in the Functional Characteristics section below, practitioners requiring more detail on particular types of riverine forests or particular portions of the country are directed to documents in the annotated bibliography. Even these often can only provide broad generalizations. Practitioners may need to investigate the primary scientific literature if the goals of their project are very narrow in focus. Once a practitioner is familiar with the general literature, local and regional experts can be contacted for further information and assistance.

Sampling and Monitoring Methods

The types of measurements used to monitor the restoration of a forested site change as the site matures. If plantings are part of the restoration project, the first few years are typically spent monitoring damage from herbivores, seedling survival, density, and growth rate as measured by plant height (Conner 1989; Kolka et al. 1998; Conner et al. 2000). Small seedlings may, however, be difficult to find amongst taller, denser grasses. In addition, plants that have been clipped by herbivores may sprout back the following year. As sites mature (e.g., starting around 10 years after planting), the monitoring of canopy closure becomes important as this factor is strongly related to light availability and understory vegetation (Fletcher et al. 2000). Growth rate can still be measured but the method changes from using seedling height to diameter at breast height (DBH).

Numerous field and identification guides are available for different areas of the country.

Practitioners should select a book (or books) from as close a region as possible to their study area. Most field guides are not comprehensive and only cover the most common species one is most likely to find. When knowing the exact species is absolutely necessary, such as when study results are to be published, then more detailed and comprehensive identification guides should be consulted. A few examples of these sorts of texts include:

- Godfrey and Wooten's *Aquatic and Wetland Plants of Southeastern United States: Dicotyledons* or their second volume *Aquatic and Wetland Plants of Northeastern North America: Angiosperms: Monocotyledons (Volume II)*
- Crow, Hellquist's, and Fassett's *Aquatic and Wetland Plants of Northeastern North America: Pteridophytes, Gymnosperms and Angiosperms: Dicotyledons and Aquatic and Wetland Plants of Northeastern North America: Angiosperms: Monocotyledons (Volume II)*, and
- Voss' three-volume *Michigan Flora*

PHYSICAL

Sediment Grain Size

The soils of riverine forests are a product of the hydrologic process of the associated river. The alternating cycle of flooding and drydown controls the physical and chemical properties of floodplain soils such as sediment grain size, bulk density, pH, redox potential, and nutrient cycling which in turn strongly influence species composition (Dunn and Stearns 1987). The cycle of flooding and drawdown:

- Continually deposits and replenishes minerals and essential nutrients in floodplain soils
- Produces anaerobic conditions in the soil that affect biological and chemical processes
- Imports and exports particulate and dissolved organic matter, and
- Exports biological waste products (Wharton et al. 1982)

Healthy, intact riverine forest communities absorb and dissipate the physical energies of overbank flooding. When water enters the floodplain and has to work its way around and through dense stand of trees and shrubs, water velocity is slowed, suspended sediments are deposited, and erosion is held in check (Wharton et al. 1982). As a result, alluvial riverine soils generally have more clay and organic matter than upland soils and thus tend to have greater nutrient and moisture-holding capacity leading to high rates of productivity[5] (Allen et al. 2001). When suspended sediments are deposited in the floodplain instead of being carried further downstream, habitat and water quality in receiving bodies of water are protected from sedimentation or increased turbidity.

At lower elevations where standing water occurs for most of the year, significant accumulations of soil organic matter can develop. Percent soil organic matter ranges from <5% for alluvial river floodplains to 30-40 % for rivers draining acid bogs, tidal forests and floodplains along spring-fed rivers. Soils in low elevations have higher organic matter content within that range (Wharton et al. 1982). The distribution of organic matter is an important factor affecting water quality, habitat, and food webs (Giese et al. 2000). Organic matter binds nutrients and metals, provides an energy source for microbes that break down pesticides and transform nutrients into non-soluble forms, and forms the basis of detrital food chains (Lockaby and Walbridge 1998).

Sampling

The Soil Science Society of America publishes a 4-volume *Methods of Soil Analysis*. These volumes cover a variety of standard methods to sample the physical, mineralogical, microbiological, biochemical, and chemical properties of soils. This would be a valuable

[5] Productivity can also be decreased by stagnant water and associated anaerobic conditions in the soil.

resource to anyone seriously considering soil sampling over the long-term. Most university libraries should also carry these volumes as well.

Topography/Bathymetry[6]

The hydrologic processes of the river shape the topography of riverine forests. River flows form and maintain the floodplain by transporting and redistributing sediments within the system. Sediments are continually eroded and deposited through the processes of point bar deposition, overbank deposition, and sheet, gully or streambank erosion during major flood events as the river moves back and forth across the floodplain (Brown and Lugo 1982; Wharton et al. 1982). As the river meanders across the floodplain, outer banks are eroded away and carried downstream and sediment from upstream is deposited on the inner bank of the meander (Figure 4). During overbank flooding, water spreads out over the floodplain, losing much of its energy and subsequently dropping its load of suspended sediment. The heavier sediments, such as sand and silt, are deposited near the stream channel and form the natural levee. Fine sediments, such as clays, are typically carried further out onto the floodplain. This increases the elevation of the local floodplain while preventing down stream areas or instream habitats from being sedimented over. As river channels move back and forth across a floodplain, new gullies and banks are formed (Brown and Lugo 1982; Wharton et al. 1982; Hupp 2000).

This process of constant erosion and deposition of nutrient rich sediments of the forest floor results in topographic complexity and contributes to the high primary productivity and species richness (Brown and Lugo 1982; Wharton et al. 1982). Other aspects of hydrology are also related to high productivity of riverine forests. Riverine forests with flowing water or seasonal wet/dry cycles have higher productivities when compared to those that are either permanently ponded or drained (Brown and Lugo 1982; Wharton et al. 1982).

Forest zones

Riverine forests are typically subdivided into six zones following an elevational gradient

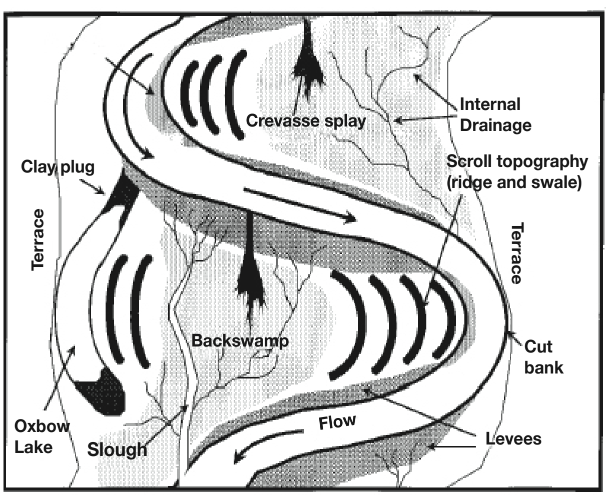

Figure 4. Diagram of an idealized alluvial floodplain showing the river channel, point bar deposits (alternating ridge and swale topography), backwater swamps, channel fill deposits (clay plug forming in an oxbow lake), natural levees around the channel, and sloughs. Taken from Hupp 2000.

Figure 4.1. A river channel in northern Lower Michigan, the picture shows a zone of erosion (left) and a zone of deposition (right). The height of the vegetation on the zone of deposition can be used to indicate the age of the area. Sandy deposits are relatively recent with herbs, shrubs, and trees growing on successively older deposits. Photo courtesy of Matthew Baker, Smithsonian Institute.

[6] Information for this section was taken liberally from these sources Wharton et al. 1982; Allen et al. 2001; Guilfoyle 2001. They are cited here instead of repeatedly throughout the text.

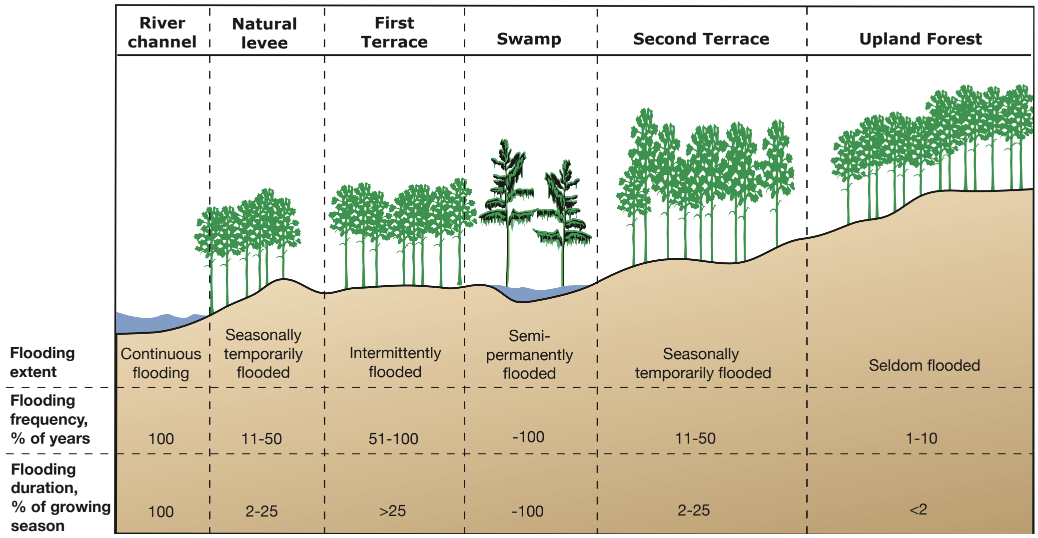

Figure 5. An idealized progression of riverine forest zones from the open water of a river to upland, along a water table gradient showing characteristic hydrologic conditions for each zone (modified from Mitsch and Gosselink 2000).

from open water in the river channel to upland forests. Although each zone may not be well represented in every location, nor follow the progression from open water to upland, a discussion of the different zones is useful in understanding the factors controlling vegetation community, wildlife habitat, and water quality functions (Figure 5).

Zone I is the main channel of the river and has a 100% probability of being flooded[7]. It provides habitat year round for fish and other aquatic organisms and may (depending on the extent of forest cover and water velocity) be dominated by submersed macrophytes in deeper water and emergent vegetation along the edge.

Zones II – V make up the active floodplain. Zone II is referred to as the Deepwater Swamp[8] and is dominated by baldcypress and tupelo in southern systems[9]. It also has a near 100% probability of being flooded and provides habitat for fish, alligators, and aquatic invertebrates. Occasional drawdown of this zone is necessary for forest regeneration.

Zone III is semi-permanently flooded with a 51-100% probability of prolonged annual flooding. This zone is often dominated by:

Willow (*Salix* spp.)
Red maple (*Acer rubrum* var *drummondii*)
Cottonwood, and
Overcup oak

In southern systems, other common overstory species include:

Water hickory (*Carya aquatica*)
Water elm (*Planera aquatica*)
Swamp tupelo (*Nyssa sylvatica* var *biflora*)
Black willow (*Salix nigra*)
Baldcypress, and
Water tupelo

Zone IV is seasonally flooded with a 51-100% probability of short-term annual (usually winter/spring) flooding. This area is typically dominated by:

Green ash
Willow oak
Water oak

[7] Percent refers to the probability of annual flooding, not the amount of time the area is flooded.
[8] The structural and functional characteristics of Deepwater Swamps useful in restoration monitoring are discussed in Chapter 12.
[9] Tree species presented as examples are drawn from southern systems, some of which may be found in northern areas as well. Practitioners should consult with regional experts and printed resources to determine which species are present in their area.

Nuttall's Oak
American elm (*Ulmus americana*)
Sweetgum (*Liquidambar styraciflua*)
Sycamore (*Platanus occidentalis*)
Cottonwood
Hackberry (*Celtis laevigata* or *C. occidentalis* in more northern areas), and
Diamondleaf oak (*Q. laurifolia*)

Zones II through IV provide seasonal spawning, nursery, and foraging habitat for fish when inundated.

Zone V is only temporarily flooded, with an 11-50% probability of annual flooding. Dominant tree species may include:

Red mulberry (*Morus rubra*)
Loblolly pine (*Pinus taeda*)
Water oak
Cherrybark oak
Shumard's oak (*Q. shumardii*), and
American beech (*Fagus grandifolia*)

Zone VI is the floodplain-upland transition ecosystem, it is only intermittently flooded, with a 1-10% probability of annual flooding.

The exact spatial location of each zone is more a function of elevation than of distance from the river channel. For example, a large levee adjacent to the active channel may have vegetation and functional characteristics of Zone IV because it is well drained due to elevation and the presence of coarse sediments. A deep swale or backwater some distance from the active channel may be dominated by Zone II-III vegetation.

Measuring and Monitoring Methods

Topographic maps available from the United States Geologic Survey can provide a rough estimate of elevations in the study area. In most cases, however, a detailed survey of the area to be restored will need to be conducted. The surface elevations and topographic diversity of the area must be measured in relation to existing or projected water level changes as differences of only a few centimeters may determine whether or not planted material survives.

HYDROLOGICAL

Hydroperiod and Water Source

The hydroperiod (depth, frequency, duration, seasonality, and source of flooding and/or soil saturation including the depth to the water table) of a riverine forest is an important factor in determining plant species distribution and composition (Allen et al. 2001). Seasonal climate differences and large storm events together with watershed slope, size, and soil drainage characteristics determine flooding and inundation patterns. Winter and spring are typically periods of high flow while low flows occur in late summer and fall, due to high evapotranspiration and low precipitation during those time periods. Larger catchments tend to have deeper, longer floods than do smaller ones (Brinson 1990).

Riverine forests can be broken down into four categories based on water source and hydrodynamics: alluvial, blackwater, spring-fed, and bog or bog-fed (Wharton et al. 1982).

Alluvial

Alluvial rivers are those with well-developed, broad, flat floodplains with sandy/gravelly sediments deposited by flowing water. The Mississippi River is a good example of an alluvial river with a well-developed and broad flood plain that extends nearly 620 miles from the confluence of the Mississippi and Ohio Rivers to the Gulf of Mexico. Other good examples can be found along the southeast coast.

The headwaters (source) of some large alluvial rivers in the southeast are in the Piedmont or Ridge and Valley area. As water flows down off the Piedmont and enters the topographically flat coastal plain, the water slows down, spreads

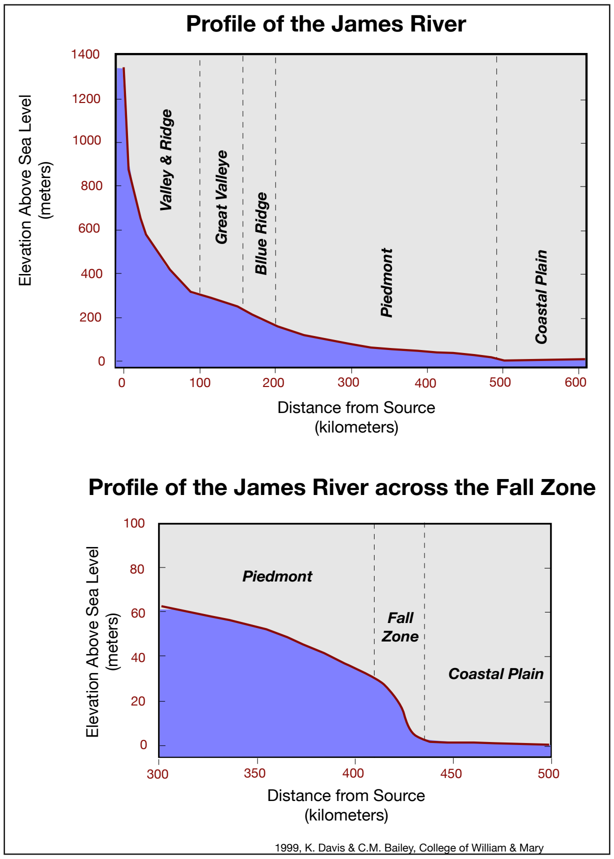

Figure 6. Elevation profile of the James River, Virginia as it flows from its headwaters in the Ridge and Valley to the Coastal Plain. Figure courtesy of C. Bailey, College of William and Mary.

out, and forms large swamps. The James River in Virginia is a good example of an alluvial river. The top graph in Figure 6 shows the elevation of the river as it makes its way from the Ridge and Valley area down to the coastal plain. The bottom graph is a close up of the Piedmont and coastal plain stretch of the river. Due to the slope of the Piedmont (and particularly the Fall Zone), water moving in the river has a lot of energy. When it hits the flat coastal plain, however, there is not enough slope to maintain fast flow toward the ocean and water spreads out horizontally across the landscape developing broad floodplains.

