NATIONAL COASTAL ECOSYSTEM

RESTORATION MANUAL

Sea Grant
Oregon

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Watershed Stewardship: A Learning Guide—Oregon State University Extension Miscellaneous 8714 (Oregon State University, Corvallis), new July 1998, revised January 2000 (revised January 2002), 485 pages, $42.00— was written "to help residents and volunteers be good stewards of their watershed." Its focus is on all salmonids west of the Cascades.

The *National Coastal Ecosystem Restoration Manual,* by contrast, is intended for a national audience and addresses a variety of species. Furthermore, it includes case studies of successful restoration projects from across the nation. We ask that the information in this book be used for noncommercial purposes.

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CHAPTER THIRTEEN

Restoring Wetlands in Your Watershed

by Jim Good

Well-functioning wetlands are vital components of healthy watersheds. They absorb flood waters, remove excess sediment and nutrients, and help maintain base streamflow. Where these and other functions are degraded, wetland restoration and enhancement can contribute greatly to recovery of fisheries and other valued aquatic life.

Wetlands are found in many locations where the soil is saturated and other conditions are right to support their development (figure 1). Typical locations include

- Along rivers and streams
- In depressions on floodplains and at higher elevations
- On hill slopes where water seeps out of the ground
- Along the shores of lakes and estuaries

Wetlands perform many valuable functions that contribute to watershed health. For example, they help to purify runoff water, reduce flood damage by temporarily storing water, supplement streamflows through gradual release of this stored water, and provide habitat for aquatic species, fish, wildlife, and pollinators.

In this chapter you'll learn

- How wetlands are defined and identified
- The principal functions and services that wetlands perform
- Actions that can improve specific wetland functions
- How different kinds of wetlands are classified
- How to obtain and use National Wetlands Inventory maps, local wetland inventories, soil surveys, and other wetland information
- The basics of several methods for classifying and assessing wetland functions

If you look around, you can see many wetlands in your area that have suffered from neglect or changes in the landscape—roads that interrupt drainage patterns, dirt fill over wetlands to provide building sites, and stream diversions that cut off the water supply to wetlands. These changes greatly diminish the watershed support functions of these wetlands. With increased care and attention, however, some degraded wetlands can be rehabilitated, thereby increasing their capacity to support fish, wildlife, and human needs.

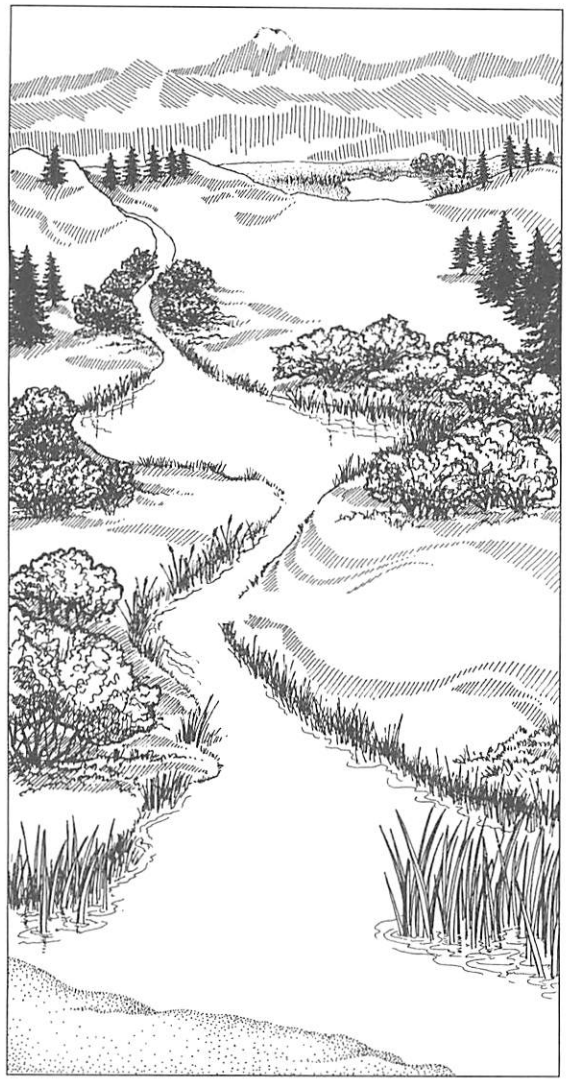

Figure 1. Wetlands are found throughout the watershed.

According to U.S. Fish and Wildlife Service reports, approximately half of the original wetlands in the lower 48 states have been altered or converted to other uses since Euro-Americans arrived. At least 10 coastal states have lost more than 50 percent of their wetlands statewide, led by California (91 percent), Connecticut (74 percent), Maryland (73 percent), and New York (60 percent). Many of the remaining wetlands have been degraded and no longer function as they should. Some of these former and degraded wetlands could be restored or enhanced to help restore fisheries, improve water quality, and contribute to flood control. Identifying wetland restoration and enhancement potential thus is an important part of watershed action planning.

What is a Wetland?

wet·land (wet′ land′), n. Often **wetlands,** land that has a wet or spongy soil, as a marsh, swamp, or bog. (*Random House Unabridged Dictionary*, 1993)

Marshes, swamps, bogs, fens, sloughs, and wet meadows are some of the more common names for particular kinds of wetlands. These terms and the definition above conjure an image of ecosystems that aren't quite aquatic and aren't quite terrestrial. In other words, they are "transitional." The freshwater swamps of coastal South Carolina are a good example of this transitional nature of wetlands (figure 2).

Many wetlands fit this image of being part of a continuum between upland and open water ecosystems. Other wetlands, however, are isolated from open-water habitats and are maintained purely by groundwater and precipitation.

So is there an accepted scientific definition of wetland that covers all types? The answer is yes. To understand these definitions, you need to know three key terms—hydric soil, wetland hydrology, and hydrophyte.

Hydric soil is soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper layer. *Anaerobic* means there is no oxygen in the soil. This condition occurs when water fills all of the pore spaces in the soil, leaving no room for oxygen. Indicators of anaerobic conditions that can be observed in the field include washed-out and mottled colors.

Wetland hydrology recognizes that the conditions that support wetlands and form hydric soils range from permanently inundated to seasonally saturated. At minimum, saturation is required within 12 inches of the surface during approximately two weeks of the growing season to meet the hydrology criteria as a jurisdictional wetland subject to regulation by the U.S. Army Corps of Engineers.

A *hydrophyte* is any plant growing in water or in soil that is at least periodically deficient in oxygen as a result of excess water. Hydrophytic also can mean plants typically found in wetland habitats. The U.S. Fish and Wildlife Service has developed a list of plants found in and near wetlands.

A well-accepted comprehensive definition of wetlands was developed in 1995 by the National Research Council:

A wetland is an ecosystem characterized by sustained or recurrent shallow

Figure 2. This bottomland hardwood forest in South Carolina has all three features of wetlands—hydric soil, hydrology, and hydrophytes. (Photo: Jim Good)

inundation or saturation at or near the surface of the substrate and the presence of physical, chemical, and biological features reflective of such inundation or saturation. Common diagnostic features of wetlands are hydric soils and hydrophytic vegetation. These features will be present except where specific physical, chemical, biotic, or human factors have removed them or prevented their development.

In other words, a wetland typically has hydric soils and hydrophytic plants, unless it has been disturbed by humans.

Another definition that is very important if you plan to do wetland restoration projects is the regulatory definition. This definition is used by the U.S. Army Corps of Engineers and most states in their regulatory programs:

> Wetlands are those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted to life in saturated soil conditions.

Three features of wetlands are common to these and most definitions:

- Water sufficient to cause saturation of the upper layers of soil for at least two weeks during the growing season
- Soils typical of saturated or ponded areas
- Plants that can tolerate such conditions

Detailed criteria for identifying upland-wetland boundaries for regulatory purposes are described in the U.S. Army Corps of Engineers' 1987 *Wetland Delineation Manual.* These criteria also are used by most other state and federal agencies. Most of the time, however, a formal delineation of wetland boundaries isn't required for nonregulatory wetland restoration or enhancement projects.

An Overview of Wetland Functions

Wetlands often are ecological "hot spots," playing a role disproportionate to their size in supporting endangered species and maintaining biodiversity. Wetlands play other roles too; they help remove excess nutrients and other contaminants from water, store flood waters, release water during low flow periods, and provide food and shelter for salmon, trout, other animals, and pollinators.

All of these roles are known as *wetland functions.* You might think of them as the services that wetlands provide to watersheds and the plants, animals, and people who live there. Although there are many ways to group and describe wetland functions, we will divide them into four categories:

- *Water-quality* functions
- *Hydrologic,* or water-flow, functions
- *Habitat and food web* functions
- *Cultural and social* functions

A variety of wetland functions within each of these four categories are discussed in this chapter. We'll describe why each function is important to watershed health, and how wetlands contribute to the function.

Note that these functions may not be unique to wetlands. Streams, lakes, riparian areas, and upland habitats also contribute to many of these functions. Although we separate watersheds into parts for analysis, the parts themselves and the functions they perform are interconnected. Thus, our analyses also must be interconnected.

Improving Wetland Functions

There are three basic kinds of wetland improvement projects—creation, enhancement, and restoration. *Wetland creation* involves the construction of a wetland at a site where no wetland has existed in the past 100–200 years (figure 3). It may take a lot of landscape manipulation or maintenance to develop and maintain such a wetland.