Blackwater

The headwaters of most blackwater rivers are in the coastal plain or other extremely flat areas. Blackwater rivers receive most of their discharge from local precipitation. Compared to rivers with headwaters in the mountains or the Piedmont, coastal plain headwater rivers have much less discharge, slower flows, clearer water, carry less sediment, and have less developed floodplains. The term blackwater refers to the dark, tea-like, color of the water due to organic substances characteristic of swamp drainage. Blackwater rivers may be tributaries to alluvial rivers as they make their way through the coastal plain to the Gulf of Mexico or Atlantic Ocean.

Spring- and Bog-fed Rivers

Spring-fed rivers are common where mineral rich groundwater discharges from highly permeable geologic formations. For many of these rivers, the source of water is predominantly groundwater, water levels are relatively stable, and they rarely experience overbank flooding. Bog and bog-fed rivers are found in areas less permeable geologic deposits. They are generally rare and quite small compared to the other river types. The sources of water to these rivers are some groundwater mixed with a larger portion of local precipitation. Unlike groundwater-fed systems, rivers with flow dependent upon precipitation patterns, can have dramatic, short-term water level fluctuations (Wharton et al. 1982).

Of these four river types, alluvial rivers have the greatest range and covered the largest acreage and therefore have greater opportunity for restoration than the others. Unless otherwise stated, all information in the following sections refers to alluvial rivers and their associated riverine forests.

Effects of Hydrology

Hydrology, soil type, and topography are the main structural characteristics that can be used to explain the variability between forest communities (Hosner and Minckler 1963; Wharton et al. 1982; King and Keeland 1999). The relationship of hydrology and topography to vegetation types introduced in Figure 5 can

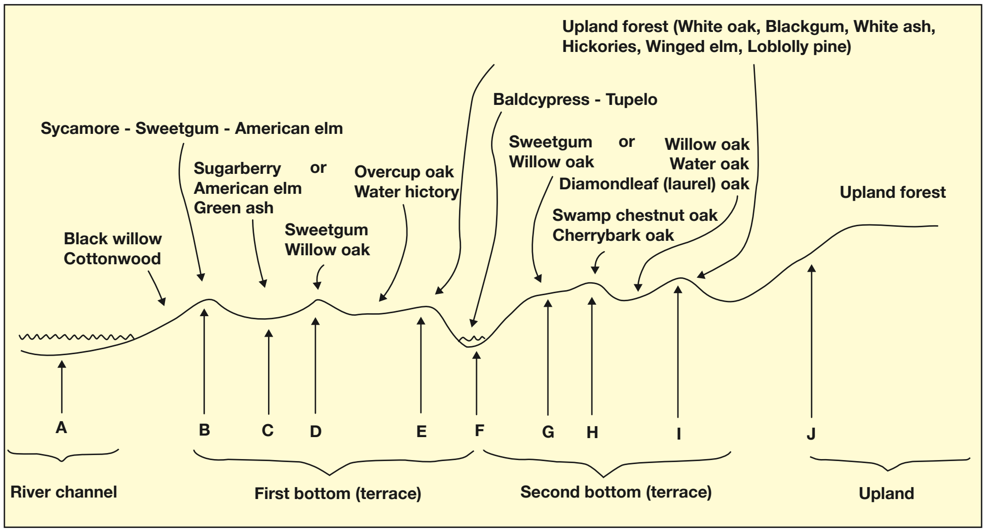

Figure 7. Dominant riverine vegetation by elevation along a southeastern alluvial floodplain. Adapted from Wharton et al. 1982.

be seen in more detail in Figure 7. Flooding can be very stressful on woody vegetation. Except for a few species, stresses associated with inundation can only be handled for short periods of time depending on the range of tolerance for the individual species (Wharton et al. 1982). Baldcypress and tupelo are better able to tolerate these stresses and tend to occupy the lowest, wettest elevations of the floodplain. Communities of sycamore-sweetgum-American elm or willow oak-water oak-diamond leaf oak, to name a few, segregate out across the floodplain depending on changes in elevation and associated depth and duration of flooding (Figure 7).

Differences in vegetation community related to drainage and soil characteristics can be seen in northern forests as well. Hosner and Minckler (1963) studied forest regeneration and succession in bottomland forests in Illinois. They found that sandy, well-drained alluvial deposits were colonized by cottonwood and willow and later dominated by:

Boxelder (*Acer negundo*)
Silver maple
Elms, and
Ash

Finer-textured, poorly drained areas were colonized by:

Buttonbush (*Cephalanthus occidentalis*)
Swamp cottonwood
Swamp privet (*Forestiera acuminata*)
Baldcypress
Tupelo
Willow, and
Ash

These areas were later succeeded by a variety of hardwood species such as:

Pin oak (*Quercus palustris*)
Bur oak (*Q. macrocarpa*)
Overcup oak
Honey locust (*Gleditsia triacanthos*),
Red maple, and eventually
Sweetgum (*Liquidambar styraciflua)*, and
Hickory (*Carya* spp.) in some cases

Given results such as these, restoration projects that carefully match species requirements to specific site conditions will increase the likelihood of success.

The structural characteristics of hydroperiod and water source are also part of a functional characteristic of riverine forests, floodwater storage. During high river flows, when water is allowed to spread out over the floodplain, water is stored in the forest and later released back to the stream channel (Winger 1986). Storage and slow release of floodwater reduces flood peaks and decreases the extent of damage downstream (Bedient and Huber 1992). By helping to moderate channel flows over time, floodwater storage in riverine forests also reduces stress on aquatic organisms within the stream channel. Although some wetland fish species such as bowfin (*Amia calva*) are able to survive a summer of desiccation by becoming dormant inside balls of dried mud (Hoover and Killgore 1998), riverine fish typically cannot do this (Moyle and Cech 1988). In addition to the direct effects little or no water has on fish, low water levels also increase temperature, turbidity, growth of aquatic plants, and decrease oxygen levels further stressing riverine fish (Moyle and Cech 1988).

Floodplain vegetation also influences hydrodynamics and water quality. As floodwaters spread out into the forest, water velocities decrease. Sediments and attached nutrients settle out onto the forest floor. High stem densities can increase this effect by further slowing water velocity (Bedient and Huber 1992). Herbaceous vegetation also increases moisture levels in upper soil layers by shading the surface and through capillary action along rhizomes bringing water up from deeper soil horizons (Kutschera and Lichtenegger 1982, cited in Tabacchi et al. 2000). Woody vegetation can increase the hydraulic conductivity of the soil through root development and decomposition (Thorne 1990). The effect floodplain vegetation has on hydrologic processes varies depending on the type, health, and patchiness of plant communities as well as how long the community has had a chance to alter soil characteristics. Tabacchi et al. (2000) provide an up-to-date and comprehensive review of the literature regarding the effect vegetation has on hydrologic processes and nutrient cycling. Readers interested in a thorough explanation of these interactions and related lphenomena are referred there.

A change in the hydrology of riverine forests in the southeastern United States has occurred since European settlement. Before settlement and subsequent alteration of riverine habitats, most of the inputs to alluvial streams came from subsurface flow with flood pulses in the winter and spring due to increased seasonal precipitation and snow melt. Today, however, due to decreases in forest cover and soil organic matter and changes in land use to agriculture and urban environments with lower soil permeability, surface water inputs have become an increasingly larger percent of river inputs and may dominate some streams (Wharton et al. 1982). A dominance of surface water in stream hydrology makes them flashier, with lower base flows in the summer and higher flood peaks throughout the year (Figure 8). This change in hydrology alters the depth, duration, and timing of flood events, and the patterns of sedimentation and erosion in riverine forests. In other areas, dams and flood control levees have completely cut the floodplain off from the river. Barnes (1997) found that areas downstream from dams had reduced rates of meandering and bank erosion and thus were less dynamic than free-flowing forest systems. This resulted in the

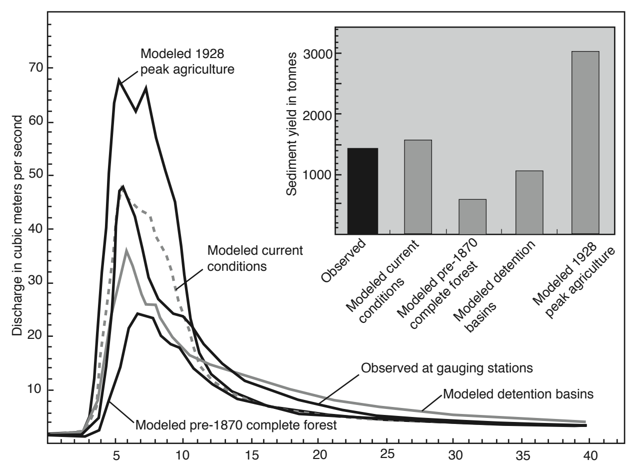

Figure 8. This series of historical hydrographs on the North Fish Creek near Moquah, WI shows how changes in land use have contributed to changes in peak flows. Higher peak flows, associated with agricultural land uses, mean that flooding is more severe than under forested conditions. Taken from Fitzpatrick et al. 1999.

Figure 9. Damage to a monitoring well by an animal chewing on the top of the well. Damage of this sort prevents water level measurements and water samples from being obtained until the top portion of the well can be cut off or a new well installed. Photo by David Merkey, NOAA/Great Lakes Environmental Research Laboratory.

dominance of a single species (silver maple) and generally lower tree species diversity compared to areas without dam. In addition to decreases in species diversity, many of the hydrologic and water quality functions a riverine forest can provide are also altered or eliminated by the presence of dams and levees.

Measuring and Monitoring Methods

The United States Geological Survey operates a series of gauging stations on rivers throughout the US. Historical and real-time data on hydroperiod and characteristics of the watershed for many of these sites are available at http://water.usgs.gov/waterwatch/. Smaller, coastal rivers may not have a gauging station, however, requiring that restoration practitioners implement other methods to collect this information. A variety of manual gauges are commercially available in different lengths and measurement intervals[10]. These can be attached to metal poles driven into the ground. Electronic gauges are also available that can be set up and left in place to continually record water level fluctuation. Thus recording data that might otherwise be missed by manual sampling alone. Monitoring wells can also be constructed for measuring the depth of water below the soil surface. Watermarks on surrounding trees should be used to estimate the depth of flooding events to ensure that the gauge will be visible and accurately measure water level no matter the depth. The gauge can also be surveyed in so that exact elevation and location can be determined. This will allow for maps to be made showing depth and duration of flooding across the floodplain.

Care should also be taken when selecting the placement of gauges and other equipment to be left in the field over extended periods of time because vandals and animals, too, can damage equipment (see Figure 9). Equipment should be placed where it is hidden from the general public to avoid random vandalism but where those taking measurements can still find them. Large animals such as deer may rub on equipment dislodging it and even smaller animals can chew on and damage plastic fixtures. If damage from animals is a persistent problem, monitoring equipment may need to be fenced off for protection.

Hydraulic models may also be useful in riverine forest restoration monitoring as they can be used to predict the timing and depth of flooding in a particular area. This information can be used to select tree species for planting at different elevations along the floodplain during the restoration planning process. It can also be used to predict changes in forest hydrodynamics as the forest matures and characteristics of flow through the system change. This sort of information would be particularly useful in

[10]Measurements are taken from the top of the well to avoid problems related to sedimentation and erosion around the well.

restoration projects that incorporate hydrologic modifications such as the breaching of dikes. The United States Army Corps of Engineers Hydrologic Engineering Center has a variety of software packages and publications available free on-line that may be of use to restoration practitioners. Additional information on the different types and applications of hydrologic modeling and downloading instructions can be found at http://www.hec.usace.army.mil/default.html.

FUNCTIONAL CHARACTERISTICS OF RIVERINE FORESTS

Riverine forests provide a variety of biological and hydrological functions. Many of these functions, such as feeding and breeding grounds for wildlife, temporary floodwater storage, and nutrient cycling are socially and eonomically important. The list of functions commonly attributed to riverine forests presented below has been broken into three categories, Biological, Physical, and Chemical functions. This list includes:

Biological

- Contributes to primary productivity
- Produces wood
- Provides breeding grounds
- Provides feeding grounds
- Provides nursery areas
- Supports a complex trophic structure
- Supports biomass production

Physical

- Affects transport/deposition of suspended/ dissolved material
- Alters turbidity
- Modifies water temperature
- Provides temporary flood water storage

Chemical

- Modifies chemical water quality
- Supports nutrient cycling

Many of the hydrological/physical functions performed by riverine forests are closely linked with primary structural characteristics were more appropriately explained therein. Biological and hydrological/chemical functions are explained below.

BIOLOGICAL

Riverine forests provide seasonal or year-round habitat for a large variety of species. Allen et al. (2001) compiled a list of 101 amphibian, reptile, bird, and mammal species that use early successional stages of southern riverine forests at some stage in their life cycle. As forested areas mature, the diversity of species increases for some time and then decreases as the vegetative associations mature. Some species are found only in early successional habitats while other can only use mature riverine forests (Buffington et al. 2000; Guilfoyle 2001). As noted earlier, a thorough description of all these interactions is beyond the scope of this document. A few examples are provided in the sections below to illustrate specific points but practitioners should make it their responsibility to learn as much as they can about the local resources they are attempting to restore.

Contributes to Primary and Biomass Production and Produces Wood

A variety of structural characteristics influence the primary productivity of riverine forests. Monitoring them will help explain trends observed in productivity measurements particularly when comparing results from a restored area to reference sites. The combination of particulate and dissolved organic matter, fluctuating water levels, and nutrient rich soils (predominantly clay and silt) leads to high primary productivity (as measured by litter fall or wood production) for many riverine forests. Stagnant water can lead to anaerobic soils and cause stress in trees, reducing productivity. Relatively high decomposition rates, except in permanently ponded areas, allows for the quick release of accumulated nutrients back to the soil where they are again available for plant uptake. Accumulated biological waste products and some of the released nutrients are periodically flushed from the area during floods. Ironically, it was this high rate of production that led to the large-scale destruction of riverine forests. Since European settlement, riverine forests have been repeatedly cut over, either selectively for commercially valuable species (e.g., baldcypress and oak) or clear cut so the area may be converted to agricultural production (typically cotton, rice, or soybeans) (Wharton et al. 1982).

Sampling

Some common methods to measure primary productivity include collection of leaf litter and calculation of growth rate from repeated measurements of seedling height or diameter at breast height (DBH) (Brown 1981; Conner and Day 1992; Conner et al. 1997; Keeland et al. 1997). Although not much is known about belowground productivity, some evidence indicates that it is similar in scale to litterfall (Symbula and Day 1988). Methods for measuring belowground biomass production include taking a series of soil cores or placing soil-filled nylon bags in the substrate allowing roots to grow into them (Symbula and Day 1988; Powell and Day 1991). The bags are then retrieved after a specified amount of time and the root content analyzed. Neither of these methods is particularly effective at sampling roots greater than 5 cm in diameter, however, and may actually underestimate total underground productivity. Litterfall, collected over several site visits, can account for approximately 39% of the above ground primary production and can be easily collected (Brown 1981; Conner and Buford 1998). Seedling height is also easily obtained although requires repeated (e.g., weekly) site visits if knowledge of seasonal differences in growth rate is desired. Annual measurements may, however, be acceptable for many restoration monitoring projects. Keeland et al. (1997) provide methods and equations for calculating growth rate from repeated measurements of DBH.

Provides Breeding, Nursery, and Feeding Grounds, and Supports Trophic Structure

Invertebrates

Macroinvertebrates tend to be most prevalent in Zone II and wetter portions of Zone III. Stoneflies (Order Plecoptera), amphipods such as *Hyallella azteca*, worms (Order Oligochaetae), and midges (Family Chironomidae) among other members of the detrital food chain can be extremely abundant in deepwater areas with sufficient accumulations of organic matter (Wharton et al. 1982). Lakly and McArthur (2000) used macroinvertebrates to monitor restoration progress on the Pen Branch Creek, a tributary of the Savannah River after thermal discharges from an upstream nuclear power plant that had severely degraded the riverine forest prior to 1988. Thermal discharges had killed off most of the canopy trees and opened up the stream to direct sunlight, allowing submerged aquatic vegetation (SAV) to grow. A structural shift in the available habitat occurred from one dominated by instream woody debris and allochthonous[11] material to a habitat dominated by SAV and autochthonous[12] production. This fundamental shift in available food sources and instream structure brought about a change in the invertebrate communities found in each portion of the stream. Ten years after thermal discharges had ceased, water temperatures had returned to normal but the overstory canopy in degraded areas had not closed. Along degraded sections, the stream was still exposed to direct sunlight and the differences in instream structure and food web remained unchanged. Differences in invertebrate community also remained unchanged. This highlights the need for monitoring forest restoration projects over an extensive period of time, depending on the particular goals of the project. It will likely take many decades for trees to grow large enough

[11] Allochthanous refers to sources of food that have come from outside of the stream, leaves falling from trees adjacent to the stream, for example.

[12] Autochthanous referes to sources of food that have come from within the stream itself, algae and submersed aquatic vegetation, for example.

to shade the water and provide enough woody debris to the stream to alter the structure of the invertebrate community.

Fish

As many as 53 species of fish such as bowfin (*Amia calva*), gar (*Lepisosteus* spp., Figure 10), and topminnows (*Gambusia* spp.) use riverine forest habitats during flooded conditions as spawning and nursery habitats, as migration routes to upstream spawning areas, or as year round residence. Roughly half of the fishes of the lower Mississippi River use floodplains as nurseries (Wharton et al. 1982). Access to a variety and abundance of new food sources is extremely important to fish, the longer the duration of inundation, the longer fish have to feed in these productive areas (Wharton et al. 1982). Fish depend on annual water level fluctuations of spring flooding and fall drydown to limit intra- and inter-specific competition for food, space, and spawning ground. Fish distribution and abundance are so closely tied to this wet/dry cycle that any change in hydrology (man made or natural) can directly impact the success of fish reproduction (Bruton and Jackson 1983; Hoover and Killgore 1998)

Since fish communities are closely correlated to instream habitat, which is in turn closely related to the riparian zone, fish can be used to monitor the success or failure of riverine forest restoration projects. Paller et al. (2000) compared fish communities in streams of undisturbed riverine forests and streams in areas recovering from thermal pollution (power plant discharges). They compared fish assemblages using nonparametric statistics[13] with an index of biotic integrity (IBI) that measured ecologically sensitive characteristics of fish assemblages. They found that the different techniques provided different information depending on the length of time sampling occurred after restoration of the floodplain. Whereas the IBI could be used in the early stages of recovery to indicate when important aspects of instream structure and function had returned, use of the IBI alone missed information concerning density of individuals (leading to inferences in biomass production) elicited with the nonparametric statistics. Killgore and Hoover (1992) also provide a list of fish species common to riverine forest communities with a breakdown of which life cycle stages are found in channel vs. floodplain habitats that may be of use in designing a sampling strategy.

Figure 10. A spotted gar. Photo from NOAA National Estuarine Research Reserve Collection.

Birds

Southern riverine forests provide habitat for a variety of bird species on a seasonal or year round basis (O'Neal et al. 1992; Guilfoyle 2001). Every fall, neotropical migratory birds forage in southern riverine forests before making the long flight across the Gulf of Mexico to wintering grounds in the Caribbean, Mexico, or Central and South America. When they return in the spring, riverine forests are their first stop to feed and replenish themselves after the long return flight. Nearctic birds use southern forests as a migration destination during the winter. Riverine forests also host a variety of year-round resident birds. During any given season, resident birds may comprise 35–55% of the population (Guilfoyle 2001). Within the mix of migratory and resident species are a number

[13]For description of statistical procedures, see Paller, M. H., M. J. M. Reichert, J. M. Dean and J. C. Seigle. 2000. Use of fish community data to evaluate restoration success of a riparian stream. *Ecological Engineering* 15:S171–S187.

of bird species (approximately 70) completely dependent upon southern riverine habitats to breed (Guilfoyle 2001).

Identification of specific bird species can be a useful means of developing restoration goals and monitoring progress. Particular tree species can be selected for planting that attract certain types of birds, provided the target species is currently found in the general area (i.e., planting to attract bird species that are extinct in an area is not likely to be particularly successful). Gabbe et al. (2002) found that certain tree species were preferred by insectivorous birds and that tree species composition is an important attribute to plan for and monitor if restoration of particular bird species is a project goal. They also found that most restoration projects were deficient in properly planning for this diversity and were often lacking in heavy-seeded tree species and/or commercially non-valuable species such as silver maple (*Acer saccharinum*, Figure 11) that are particularly valuable to birds.

There is, however, a weakness with using birds to monitor specific restoration projects. Birds must also use resources outside of a particular wetland area. They are, therefore, susceptible to negative impacts in the other habitats they use. Galatowistch et al. (1998-1999) found that bird-related metrics such as proportion of wetland birds, wetland bird richness, and proportion of insectivorous birds showed consistent relationships to land cover types regardless of the scale of assessment. They concluded that bird-related metrics are better suited to studies at the landscape-scale and if used to monitor a local restoration project, need to be used with caution.

When developing a restoration-monitoring plan, one should consider that the structural aspects of riverine forests influence how the forest as a whole is used by individual species. Specifically, since hydrology and elevation strongly influence the structural habitat (i.e., dominant vegetation) creating the different zones within these systems, hydrology, as well as seasonality, has an influence on what bird species are present within any given zone (Guilfoyle 2001). Any perceived changes in bird community could therefore be a result of seasonality or annual variations in climate, flood regime, vegetation zonation, and/or the success or failure of restoration efforts. In addition, it may take up to 60 years after restoration efforts have begun to measure any change in avian community, particularly for those species dependent on mature forested systems (Buffington et al. 2000; Guilfoyle 2001). This also applies to other wildlife such as fish, amphibians, and reptiles that are also dependent on mature riverine forest habitats (Bowers et al. 2000).

Figure 11. A leaf from a silver maple, a common riverine forest tree species that provides abundant seeds eaten by migratory birds and other wildlife. Photo by David Merkey, NOAA/Great Lakes Environmental Research Laboratory.

Mammals

Riverine forests are home to a variety of mammal species, many of which browse on or uproot seedlings and planted trees. The animals most likely to cause damage include white-tailed deer (*Odocoileus virginianus*), raccoons (*Procyon lotor*), beaver (*Castor canadensis*) and other small rodents, and hogs (*Sus scrota*) (Allen et al. 2001). Use of small, native mammals to monitor restoration activities at local scales (Pen Branch Creek of the Savannah River Site) has been tried and proven unsuccessful, possibly due to the large ranges some small animals are able to cover and the diversity of habitats they may traverse to get from one area to another (Wike et al. 2000). It is possible that on larger scales, native mammals may still be useful for restoration monitoring. However, sufficient research has not yet been conducted. It is advisable, at this point, to limit monitoring of mammals to presence/absence of particular species depending on the goals of the restoration effort and to assessing and minimizing herbivore damage to planted trees.

PHYSICAL

The main physical functions performed by riverine forests (i.e. transport of suspended/dissolved material, alteration of turbidity, modification of water temperature, and temporary flood water storage) have been described in the associated structural characteristics above.

CHEMICAL

Modifies Water Quality and Supports Nutrient Cycling

The alternating cycle of aerobic and anaerobic soil conditions brought about by seasonal flooding patterns allows several biochemical and nutrient cycling processes such as nitrification, denitrification, ammonification, methanogenesis, sulfate reduction, and general nutrient mineralization to take place in riverine forests that do not occur in upland forests (Wharton et al. 1982). These biochemical processes either increase nutrient availability for immediate uptake by plants within the forest or transform nutrients to biologically inactive forms. Downstream water quality is preserved in either case, as long as anthropogenic inputs do not overwhelm the system. Nitrate (NO_3) in the water column or soil, for example, can be taken up by plants, converted to nitrite (NO_2) by microbes, or bound to sediments (Walbridge 1993). These processes are also influenced by hydrology. The longer the residence time of water, the more time microbes and plants have to transform nutrients.

Riverine forests often act as sinks for phosphorus (P) (Winger 1986). When phosphorus enters the riverine forest with floodwater it is adsorbed to sediments or taken up by plants. Phosphorus is returned to the forest floor when leaves fall and quickly decomposed. Under aerobic conditions, phosphorus is bound to the sediments. Under anaerobic conditions, phosphorus is soluble and is again taken up by roots of other plants during the growing season or by green algae growing in floodplain pools during winter (Winger 1986; Walbridge 1993; Lockaby and Walbridge 1998). Although large flows may move some phosphorus downstream, it is generally believed that most phosphorus is held within the forested floodplain.

The ability of riverine forests to act as nutrient transformers and preserve downstream water quality, within limits, may be their most valuable function to society (Walbridge 1993). It is, however, only when floodwaters are able to flow out into the riverine forests that the nutrient transformation and sediment trapping function of these wetland systems can occur. When riverine forests are isolated from the river channel by a constructed levee system, the nutrient transformation function is disrupted and excess nutrients and sediments are carried downstream and eventually to the coast. Restoration of riverine forests could contribute greatly to the preservation and restoration of coastal water quality. It has been suggested that restoring riverine forests throughout the Mississippi alluvial valley and tributaries could be used to improve the water quality of the Gulf of Mexico, lessening the extent and severity of the hypoxic zone off the coast of Louisiana (Mitsch et al. 2001).

PARAMETERS FOR MONITORING STRUCTURAL/FUNCTIONAL CHARACTERISTICS

The matrices of structural and functional parameters for restoration monitoring featured on the following pages were developed through extensive review of restoration and ecological monitoring-related literature. Additional input was received from recognized experts in the field of riverine forest ecology. This listing of parameters is not exhaustive, it is merely intended as a starting point to help restoration practitioners develop monitoring plans for this habitat. Additional parameters not in this list may also be appropriate for restoration monitoring efforts. Parameters with a closed circle (●) are those that, at the minimum, should be considered in monitoring restoration progress. Parameters with an open circle (❍) may also be monitored depending on specific restoration goals. Information on why these parameters are important for monitoring and how they relate to structural and functional characteristics as well as to one another is found throughout the text. Literature directing readers toward additional information on the ecology of riverine forests, restoration case studies, and sampling strategies and techniques can be found in the *Annotated Bibliography of Riverine Forests* and the associated *Review of Technical Methods Manuals*.

Parameters to Monitor the Structural Characteristics of Riverine Forests

Parameters to Monitor	**Biological**	Habitat created by plants	**Physical**	Sediment grain size	Topography/Bathymetry	**Hydrological**	Tides/Hydroperiod	Water sources
Geographical								
Acreage of habitat types		●						
Biological								
Plants								
Species, composition, and % cover of:								
Herbaceous vascular		❍						
Woody		●						
Basal area		❍						
Canopy aerial extent and structure		❍						
Plant height		❍						
Seedling survival		●						
Stem density		●						
Woody debris (root masses, stumps, logs)		❍			❍			
Hydrological								
Physical								
Temporary water							❍	
Temperature							❍	❍
Upstream land use								●
Water level fluctuation over time							●	●
Chemical								
Groundwater indicator chemicals[14]								❍
Nitrogen and phosphorus								
Toxics								
Soil/Sediment								
Physical								
Basin elevations					❍			
Bulk density				❍				
Depth of mottling							❍	
Geomorphology (slope, basin cross section)					●		●	
Moisture levels and drainage							❍	
Organic content				❍			❍	
Percent sand, silt, and clay				❍				
Sedimentation rate and quality				❍	❍		❍	

[14]Calcium and magnesium.

Parameters to Monitor the Functional Characteristics of Riverine Forests

Parameters to Monitor	Biological: Contributes primary production	Produces wood	Provides breeding grounds	Provides feeding grounds	Provides nursery areas	Supports a complex trophic structure	Supports biomass production	Physical: Affects transport of suspended/ dissolved material	Alters turbidity	Modifies water temperature	Provides temporary floodwater storage	Chemical: Modifies chemical water quality	Supports nutrient cycling
Geographical													
Acreage of habitat types	●	●	●	●	●	●	●	●	●	●	●	●	●
Biological													
Plants													
Species, composition, and % cover of:													
Herbaceous vascular	❍		❍	❍	❍	❍	❍	❍	❍	❍		❍	❍
Invasives			❍	❍	❍	❍							
Woody	●	●	●	●	●	●	●	●	●	●	●		●
Basal area	❍	❍					❍						
Canopy aerial extent and structure			❍		❍		❍			❍			
Interspersion of habitat types			❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Litter fall	❍			❍		❍	❍		❍				❍
Mast/seed production	❍			❍			❍						
Plant health (herbivory damage, disease[15])				❍									
Plant height	❍					❍	❍			❍			
Rate of canopy closure	❍	❍					❍			❍			
Seedling survival[15]		●											
Stem density					❍	❍		❍	❍	❍			
Woody debris (root masses, stumps, logs)		❍	❍	❍	❍	❍		❍					

15 □

Parameters to Monitor the Functional Characteristics of Riverine Forests (cont.)

Parameters to Monitor	Biological: Contributes primary production	Biological: Produces wood	Biological: Provides breeding grounds	Biological: Provides feeding grounds	Biological: Provides nursery areas	Biological: Supports a complex trophic structure	Biological: Supports biomass production	Physical: Affects transport of suspended/dissolved material	Physical: Alters turbidity	Physical: Modifies water temperature	Physical: Provides temporary floodwater storage	Chemical: Modifies chemical water quality	Chemical: Supports nutrient cycling
Biological													
Animals													
Species, composition, and abundance of:													
Amphibians			❍	❍	❍	❍	❍						
Birds			❍	❍	❍	❍	❍					❍	
Invertebrates			❍	❍	❍	❍	❍						
Mammals			❍	❍	❍	❍	❍						
Reptiles			❍	❍	❍	❍	❍						
Hydrological													
Physical													
PAR[16]	❍						❍	❍	❍				
Secchi disc depth	❍						❍	❍	❍				
Sheet flow								❍	❍		❍	❍	❍
Temperature			❍		❍					❍		❍	
Temporary water			❍	❍	❍	❍					❍	❍	❍
Trash				❍				❍	❍			❍	
Upstream land use								●	●			●	
Water level fluctuation over time			●	●	●			●	●		●		●
Chemical													
Nitrogen and phosphorus	❍						❍		❍			❍	❍
Toxics			❍	❍	❍							❍	

[16] PAR - Photosynthetically active radiation.

Parameters to Monitor the Functional Characteristics of Riverine Forests (cont.)

Parameters to Monitor	Biological: Contributes primary production	Produces wood	Provides breeding grounds	Provides feeding grounds	Provides nursery areas	Supports a complex trophic structure	Supports biomass production	Physical: Affects transport of suspended/dissolved material	Alters turbidity	Modifies water temperature	Provides temporary floodwater storage	Chemical: Modifies chemical water quality	Supports nutrient cycling
Soil/Sediment													
Physical													
Bulk density							❍						❍
Depth of mottling							❍				❍		❍
Geomorphology (slope, basin cross section)			●	●	●			●	●	●	●	●	
Moisture levels and drainage							❍				❍		❍
Sediment grain size (OM[17]/sand/silt/clay/gravel/cobble)							❍	❍	❍			❍	❍
Sedimentation rate and quality								❍	❍				
Chemical													
Organic content in sediment				❍		❍	❍	❍	❍			❍	❍
Pore water nitrogen and phosphorus	❍						❍					❍	❍
Redox potential							❍					❍	❍

[17] Organic matter

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APPENDIX I: RIVERINE FORESTS ANNOTATED BIBLIOGRAPHY

This annotated bibliography contains summaries of restoration case studies and basic ecological literature. It is designed to provide restoration practitioners with examples of previous restoration projects as well as overviews of papers from the ecological literature that offer more detail than that covered in the associated chapter. Entries are presented from both peer reviewed and grey literature. They were selected through extensive literature and Internet searches as well as input from reviewers. They are not, however, a complete listing of all of the available literature. Entries are arranged alphabetically by author. Wherever possible, web addresses or other contact information has been included in the reference to assist readers in easily obtaining the original resource. Summaries preceded by the terms 'Author Abstract', 'Publisher Introduction', or similar descriptors were taken directly from their original source. Summaries without such descriptors were written by the authors of the associated chapter.

Allen, J. A. 1990. Establishment of bottomland oak plantations on the Yazoo National Wildlife Refuge complex. *Southern Journal of Applied Forestry* 14:206-210.

This paper reviews a study of the survival and growth rate of trees planted during 10 riverine forest restoration projects on abandoned agricultural fields by the U. S. Fish and Wildlife Service. The restoration sites were all within the Yazoo National Wildlife Refuge Complex located on the Mississippi-Yazoo Rivers alluvial plain in west-central Mississippi. Stands varied in age from 4-8 years after planting. Planted material at each site consisted of either locally collected acorns or 1-0 bare root nursery stock. Five species of oak were typically planted: cherrybark (*Quercus pagoda*), Nuttall (*Q. nuttallii*), Shumard (*Q. shumardii*), water (*Q. nigra*), and willow (*Q. phellos*). Oaks were selected under the assumption that such heavy seeded tree species would be slow to colonize agricultural fields, whereas lighter seeded trees such as American elm (*Ulmus americana*) and green ash (*Fraxinus pennsylvanica*) would more readily establish themselves naturally across a restoration site if a local seed source was available.