Wetland enhancement involves the alteration, maintenance, or management of existing wetlands for long-term improvement of particular functions or services. In many cases, by choosing to enhance certain functions, you may diminish a wetland's ability to perform other functions or services.

Wetland restoration is the return of a former or degraded wetland to a close approximation of a previous higher functioning state. *Former wetlands* are areas that once were wetlands, but now are nonwetland. *Degraded wetlands* are those that have been damaged but still perform some wetland functions (figure 4).

In restoration, both the structure and the functions of the ecosystem are recreated, and ecological damage is repaired. The goal is to recreate a natural, functioning system that is integrated into the surrounding ecological landscape (figure 5).

Figure 3. Wetland creation projects, even in urban settings like this one next to a shopping center, help reestablish some of the functions of stream and wetland corridors important to fish and wildlife. (Photo: Jim Good)

Wetland enhancement generally aims to improve a specific wetland function. The following discussion suggests some actions you might take to identify potential wetland enhancement projects, depending on your assessment of wetlands in your watershed and the functions you want to improve. At the end of this chapter, several case studies are presented that illustrate how different communities and watershed groups are restoring and enhancing wetlands.

Understanding Wetland Functions

Sixteen wetland functions are outlined below. For each, the importance of the function and contributions of wetlands to it are described. Note that there is considerable overlap among some of the functions described. In part, that is the result of the interconnectedness of the things we as humans value about wetlands.

Figure 4. These farmed fields are an example of degraded but still functioning wetlands with good restoration potential. (Photo: Jim Good)

As a result, the functions described are easily matched up to goals that watershed and community groups might have. For example, lowering nutrient concentrations in surface waters flowing into a wetland might be the goal of a wetland enhancement project (see function 4).

Water-quality functions

Function 1—Maintaining water temperature

Why important: High water temperature can limit a stream's habitat value for fish and wildlife. High temperature can decrease fish survival, encourage the growth of disease-causing organisms and undesirable algae, and reduce dissolved oxygen concentration.

Weather, volume of streamflow, streamside vegetation, flows to and from groundwater, and water released from industrial plants can influence stream temperature. Solar heating is the major cause of increased water temperature.

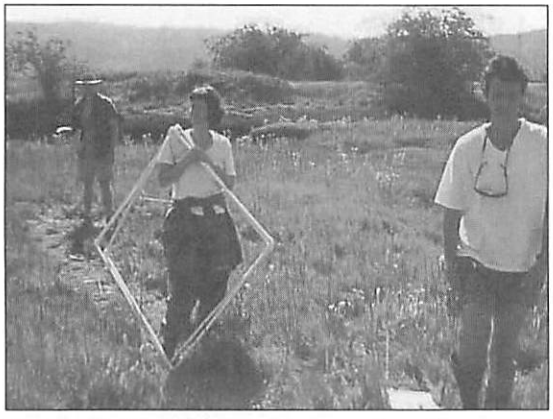

Figure 5. Periodic monitoring of wetland restoration projects is necessary to judge progress toward goals and to implement needed corrective measures. (Photo: U.S. Fish and Wildlife Service)

How wetlands contribute: Wetlands can help maintain desirable stream temperatures. In summer, wetlands discharge cool groundwater into streams. In winter, wetlands receiving substantial groundwater discharge may maintain ice-free conditions, which are required by wintering waterfowl. Riparian vegetation also can play an important role in shading streams from solar heating.

Function 2—Reducing bacterial concentration

Why important: Many *pathogenic* (disease-causing) intestinal bacteria pose a substantial health risk to humans. Fecal coliform bacteria *(Escherichia coli)* are used as a general indicator of the presence of this group of bacteria. The presence of these indicator organisms represents a strong possibility of the presence of pathogenic bacteria that threaten public health. Reduction of these bacteria in aquatic systems makes it safe for humans to use water and eat shellfish from the water.

Intestinal bacteria come from human and animal waste. For example, bacteria may enter streams from septic tank failure, poor pasture and livestock management, city sewage, pet wastes, urban runoff, and sewage from storm-water overflows.

How wetlands contribute: Wetlands can retain and destroy intestinal bacteria. Wetland size, location, water source, and volume of inflow are key factors in

determining how well a wetland performs this function. For example, wetlands constructed for wastewater treatment can assist with this function. A healthy riparian area also can play an important role by filtering runoff.

Function 3—Capturing sediment

Why important: Excess suspended sediments can cause many problems in streams. For example, they

- Reduce stream channel capacity
- Transport bacteria and pollutants
- Fill gravel spaces, thus smothering eggs and juvenile fish
- Reduce algal growth
- Reduce fish feeding and growth
- Reduce dissolved oxygen concentrations
- Bury benthic (bottom-dwelling) organisms

Many human activities can increase suspended sediments, including timber harvest and related road development, construction-related earth moving, poor pasture or cropland management, and building of dikes. Loss of instream large woody debris, which often is caused by human activity, also reduces a stream's ability to store sediment.

How wetlands contribute: Wetlands can reduce the amount of suspended sediments in streams. Some wetlands capture and keep sediments from reaching a stream, whereas others alongside channels capture sediments that already have entered a stream system. The flow of sediment-bearing runoff slows down when it enters a wetland, allowing suspended sediment to drop out of the water before entering a stream. Wetland creation for sediment removal is a challenge in areas where land-use practices create large pulses of sediments.

Function 4—Removing and Transforming nutrients

Why important: Nitrogen and phosphorus are essential nutrients for all aquatic systems. Each ecosystem has its own level of nutrient inputs and outputs. When inputs and outputs change, problems can occur. For example, excess phosphorus can cause lake eutrophication or algal blooms. Too much nitrogen in the form of nitrate also can cause problems, including fish habitat degradation, excess plant and algae growth, and reduced concentration of dissolved oxygen.

Human activities can substantially increase nutrient inputs to stream systems, thus changing the ecosystem. Instream increases in nitrogen and phosphorus can come from agricultural and residential fertilizers, detergents, cleaning products, sewage, septic tank effluent, food residues, soil erosion, and decomposing vegetation.

How wetlands contribute: Wetlands can retain nutrients and change them into less harmful forms. For example, they can convert inorganic nutrients to their organic forms, which don't move as easily in water so are less likely to end up in streams. They also can change nitrate nitrogen into gaseous nitrogen through a process known as *denitrification.* Nitrogen gas then can

escape harmlessly into the air. By keeping excess nutrients out of streams, wetlands help maintain fish habitat, dissolved oxygen levels, and nitrogen balance, while reducing algae blooms.

Function 5—Improving groundwater quality

Why important: In many areas, domestic water supplies are taken from groundwater *aquifers.* Aquifers are resupplied with groundwater as water percolates downward in *groundwater recharge areas.* The greatest potential for groundwater recharge occurs within *alluvial outwash deposits* (areas where flooding has deposited sediment).

Human activities within groundwater recharge areas can diminish groundwater quality and quantity. Drinking water contaminated with nitrate at levels above 10 mg/l can cause infant sickness or, in extreme cases, death. Threats to groundwater quality come from commercial and industrial development, concentrated dairy farming, and the use of agricultural chemicals within recharge areas.

How wetlands contribute: Wetlands in groundwater recharge areas can capture and retain nitrate-nitrogen from overland flows before it percolates downward into groundwater aquifers. Wetlands can store and release nitrate seasonally or retain it for a long time. How effective a wetland is in playing this role depends on how long the water and nitrate are retained, the level of dissolved oxygen, and how much of the nitrogen is converted to gas.

Hydrologic or water-flow functions

Function 6—Storing high flows and reducing peak flows

Why important: Flooding can result in property damage, soil erosion, increased bed load movement, loss of fish redds (nests) and stream habitat, increased sediment, invasion by nonnative plants, and stream channel erosion.

Runoff volume is related to human development. For example, hard surfaces such as pavement don't let water enter the soil. Soils that have been compacted by heavy equipment don't let water percolate very well. In these soils, plants also have a hard time taking up water and transferring it to the air through transpiration. Furthermore, water flowing just beneath the soil surface becomes surface runoff when road cuts send it into road ditches. Thus, development, soil disturbance, timberland conversion, timber harvest, and slope alterations within the watershed all can increase the intensity of high flow or flood events.

How wetlands contribute: Wetlands can store waters that otherwise would intensify downstream high flows. In concert with other floodplain management activities, wetland restoration can reduce property damage, crop loss, and soil erosion by minimizing the effects of current and future development.

Function 7—Maintaining streamflow

Why important: Base flow is groundwater discharge and detained storm water that contributes to streamflow during periods of little or no direct precipitation. To function properly, a stream needs a minimum base flow. When flows drop below this rate, the stream is more susceptible to temperature increases and pollution from industrial, municipal, and agricultural wastes. Low flows also can obstruct fish passage to available habitat or can change habitat conditions.

Human activities have substantially altered both the timing and extent of surface and groundwater inputs to many streams by decreasing groundwater recharge and increasing overland flows. The result in many cases is reduced base flows.

Examples of factors that reduce base flows include

- Draining of bottomland and depressions with seasonally high water tables
- Shallow excavations (e.g., road cuts) on well-drained soils, which intercept subsurface flows and convert them to overland flows
- Groundwater withdrawals for irrigation or domestic use
- Increased runoff resulting from forest conversion to agricultural or residential use
- The increase of hard surface areas

How wetlands contribute: Wetlands can help regulate the release of groundwater into streams and can recharge the aquifers that discharge groundwater to streams.