A variety of methods were employed to test the affect of controlling competition on young seedlings. Sites were either burned, treated with herbicide, or bushhogged, and some sites were left untreated as controls. However, any impact competition may have had on the survivorship of seedlings was masked by a drought. Even seedlings in areas with vegetation control measures in place showed high mortality when water tables dropped below 12 inches.

Growth rate was compared between trees planted from nursery stock and those planted as acorns in the field. Diameter at breast height (DBH) and overall tree height were greater for the areas planted with nursery stock seedlings.

Natural invasion of other tree and shrub species was also studied. Where large, mature stands of light seeded trees were present near restoration sites, the number of volunteer trees and shrubs outnumbered planted trees. Volunteer species were typically from light seeded species including American elm, green ash, and sweetgum (*Liquidambar styraciflua*).

The monitoring studies used the measures of species presence, survivorship, and growth rate (DBH and total tree height). Using the results from these studies, the author concluded that even just 4 to 8 years after planting, all the restoration efforts were developing diverse vegetation communities capable of becoming fully functioning riverine forests.

Buffington, J. M., J. C. Kilgo, R. A. Sargent, K. V. Miller and B. R. Chapman. 2000. Effects of restoration techniques on breeding birds in a thermally-impacted bottomland hardwood forest. Ecological Engineering 15:S115-S120.

Author Abstract. We evaluated the effects of revegetation techniques on breeding bird communities in a riverine hardwood forest impacted by thermal effluent. In 1993, sections of the Pen Branch riverine on the Savannah River Site, South Carolina, were herbicide-treated (glyphosate), burned, and planted; other sections were planted only while others were unaltered and served as controls. Few differences in the avian community occurred at 1 and 2 years post-treatment among treatments. Plots that were herbicide-treated, burned, and planted had greater species richness in 1994 and abundance in 1995 than sections that were planted only (*P*B0.05). Bird species composition differed slightly among treatments and White-eyed Vireos (*Vireo griseus*), Common Yellowthroats (*Geothlypis trichas*), Indigo Buntings (*Passerina cyanea*), and Red-winged Blackbirds (*Agelaius phoeniceus*) were the most abundant species in the corridor. Revegetation techniques used to restore this thermally-impacted riverine had little effect on the avian communities 1 and 2 years post-treatment.

Clewell, A. F. 1999. Restoration of riverine forest at Hall Branch on phosphate-mined land, Florida. Restoration Ecology 7:1-14.

Author Abstract. I describe a 1.5-ha riverine headwater forest (Hall Branch) that was created 11 years earlier on phosphate-mined and reclaimed land near Tampa, Florida, U.S.A. Favorable hydrologic and edaphic conditions were realized, owing to the proper positioning of the project site in an effectively reclaimed landscape. The soil had developed a distinct A horizon and an incipient B horizon. Planted trees, mainly species of *Acer, Fraxinus, Ilex, Liquidambar, Magnolia, Persea, Quercus, Taxodium*, and *Ulmus*, shared dominance with short-lived volunteer willows (*Salix caroliniana*) that had already begun to senesce. The tree canopy exhibited 85 cover, and some trees had grown to 12.5 m tall. Basal area reached 8.31 m^2/ha for trees 10 cm or more in diameter at breast height. Ten planted tree species produced seeds and yielded seedlings. The floristic composition over the decade consisted of 22 species of trees and 208 shrubs, vines, epiphytes, ferns, graminoids, and forbs. Thirty-eight non-arboreal species were directly transplanted, others arose from a seed bank in muck that was amended on wetter sites, and the rest volunteered via natural dissemination. The frequency of non-arboreal plants was collectively 98. Seventy-three species at the restoration site were characteristic of the mature, undisturbed reference ecosystem. A corresponding area within the reference ecosystem contained essentially the same number of species and the same array of life forms. Copious plant reproduction has transformed the planted forest into an intact ecosystem that no longer needs restoration assistance.

Clewell, A. F. and R. Lea. 1990. Creation and restoration of forested wetland vegetation in the southeastern United States, p. 195-231. In Kusler, J. A. and M. E. Kentula (eds.), Wetland Creation and Restoration: the Status of the Science. Island Press, Washington, D.C.

Author Abstract. This chapter describes forested wetland creation and restoration project experience and establishment methods in the region from Virginia to Arkansas south to Florida and Louisiana. In contrast to marshes, forest replacement is more complex and requires a much longer development period. A wide variety of forest establishment techniques have been employed, some with initial success but none of them proven. Most projects began during the 1980's and are too new for critical evaluation. Most of these projects pertain to bottomland hardwood and cypress replacement. The two most significant trends in project activity have been the direct seeding of oaks on abandoned croplands and the replacement of all trees and sometimes the undergrowth at reclaimed surface mines. Although some young projects appear promising in terms of species composition and structure, it is still too early to assess functional equivalency.

Project success depends largely on judicious planning and careful execution. The most critical factor for all projects is to achieve adequate hydrological conditions. Other important factors may include substrate stability, availability of adequate soil rooting volume and fertility, and the control of herbivores and competitive weeds. A checklist of these and other important issues is appended for the benefit of personnel who prepare project plans and review permit applications.

Success criteria for evaluating extant projects throughout the southeast are either inadequately conceived or usually lacking. Emphasis needs to be placed upon the presence of preferred species (i.e., indigenous trees and undergrowth characteristic of mature stands of the community being replaced) and on the attainment of a threshold density of trees that are at least 2 meters tall. Once such a stand of trees is attained, survival is virtually assured and little else could be done that would further expedite project success. At that point, release from regulatory liability should be seriously considered.

A list of several critical information gaps concerning bottomland restoration in the southeast is also provided and discussed.

Haynes, R. J., J. A. Allen and E. C. Pendleton. 1988. Reestablishment of bottomland hardwood forests on disturbed sites: An annotated bibliography, pp. 104. Biological Report 88(42), U.S. Fish and Wildlife Service.

This annotated bibliography was prepared for people interested in bottomland forest restoration on previously disturbed land such as abandoned or flood-prone agricultural land, surface-mined land, and other areas degraded by alterations in hydrology or vegetative cover. Though prepared in 1988 and thus does not represent the most up to date information, it does list or review over 400 documents relating to bottomland forests or their restoration. References containing information that is directly applicable to bottomland restoration are annotated while many others relating to hydrology, plant propagation, and various plant communities and individual species just listed. Two appendixes are included listing common and scientific names for bottomland forest species and a table of flooding, shade tolerance, and reproductive characteristics of some bottomland forest species.

Johns, D. T., B. Williams, H. M. Williams and M. Stroupe. 1999. Seedling survival and natural regeneration for a riverine hardwood planting on sites differing in site preparation. Tenth Biennial Southern Silvicultural Research Conference. Shreveport, LA. http://www.srs.fs.fed.us/pubs/viewpub.jsp?index=2190

Three pine plantations in the first bottom of Village Creek on the Roy E. Larson Sandylands Preserve in Hardin County, Texas were clear cut and replanted with riverine hardwood species. Three different methods were used to prepare the sites for planting. One was burned, another was treated with herbicide, and the third was sheared, piled, burned, and ripped. Initial seedling density was recorded and survival was monitored monthly to assess which method had the greatest impact on planting success. Nested plots were measured for species composition and relative density of dominant species before clear cutting took place to assess initial community structure. Species composition and percent area cover of herbaceous plants, percent bare ground, and percent debris were also measured. The site that was sheared, piled, burned, and ripped had the highest initial density and survivorship. This was attributed to the beneficial affect of ripping on seedling establishment and burning to control Chinese tallow (*Sapium sebiferum*) and invasive exotic species that otherwise out competes the native species planted. The sites that were burned or treated with herbicide also had low occurrence of Chinese tallow but had low survivorship of seedlings, possibly due to the difficulty of properly planting seedlings without ripping. This project illustrates the necessity of proper pre-planting site preparation and control of exotic species to increase the survivorship of seedlings in reaching restoration goals.

King, S. L. and B. D. Keeland. 1999. Evaluation of reforestation in the Lower Mississippi River alluvial valley. *Restoration Ecology* 7:348-359.

Author Abstract. Only about 2.8 million ha of an estimated original 10 million ha of bottomland hardwood forests still exist in the Lower Mississippi River Alluvial Valley (LMAV) of the United States. The U.S. Fish and Wildlife Service, the U.S. Forest Service, and state agencies initiated reforestation efforts in the late 1980s to improve wildlife habitat. We surveyed reforestations responsible for reforestation in the LMAV to determine the magnitude of past and future efforts and to identify major limiting factors. Over the past 10 years, 77,698 ha have been reforested by the agencies represented in our survey and an additional 89,009 ha are targeted in the next 5 years. Oaks are the most commonly planted species and bare-root seedlings are the most commonly used planting stock. Problems with seedling availability may increase the diversity of plantings in the future. Reforestation in the LMAV is based upon principles of landscape ecology; however, local problems such as herbivory, drought, and flooding often limit success. Broad-scale hydrologic restoration is needed to fully restore the structural and functional attributes of these systems, but because of drastic and widespread hydrologic alterations and socioeconomic constraints, this goal is generally not realistic. Local hydrologic restoration and creation of specific habitat features needed by some wildlife and fish species warrant attention. More extensive analyses of plantings are needed to evaluate functional success. The Wetland Reserve Program is a positive development, but policies that provide additional financial incentives to landowners for reforestation efforts should be seriously considered.

Kolka, R. K., C. C. Trettin, E. A. Nelson and W. H. Conner. 1998. Tree seedlings establishment across a hydrologic gradient in a bottomland restoration. pp. 89-102. The Twenty Fifth Annual Conference on Ecosystems Restoration and Creation.

Author Abstract. Seedling establishment and survival on the Savannah River Site in South Carolina is being monitored as part of the Pen Branch Bottomland Restoration Project. Bottomland tree species were planted from 1993-1995 across a hydrologic gradient encompassing the drier upper floodplain corridor, the lower floodplain corridor and the continuously inundated delta. Twelve species were planted in the three areas based on their flood tolerance and the hydrology of the area. Planted areas are separated with unplanted control strips to assess natural regeneration. A seedling survey conducted in 1997 showed that planted areas had significantly greater seedling

densities than unplanted control sections. Water tupelo (*Nyssa aquatica*), green ash (*Fraxinus pennsylvanica*), sycamore (*Platanus occidentalis*), and persimmon (*Diospyros virginiana*) had the highest percent survival in the upper corridor while baldcypress (*Tarodium distichum*) had the best survival in the wetter lower corridor and delta. Water tupelo and green ash survival was low in wetter areas. Survival of planted species is dependent on hydrology, competition and herbivory although it is not possible to differentiate these effects from the available data.

Lakly, M. B. and J. McArthur. 2000. Macroinvertebrate recovery of a post-thermal stream: habitat structure and biotic function. *Ecological Engineering* 15:S87-S100.

This study was conducted on the Pen Branch of the Savannah River as part of a series of tested methods to assess the progress of restoration efforts.

Author Abstract. Macroinvertebrate faunal assemblages, organic matter availability and instream structural complexity were investigated in three systems to determine the current state of recovery of a post-thermal stream. The abundance and diversity of the lower foodchain community has recovered substantially since cessation of thermal flows in 1988; however, the biotic communities remain structurally and functionally distinct as a result of past thermal perturbation. Disparate instream habitat structural components and stream physical changes in the post-thermal and reference systems drive functional differences in the macroinvertebrate community. The post-thermal stream is physically and biologically structured by high densities of aquatic macrophytes while the reference system is driven by high concentrations of coarse woody debris. Consequently, the abundant, diverse macroinvertebrate communities in both systems illustrate a post-thermal shift in energy source from a reliance on allochthonous to autochthonous inputs. Biotic indices such as taxa richness, a family level index and similarity index may not be sufficient to determine functional changes as a result of thermal impacts. However, the distribution of diverse functional feeding groups across streams was successful at characterizing divergence in resource utilization and processing. This distinction between macroinvertebrates' abundance and diversity, and their function in the ecosystem is essential in establishing relevant mitigation plans and endpoints for stream restoration.

McLeod, K. W., M. R. Reed and L. D. Wike. 2000. Elevation, competition control, and species affect bottomland forest restoration. *Wetlands* 20:162-168.

Author abstract. This experiment examined how elevation and control of early successional vegetation would affect the growth and survival of tree species used in restoration. Vegetation was controlled by mowing or spraying with Accord [glyphosate, (phosphononomethyl) glycine in the form of its isopropylamine salt] herbicide. These control methods were applied to either the entire plot or a narrow 1-m strip where seedlings were to be planted. A fifth treatment (control) had seedlings planted into the existing vegetation. Species planted were baldcypress (*Taxodium distichum*), water tupelo (*Nyssa aquatica*), willow oak (*Quercus phellos*), nuttall oak (*Q. nuttallii*), overcup oak (*Q. lyrata*), and cherrybark oak (*Q. falcata* var. *pagodaefolia*). Seedlings were randomly planted in late April 1993 with six rows in each plot and six trees per row on a 2 x 2 m spacing with five replicate plots per treatment. Survival was not enhanced by any competition control treatment, but survival among species differed. All six species had overall survival > 90% in autumn 1993. Species' survival was affected by several summer floods during 1994. Baldcypress and overcup oak survival was greater than 89%, while water tupelo, nuttall oak, and willow oak were all approximately 70%, and cherrybark oak was only 29%. By the end of 1995, survival of all species decreased further, but the species groupings remained the same. Survival and height growth of baldcypress and water tupelo were greatest at lower planting elevations. At higher elevations, survival of cherrybark oak and willow oak were greatest, while overcup oak and Nuttall oak were unaffected by elevation. Thus, controlling the herbaceous vegetation did not affect survival or growth as much as relative planting elevation due to site flooding and the flood tolerance of the species. All of the species in this experiment except cherrybark oak were successfully established.

Nelson, E. A., N. C. Dulohery, R. K. Kolka and W. H. McKee, Jr. 2000. Operational **restoration** of the Pen Branch bottomland hardwood and swamp wetlands - the research setting. *Ecological Engineering* 15:S23–S33.

The Savannah River swamp, a 3020 ha forested wetland on the floodplain of the Savannah River, USA is located on the Department of Energy's Savannah River site (SRS) near Aiken, SC. Historically, the swamp consisted of approximately 50% bald cypress–water tupelo (*Taxodium distichum–Nyssa aquatica*) stands, 40% mixed bottomland hardwood stands, and 10% shrub, marsh, and open water. Creek corridors were typical of southeastern bottomland hardwood forests. Hydrology was controlled by flooding of the Savannah River and by flow from four creeks that drain into the swamp prior to flow into the Savannah River. Upstream dams have caused some alteration of the water levels and timing of flooding within the floodplain. Major impacts to the swamp hydrology occurred with the completion of the production reactors and one coal-fired powerhouse at the SRS in the early 1950s. Flow in one of the tributaries, Pen Branch, was typically 0.3 $m^3 s^{-1}$ (10–20 cfs) prior to reactor pumping and 11.0 $m^3 s^{-1}$ (400 cfs) during pumping from 1954 to 1988. Sustained increases in water volume resulted in overflow of the original stream banks, the creation of additional floodplains, considerable erosion of the original stream corridor, and deposition of a deep silt layer on the newly formed delta. Heated water was discharged directly into Pen Branch and water temperature in the stream often exceeded 65°C. The nearly continuous flooding of the swamp, the thermal load of the water, and the heavy silting resulted in complete mortality of the original vegetation in large areas of the floodplain. In the years since pumping was reduced, no volunteer seedlings of heavy-seeded hardwoods or cypress have been found in the floodplain corridor. Research was conducted to determine methods to reintroduce tree species characteristic of more mature forested wetlands. Species composition and selection were altered based on the current and expected hydrological regimes that the reforestation areas will be experiencing.

Paller, M. H., M. J. M. Reichert, J. M. Dean and J. C. Seigle. 2000. Use of fish community data to evaluate restoration success of a riparian stream. *Ecological Engineering* 15: S171–S187.

Author Abstract. From 1985 to 1988, stream and riparian habitats in Pen Branch and Four Mile branch began recovering from deforestation caused by the previous release of hot water from nuclear reactors. The Pen Branch corridor was replanted with wetland trees in 1995 to expedite recovery and restore the Pen branch ecosystem. Pen branch, Four Mile branch, and two relatively undisturbed streams were electrofished in 1995:1996 to determine how fish assemblages differed between the previously disturbed and undisturbed streams and whether such difference could be used to measure restoration success in

Pen branch. Fish assemblages were analyzed using nonparametric multivariate statistical methods and the index of biotic integrity (IBI), a bioassessment method based on measurement of ecologically sensitive characteristics of fish assemblages. Many aspects of fish assemblage structure (e.g. species richness, disease incidence, taxonomic composition at the family level) did not differ between disturbed and undisturbed streams; however, disturbed streams had higher densities of a number of species. These differences were successfully detected with the multivariate statistical methods; whereas, the IBI did not differ between most recovering and undisturbed sampling sites. Because fish assemblages are strongly influenced by instream habitat, and because instream habitat is strongly influenced by the riparian zone, fish assemblages can be used to measure restoration success. Nonparametric ordination methods may provide the most sensitive measure of progress towards restoration goals, although the IBI can be used during early stages of recovery to indicate when certain ecologically important aspects of structure and function in recovering streams have reached levels typical of undisturbed streams.

Schweitzer, C. J., E. S. Gardiner, J. A. Stanturf and A. W. Ezell. 1999. Methods to improve establishment and growth of bottomland hardwood artificial regeneration, 293 pp. 12th Central Hardwood Forest Conference. Lexington, KY.

Author Abstract. With ongoing attempts to reforest both cut-over and abandoned agricultural land in the lower Mississippi alluvial plain, it has become evident that there exists a need for an efficient regeneration system that makes biological and economic sense. Also, there is a need to address how to minimize competition from invading weeds, to deter predation by small mammals, and to achieve adequate tree establishment. This study was designed as a randomized complete block experiment with treatments arranged as factors (3 species X 2 levels of protection X 4 weed control treatments) with three replications to assess efficacy of seedling protection and weed control to improve seedling growth and survival. The study was conducted on a cleared area in the Delta Experimental Forest, Stoneville, MS. Three tree species, nuttall oak (*Quercus nuttallii* Palmer), green ash (*Fraxinus pennsylvanica* Marsh.), and persimmon (*Diospyros virginia* L) were planted as 1-0 bareroot seedlings in March 1997. Each treatment plot had 25 seedlings, spaced at 0.75 meters X 0.75 meters. Shelter protection was installed on half of the seedlings. Shelters were 1-meter tall, 15-centimeter diameter plastic tree shelters. Each shelter treatment (with or without shelter) received one of four weed control treatments: mechanical mowing (gas-powered weed tilter), fabric mat (woven, black polypropylene material), chemical herbicide (Oust, suffometurcin-rnethyl at 210 grams per hectare), or undisturbed (control). Response of shelters and weed control treatments on seedling survival, height and diameter were followed for one growing season. Seedlings in shelters had greater survival (98 percent) than seedlings without shelters (93 percent). For all three species, height growth was significantly greater for sheltered seedlings (43 centimeters) compared to unsheltered seedlings (15 centimeters). For the unsheltered seedlings, fabric mat weed control increased survival relative to chemical weed control. All seedlings had significantly greater height and diameter growth under the fabric mat weed control compared to growth under the other treatments except for unsheltered oak seedlings.

Stanturf, J. A., E. S. Gardiner, P. B. Hamel, M. S. Devall, T. D. Leininger and M. E. Warren, Jr. 2000. Restoring bottomland hardwood ecosystems in the lower Mississippi alluvial valley. *Journal of Forestry* 98:10-16.

This article offers a critique of several federal programs that are currently used to restore southern bottomland hardwood forests to the floodplains of the Mississippi River. The article explains that several techniques successfully used on federal land are now being applied to private holdings. However, some of the techniques and assumptions used on public land may be inappropriate when applied to smaller, private holdings. These are explained and adaptations to existing programs are offered.

The article also offers a few site-specific techniques for increasing the efficiency and success of bottomland forest restorations. Advise on site preparation, seed handling and storage, and methods to prevent herbivory are among the suggestions. A comparison of costs per acre of each of the different restoration practices is given. The article closes with comments on the future directions and limitations of bottomland forest restoration.

Stanturf, J. A., S. H. Schoenholtz, C. J. Schweitzer and J. P. Shepard. 2001. Achieving restoration success: myths in bottomland hardwood forests. *Restoration Ecology* 9:189-200.

This paper presents the ecological and sociopolitical context of ecological restoration of bottomland forests and discusses nine commonly held misconceptions (the authors use the term 'myths') about it. The nine myths and talking points include:

1. Afforestation is not the same as restoration - the authors stipulate that afforestation is a critical first step in almost every restoration effort.
2. Restoration is easy, anyone can do it - a successful ecological restoration requires selection of the proper plant species and planting techniques for the site. Successful restorations require that a variety of environmental variables be taken into consideration as well as a plan for post-restoration monitoring. These abilities are not often held by the general public.
3. Desired future condition can be specified - though setting restoration goals is important, there are several potential problems with the use of reference sites or historical conditions.
4. The same strategy is appropriate to all ownerships - successful techniques useful in restoring small plots may not be economical when applied to larger scale restorations. Larger scale restorations can manipulate and take advantage of off-site conditions that smaller projects cannot.
5. Plantations have no wildlife value - though not as valuable as ecological restorations with more species diversity, plantations can offer some wildlife benefits, particularly to migratory birds.
6. Understocked stands are sufficient - two common restoration goals are canopy closure and regaining vertical structure, understocked restoration projects (though less expensive in the short-term) will take longer to achieve those goals.
7. Preservation is the only valid goal - site conditions may be present which prevent a fully functioning forest from developing on the site, in these situations active management (i.e. restoration) must be carried out.
8. Ecological and economic goals are incompatible - depending on the goals of restoration and management of bottomland forests, forests can provide wildlife and other benefits while providing income from harvesting or other activities.
9. Restoration can proceed without management - restoration produces the maximum benefits only when sites are monitored and managed over time.

Twedt, D. J., R. R. Wilson, J. L. Henne-Kerr and D. A. Grosshuesch. 2002. Avian response to bottomland hardwood reforestation: the first 10 years. *Restoration Ecology* 10:645-655.

Author Abstract. Riverine hardwood forests were planted on agricultural fields in Mississippi and Louisiana predominantly using either *Quercus* species (oaks) or *Populus deltoides* (eastern cottonwood). We assessed avian colonization of these reforested sites between 2 and 10 years after planting. Rapid vertical growth of cottonwoods (circa 2-3 m/year) resulted in sites with forest structure that supported greater species richness of breeding birds, increased Shannon diversity indices, and supported greater territory densities than on sites planted with slower-growing oak species. Grassland birds (*Spiza americana* [Dickcissel] and *Sturnella magna* [Eastern Meadowlark]) were indicative of species breeding on oak-dominated reforestation no more than 10 years old. *Agelaius phoeniceus* (Red-winged Blackbird) and *Colinus virginianus* (Northern Bobwhite) characterized cottonwood reforestation no more than 4 years old, whereas 14 species of shrub-scrub birds (e.g., *Passerina cyanea* [Indigo Bunting]) and early-successional forest birds (e.g., Vireo gilvus[Warbling vireo]) typified cottonwood reforestation 5 to 9 years after planting. Rates of daily nest survival did not differ between reforestation strategies. Nest parasitism increased markedly in older cottonwood stands but was overwhelmed by predation as a cause of nest failure. Based on Partners in Flight prioritization scores and territory densities, the value of cottonwood reforestation for avian conservation was significantly greater than that of oak reforestation during their first 10 years. Because of benefits conferred on breeding birds, we recommend reforestation of riverine hardwoods should include a high proportion of fast-growing early successional species such as cottonwood.

Wharton, C. H., W. M. Kitchens, E. C. Pendleton and T. W. Snipe. 1982. The ecology of bottomland hardwood swamps of the Southeast: a community profile, 133 pp. FWS/OBS-81/37, U.S. Fish and Wildlife Service, Biological Services Program, Washington, DC.

Author Abstract. This report is one in a series of community profiles whose objective is to synthesize extant literature for specific wetland habitats into definitive, yet handy ecological references. To the extent possible, the geographic scope of this profile is focused on bottomland hardwood swamps occupying the riverine floodplains of the Southeast whose drainage originates in the Appalachian Mountains/ Piedmont or Coastal Plain. References are occasionally made to studies outside this area, primarily for comparative purposes or to highlight important points. The sections detailing the plant associations and soils in the study area are derived from field investigations conducted specifically for this project.

In order to explain the complexities of the ecological relationships that are operating in these bottomland hardwood ecosystems, this report details not only the biology of floodplains but also the geomorphology and hydrological components and processes that are operating on various scales. These factors, in concert with the biota, dictate both the ecological structure and function of the bottomland hardwood ecosystems. We have utilized the ecological zone concept developed by the National Wetlands Technical Council to organize and explain the structural complexity of the flora and fauna.

The information in this profile will be useful to environmental managers and planners, wetland ecologists, students, and interested laymen concerned with the fate and the ecological nature and value of these ecosystems. The format, style, and level of presentation should make this report adaptable to a variety of uses, ranging from preparation of environmental assessment reports to supplementary or topical reading material for college wetland ecology courses. The descriptive materials detailing the floristics of these swamps have been cross-referenced to specific site locations and give the report the utility of a field guide handbook for the interested reader.

APPENDIX II: RIVERINE FORESTS
REVIEW OF TECHNICAL METHODS MANUALS

This Review of Technical Methods Manuals includes a variety of sampling manuals, Quality Assurance/Quality Control (QA/QC) documents, standardized protocols, or other technical resources that may provide practitioners with the level of detail needed when developing a monitoring plan for a coastal restoration project. Examples from both peer reviewed and grey literature are presented. Entries were selected through extensive literature and Internet searches as well as input from reviewers. As with the Annotated Bibliographies, these entries are not, however, a complete list. Entries are arranged alphabetically by author. Wherever possible, web addresses or other contact information is included in the reference to assist readers in easily obtaining the original resource. Summaries preceded by the terms 'Author Abstract', 'Publisher Introduction', or similar descriptors were taken directly from their original source. Summaries without such descriptors were written by the authors of the associated chapter.

Allen, J. A., B. D. Keeland and J. A. Stanturf. 2001. A guide to bottomland hardwood restoration, 132 pp. Information and Technology Report USGS/BRD/ITR-2000-0011 General Technical Report SRS-40, U.S. Geological Survey, Biological Resources Division U.S. Department of Agriculture, Forest Service, Southern Research Station, Asheville, NC. http://www.srs.fs.fed.us/pubs/viewpub.jsp?index=2813

This guidebook is an essential resource to anyone planning to restore an area of bottomland forest. It briefly introduces the ecology of bottomland forests, their extent, the degree of degradation, and need for restoration. It then guides readers through the entire restoration process from general planning issues such as where to obtain planted material through to post-restoration monitoring and management of existing forests. It instructs readers on how to evaluate sites for restoration, which factors biotic and abiotic need to be taken into consideration before the proper species can be selected and planting begin. It covers: site preparation, seed collection, handling, and storage, and also has chapters on planting seeds vs. seedlings, including the tools and methods used in each. The guidebook also touches on methods of restoration other than direct planting. It covers the selection and planting of not only canopy species but understory plants as well, something that is otherwise not well documented in the literature. The guidebook also instructs readers on how to control undesirable species and protect the restoration site from animals, fire, and human impacts. Post-restoration monitoring is also covered in this document, what to measure, how to measure it, and what this information tells you is presented clearly and concisely. Lastly, management and rehabilitation of existing bottomland forests is covered for restoration of sites that haven't been completely denuded of trees. The guidebook also has a series of appendixes that include information on different forest cover types, common and scientific names of plant species common to bottomland forests, a partial list of seed and seedling suppliers, as well as species to site relationships for the Midsouth and Southern Atlantic Coastal Plain to aid restoration practitioners in selecting the proper plant materials for their site conditions.

Dane, J. H. and G. C. Topp. 2002. Methods of Soil Analysis: Part 4-Physical Methods, 1692 pp. Soil Society of America, Madison, WI.

Publisher's Description. Due to the rapid and numerous changes in measurement methods associated with soil physical and mineralogical properties, it was decided not to print a third edition of the highly popular Methods of Soil Analysis. Part 1—Physical and Mineralogical Methods. The decision was made to split the volume into two parts. The part containing soil physical measurements is now published as Methods of Soil Analysis: Part 4—Physical Methods. The approach in Part 4 differs substantially from that in Part 1 in that the new book uses a more hierarchical approach. As such it is divided into eight chapters, with each chapter covering a major aspect of soil physical properties. Following the table of contents, the reader can easily find the specific topic or measurement that is of interest. Compared with Part 1, new methods have been added and some of the older methods have been updated or deleted.

Delaware Riverkeeper Network. 2003. Adopt-a-buffer toolkit: monitoring and maintaining restoration projects, 124 pp. Delaware Riverkeeper Network, Washington Crossing, PA. www.delawareriverkeeper.org/

The Delaware Riverkeeper's monitoring manual was written to help maintain consistency and accuracy of data collected by volunteers during riparian restoration projects in Delaware and Pennsylvania. Although some of the species discussed are important only to those areas, the rest of the guidance offered in the manual could be extremely useful to riverine forest restoration monitoring projects throughout the country. The manual briefly describes a few common restoration techniques and closes with a variety of adaptive management/maintenance suggestions to minimize the negative impact of invasive species and damage to trees and herbaceous plantings. Ideas on how to retain volunteers are also presented. The majority of the manual is devoted to describing a 2-tier monitoring system. The first tier is a quick assessment of plant species present and status of constructed portions of the restoration project (e.g., to assess damage caused by erosion). Guidance on the use of photo points is also provided. Tier two measurements are more detailed and include the use of wildlife and macroinvertebrate surveys as well as methods for performing stream cross sections. The manual also includes blank data collection forms that could be used or easily adapted for use as needed depending on location.

de Vries, P. G. 1986. Sampling Theory for Forest Inventory: A Teach-Yourself Course. Springer-Verlag, Berlin.

de Vries has attempted to address many of the shortcomings of other statistical sampling texts by simplifying the process of learning advanced statistics and putting them to practical use in forestry sampling. His book covers a variety of sampling techniques including: random sampling, cluster and double sampling, use of points and circular plots, line intersect and list sampling, and a variety of others. de Vries has tried, where ever possible, to provide examples and take readers through the step by step process of how statistical analyses have been developed in order to gain a more thorough understanding of the theory and proper application of different procedures. Several appendices are also included that review many introductory statistical concepts, however, the text is not intended for the uninitiated. An existing background in calculus and introductory statistics is encouraged before using this resource. Upon completion of his book and a short period of time for the new material to sink in, de Vries confidently states that readers will 'experience the satisfaction of mastering some sampling methods widely used in forest inventory, that he will be able to read critically more professional literature than before, and that he will possess a sound basis on which to expand his knowledge of sampling.'

Hoover, J. J., K. J. Killgore and G. L. Young. 2000. Quantifying habitat benefits of restored backwaters. EMRRP Technical Notes Collection ERDC TN-EMRRP-EI-01, U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://www.wes.army.mil/el/emrrp/pdf/ei01.pdf

Backwater areas act as important nursery and spawning habitats for fish. This technical report describes methods of quantifying and enhancing fish species that use backwater areas, areas subject to dewatering during low river flows. Brief lists or descriptions of fish species that use backwater habitats and methods to sample young-of-the-year populations are presented. The use of plexiglas light-traps to efficiently sample young-of-year is explained for a variety of circumstances. The development of Habitat Suitability Indexes (HSI), a statistical method useful in determining which species use particular habitats and therefore might benefit from a restoration, is presented in greater detail. Example restoration projects where the HIS method was used (Lake Whittington, a Mississippi River oxbow lake and Lake George, a Mississippi delta backwater) are also provided. Contact information of the authors is also included.

Killgore, K. J. and J. J. Hoover. 1992. A guild for monitoring and evaluating fish communities in bottomland hardwood wetlands, 7 pp. WRP Technical Note WRP TN FW-EV-2.2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This technical note is a summary of the adult and larval fish communities of the Rex Hancock/Black Swamp Wildlife Management Area, Cache River system, Arkansas. Fish communities are classified according to habitat preference and reproductive strategy. Brief descriptions of three habitat categories are given: lentic-oxbow lakes, lentic-floodplain ponds, and lotic-channels. Four reproductive modes are also defined. Tables listing which bottomland forest fish species use which habitats at varying life stages is also presented. By knowing which communities of fish are capable of using each habitat, the classifications provided can be used to select and evaluate fish species for monitoring studies in southern bottomland forest wetlands.

Klute, A. 1986. Methods of Soil Analysis: Part 1-Physical and Mineralogical Methods, 1188 pp. Soil Science Society of America, Madison, WI.

Publisher's Description. Great strides have been made in the conception of physical and mineralogical characteristics of soils and how they relate to each other and to chemical properties. The methods of analyses included here provide a uniform set of procedures that can be used by the majority of soil scientists and engineers.