Function 8—Recharging groundwater

Why important: Groundwater is an important water source for domestic use. The opportunity for surface water to recharge an underlying aquifer system depends largely on several physical conditions that don't change very much, including soil permeability, type of rock the surface soil was derived from, depth to water table, and topography. However, human activities often change these physical conditions so that less surface water recharges aquifers. Examples of factors that increase surface water runoff and reduce recharge potential include

- Wetland drainage
- Forest clearing
- Soil compaction from agricultural activities, residential development, and other landscape-altering activities
- Road cuts that intercept groundwater and bring it to the surface
- Hard-surface barriers such as roads, parking lots, and roofs
- Incorrect riparian conversions that damage fragile streamside wetland areas

How wetlands contribute: Within groundwater recharge areas, wetlands capture and hold water that otherwise might become surface runoff, thus allowing it to move downward into groundwater aquifers.

Function 9—Stabilizing shoreline

Why important: Erosion caused by waves, currents, tides, or ice can cause substantial

shoreline property damage, loss of fish and wildlife habitat, and increased turbidity (cloudiness of water).

How wetlands contribute: Wetlands serve as a buffer between open water and upland areas. Wetland plants stabilize shorelines by binding soil at the water's edge, thus making the soil less susceptible to erosion. Wetlands, therefore, protect beaches, stream edges, property, and ecosystems from erosion.

Habitat and food web support functions

Function 10—Contributing to the diversity and abundance of fish

Why important: Development and land-use change have had a significant negative impact on fish habitat. While each river system is unique in the type and amount of habitat it has lost, fish habitat degradation has occurred throughout the United States. Timber harvest, agricultural activities, residential development, and other activities have altered wetlands, riparian areas, and floodplains. As a result, there is less food, spawning gravel, and refuge for anadromous (migratory) and resident fish. Some of the biggest problems include

- Loss of channel structure
- Sedimentation in the upper watershed
- Loss of riparian trees, plants, and large organic debris
- High stream temperatures and low water quality
- Blocked access to wetland habitats
- Excessive sediment in the estuary
- Increased flooding frequency and intensity
- Loss of estuarine wetlands
- Tide gate and culvert passage problems
- Low summer flows
- Loss of winter cover
- Excessive bed load
- Degradation of nearshore habitat
- Scouring of spawning habitat
- Incorrect riparian conversion schemes that damage instream habitat

Damage to wetlands has contributed to these problems. The loss of wetland and riparian habitat, along with other factors, has increased flows and frequency, sediment inputs, water temperature, and barriers to fish passage. The same factors have reduced stream base flows and stream habitat diversity.

How wetlands contribute: Wetlands help maintain cool water temperatures, retain sediments, store high flows, augment stream base flows, and provide food and cover for fish.

Along with these broad watershed-level contributions to fish habitat, some wetlands may play other specific roles. For example, juvenile salmon survive high streamflows during winter by using small tributary wetlands as winter habitat. In these cases, the best way to improve coho smolt production may be to restore side-channel and slough wetlands (figure 6).

Function 11—Contributing to the diversity and abundance of migratory water birds

Why important: Many migratory water birds have recreational and economic importance to humans. Extensive agricultural, industrial, and residential development within estuaries and river floodplains has destroyed or disturbed water bird wintering and migration habitat. As a result, birds are forced to seek alternative habitats. As birds are crowded into smaller areas, they must compete for limited food and space, and they're more exposed to predators, adverse weather, and disease.

In some cases, however, human activities create new habitats. Many waterfowl species, in particular, have adapted to new habitat opportunities. For example, farming practices in Oregon's Willamette Valley now provide abundant, readily available winter food that didn't exist before the area was cleared for agriculture. Some waterfowl that traditionally wintered in the central valley of California now winter in this area. On the other hand, many migratory shorebirds and wading birds haven't been able to adapt when confronted with a loss or change in their habitat.

How wetlands contribute: Wetlands provide important migration and wintering habitat for migratory water birds (figure 7). Restoring degraded wetlands where there is a shortage of habitat can help stabilize and, in some cases, increase populations. The conversion of forested wetlands to emergent/open water wetlands also can create new wintering, migration, and production habitat for some migratory water bird species, although it may degrade habitat for others.

Figure 6. Restoration of streamside habitat can provide additional areas for fish spawning and rearing. (Photo: Jim Good)

Function 12—Providing aquatic diversity and abundance

Why important: Both direct and indirect impacts,

such as changing patterns of water movement, land-use change, and habitat fragmentation, adversely affect native plant and animal communities. As wetlands are disturbed, the *number* of species may increase or decrease, but *complexity* usually decreases as nonnative species tend to invade and dominate.

How wetlands contribute: Healthy wetlands support a wide variety of native plant and animal communities. Thus, by reestablishing near-natural conditions, wetland restoration can restore the richness and abundance of native species. This process takes time, though. Once the natural water cycle is reestablished, it can take years to recreate the conditions most suited for native plants and animals.

Figure 7. Wetlands provide important resting and feeding areas for migratory waterfowl. (Photo: U.S. Fish and Wildlife Service)

Function 13—Rare, threatened, and endangered species diversity and abundance

Why important: Natural systems are made up of many related parts that are in a constantly changing state of balance (*equilibrium*). The loss of species diversity and abundance alters this equilibrium and the food chain it supports, thereby affecting many other species.

As species are lost, humans lose opportunities to find solutions to medical, agricultural, and industrial problems. Species loss is important in another way: it's a good indicator of how well or poorly we take care of our environment.

The exact causes of species declines are complex and not fully understood. We do know that species declines and extinction result from both human impacts and climate change. Some of the problems caused by humans are habitat destruction, poisoning from pesticides, competition from nonnative species, and indiscriminate killing and overharvest.

How wetlands contribute: Wetlands provide habitat for many rare, threatened, or endangered plants

and animals. The restoration of wetlands close to populations of these species can provide opportunities for them to relocate or expand their range.

Function 14—Food web support

Why important: Within a watershed or basin, there is a food web consisting of producers, consumers, and decomposers. Organic matter that reaches a stream system is eaten by fish and aquatic invertebrates, which in turn are eaten by predators.

How wetlands contribute: Wetlands are highly productive biological systems. *Food web support* is the production of organic material and its movement out of a wetland to areas downstream where it provides food for many fish and wildlife species. Thus, loss of wetland areas can adversely affect fish and wildlife that depend on these food sources.

Cultural and social functions

Function 15—Recreation

Why important: As our population grows and prospers, interest in outdoor activities increases. At the same time, nature-centered recreational opportunities continue to be pushed farther from city centers as development spreads into previously "undeveloped" land. As a result, outdoor recreational opportunities become less accessible. Increasing development and population also cause more pollution in areas used for recreation.

How wetlands contribute: Fishing, hunting, shellfish gathering, swimming, kayaking, boating, sightseeing, bird watching, and nature photography are just some of the recreational opportunities that wetlands provide. The restoration of wetlands and provision for public access provide new opportunities for recreation (figure 8).

Function 16—Outdoor education

Why important: The use of outdoor classroom settings has increased substantially as educators recognize the benefits of allowing students to explore and test what they learn in the classroom (figure 9). Opportunities to use an outdoor

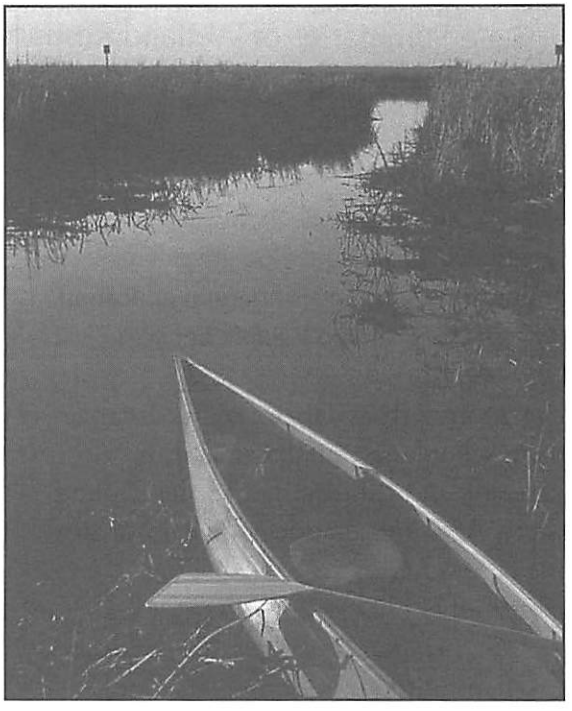

Figure 8. In addition to their ecological functions, wetlands are also valued as recreational resources. (Photo: U.S. Geological Survey)

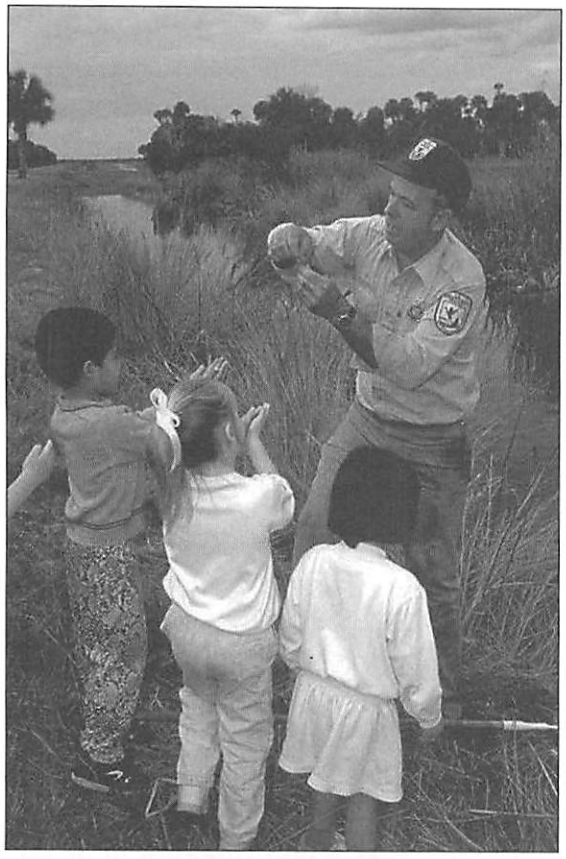

Figure 9. Wetlands provide abundant opportunities for environmental education. (Photo: U.S. Fish and Wildlife Service)

classroom setting depend on its distance from school, ease of access, and the diversity and condition of habitats found there. Activities that degrade natural areas mean fewer areas are available for educational use.

How wetlands contribute: Wetlands are excellent outdoor education classrooms because of the diversity of plants and animals that live there and because of their combination of aquatic, transitional, and terrestrial environments.

Classifying and mapping wetlands for inventory and management

The National Wetlands Inventory and the Cowardin classification system

The most widely available and comprehensive wetlands information in the United States is the U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI). But the NWI does more than locate and classify wetlands by type. It also maps the entire aquatic ecosystem network—rivers, lakes, streams, estuaries, and wetlands. NWI maps contain information on the location of these features in the watershed, vegetation class or subclass, morphology, and water flow. Thus, the NWI is a useful starting point for evaluating restoration opportunities for all aquatic ecosystems, not just for wetlands. It also is useful for planning at a watershed or subwatershed level. The NWI wasn't developed for use in regulatory programs, although it has proved useful as an initial indicator of the presence of wetlands.

The NWI is based on the *Cowardin classification system*, which was published as the *Classification for Wetland and Deepwater Habitats of the United States* in 1979 (see "Resources"). This system is the most widely used wetland classification system in the United States. It has four objectives:

- To describe ecological units whose natural attributes are fairly homogenous
- To arrange these units in a system that will help people make decisions about resource management
- To provide information for inventory and mapping

- To create standard concepts and terminology for use in classifying aquatic ecosystems

An electronic version of the *Classification for Wetland and Deepwater Habitats of the United States* is available on the World Wide Web at http://www.npwrc.usgs.gov/resource/1998/classwet/classwet.htm.

The Cowardin system includes five major *systems:* Palustrine (marshes), Lacustrine (lakes), Estuarine (estuaries), Riverine (rivers), and Marine (ocean). These systems are divided into *subsystems,* which reflect water flow regimes. Finally, the subsystems are divided into many different *classes* (figure 10). If site data are available, users also can include information on plants, water chemistry, soil types, wetland origin, and other site-specific factors. NWI maps use codes to convey all of this information (figure 11).

The Cowardin system classifies wetlands by structural vegetative characteristics such as forest or meadow. It's easy to identify these characteristics through aerial photos.

A major weakness of the Cowardin system and the NWI is that the descriptors of mapped units often don't relate consistently to ecosystem functions. Because of the system's reliance on plant types as identifying criteria, wetlands that function very differently often are grouped into the same Cowardin class simply because they have the same vegetation.

Nevertheless, because the NWI is the only universally available data, people try to identify wetland functions from NWI maps and descriptors. Often, scientists create hybrid systems that use both NWI data and other information.

NWI maps are available for virtually all areas in the United States and are a good place to start for local citizens interested in identifying wetland areas in their communities or watersheds. More detailed wetland inventories are also available in many states and localities. Consult with your state wetland management agency or city or county government to see what other kinds of wetland maps are available.

Hydrogeomorphic classification

The *hydrogeomorphic* (HGM) wetland classification does address differences in wetland functions. This system is under development in many parts of the United States and will use three criteria for classifying a wetland—its *geomorphology* (where a wetland is positioned in the landscape), its *water source* (precipitation, surface water, or groundwater), and its *hydrodynamics* (how water moves through it). There are seven general wetland classes in the HGM system (table 1).

The strength of HGM is that variations in these hydrogeomorphic properties are directly related to the ecological functions of wetlands. Wetlands also will be evaluated in comparison to regional reference sites that are established by agencies during the process of developing the HGM for a particular state or region. However, the HGM classification system isn't intended to replace other wetland classification systems such as the NWI's

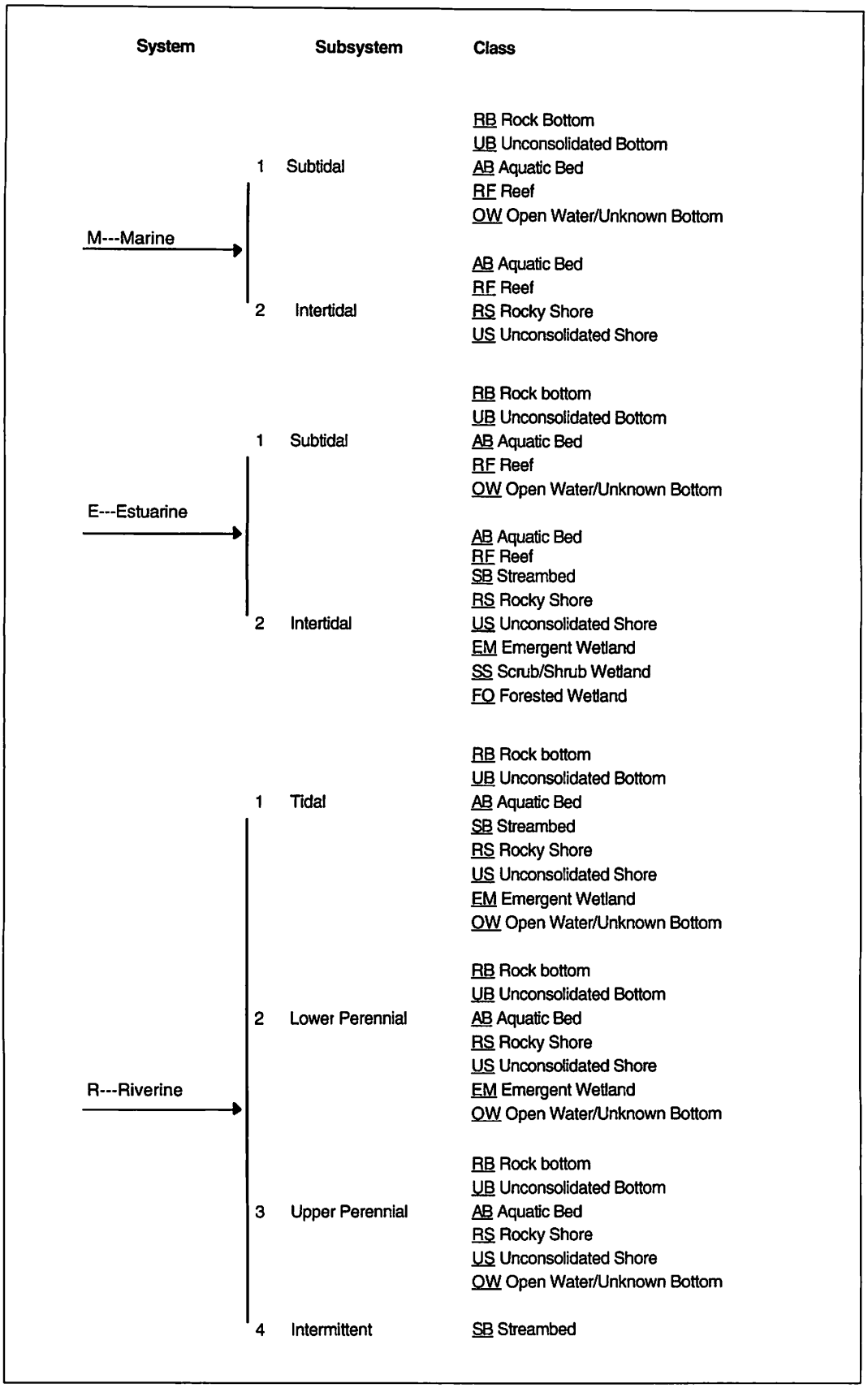

Figure 10. Cowardin wetland classification system, showing systems, subsystems, and classes (continued on next page).