Kolka, R. K., C. C. Trettin and E. A. Nelson. 1998. Development of an assessment framework for restored forested wetlands. Proceedings of the Conference on Ecosystems Restoration & Creation. Tampa, Florida. May 14-15. http://www.srs.fs.fed.us/pubs/viewpub.jsp?index=1541

Author Abstract. Development of an assessment framework and associated indicators that can be used to evaluate the effectiveness of a wetland restoration is critical to demonstrating the sustainability of restored sites. An interdisciplinary approach was developed to assess how succession is proceeding on a restored bottomland site in South Carolina relative to an undisturbed reference and a naturally agrading site. Comparison of populations and processes across successional gradients and treatments allows the effect of disturbance and restoration activities to be evaluated. Studies involving vegetation communities, organic matter and nutrient dynamics, seedling establishment and competition, and avian, herpetofauna, fish and macroinvertebrate communities have been implemented. Seedling establishment and competition studies suggest non-chemical and minimal mechanical site preparation techniques, tree shelters and root pruning should be considered as alternatives depending on restoration objectives and site conditions. The restored site contains many of the functional capabilities of a wetland with respect to fauna, however certain species tend to dominate populations in Pen Branch when compared to late successional wetlands. Fish populations show higher population densities in the restored site as compared to the reference site. A conceptual framework for integrating biotic and abiotic processes into a restoration response model will be used to synthesize ecosystem response and to identify indicators for restoration assessments.

Lindbo, D. T. and S. L. Renfro. 2003. Riparian and Aquatic Ecosystem Monitoring: A Manual of Field and Lab Procedures. 4th ed. Saturday Academy's Student Watershed Research Project, Beaverton, OR.

The Student Research Watershed Project has developed a set of field and lab data collection procedures that has successfully translated scientific methodologies for use by non-scientists. The procedures were designed for use by students (grades 8 – 12) and can easily be adapted for volunteer efforts to collect baseline and restoration monitoring data for streamside and aquatic (in-stream) habitats. Methods for the collection of physical, chemical, and biological criteria are included. The manual covers the steps necessary to design a monitoring plan as well as a quality assurance project plan. Rationale behind and the steps involved in monitoring the following parameters are also included: stream flow, temperature, dissolved oxygen, pH, alkalinity, solids and turbidity, conductivity, phosphorus, nitrogen, chlorine, microbes, and macroinvertebrates. Information on the collection of data on in-stream habitat, riparian vegetation, stream reach mapping, photo monitoring, and soils is also included. Example data sheets are provided to assist in the systematic and complete recording of monitoring results by different parties.

McCobb, T. D. and P. K. Weiskel. 2002. Long-term hydrologic monitoring protocol for coastal ecosystems, 93 pp. Protocol, USGS Patuxent Wildlife Research Center, Coastal Research Field Station, University of Rhode Island, Narragnasett, RI. http://science.nature.nps.gov/im/monitor/protocols/caco_hydrologic.pdf

Author Abstract. Long-term monitoring of hydrologic change using a standard data-collection protocol is essential for the effective management of terrestrial, aquatic, and estuarine ecosystems in the coastal park environment. This study develops a consistent protocol for monitoring changes in ground-water levels, pond levels, and stream discharge using methods and techniques established by the U.S. Geological Survey for use in the Long-term Coastal Monitoring Program at the Cape Cod National Seashore. The protocol establishes a hydrologic sampling network in the four ground-water-flow cells in the Seashore area, and provides justification for the measurement methods selected and for the spatial and temporal sampling frequency. Data collected during the first year of monitoring are included in this report; common hydrologic analyses such as hydrographs for ground-water and pond levels, and rating curves between stream stage and discharge for streamflow, are presented for selected sites. Long-term hydrologic monitoring at the Seashore will aid in interpretation of the findings of other monitoring programs. Developing and initiating long-term hydrologic monitoring programs will provide a better understanding of effects of natural and human-induced change at both the local and global scales on coastal water resources in park units.

Merritt, R. W. and K. W. Cummins, (eds.). 1996. An Introduction to the Aquatic Insects of North America. Third edition ed. Kendall/Hunt Publishing Company, Dubuque, IA.

While the bulk of Merritt and Cummins is on identification of aquatic insects of North America, they include several chapters useful in project planning as well. Various experts in the field of aquatic insect collection and identification have submitted chapters on: the general morphology of aquatic insects, designing studies, collection equipment and techniques, aquatic insect respiration, habitat and life history, and the ecology and distribution of aquatic insects. The rest of the manual is devoted to identification keys for each family of aquatic insect found in North America with many detailed and useful pictures of identifying characteristics.

Since this book is continental in scope, it is suggested that practitioners first look for identification keys prepared for their local or regional waterways. This will reduce much confusion in the identification process by eliminating species that are not found locally. Any local aquatics expert or science librarian should be able to locate these materials. If local materials are not available, then Merritt and Cummins will be useful, however, be sure to check the distribution of species identified whenever possible.

Ossinger, M. 1999. Success standards for wetland mitigation projects - a guideline, 31 pp. Washington State Department of Transportation, Environmental Affairs Office. http://pnw.sws.org/forum/success.PDF

This report offers guidance and examples on how to write specific success criteria for mitigation and restoration projects. Though it was designed to address mitigation projects in the Pacific Northwest, its information and approach make it useful throughout the United States. It outlines the steps necessary for planning the monitoring and management of a mitigation/restoration project. Guidance in writing the following program elements is provided: how to set project goals, how to select specific project objectives (i.e. what functions or values will the mitigation/restoration provide), how to select performance objectives (i.e. what structural characteristics need to be in place to provide desired functions), selection of success standards (measurable benchmarks used to determine success of performance objectives), monitoring method (how will the success standard be measured), contingency measure (what to do if the success standards are not met). Several examples are provided of each of these steps. These examples, while not all-inclusive, facilitate the application of this method to diverse areas and project types.

Shiver, B. D. and B. E. Borders. 1996. Sampling Techniques for Forest Resource Inventory. John Wiley and Sons, Inc., NewYork, NY.

Author Preface. The purpose for writing this book was to create a forest inventory textbook that clearly explains the sampling methods associated with the inventory of forest resources. There are several books available which do a good job of explaining the theory of the various

sampling techniques used in forest inventory. However, the transition from theory to practice is not easily made without extensive course work in theoretical statistics and mathematics. This book provides thorough coverage of forest inventory topics for the practitioner rather than the theoretician and should be understandable to undergraduate forest resources students and professionals who must inventory forest resources.

Examples are used extensively throughout the book to illustrate various estimators and to demonstrate different uses for sampling methods. Problems are also included at the end of each chapter to help instructors and students.

Some of the topics discussed, such as point sampling and 3P sampling, were developed specifically for timber inventory. Other topics, such as mark-recapture methods were developed for inventory of mobile wildlife populations. Many of the topics, however, can be utilized to inventory virtually any of the resources in a forest (understory vegetation, soils, water, etc.)

As the book has developed over the last several years, we find that we are using it as a reference as well as a textbook. Some of the topics such as double sampling with point sampling and sampling with partial replacement have been available only in scattered journal articles or in more theoretically oriented textbooks. Inventory is a job which most forest resource managers will use repeatedly throughout their careers. This book should allow them to work confidently in forest inventory regardless of the specific inventory problem.

Sparks, D. L., A. L. Page, P. A. Helmke, R. H.Loeppert, P. N. Soltanpour, M. A. Tabatabai, C. T. Johnson and M. E. Sumner. 1996. Methods of Soil Analysis: Part 3-Chemical Methods, 1358 pp. Soil Science Society of America, Madison, WI.

Publisher's Description. This volume covers newer methods for characterizing soil chemical properties as well as several methods for characterizing soil chemical processes. This book will serve as the primary reference on analytical methods. Updated chapters are included on the principles of various instrumental methods and their applications to soil analysis. New chapters are included on Fourier transform infrared, Raman, electron spin resonance, x-ray photoelectron, and x-ray absorption fine structure spectroscopies.

Steyer, G. D., R. C. Raynie, D. L. Steller, D. Fuller and E. Swenson. 1995. Quality management plan for Coastal Wetlands Planning, Protection, and Restoration Act monitoring program, 82 pp. Open-File Report 95-01, Louisiana Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA. http://www.lacoast.gov/cwppra/reports/MonitoringPlan/index.htm

This document is a Quality Assurance Project Plan (QAPP) used for all restoration projects conducted under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) and similar legislation for coastal Louisiana. Though it does not explain how to develop a QAPP for new wetland restoration monitoring projects, it can be used as a template by which monitoring plans can be developed. Detailed explanations of how data is to be collected, acceptable error rates, and methods to ensure high quality data is collected, recorded, and analyzed are included. Quality assurance guidelines are provided for field data collection, remote sensing and airphoto interpretation, computer systems to be used, data entry procedures, data review, laboratory procedures, and documentation and reporting. Any restoration practitioner attempting to develop a monitoring plan or preparing a QAPP for their project may find this document a valuable example to follow.

Uranowski, C., Z. Lin, M. DelCharco, C. Huegel, J. Garcia, I. Bartsch, M. S. Flannery, S. J. Miller, J. Bacheler and W. Ainslie. 2003. A regional guidebook for applying the hydrogeomorphic approach to assessing wetland functions of low-gradient, blackwater riverine wetlands in peninsular Florida, 590 pp. ERDC/EL TR-03-3, U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://www.wes.army.mil/el/wetlands/wlpubs.html

This manual was prepared for use in assessing the functional capacity of blackwater, forested wetlands on the western coast of Florida using the Hydrogeomorphic (HGM) method. It provides a brief overview of the general HGM method for classification and assessment and explains how the HGM process was implemented for this particular type of forested wetland system and why. Although the equations provided for assessing functions were calibrated using data from western Florida, they can be adapted and re-calibrated using data from other areas. Methods for determining a blackwater forest's ability to perform the functions of temporary surface water storage, maintenance of characteristic subsurface hydrology, cycling of nutrients, removal and sequester of elements and compounds, retention of particles, export of organic matter, maintenance of plant communities, and provision of wildlife habitat are provided in detail. References to additional literature as needed are also provided.

U.S. EPA. 1996. The volunteer monitor's guide to quality assurance project plans, 59 pp. EPA 841-B-96-003, U.S. Environmental Protection Agency, Washington D.C. http://www.epa.gov/volunteer/qapp/vol_qapp.pdf

Author Abstract. The Quality Assurance Project Plan, or QAPP, is a written document that outlines the procedures a monitoring project will use to ensure that the samples participants collect and analyze, the data they store and manage, and the reports they write are of high enough quality to meet project needs.

U.S. Environmental Protection Agency-funded monitoring programs must have an EPA-approved QAPP before sample collection begins. However, even programs that do not receive EPA money should consider developing a QAPP, especially if data might be used by state, federal, or local resource managers. A QAPP helps the data user and monitoring project leaders ensure that the collected data meet their needs and that the quality control steps needed to verify this are built into the project from the beginning.

Volunteer monitoring programs have long recognized the importance of well-designed monitoring projects; written field, lab, and data management protocols; trained volunteers; and effective presentation of results. Relatively few programs, however, have tackled the task of preparing a comprehensive QAPP that documents these important elements. This document is designed to help volunteer program coordinators develop such a QAPP.

U.S. EPA. 2002. Guidance for quality assurance project plans, 57 pp. EPA QA/G-5, U. S. Environmental Protection Agency, Washington, D. C. http://www.epa.gov/swerust1/cat/epaqag5.pdf

This document is designed to guide those involved with Quality Assurance Project Plan (QAPP) development for environmental monitoring and data analysis. It describes various issues to be addressed when preparing a QAPP, with an emphasis on systematic planning. The report is divided into three chapters. An introduction that describes the target audience and the importance of systematic sampling. A second chapter describes all of the pieces of a QAPP, focusing on environmental data collection and analysis. The third chapter describes methods for developing QAPPs for projects that use previously collected data.

The importance of having high quality, reliable data cannot be over estimated. Use of this document or the EPA's *Volunteer monitor's guide to quality assurance project plans*, will help restoration practitioners develop monitoring plans that will provide the high quality, reliable data necessary to monitor and manage restoration projects. The step-by-step approach of this document takes restoration practitioners through the entire planning, data collection, data analysis, and reporting process from start to finish. Ensuring that all aspects of the monitoring project are well thought out ahead of time and that contingency plans are in place.

Weaver, R. W., S. Angle, P. Bottomley, D. Bezdicek, S. Smith, A. Tabatabai and A. Wollum. 1994. Methods of Soil Analysis: Part 2-Microbiological and Biochemical Properties, 1121 pp. Soil Science Society of America, Madison, WI.

Publisher's Description. Laboratories interested in soil science analysis will find it advantageous to use the methods contained in this book. It is particularly relevant and useful to laboratories with interest in environmental microbiology or bioremediation. Analytical methods are essential to progress in science and the methods presented in this book are recognized as being among the best currently available.

APPENDIX III: LIST OF RIVERINE FOREST EXPERTS

The experts listed below have provided their contact information so practitioners may contact them with questions pertaining to the restoration or restoration monitoring of this habitat. Contact information is up-to-date as of the printing of this volume. The list below includes only those experts who were 1) contacted by the authors and 2) agreed to submit their contact information. Some of those listed also reviewed the associated habitat chapter. In addition to these resources, practitioners are encouraged to seek out the advice of local experts as well faculty members and researchers at colleges and universities. Engineering, planning, and landscape architecture firms also have experts on staff or contract out the services of botanists, biologists, ecologists, and other experts whose skills are needed in restoration monitoring. These people are in the business of providing assistance in restoration and restoration monitoring and are often extremely knowledgeable in local habitats and how to implement projects on the ground. Finally local, state, and Federal environmental agencies also house many experts who monitor and manage coastal habitats. In addition to the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), the Army Corps of Engineers (ACE), Fish and Wildlife Service (FWS), and the United States Geologic Survey (USGS) are important Federal agencies to contact for assistance in designing restoration and monitoring projects as well as potential sources of funding and permits to conduct work in coastal waterways.

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GLOSSARY

Abiotic - non-living

Adaptive management - a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Its most effective form–"active" adaptive management–employs management programs that are designed to experimentally compare selected policies or practices, by evaluating alternative hypotheses about the system being managed.

Aerobic - (of an organism or tissue) requiring air for life; pertaining to or caused by the presence of oxygen

Algae - simple plants that are very small and live in water through photosynthesis, algae are the main producers of food and oxygen in water environments

Allochthanous - carbon that is formed outside of a particular area as opposed to an autochthanous carbon that is produced within a given area

Alluvial plain - the floodplain of a river, where the soils are alluvial deposits carried in by overflowing river

Alluvium - any sediment deposited by flowing water, as in a riverbed, floodplain, or delta

Alternate hypothesis - a statement about the values of one or more parameters usually describing a potential change

Anaerobic - living in the absence of air or free oxygen; pertaining to or caused by the absence of oxygen

Anoxic - without oxygen

Anthropogenic - caused by humans; often used when referring to human induced environmental degradation

Apical - the tips of the plants

Aquatic - living or growing in or on water

Asset mapping - a community assessment research method that provide a graphical representation of a community's capacities and assets

Assigned values - the relative importance or worth of something, usually in economic terms. Natural resource examples include the value of water for irrigation or hydropower, land for development, or forests for timber supply (see held values).

Attitude - an individual's consistent tendency to respond favorably or unfavorably toward a given attitude object. Attitudes can be canvassed through survey research and are often defined utilizing scales ranging from positive to negative evaluations.