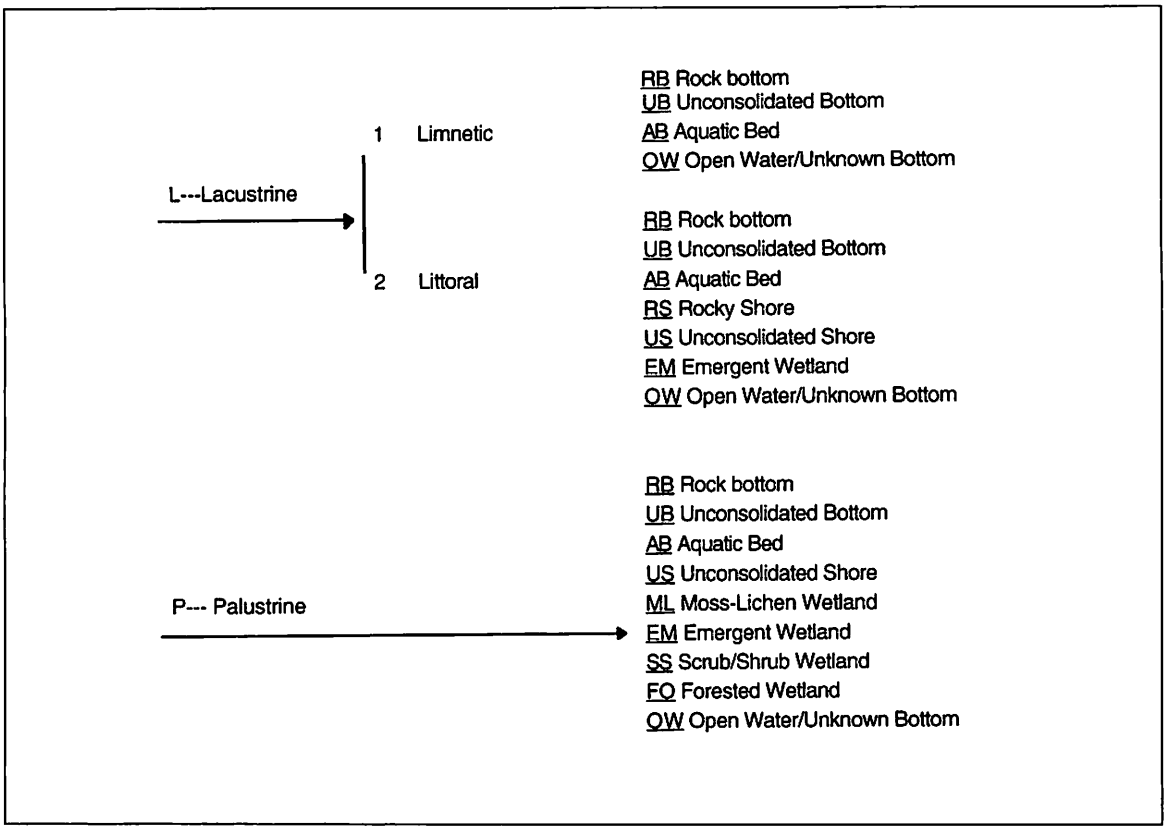

Figure 10 (continued). Cowardin wetland classification system, showing systems, subsystems, and classes.

Cowardin system. Both systems are useful in wetlands management. More on using HGM for wetland assessment is included in the following section.

Assessing Wetland Functions

Wetlands provide many benefits because of their functions. Therefore, it is important to evaluate each wetland from a functional point of view. What functions does it or could it perform, and how well is it performing them? This kind of evaluation is called a *wetland functional assessment.*

One of the frequent criticisms of wetland management and regulation is that all wetlands are treated equally, when in fact they often are very different in structure, function, and quality. Although these criticisms often are overstated, it's true that wetland managers haven't settled on a standard way to characterize and compare the functions of one wetland to another. There are many reasons for this lack of consistency:

- The ecological processes that support wetland functions often are quite complex.

The classification of a mapped wetland is coded by a series of letters and numbers. The classification legend at the bottom of each map includes the alpha-numeric code. The first letter of the code represents the system, the subsequent number represents the subsystem, and the next two letters indicate the class. If a wetland contains two different classes, they are separated by a horizontal line (see third example, below). Modifiers, when used, may be a letter or number.

CLASSIFICATION EXAMPLES

E2EM
System: Estuarine (E)
Subsystem: Intertidal (2)
Class: Emergent (EM)

Typical vegetation:
Lyngby's sedge *(Carex lyngbyei)*
seaside arrowgrass *(Triglochin maritimum)*
pickleweed *(Salicornia virginica)*
saltgrass *(Distichlis spicata)*

PSSC
System: Palustrine (P)
Subsystem: none
Class: Scrub-Shrub (SS)
Modifier: Water Regime—Seasonally Flooded (C)
Note: Palustrine system does not have subsystems

Typical vegetation:
willow (*Salix* spp.)
salmonberry *(Rubus spectabilis)*
Douglas Spiraea *(Spiraea douglasii)*
red-osler dogwood *(Cornus stolonifera)*

P EM Hx
AB
System: Palustrine (P)
Subsystem: none
Class: Mixed—Emergent (EM)/Aquatic Bed (AB)
Modifers: Water Regime—Permanently Flooded (H)
Special Modifier—Excavated (x)

Typical emergent vegetation:
cattail (*Typha* spp.)
skunk cabbage *(Lysichitum americanum)*
reed canarygrass *(Phalaris arundinacea)*
slough sedge *(Carex obnupta)*

Typical Aquatic Bed vegetation:
common duckweed *(Lemna minor)*
white water lily *(Nymphaea odorata)*

Figure 11. Cowardin classification codes for wetlands.

- These processes aren't well understood, and there isn't enough information about them.
- Wetlands vary a lot, even within a particular type.
- Wetland functions have many parts, all of which must be considered as part of the whole.
- Assessments often have very different purposes.

Despite these very real limitations, it still is important to use the best available scientific information about wetlands to assess their functions. To accomplish this, many rapid assessment methods have been developed. The U.S. Army Corps of Engineers wetlands research program describes 39 such methods, many of which are local modifications of methods developed elsewhere, at their Web site: http://www.wes.army.mil/el/emrrp/emris/emrishelp6/wetland_procedure_descriptions.htm. There are also specific Web sites for many of the methods. They can be found through Internet search engines.

Many of these approaches were developed in response to the need to better evaluate tradeoffs in the wetland compensatory mitigation process, that is, the process whereby the applicant for a wetland alteration permit must create or restore wetland of at least equal value to that which is proposed for alteration. Other methods were developed to support the planning efforts of municipalities or for watershed-level effort. Although no one method is considered best, a great deal of effort is going into tailoring the hydrogeomorphic, or HGM, approach to different regions of the United States. Several examples, described below, include

- Best professional judgment
- Wetland Evaluation Technique (WET)

Table 1. Hydrogeomorphic classes of wetlands, showing associated dominant water sources, hydrodynamics, and examples of subclasses.

Hydrogeomorphic class	Dominant water source	Examples of hydrodynamics	Examples of subclasses
Riverine	Overbank flow from channel	Unidirectional, horizontal	Riparian forested
Depressional	Return flow from groundwater and interflow	Vertical	Vernal pools
Slope	Return flow from groundwater	Unidirectional, horizontal	Avalanche chutes
Mineral soil flats	Precipitation	Vertical	Large playas
Organic soil flats	Precipitation	Vertical	Peat bogs
Estuarine fringe	Overbank flow from estuary	Bidirectional, horizontal	Tidal salt marshes
Lacustrine fringe	Overbank flow from lake	Bidirectional, horizontal	Lakeside emergent marshes

- North Carolina's Coastal Region Evaluation of Wetlands Significance (NC-CREWS)
- Oregon's Freshwater Assessment Methodology (OFWAM)
- Hydrogeomorphic approach (HGM)

Most of these methods require some training, in either wetlands science or the use of the particular method. They all rely on *indicators* of wetland function that can be observed in the field or gleaned from aerial photos, wetland or soil maps, and other resource materials.

Each of these methods is described briefly below. More information is available for each method at the Web site noted above. In addition, NWI maps, local wetland inventories, soil surveys, and other sources can help you characterize existing wetlands and identify restoration and enhancement opportunities in your watershed. See the "Resources" section of this chapter for more information.

Best professional judgment

Best professional judgment is not a formal approach but is probably the most commonly used and flexible method for evaluating wetland functions. In this approach, well-trained, experienced wetland professionals evaluate the principal functions and conditions of a wetland based on extensive field experience and information from NWI maps, soil maps and surveys, and aerial photos.

However, because best professional judgment is not a standardized approach, it isn't very precise, and no two individuals are likely to get the same results. Thus, it's often criticized in terms of scientific, legal, and public credibility. These shortcomings are the driving force behind the development of more precise, standardized approaches.

Wetland Evaluation Technique

The Wetland Evaluation Technique (WET) is a broad-brush, field-based approach to wetland evaluation. It's based on information about predictors of 11 wetland functions and values. *Predictors* are variables whose presence is highly correlated with certain watershed functions.

Data on correlative predictors can be gathered quickly in the field. On the basis of these correlative predictors, the WET process generates high, moderate, or low probability ratings that a particular wetland performs a given function.

A site-specific method, WET has been used mostly by regulatory agencies to assess wetlands proposed for alteration and to design and monitor restored or created wetlands. It also has been used to identify important wetlands needing protection and to set priorities for acquisition or research. WET isn't easily adaptable to landscape-level evaluation of wetland functions.

North Carolina's Coastal Region Evaluation of Wetland Significance

One of the more sophisticated large-area functional assessment systems for existing wetlands is the North Carolina Coastal Region Evaluation of Wetland Significance

(NC-CREWS) system. Eleven functions are addressed in NC-CREWS: surface runoff storage, floodwater storage, shoreline stabilization, terrestrial wildlife, aquatic life, nonpoint source, floodwater cleansing, landscape character, water characteristics, replacement difficulty, and restoration potential. With the use of geographic information system (GIS) analysis, a high, medium, or low rating is assigned to each of 39 variables that are successively combined to produce ratings for individual functions. The function ratings are then combined to form an overall rating of the wetlands ecological significance. The rating results can be used to set priorities for protection of significant wetlands at a landscape scale—generally at the watershed level. The NC-CREWS system has also been adapted to identify and evaluate the restoration potential of former and degraded wetlands. With the use of GIS techniques similar to those described above, the potential for sites to perform hydrologic, water quality, and habitat functions are evaluated qualitatively, scored or rated, and combined to give an overall restoration potential rating. The functional assessment capabilities of NC-CREWS have also been applied for local land-use planning and classification mapping, as well as in the review of the Clean Water Act's Section 404 permits.

Oregon Freshwater Wetland Assessment Methodology

The Oregon Freshwater Wetland Assessment Methodology (OFWAM), an adaptation of a similar approach developed for New Hampshire, assesses six wetland functions (wildlife habitat, fish habitat, water quality, hydrologic control, education, and recreation) and three wetland conditions (sensitivity to impacts, enhancement potential, and aesthetics). This method involves asking a series of questions about each of these functions or conditions. On the basis of the answers to these questions, functional assessments have three possible outcomes:

- The function is performed or is intact.
- Some of the function is performed, or it may be impacted or degraded.
- The function is not performed or has been lost.

OFWAM is used extensively as a planning tool by communities because it allows the functions and conditions of several wetlands to be assessed and compared. Its most common use has been as a follow-up to local wetland inventories. In this case, each wetland is assessed, and the results are used by a community to help decide which wetlands are significant and deserve special protection.

OFWAM's use for watershed-level restoration planning is limited for two reasons. First, only one of the assessed conditions addresses restoration potential. Second, OFWAM focuses solely on existing rather than on former wetlands.

Nevertheless, it could be adapted for restoration purposes by asking the question, "If we restored or created a wetland here, how might each of these functions be performed?"

See the "Resources" section of this chapter for information on how to obtain the OFWAM.

The hydrogeomorphic approach

The hydrogeomorphic (HGM) wetlands classification system was described above as the first step in an HGM approach to assessing wetland functions. Recall that this classification is based primarily on three principal characteristics of wetlands (although water chemistry and soil properties are other important variables):

- *Geomorphic setting* (the wetland's topographic position in the landscape)
- *Water source* (for example, precipitation or groundwater) and *transport mechanism* (for example, surface flows or subsurface flows)
- *Hydrodynamics* (how water moves)

Many states—Washington, for example—are developing regional applications of HGM for use in their areas. Once the seven national HGM classes (table 1) are described for a particular regional class or subclass of wetlands, a profile of the functions a class or subclass performs is developed. Models for each wetland function are then developed. After field testing and verification, the models serve as reference standards against which other wetlands in a class can be assessed.

Wetland Management Today

Don't it always seem to go that you don't know what you've got 'til it's gone?

—Joni Mitchell

Historically, numerous federal and state government programs have contributed to and even promoted the conversion of "worthless" wetland areas in the U.S. to other "more productive" uses. In 1849, Congress passed the first of the Swamp Land Acts, which granted all swamp and overflow lands in Louisiana—nearly 10 million acres—to the state for reclamation. This authority was extended to 12 other states in 1850 and 2 more in 1860. More than 43 million additional acres were ceded to them by the federal government for reclamation. Although most states did not immediately begin large-scale reclamation projects, these actions set the tone for federal policy for the next century.

There are still some federal programs that encourage or indirectly result in wetland conversion and estuarine alteration. A number of these relate to highway and other transportation improvements, projects that represent a major continuing source of wetland loss, particularly nontidal, freshwater wetlands. Other programs related to agriculture, water development, and the navigation projects noted above continue to take their toll on wetlands. The U.S. Army Corps of Engineers, for example, has been the major player in the construction and maintenance of hundreds of

congressionally authorized and funded navigation projects in the U.S., with much of the dredged materials used to create new uplands from coastal wetland and shallow-water areas. Over the past two decades, however, water projects have been drastically cut back. This trend continued with the 1990 Water Resource Development Act, which deactivated many navigation projects, established environmental protection as a primary Corps mission, and established an interim goal of "no net loss of the nation's remaining wetland base," and a long-term goal "to increase the quality and quantity of the nation's wetlands, as defined by acreage and function."

Today, the protection, restoration, and enhancement of wetlands involves many players, with federal, state, and local government agencies each having certain legal responsibilities and authority. Private nonprofit land trusts and other nongovernmental organizations also play important roles. Responsibilities generally break out along functional lines and governmental levels as summarized in table 2.

Mapping, assessment, and research

Responsibilities in this area are shared among levels of government and agencies and relate primarily to assigned management responsibilities. The U.S. Fish and Wildlife Service conducts the NWI. Virtually all wetlands in coastal regions have been mapped, but in some regions maps are of lower quality than others—see http://wetlands.fws.gov/Maps/maps.htm—for a map showing the status of mapping and digital data availability for the lower 48 states.

Wetland functional assessment also is a priority at each governmental level and is used for a variety of purposes. Versions of WET and HGM, discussed earlier, are used by federal agencies for evaluating wetland functions affected by proposals for filling permits under Section 404 of the Clean Water Act. Other methods are used for local wetland inventories and land-use planning.

Wetland research in the United States is conducted mainly by federal agencies—the Environmental Protection Agency, the U.S. Fish and Wildlife Service, the Natural Resources Conservation Service, and the U.S. Geological Survey in particular. But state agencies, university academics, and private nonprofits such as The Nature Conservancy also conduct important research on wetland functions and characteristics, providing useful management information.

Nonregulatory wetland management

A variety of federal, state, and private programs focus on nonregulatory wetland management. The principal activities of both public agencies and private organizations are land acquisition; management, restoration, or enhancement of wetlands; public education; and technical assistance to private landowners undertaking restoration or enhancement (figure 12).

Table 2. Principal wetland management functions, governmental agencies, private organizations, and authorities.

Function	Federal Government	State Government	Local Government	Private/Nonprofit
Mapping, assessment, and research	• *U.S. Geological Survey*: hydrology, nutrients, habitat •*U.S. Fish and Wildlife Service:* National Wetlands Inventory, habitat research and functions assessment • *U.S. Army Corps of Engineers:* restoration and assessment research • *U.S. Environmental Protection Agency:* mitigation, risks, and cumulative impacts • *Natural Resources Conservation Service:* agricultural wetlands, functions assessment	• *State coastal management agency and/or other fish, wildlife, land, parks, and environmental management agencies*: state and local wetland inventories, regional assessment agencies, wetlands research through Environmental Protection Agency state grants program • *Universities and colleges:* conduct scientific research on wetland characteristics, functions, and restoration	• *Cities and counties:* local wetland inventories, wetland functions assessment	• *The Nature Conservancy:* research on wetland characterization and mapping, historical ecology, functions assessment, and restoration monitoring • *State and local land trusts:* site mapping, assessment, and research
Nonregulatory: Land acquisition, management, restoration, enhancement, education, and technical assistance	• *U.S. Fish and Wildlife Service:* national wildlife refuges, Partners for Wildlife • *U.S. Forest Service:* natural areas management and restoration • *U.S. Bureau of Land Management:* natural areas • *Natural Resource Conservation Service:* Wetland Reserve Program, Conservation Reserve Program • *National Park Service:* national parks and monuments	• *State coastal management agency and/or other fish, wildlife, land, parks, and environmental management agencies*: wildlife management areas, funding and technical assistance, public education, management of public trust lands and waters of the state, National Estuarine Research Reserves, forest and range lands, state parks, funding for restoration and enhancement projects	• *Counties and cities:* parks, green spaces, and natural areas • *Local conservation commissions and watershed councils:* facilitate private landowner cooperation and do on-the-ground restoration	• *The Nature Conservancy:* acquisition, restoration, and enhancement projects • *Ducks Unlimited:* acquisition, restoration, and enhancement projects • *Trust for Public Lands:* acquisition, restoration, and enhancement • *Other state local land trusts:* acquisition, restoration, and enhancement projects

Table 2, cont.

Function	Federal Government	State Government	Local Government	Private/Nonprofit
Regulation, mitigation, and permit review	• *U.S. Army Corps of Engineers*: Clean Water Act Section 404 • *U.S. Environmental Protection Agency:* Section 404 oversight • *Natural Resources Conservation Service*: "Swampbuster" agricultural wetlands • *U.S. Fish and Wildlife Service:* coordination under Fish and Wildlife Coordination Act • *National Marine Fisheries Service:* coordination under Fish and Wildlife Coordination Act	• *State coastal management agencies and other state regulatory agencies:* state and federal consistency certification; control of dredging, filling, and other alternations; wetland mitigation and mitigation banking; Clean Water Act Section 401 wetland water quality certification; control over special management areas, hunting, and fishing	• *Counties and cities:* local wetland and natural resource protection ordinances; federal and state permit review for consistency with local plan	No role except as occasional public commenter or as permit applicant
Land-Use and Watershed Planning	• *U.S. Forest Service:* on national forest lands • *U.S. Bureau of Land Management:* on BLM-managed forest and rangelands • *National Park Service:* on national parks and monuments	• *State coastal management and land use agencies:* watershed and land use planning on state lands; enabling and oversight authorities for local land use planning; funding watershed and community action programs and plans	• *Counties and cities:* primary land-use planning authorities • *Conservation commissions:* planning and regulatory responsibility in local areas • *Watershed councils and associations:* watershed restoration action plans; facilitate private landowner cooperation	No significant role unless lands under control encompass large areas of landscapes and watersheds

The U.S. Fish and Wildlife Service, Bureau of Land Management, U.S. Forest Service, Natural Resources Conservation Service, the National Parks Service, state natural resource and parks agencies, and local soil and water conservation districts are the principal government agencies involved. Private nonprofit land trusts and similar groups involved in wetlands acquisition and management include The Nature Conservancy, Ducks Unlimited, and many local groups.