Backwater - a body of water in which the flow is slowed or turned back by an obstruction such as a bridge or dam, an opposing current, or the movement of the tide

Baseline measurements - a set of measurements taken to assess the current or pre-restoration condition of a community or ecosystem

Basin morphology - the shape of the earth in the area a coastal habitat is found

Benefit-cost analysis - a comparison of economic benefits and costs to society of a policy, program, or action

Benthic - on the bottom or near the bottom of streams, lakes, or oceans

Bequest value - the value that people place on knowing that future generations will have the option to enjoy something

Biogenic - produced by living organisms

Biomass - the amount of living matter, in the form of organisms, present in a particular habitat, usually expressed as weight- per-unit area

Blackwater streams - streams that do not carry sediment, are tannic in nature and flow through peat-based areas

Brackish - water with a salinity intermediate between seawater and freshwater (containing from 1,000 to 10,000 milligrams per liter of dissolved solids)

Calcareous - sediment/soil formed of calcium carbonate or magnesium carbonate due to biological deposition or inorganic precipitation

Canopy formers - plants that form a diverse vertical habitat structure

Carnivores - organisms that feed on animals

Catchment - the land area drained by a river or stream; also known as "watershed" or "drainage basin"; the area is determined by topography that divides drainages between watersheds

Causality - or causation, refers to the relationship between causes and effects: i.e., to what extent does event 'A' (the cause) bring about effect 'B'

Coastal habitat restoration - the process of reestablishing a self-sustaining habitat in coastal areas that in time can come to closely resemble a natural condition in terms of structure and function

Coastal habitat restoration monitoring - the systematic collection and analysis of data that provides information useful for measuring coastal habitat restoration project performance

Cognitive mapping - a community assessment research method used to collect qualitative data and gain insight into how community members perceive their community and surrounding natural environment

Cohort studies - longitudinal research aimed at studying changing in a particular subpopulation or cohort (e.g., age group) over time (see longitudinal studies)

Community - all the groups of organisms living together in the same area, usually interacting or depending on each other for existence; all the living organisms present in an ecosystem

Community (human) - a group of people who interact socially, have common historical or other ties, meet each other's needs, share similar values, and often share physical space; A sense of "place" shaped by either natural boundaries (e.g., watershed), political or administrative boundaries (e.g., city, neighborhood), or physical infrastructure

Computer-assisted telephone interviewing (CATI) - a system for conducting telephone survey interviews that allows interviewers to enter data directly into a computer database. Some CATI systems also generate phone numbers and dial them automatically.

Concept mapping - community assessment research method that collects data about how community members perceive the causes or related factors of particular issues, topics, and problems

Content validity - in social science research content validity refers to the extent to which a measurement (i.e., performance standard) reflects the specific intended domain of content (i.e., stated goal or objective). That is, how well does the performance standard measure whether or not a particular project goal has been met?

Contingent choice method - estimates economic values for an ecosystem or environmental service. Based on individual's tradeoffs among sets of ecosystems, environmental services or characteristics. Does not directly ask for willingness to pay; inferred from tradeoffs that include cost as an attribute.

Contingent valuation method (CVM) - used when trying to determine an individual or individuals' monetary valuation of a resource. The CVM can be used to determine changes in resource value as related to an increase or decrease in resource quantity or quality. Used to measure non-use attributes such as existence and bequest values; market data is not used.

Coral reefs - highly diverse ecosystems, found in warm, clear, shallow waters of tropical oceans worldwide. They are composed of marine polyps that secrete a hard calcium carbonate skeleton, which serves as a base or substrate for the colony.

Coralline algae - algae that contains a coral-like, calcareous outer covering

Cost estimate - estimates on costs of planning and carrying out a project. Examples of items that may be included in a cost estimate for a monitoring plan may be personnel, authority to provide easements and rights-of-way, maintenance, labor, and equipment.

Coulter counter - a device that measures the amount of particles in water

Coverage error - a type of survey error that can occur when the list – or frame – from which a sample is drawn does not include all elements of the population that researchers wish to study

Cross-sectional studies - studies that investigate some phenomenon by taking a cross section (i.e., snapshot) of it at one time and analyzing that cross section carefully (see longitudinal studies)

Crowding - in outdoor recreation, crowding is a form of conflict (see outdoor recreation conflict) that is based on an individual's judgment of what is appropriate in a particular recreation activity and setting. Use level is not interpreted negatively as crowding until it is perceived to interfere with one's objectives or values. Besides use level, factors that can influence perceptions of crowding include participant's motivations, expectations, and experience related to the activity, and characteristics of those encountered such as group size, behavior, and mode of travel.

Cryptofauna - tiny invertebrates that hide in crevices

Cultch - empty oyster shells and other materials that are on the ground and used as a place of attachment

Culture - a system of learned behaviors, values, ideologies, and social arrangements. These features, in addition to tools and expressive elements such as graphic arts, help humans interpret their universe as well as deal with features of their environments, natural and social.

Cyanobacteria - blue-green pigmented bacteria; formerly called blue-green algae

Dataloggers - an electronic device that continually records data over time

Deepwater swamps - forested wetlands that develop along edges of lakes, alluvial river swamps, in slow-flowing strands, and in large, coastal-wetland complexes. They can be found along the Atlantic and Gulf Coasts and throughout the Mississippi River valley. They are distinguished from other forested habitats by the tolerance of the dominant vegetation to prolonged flooding.

Demersal - bottom-feeding or bottom-dwelling fish, crustaceans, and other free moving organisms

Detritivorous - the practice of eating primarily detritus

Detritus - fine particles of decaying organic and inorganic matter fomed by excrement and by plant and animal remains; maybe suspended in water or accumulated on the bottom of a water body

Diatoms - any of a class (Bacillariophyceae) of minute planktonic unicellular or colonial algae with silicified skeletons that form shells.

Direct impacts - the changes in economic activity during the first round of spending. For tourism this involves the impacts on the tourism industries (businesses selling directly to tourists) themselves (see Secondary Effects)

Dissolved oxygen - oxygen dissolved in water and available to aquatic organisms; one of the most important indicators of the condition of a water body; concentrations below 5 mg/l are stressful and may be lethal to many fish and other species

Dominant species - a plant species that exerts a controlling influence on or defines the character of a community

Downwelling - the process of build-up and sinking of surface waters along coastlines

Driving forces - the base drivers that play a large role in people's decision making processes and influence human behavior. Societal forces such as population, economy, technology, ideology, politics and social organizations are all drivers of environmental change.

Duration - a span or interval of time

Ebb - a period of fading away, low tide

Echinoderms - any of a phylum (Echinodermata) of radially symmetrical coelomate marine animals including the starfishes, sea urchins, and related forms

Economic impact analysis - used to estimate how changes in the flow of goods and services can affect an economy. Measure of the impact of dollars from outside a defined region/area on that region's economy. This method is often used in estimating the value of resource conservation.

Ecosystem - a topographic unit, a volume of land and air plus organic contents extended aerially for a certain time

Ecosystem services - the full range of goods and services provided by natural ecological systems that cumulatively function as fundamental life-support for the planet. The life-support functions performed by ecosystem services can be divided into two groups: production functions (i.e., goods) and processing and regulation functions (i.e., services).

Emergent plants - water plants with roots and part of the stem submerged below water level, but the rest of the plant is above water; e.g., cattails and bulrushes

Environmental equity - the perceived fairness in the distribution of environmental quality across groups of people with different characteristics

Environmental justice - a social movement focused on the perceived fairness in the distribution of environmental quality among people of different racial, ethnic or socio-economic groups

Ephemeral - lasting a very short time

Epifaunal - plants living on the surface of the sediment or other substrate such as debris

Epiphytes - plants that grow on another plant or object upon with it depends for mechanical support but not as a source of nutrients

Estuary - a part of a river, stream, or other body of water that has at least a seasonal connection with the open sea or Great Lakes and where the seawater or Great Lakes water mixes with the surface or subsurface water flow, regardless of the presence of man-made structures or obstructions.

Eukaryotic - organisms whose cells have a nucleus

Eulittoral - refers to that part of the shoreline that is situated between the highest and lowest seasonal water levels

Eutrophic - designating a body of water in which the increase of mineral and organic nutrients has reduced the dissolved oxygen, producing an environment that favors plant over animal life

Eutrophication - a natural process, that can be accelerated by human activities, whereby the concentration of nutrients in rivers, estuaries, and other bodies of water increases; over time this can result in anaerobic (lack of oxygen) conditions in the water column; the increase of nutrients stimulates algae "blooms; " as the algae decays and dies, the availability of dissolved oxygen is reduced; as a result, creatures living in the water accustomed to aerobic conditions perish

Evapotranspiration - a term that includes water discharged to the atmosphere as a result of evaporation from the soil and surface-water bodies and by plant transpiration

Existence value - the value that people place on simply knowing that something exists, even if they will never see it or use it

Exotic species - plants or animals not native to the area

Fauna - animals collectively, especially the animals of a particular region or time

Fecal coliforms - any of several bacilli, especially of the genera *Escherichia*, found in the intestines of animals. Their presence in water suggests contamination with sewage of feces, which in turn could mean that disease-causing bacteria or viruses are present. Fecal coliform bacteria are used to indicate possible sewage contamination. Fecal coliform bacteria are not harmful themselves, but indicate the possible presence of disease-causing bacteria, viruses, and protozoans that live in human and animal digestive systems. In addition to the possible health risks associated with them, the bacteria can also cause cloudy water, unpleasant odors, and increased biochemical oxygen demand.

Fetch - the distance along open water or land over which the wind blows

Fishery dependent data - data on fish biology, ecology and population dynamics that is collected in connection with commercial, recreational or subsistence fisheries.

Flooding regime - pattern of flooding over time

Floodplain - a strip of relatively flat land bordering a stream channel that may be overflowed at times of high water; the amount of land inundated during a flood is relative to the severity of a flood event

Flora - plants collectively, especially the plants of a particular region or time

Fluvial - of, relating to, or living in a stream or river

Focus group - a small group of people (usually 8 to 12) that are brought together by a moderator to discuss their opinions on a list of predetermined issues. Focus groups are designed to collect very detailed information on a limited number of topics.

Food chain - interrelations of organisms that feed upon each other, transferring energy and nutrients; typically solar energy is processed by plants who are eaten by herbivores which in turn are eaten by carnivores: sun –> grass –> mouse –> owl

Food webs - the combined food chains of a community or ecosystem

Frequency - how often something happens

Fronds - leaf-like structures of kelp plants

Function - refers to how wetlands and riparian areas work – the physical, chemical, and biological processes that occur in these settings, which are a result of their physical and biological structure

Functional habitat characteristics - characteristics that describe what ecological service a habitat provides to the ecosystem

Gastropods - any of a large class (Gastropoda) of mollusks (as snails and slugs) usually with a univalve shell or none and a distinct head bearing sensory organs

Geomorphic - pertaining to the form of the Earth or of its surface features

Geomorphology - the science that treats the general configuration of the Earth's surface; the description of landforms

Habitat - the sum total of all the living and non-living factors that surround and potentially influence an organism; a particular organism's environment

Hard bottom - the floor of a water body composed of solid, consolidated substrate, including reefs and banks. The solid floor typically provides an attachment surface for sessile organisms as well as a rough three-dimensional surface that encourages water mixing and nutrient cycling.

Hedonic pricing method - estimates economic values for ecosystem or environmental services that directly affect market prices of some other good. Most commonly applied to variations in housing prices that reflect the value of local environmental attributes.

Held values - conceptual precepts and ideals held by an individual about something. Natural resource examples include the symbolic value of a bald eagle or the aesthetic value of enjoying a beautiful sunset (see assigned values).

Herbivory - the act of feeding on plants

Holdfasts - a part by which a plant clings to a flat surface

Human dimensions - an multidisciplinary/interdisciplinary area of investigation which attempts to describe, predict, understand, and affect human thought and action toward natural environments in an effort to improve natural resource and environmental stewardship. Disciplines within human dimensions research is conducted include (but are not limited to) sociology, psychology, resource economics, geography, anthropology, and political science.

Human dominant values - this end of the natural resource value continuum emphasizes the use of natural resources to meet basic human needs. These are often described as utilitarian, materialistic, consumptive or economic in nature.

Human mutual values - the polar opposite of human dominant values, this end of the natural resource value continuum emphasizes spiritual, aesthetic, and nonconsumptive values in nature

Hydric soil - a soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation; field indicators of hydric soils can include: a thick layer of decomposing plant material on the surface; the odor of rotten eggs; and colors of bluish–gray, gray, black, or sometimes gray with contrasting brighter spots of color

Hydrodynamics - the motion of water that generally corresponds to its capacity to do work such as transport sediments, erode soils, flush pore waters in sediments, fluctuate vertically, etc. Velocities can vary within each of three flow types: primarily vertical, primarily bidirectional and horizontal, and primarily unidirectional and horizontal. Vertical fluxes are driven by evapotranspiration and precipitation. Bidirectional flows are driven by astronomic tides and wind-driven seiches. Unidirectional flows are downslope movement that occurs from seepage slopes and floodplains.

Hydrogeomorphology - a branch of science (geology) that studies the movement of subsurface water through rocks, either as underground streams or percolating through porous rocks.

Hydrology - the study of the cycle of water movement on, over and through the earth's surface; the science dealing with the properties, distribution, and circulation of water

Hydroperiod - depth, duration, seasonality, and frequency of flooding

Hydrostatic pressure - the pressure water exerts at any given point when a body of water is in a still motion

Hypersaline - extremely saline, generally over 30 ppt salinity (average ocean water salinity)

Hypoxic - waters with dissolved oxygen less than 2 mg/L

IMPLAN - a micro-computer-based input-output (IO) modeling system (see Input-output model below). With IMPLAN, one can estimate 528 sector I-O models for any region consisting of one or more counties. IMPLAN includes procedures for generating multipliers and estimating impacts by applying final demand changes to the model.

Indirect impacts - the changes in sales, income or employment within the region in backward-linked industries supplying goods and services to tourism businesses. The increase in sales of linen supply firms that result from more motel sales is an indirect effect of visitor spending.

Induced impacts - the increased sales within the region from household spending of the income earned in tourism and supporting industries. Employees in tourism and supporting industries spend the income they earn from tourism on housing, utilities, groceries, and other consumer goods and services. This generates sales, income and employment throughout the region's economy.

Infauna - plants that live in the sediment

Informed consent - an ethical guideline for conducting social science research. Informed consent emphasizes the importance of both accurately informing research participants as to the nature of the research and obtaining their verbal or written consent to participate. The purpose, procedures, data collection methods and potential risks (both physical and psychological) should be clearly explained to participants without any deception.

Infralittoral - a sub-area of the sublittoral zone where upward-facing rocks are dominated by algae, mainly kelp

Input-output model (I-O) - an input-output model is a representation of the flows of economic activity between sectors within a region. The model captures what each business or sector must purchase from every other sector in order to produce a dollar's worth of goods or services. Using such a model, flows of economic activity associated with any change in spending may be traced either forwards (spending generating income which induces further spending) or backwards (visitor purchases of meals leads restaurants to purchase additional inputs -- groceries, utilities, etc.). Multipliers may be derived from an input-output models (see multipliers).

Instrumental values - the usefulness of something as a means to some desirable human end. Natural resource examples include economic and life support values associated with natural products and ecosystem functions (see non-instrumental values).

Intergenerational equity - the perceived fairness in the distribution of project costs and benefits across different generations, including future generations not born yet

Interstices - a space that intervenes between things; especially one between closely spaced things

Intertidal - alternately flooded and exposed by tides

Intrinsic values - values not assigned by humans but are inherent in the object or its relationship to other objects

Invasive species - a species that does not naturally occur in a specific area and whose introduction is likely to cause economic or environmental harm

Invertebrate - an animal with no backbone or spinal column; invertebrates include 95% of the animal kingdom

Irregularly exposed - refers to coastal wetlands with surface exposed by tides less often than daily

Lacunar - a small cavity, pit, or discontinuity

Lacustrine - pertaining to, produced by, or formed in a lake

Lagoons - a shallow stretch of seawater (or lake water) near or communicating with the sea (or lake) and partly or completely separated from it by a low, narrow, elongate strip of land

Large macroalgae - relatively shallow (less then 50 m deep) subtidal algal communities dominated by very large brown algae. Kelp and other large macroalgae grow on hard or consolidated substrates forming extensive three-dimensional structures that support numerous flora and fauna assemblages.

Large-scale commercial fishing - fishing fleets that are owned by corporations with large capital investments, and are highly mobile in their global pursuit of fish populations

Littoral - refers to the shallow water zone (less than 2 m deep) at the end of a marine water body, commonly seen in lakes or ponds

Longitudinal studies - social science research designed to permit observations over an extended period of time (see trend studies, cohort studies, and panel studies)

Macrofauna - animals that grow larger than 1 centimeter (e.g., animals exceeding 1 mm in length or sustained on a 1 mm or 0.5 mm sieve)

Macroinvertebrate - animals without backbones that can be seen with the naked eye (caught with a 1 mm^2 mesh net); includes insects, crayfish, snails, mussels, clams, fairy shrimp, etc

Macrophytes - plant species that are observed without the aid of an optical magnification e.g., vascular plants and algae

Mangroves - swamps dominated by shrubs that live between the sea and the land in areas that are inundated by tides. Mangroves thrive along protected shores with fine-grained sediments where the mean temperature during the coldest month is greater than 20º C, which limits their northern distribution.

Marine polyps - refer to the small living units of the coral that are responsible for secreting calcium carbonate maintaining coral reef shape

Market price method - estimates economic values for ecosystem products or services that are bought and sold in commercial markets

Marshes (marine and freshwater) - coastal marshes are transitional habitats between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water tidally or seasonally. Freshwater species are adapted to the short- and long-term water level fluctuations typical of freshwater ecosystems.