Regulation, mitigation, and permit review

At the federal level, Section 404 of the Clean Water Act (40 CFR 230) is the principal nationwide wetland regulatory program. Section 404 requires that anyone discharging dredge or fill material in the waters of the United States, including wetlands, obtain a permit from the U.S. Army Corps of Engineers. The permit is subject to review by a number of agencies, principally the Environmental Protection Agency (which also may veto the permit), the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the state fish and wildlife management agency. In addition, state water-quality agencies must certify that the proposed action meets state water-quality standards. Finally, in coastal zones, the federal consistency provision of the national Coastal Zone Management Act requires that the state coastal management agency certify that the action is consistent with state coastal policies.

As part of the effort to implement the federal no-net-loss policy for wetlands, Section 404 applicants must follow a sequential mitigation process. First, wetland impacts must be avoided if at all possible, usually by maximizing use of nonwetland areas on or off the property. Next, on-site wetland impacts must be minimized. Finally, unavoidable wetland losses must be compensated by restoring, creating, or enhancing wetlands. Most states have similar requirements.

In practice, wetland compensatory mitigation (WCM) occurs on a project-by-project basis. In recent years, *mitigation banking* has become a popular alternative to the project-by-project approach. Mitigation banking involves restoration (or creation) of large wetland areas in advance of use as WCM. In some areas, WCM credits are sold to permit applicants by the bank sponsor in lieu of requiring separate WCM projects.

The "swampbuster" provisions of the Food Security Act of 1985—often referred to as the "Farm Bill"—reversed a long-standing national policy of promoting drainage of wetlands for agricultural cropping. Instead, farmers who convert wetlands to agricultural uses may be penalized by removal of certain agricultural price supports and other subsidies. Wetlands that were converted to cropland prior to 1985 are exempted from the law.

The swampbuster provision of the farm bill is administered by the Natural Resources Conservation Service and was amended in 1990 and again in 1996. The most recent farm bill gives farmers more flexibility in

Figure 12. Technical assistance teams with a range of expertise can be effective for designing specific projects. (Photo: Oregon Department of Fish and Wildlife)

meeting wetland conservation requirements, in particular expanded mitigation provisions that allow for restoration, creation, and enhancement of wetlands.

Wetlands regulatory policy and programs have been a lightning rod in recent years, as farming interests, developers, and private property rights advocates generally have sought to reverse the expanding jurisdiction of federal regulatory programs, speed up the permit process for development, and as much as possible, externalize the costs associated with cropping, dredging, filling, and other wetland conversions.

These efforts have been blunted to some degree by conservationists and resource managers who are promoting even stronger wetlands protection. Although protection of remaining wetlands remains a federal and state priority, the impasse over regulatory program changes has provided at least part of the rationale for putting more emphasis on nonregulatory programs such as restoration.

Land-use and watershed planning

Land-use planning in the United States is generally the prerogative of local governments—cities, counties, boroughs, townships, and so on. States have delegated this responsibility under enabling legislation, but increasingly have set standards and requirements for local planning and zoning. This is particularly true in the coastal zone, where most of the states and territories have established specific requirements to protect and conserve wetlands for the public good. The importance of land-use planning as a wetland protection tool is well documented. For example, a 1998 study—the *National Coastal Zone Management Effectiveness Study: Protecting Estuaries and Coastal Wetlands*—reported that land-use planning was judged the second most important wetland management tool at the state level, following tidal and freshwater wetlands permitting. However, the same study found that most states do not have active restoration programs as part of their coastal management efforts.

Watershed planning in the United States is carried out by federal, state, and private landowners and organizations. In recent years, the *watershed approach* (see chapter 7, "Planning for Improved Watershed Health") has been institutionalized in many federal and state programs, with provisions encouraging establishment of local watershed councils and associations.

This brief overview of wetland management in the United States illustrates the diversity and complexity of programs

and activities addressing restoration in the country. In many ways, this diversity mirrors the larger society within which wetland and other aquatic ecosystem management occurs. What becomes very obvious as you examine these programs is the need and opportunity for improved public-private and interagency cooperation, better integration of wetland restoration into existing watershed and planning programs, and the enhancement and redirection of human and other resources if such goals are to be accomplished.

Summary

Wetlands are areas where water is at or near the surface at least part of the year, where soil development reflects this saturation, and where vegetation is dominated by plants adapted to a wet environment. Many wetlands are found at the transition between upland and aquatic environments, but others are isolated from open water.

Wetlands are ecological hot spots in watersheds, performing a variety of valuable functions that can be divided into four categories:

- Water quality-related functions
- Hydrologic functions
- Habitat and food web support functions
- Cultural and social functions

Functional interconnectedness with stream, lake, estuarine, and riparian ecosystems also is important. Thus, none of these environments can be considered in isolation from the others.

Wetland types are classified using a number of systems. The most important are the Cowardin classification system (used for inventory and mapping) and the HGM classification system (being regionalized in many states to provide a better basis for functional assessment at a variety of scales).

Wetland functions can be evaluated using a variety of methods, such as WET or HGM. The PSWA method in Washington State is one of the few truly "watershed-level" methods applicable to small and large watersheds alike.

Resources

Training

Training on the following topics may be offered by the agencies listed, or these agencies can provide contacts or information for other scheduled training programs, some of which are fee based.

The Cowardin classification system, the NWI, and local wetland inventories

State coastal management agencies: http://www.ocrm.nos.noaa.gov/czm/czmsitelist.html

State wetlands management agencies: http://www.aswm.org/wetlinks.htm

U.S. Fish and Wildlife Service: http://fws.gov/

US Geological Survey Wetlands Research Center: http://www.nwrc.usgs.gov/

Agricultural wetlands, soil surveys, hydric soils

Natural Resources Conservation Service, state and local offices: http://www.nhq.nrcs.usda.gov/

Wetland function assessment

State coastal management agencies: http://www.ocrm.nos.noaa.gov/

State wetlands management agencies: http://www.aswm.org/wetlinks.htm

U.S. Army Corps of Engineers: http://www.wes.army.mil/el/emrrp/emris/emrishelp6/wetland_procedure_descriptions.htm

Wetland identification and delineation

U.S. Geological Survey Wetlands Research Center: http://www.nwrc.usgs.gov/educ_out.html

U.S. Army Corps of Engineers, District Offices: http://www.usace.army.mil/where.html#Divisions

Information

National Wetlands Inventory maps

You can order NWI maps for your area or watershed from two sources. Specify the U.S. Geological Survey quadrangle sheets you wish to order.

USGS/Earth Science Information Center
National Headquarters
507 National Center
Reston, Virginia 20192
703-648-5920
1-888-ASK-USGS / 1-888-275-8747
Western Mapping Center—ESIC

Inventories of farmed wetlands, hydric soils, and soil surveys

The Natural Resources Conservation Service (NRCS) is compiling an inventory

of farmed wetlands. State NRCS contacts can be found at the NRCS Web site: http://www.nhq.nrcs.usda.gov/

Local NRCS offices also can supply your county soil survey, which includes upland and hydric soils. Contact your local NRCS office or county Extension agent for more information.

Wetlands Reserve Program

Local NRCS contacts for the Wetland Reserve Program can be found at

http://www.wl.fb-net.org/st-prog.htm

U.S. Geological Survey Wetlands Research Center

http://www.nwrc.usgs.gov/

Local NRCS contacts for the Wetland Reserve Program can be found at

http://www.wl.fb-net.org/st-prog.htm

Other materials

The U.S. Army Corps of Engineers also has information on wetlands functions assessment, restoration, and other topics. For a list of available publications, contact

U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180
Phone: 601-634-2355

The following publication is available online or in hard coy from the Washington State Department of Ecology:

Publications Distribution Center
PO Box 47600
Olympia, WA 98504-7600

Restoring Wetlands at a River Basin Scale: A Guide for Washington's Puget Sound: Operational Draft, Publication No. 97-99, on the Web at http://www.ecy.wa.gov/biblio/97099.html.

The Association of State Wetland Managers, Inc., is a nonprofit organization dedicated to the protection and restoration of our nation's wetlands. Its goal is to help public and private wetland decision makers use the best possible scientific information and techniques in wetland delineation, assessment, mapping, planning, regulation, acquisition, restoration, and other management. Find them at http://www.aswm.org/

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Case Study

Tampa BayWatch High School Wetland Nursery Program

by Mike Liffmann and Pam Blanchard

The Problem

Over the past hundred years, nearly half of all the mangrove and salt marsh habitats that once existed in the Tampa Bay estuary have been destroyed because of urban and industrial shoreline development and poor water quality. Tampa BayWatch's High School Wetland Nursery Program teaches students the value of maintaining a healthy environment while promoting public education and involvement in restoration activities. Students increase their understanding of the Tampa Bay estuary and the watershed that feeds it. Their heightened awareness of estuary issues is an incentive to students to become better stewards of the estuary they live in.