Mast - the nuts of forest trees accumulated on the ground

Measurement error - a type of survey error that occurs when a respondent's answer to a given question is inaccurate, imprecise, or cannot be compared to other respondent's answers

Meiofauna - diverse microorganisms that are approximately between .042 mm and 1 mm in size

Meristematic - the ability to form new cells that separate to form new tissues

Mesocosm - experimental tanks allowing studies to be performed on a smaller scale

Metadata - data that describes or provides background information on other data

Microfauna - animals that are very small and best identified with the use of a microscope, such organisms include protozoans and nematodes

Microinvertebrates - invertebrate animals that are so small they can only be observed with a microscope

Micro-topography - very slight changes in the configuration of a surface including its relief and the position of its natural and man-made features

Migratory - a creature that moves from one region to another when the seasons change

Morphology - the study of structure and form, either of biological organisms or features of the earth surface

Mottling - contrasting spots of bright colors in a soil; an indication of some oxidation or ground water level fluctuation

Mudflat - bare, flat bottoms of lakes, rivers and ponds, or coastal waters, largely filled with organic deposits, freshly exposed by a lowering of the water level; a broad expanse of muddy substrate commonly occurring in estuaries and bays

Multipliers - capture the size of the secondary effects in a given region, generally as a ratio of the total change in economic activity in the region relative to the direct change. Multipliers may be expressed as ratios of sales, income or employment, or as ratios of total income or employment changes relative to direct sales. Multipliers express the degree of interdependency between sectors in a region's economy and therefore vary considerably across regions and sectors

Nanoplankton - plankton of minute size, generally size range is from 2 to 20 micrometers

Native - an animal or plant that lives or grows naturally in a certain region

Nearshore - nearshore waters begin at the shoreline or the lakeward edge of the coastal wetlands and extend offshore to the deepest lakebed depth contour, where the thermocline typically intersects with the lake bed in late summer or early fall

Nekton - free-swimming aquatic animals (such as fish) essentially independent of wave and current action

Non-instrumental values - something that is valued for what it is; a good of its own; an end in itself. Natural resource examples include aesthetic and spiritual values found in nature (see instrumental values)

Non-market goods and services - goods and services for which no traditional market exists whereby suppliers and consumers come together and agree on a price. Many ecosystem services and environmental values fall under this category

Non-point source - a source (of any water–carried material) from a broad area, rather than from discrete points

Nonresponse error - a type of survey error that occurs when a significant proportion of the survey sample do not respond to the questionnaire and are different from those who do in a way that is important to the study

Non-use values - also called “passive use” values, or values that are not associated with actual use, or even the option to use a good or service

Norms - perceived standards of acceptable attitudes and behaviors held by a society (social norms) or by an individual (personal norms). Serve as guideposts for what is appropriate behavior in a specific situation.

Nuisance species - undesirable plants and animals, commonly exotic species

Null hypothesis - a statement about the values of one or more parameters usually describing a condition of no change or difference

Nutria - a large South American semiaquatic rodent (*Myocastor coypus*) with webbed hind feet that has been introduced into parts of Europe, Asia, and North America

Nutrient - any inorganic or organic compound that provides the nourishment needed for the survival of an organism

Nutrient cycling - the transformation of nutrients from one chemical form to another by physical, chemical, and biological processes as they are transferred from one trophic level to another and returned to the abiotic environment

Octocorals - corals with eight tentacles on each polyp. There are many different forms that may be soft, leathery, or even those producing hard skeletons.

Oligohaline - an area of an estuary with salinities between 0.5 and 5.0 ppt

Oligotrophic - a water body that is poor in nutrients. This refers mainly to lakes and ponds

One-hundred year flood - refers to the floodwater levels that would occur once in 100 years, or as a 1.0 percent probability per year

Opportunity cost - the cost incurred when an economic decision is made. This cost is equal to the benefit of the most highly valued alternative that would have been gained if a different decision had been made. For example, if a consumer has $2.00 and decides to purchase a sandwich, the economic cost may be that consumer can no longer use that money to buy fruit.

Option value - the value associated with having the option or opportunity to benefit from some resource in the future

Organic - containing carbon, but possibly also containing hydrogen, oxygen, chlorine, nitrogen, and other elements

Organic material - anything that is living or was living; in soil it is usually made up of nuts, leaves, twigs, bark, etc.

Osmotic stress - water stresses due to differences in salinity between an organism and its aquatic environment

Outdoor recreation conflict - defined as behavior of an individual or group that is incompatible with the social, psychological or physical goals of another person or group

Oyster beds - dense, highly structured communities of individual oysters growing on the shells of dead oysters

Panel studies - longitudinal research that studies the same set of people through time in order to investigate changes in individuals over time (see longitudinal studies)

Pelagic - pertaining to, or living in open water column

Personal area network (PAN) - a computer network used for communicating between computer devices (including telephones and personal digital assistants) and a person

Petiole - the stalk of a leaf, attaching it to the stem

pH - a measure of the acidity (less than 7) or alkalinity (greater than 7) of a solution; a pH of 7 is considered neutral

Phenology - refers to the life stages a plant/ algae experiences (e.g., shoot development in kelp)

Physiographic setting - the location in a landscape, such as stream headwater locations, valley bottom depression, and coastal position. Similar to geomorphic setting.

Physiography - a description of the surface features of the Earth, with an emphasis on the mode or origin

Phytoplanktivores - animals that eat planktonic small algae that flow in the water column

Phytoplankton - microscopic floating plants, mainly algae that are suspended in water bodies and are transported by wave currents because they cannot move by themselves swim effectively against a current.

Piscivorous - feeding on fish

Planktivorous - eating primarily plankton

Plankton - plant and animal organisms, generally microscopic, that float or drift in water

Pneumatocysts - known as gas bladders or floaters that help the plant stay afloat such as the bladders seen in the brown alga *Macrocystis*

Pneumatophores - specialized roots formed on several species of plants occurring frequently in inundated habitats; root is erect and protrudes above the soil surface

Polychaete - a group of chiefly marine annelid worms armed with setae, or bristles, extending from most body segments

Population - a collection of individuals of one species or mixed species making up the residents of a prescribed area

Population list - in social science survey research, this is the list from which the sample is drawn. This list should be as complete and accurate as possible and should closely reflect the target population.

ppt - parts per thousand. The salinity of ocean water is approximately 35 ppt

Precision - a statistical term that refers to the reproducibility of the result or measurement. Precision is measured by uncertainty and is usually expressed as the standard error or some confidence interval around the estimated mean.

Prop roots - long root structures that extend midway from the trunk and arch downward creating tangled branching roots above and below the water's surface, such as the mangrove *Rhizophora*

Propagules - a structure (cutting, seed, spore, rhizome, etc.) that causes the continuation or increase of a plant, by sexual or asexual reproduction

Protodeltaic - similar in form to the early stages of delta formation

Pseudofeces - material expelled by the oyster without having gone through the animal's digestive system

Quadrats - are rectangular, or square shaped instruments used to estimate density, cover and biomass of both plants and animals

Quality assurance/quality control plan - a detailed plan that describes the means of data collection, handling, formatting, storage, and public accessibility for a project

Random utility models - a non-market valuation technique that focuses on the choices or preferences of recreationists among alternative recreational sites. Particularly appropriate when substitutes are available to the individual so that the economist is measuring the value of the quality characteristics of one or more site alternatives (e.g., a fully restored coastal wetland and a degraded coastal wetland).

Receiving water bodies - lakes, estuaries, or other surface waters that have flowing water delivered to them

Recruitment - the process of adding new individuals to a population or subpopulation (as of breeding individuals) by growth, reproduction, immigration, and stocking; also a measure (as in numbers or biomass) of recruitment

Redox potential - oxidation-reduction potential; often used to quantify the degree of electrochemical reduction of wetland soils under anoxic conditions

Reference condition - set of selected measurements or conditions of minimally impaired waterbodies characteristic of a waterbody type in a region

Reference site - a minimally impaired site that is representative of the expected ecological conditions and integrity of other sites of the same type and region

Reflectance - The ratio of the light that radiates onto a surface to the amount that is reflected back

Regime - a regular pattern of occurrence or action

Reliability - the likelihood that a given measurement procedure or technique will yield the same result each time that measure is repeated (i.e., reproducibility of the result) (see Precision)

Remote sensing - the process of detecting and monitoring physical characteristics of an area by measuring its reflected and emitted radiation and without physically contacting the object

Restoration - the process of reestablishing a self-sustaining habitat that in time can come to closely resemble a natural condition in terms of structure and function

Restoration monitoring - the systematic collection and analysis of data that provides information useful for measuring restoration project performance at a variety of scales (locally, regionally, and nationally)

Rhizome - somewhat elongate usually horizontal subterranean plant stem that is often thickened by deposits of reserve food material, produces shoots above and roots below, and is distinguished from a true root in possessing buds, nodes, and usually scale-like leaves

Riparian - a form of wetland transition between permanently saturated wetlands and upland areas. These areas exhibit vegetation or physical characteristics reflective of permanent surface of subsurface water influence. Lands along, adjacent to, or contiguous with perennially and intermittently flowing rivers and streams, glacial potholes, and the shores of lakes and reservoirs with stable water levels are typically riparian areas. Excluded are such sites as ephemeral streams or washes that do not exhibit the presence of vegetation dependent upon free water in the soil.

Riverine - of, or associated with rivers

Riverine forests - forests found along sluggish streams, drainage depressions, and in large alluvial floodplains. Although associated with deepwater swamps in the SE United States, riverine forests are found throughout the US and do not exhibit prolonged flooding.

Rocky shoreline - extensive hard bottom littoral habitats on wave-exposed coasts

RVD (recreational visitor day) - one RVD is defined as 12 hours of use in some recreational activity. This could be one person using an area for 12 hours, or 2 people using an area for 6 hours each, or any combination of people and time adding to 12 hours of use.

Salinity - the concentration of dissolved salts in a body of water; commonly expressed as parts per thousand

Salt pans - an undrained natural depression in which water gathers and leaves a deposit of salt on evaporation

Sample - in social science survey research, this is a set of respondents selected from a larger population for the purpose of a survey

Sampling designs - the procedure for selecting samples from a population and the subsequent statistical analysis

Sampling error - a potential source of survey error that can occur when researchers survey only a subset or sample of all people in the population instead of conducting a census. To minimize this error the sample should be as representative of the population as possible.

Satisfaction - in outdoor recreation, satisfaction is defined as the difference between desired and achieved goals. Can be measured through surveys of recreation participants.

SAV (submerged aquatic vegetation) - marine, brackish, and freshwater submerged aquatic vegetation that grows on soft sediments in sheltered shallow waters of estuaries, bays, lagoons, and lakes

Seasonality - the change in naturally cycles, such as lunar cycles and flooding cycles, from one season to the next

Secondary data - information that has already been assembled, having been collected for some other purpose. Sources include census reports, state and federal agency data, and university research.

Secondary effects - the changes in economic activity from subsequent rounds of re-spending of tourism dollars. There are two types of secondary effects: indirect effects and induced effects.

Sector - a grouping of industries that produce similar products or services. Most economic reporting and models in the U.S. are based on the Standard Industrial Classification system (SIC code). Tourism is more an activity or type of customer than an industrial sector. While hotels (SIC 70) are a relatively pure tourism sector, restaurants, retail establishments and amusements sell to both tourists and local customers. There is therefore no simple way to identify tourism sales in the existing economic reporting systems, which is why visitor surveys are required to estimate tourist spending.

Sediment porewater - water in the spaces between individual grains of sediment

Seiches - a sudden oscillation of the water in a moderate-size body of water, caused by wind

Seine - a net weighted at the bottom with floats at the top so it remains vertical in the water. A seine can be towed behind a boat or smaller versions, attached to poles, may be operated by hand.

Senescence - the growth phase in a plant or plant part (as a leaf) from full maturity to death, also applies to winter dormancy

Sessile - plants that are permanently attached or established; animals that do not freely move about

Simple random sampling (SRS) - in survey research, when each member of the target population has an equal change of being selected. If a population list exists, SRS can be achieved using a computer-generated random numbers.

Small-scale commercial fishing - fishing operations that have relatively small capital investment and levels of production, and are more limited in terms of mobility and resource options (compared to large-scale operations). Terms that are commonly used to describe small-scale fishermen include native, coastal, inshore, tribal, peasant, artisanal, and traditional.

Social capital - describes the internal social and cultural coherence of society, the norms and values that govern interactions among people and the institutions in which they are embedded

Social impact assessment (SIA) - analysis conducted to assess, in advance, the social consequences that are likely to follow from specific policy actions and alternatives. Social impacts in this context refers to the consequences to human populations that alter the ways in which people live, work, play, relate to one another, organize and generally cope as members of society.

Social network mapping - community assessment research method used to collect, analyze, and graphically represent data that describe patterns of communication and relationships within a community

Socioeconomic monitoring - tracking of key indicators that characterize the economic and social state of a community

Soft bottom - loose, unconsolidated substrate characterized by fine to coarse-grained sediment

Soft shoreline - sand beaches, dunes, and muddy shores. Sandy beaches are stretches of land covered by loose material (sand), exposed to and shaped by waves and wind.

Stakeholders - individuals, groups, or sectors that have a direct interest in and/or are impacted by the use and management of natural resources in a particular area, or that have responsibility for management of those resources

Statistical protocol - a method of a analyzing a collection of observed values to make an inference about one or more characteristic of a population or unit

Strands - a diffuse freshwater stream flowing through a shallow vegetated depression on a gentle slope

Structural habitat characteristics - characteristics that define the physical composition of a habitat

Subsistence - describes the customary and traditional uses of renewable resources (i.e., food, shelter, clothing, fuel) for direct personal/family consumption, sharing with other community members, or for barter. Subsistence communities are often held together by patterns of natural resource production, distribution, exchange, and consumption that helps maintain a complex web of social relations involving authority, respect, wealth, obligation, status, power and security.

Subtidal - continuously submerged; an area affected by ocean tides

Supralittoral region - is that area which is above the high tide mark receiving splashing from waves

Target population - the subset of people who are the focus of a survey research project

Taxa - a grouping of organisms given a formal taxonomic name such as species, genus, family, etc. (singular form is taxon)

Temporal - over time

Thermocline - the region in a thermally stratified body of water which separates warmer oxygen-rich surface water from cold oxygen-poor deep water and in which temperature decreases rapidly with depth

Tide - the rhythmic, alternate rise and fall of the surface (or water level) of the ocean, and connected bodies of water, occurring twice a day over most of the Earth, resulting from the gravitational attraction of the Moon, and to a lesser degree, the Sun

Topography - the general configuration of a land surface or any part of the Earth's surface, including its relief and the position of its natural and man–made features

Transect - two types of transects, point and line. Point intercept transect methods is performed by placing a point frame along a set of transect lines. Line transects are when a line is extended from one point to the next within the designated sample area

Transient - passing through or by a place with only a brief stay or sojourn

Transit - a surveying instrument for measuring horizontal and vertical angles; appropriate to help determine actual location of whale surfacing. It contains a small telescope that is placed on top of a tripod.

Travel cost method (TCM) - TCM is used to estimate monetary value of a geographical site in its current condition (i.e., environmental health, recreational use capacity, etc.) by site-users. Individuals or groups report travel-related expenditures made while on trips to single and multiple recreational sites. Market values are used.

Trend studies - longitudinal research that studies changes within some general population over time (see longitudinal studies)

Trophic - refers to food, nutrition, or growth state

Trophic level - a group of organisms united by obtaining their energy from the same part of the food web of a biological community

Turf - cover (the ground) with a surface layer of grass or grass roots

Unconsolidated - loosely arranged

Utilitarian value - valuing some object for its usefulness in meeting certain basic human needs (e.g., food, shelter, clothing). Also see human-dominant values

Validity - refers to how close to a true or accepted value a measurement lies

Vibracore - refers to a high frequency, low amplitude vibration, coring technique used for collecting sediment samples without disrobing the sample

Viviparous - producing living young instead of eggs from within the body in the manner of nearly all mammals, many reptiles, and a few fishes; germinating while still attached to the parent plant

Water column - a conceptual volume of water extending from the water surface down to, but not including the substrate. It is found in marine, estuarine, river, and lacustrine systems.

Watershed - surface drainage area that contributes water to a lake, river, or other body of water; the land area drained by a river or stream

Willingness-to-pay - the amount in goods, services, or dollars that a person is willing to give up to get a particular good or service

Zonation - a state or condition that is marked with bands of color, texture, or plant species

Zooplanktivorus - animals that feed upon zooplankton

Zooplankton - free-floating animals that drift in the water, range from microscopic organisms to larger animals such as jellyfish

References

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