What Was Done

Tampa BayWatch established salt marsh grass nurseries within the bay region's middle and high school ecology or science clubs. These student-constructed and maintained nurseries cultivate salt marsh grasses that are then available for transplanting into habitat restoration projects throughout Tampa Bay. The first nursery was established in 1994. There were 10 nurseries operating during the 1999–2000 school year. Students construct a 16' x 16' nursery that is lined with plastic liner to hold water and salt in the newly constructed pond. Native *Spartina alterniflora* is planted in a mixture of beach sand, vermiculite, and peat and then placed in rooting trays within the nursery pond. The pond is flooded one to two times each week, using a battery-operated timer irrigation system. Salt is added to the irrigation water as needed to mimic natural conditions. After the original construction costs, the school nurseries are self-sustaining with minimal yearly maintenance costs. The school's nursery should be ready for harvest six to eight months after initial planting. At this time, a third to a half of the nursery is harvested and used in a local restoration project. The remaining plants are divided into individual sprigs and replanted in the nursery for another growing cycle. Restoration field trips are typically scheduled during the fall or spring. Each school participates in one revegetation project during the school year.

Students from Tampa Bay area schools plant smooth cordgrass (Spartina alterniflora) *that they have grown in their school wetland nursery along an eroding beach within the Tampa Bay estuary.*

Outcomes

The 10 existing nursery ponds are capable of producing between 70,000 and 140,000 plants. Students who maintain these nurseries use the plants they grow to assist in revegetation projects. Salt marsh grasses grown in these nurseries are used to restore 14 to 20 acres of salt marsh each year. In addition, over 2,000 student and community volunteers are educated about bay issues and participate in restoration activities through their involvement in the Wetland Nursery Program.

Awards received

- 1995—Tampa Bay Association of Environmental Professionals Innovative Educational Program award
- 1996—Society for Ecological Restoration Project Facilitation Award
- 1997—Governor Lawton Chiles and the Governor's Council for Sustainable Florida recognized the nursery program's outstanding contribution to environmental education.
- 1998—Tampa Bay Regional Planning Council's Future of the Region Environmental Award.

Contacts

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Case Study

Marsh Maneuvers 4-H Coastal Revegetation Program

by Mike Liffmann, Pam Blanchard, and Rex Caffey

The Problem

Coastal erosion, fishery and resource management, water quality, disappearing marshes—these are just a few of the serious problems that face the citizens of coastal Louisiana. Managing Louisiana's coastal resources is a complex task that requires input from a diverse group of stakeholders and agencies. Loss of coastal land is one of the biggest problems facing Louisiana. Each year, more than 20 square miles of coastal lands are lost through sediment deprivation, subsidence, saltwater intrusion, and herbivory by nonnative nutria. Marsh Maneuvers, a joint project of the Louisiana State University Cooperative Extension Service, the Barataria-Terrebonne National Estuary Program, the Louisiana Department of Wildlife and Fisheries, and the Louisiana Sea Grant College Program, makes it possible for selected 4-H students to understand the depth and breadth of the coastal land-loss problem facing Louisiana's citizens.

What Was Done

Each July, a steady procession of 4-H students and chaperones journeys to the Lyle St. Amant Marine Research Laboratory, located on Grand Terre, a barrier island off the Louisiana coast. The Louisiana Department of Wildlife and Fisheries, which has used the facility for 40 years of on-site marine research, operates the remote lab.

While attending a typical week-long Marsh Maneuvers camping session, students from parishes across Louisiana participate in hands-on activities to learn about a variety of environmental issues related to marine biology, estuarine ecology, and natural resource management. One activity that is a perennial favorite of the camp is a coastal stewardship exercise that allows campers to help restore the native vegetation of Grand Terre Island. The project is especially relevant because the island, like other Louisiana barrier islands, is rapidly succumbing to erosional processes that continue to shrink its area.

Outcomes

Over the years, Marsh Maneuvers campers have planted over 5,000 native plants, many of which were supplied through a partnership with the USDA-Natural Resource Conservation Service. Coastal marsh grasses such as smooth cordgrass *(Spartina alterniflora)* and bitter panicum *(Panicum amarum)* are typically planted within and adjacent to sand fencing in an effort to stabilize marshes and beachfronts. The results have been phenomenal, with vegetative growth and vertical sediment accretion exceeding expectations. Each summer, groups of Marsh Maneuvers campers make increasingly longer treks to plant more vegetation on Grand Terre. On their way to new planting sites, they pass robustly vegetated dunes and marshes planted by students in years past. This visual display of the project's success always provides context and motivation.

Bitter panicum (Panicum amarum) *has been planted by 4-H Marsh Maneuver participants within and adjacent to sand fencing on the barrier island in an effort to help stabilize the island. Over the past several years, Marsh Maneuver participants have helped plant native plants on the Isles Dernieres barrier island chain. These barrier islands, which protect fragile marshes and bays behind them, are undergoing rapid erosion caused by storm damage and natural subsidence.*

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CHAPTER FOURTEEN

Restoring Estuaries

by Jim Good

Estuaries—are they inland extensions of the sea or downstream extensions of a watershed's aquatic ecosystem? An oceanographer might find the first definition more satisfying, whereas a stream ecologist might prefer the latter. They are likely to agree, however, that estuaries are unique transition ecosystems—complex, dynamic, productive, and in many ways different from either the adjacent ocean or the river upstream.

Estuaries provide many goods and services to humans and other organisms. Examples include fish and shellfish production, water purification, shoreline stabilization, wildlife habitat, and recreational opportunities.

Estuaries are home to an incredible array of plants and animals, many so small and abundant that there may be billions in a single glass of bay water. Estuaries play a key role in the life cycles of important marine and anadromous (migratory) aquatic species—crab, salmon, and herring, to name a few—as well as migratory waterfowl and shorebirds.

With a twice-daily ebb and flood of the tide, salt water and freshwater mixing, and rapid fluctuations in temperature and salinity, estuaries can be difficult places to live. But the plants and animals that thrive there have developed remarkable adaptations to these difficult conditions—adaptations for feeding, reproducing, rearing their young, avoiding predators, and regulating their bodies' temperature and salt concentrations. Estuarine ecosystems and their inhabitants thus are by nature resilient. At the same time, however, past changes and present threats make them highly vulnerable.

Human history and economic development are intimately linked to estuaries. Estuaries provide abundant, easy-to-access fish and shellfish. We build cities on their shores and ports in their sheltered harbors. We come to the sea to breathe the salt air and be renewed.

In this chapter you'll learn

- What an estuary is
- Why estuaries are important
- How physical and biological processes drive these ecosystems
- How estuaries function and how they are used and managed
- Basic principles for estuarine restoration
- How to assess estuarine health and develop a restoration action plan

Some of the ways we use estuaries change these ecosystems, often significantly. We selectively harvest plants and animals. We consciously or inadvertently introduce nonnative organisms, including invasive pest species. We dredge navigation channels, build jetties, fill tidelands, dike salt marshes, dump wastes, and more. Although some of these uses have economic and other benefits, they often adversely affect the natural goods and services that estuaries provide to society.

Over the past several decades, we have come to understand the value of the goods and services healthy estuaries provide. We also have learned it is not too late to protect what remains and to restore damaged areas to health. All along our nation's coasts, estuarine habitats are being protected, development is being directed to areas where adverse impacts can be avoided or minimized, and new pollution controls are being put in place.

Improving damaged and degraded estuaries is the next logical step. Local citizen groups, land trusts, other nongovernmental organizations, and state and federal biologists are surveying the nation's estuaries, identifying potential restoration actions, and examining pollution sources and other problems. They're using lessons learned from completed restoration projects to design and evaluate new projects.

Nevertheless, old threats to estuaries remain and new ones emerge. Examples of emerging threats include the Asian whelk in Chesapeake Bay and the green crab invasion of west coast estuaries. Restoration and rehabilitation of our estuaries has started, but much remains to be done.

What is an Estuary?

es·tu·ar·y (es′-chew-wer′-ee), n. 1. that part of the mouth or lower course of a river in which the river's current meets the sea's tide. 2. an arm or inlet of the sea at the lower end of a river. (*Random House Unabridged Dictionary,* 1993)

The dictionary provides a simple, intuitive definition of an estuary. But it leaves many questions unanswered. For example, how far does an estuary extend upriver? Is a lagoon with little freshwater inflow an estuary? Why are these ecosystems so important and highly regulated? What is the role of estuaries in the life cycle of salmon on the west coast, striped bass on the east coast, shrimp along the southeast and gulf coasts, and dozens of other species of commercial, recreational, or ecological importance? More technical definitions begin to answer these questions.

A classic, often-quoted scientific definition advanced by oceanographer Donald Pritchard in 1967 is that an estuary is "a semi-enclosed coastal body of water which has a free connection with the open sea and, within which, seawater mixes and usually is measurably diluted with freshwater from land runoff." From a geographic perspective, an estuary "includes estuarine waters, tidelands, tidal marshes and swamps, and channels and the submerged lands below; they extend upriver to the head of tide—the place where vertical

fluctuations of the tides cease." This may be far upstream in some estuaries—all the way to Albany on the Hudson River in New York for example.

I use this expanded definition in this chapter.

Why We Need Estuaries

Healthy estuaries provide important *habitats* for many species we value such as striped bass, salmon, herring, flounder, crabs, oysters, clams, wading birds, ducks, geese, shorebirds, and harbor seals (figure 1). Deep channels, sloughs, tidal flats, salt marshes, eelgrass beds, and other habitats provide food, shelter, resting areas, and nursery grounds. These habitats also are home to thousands of lesser-known species that are vital to healthy estuarine ecosystems—burrowing ghost shrimp; strange-looking polychaete worms; and

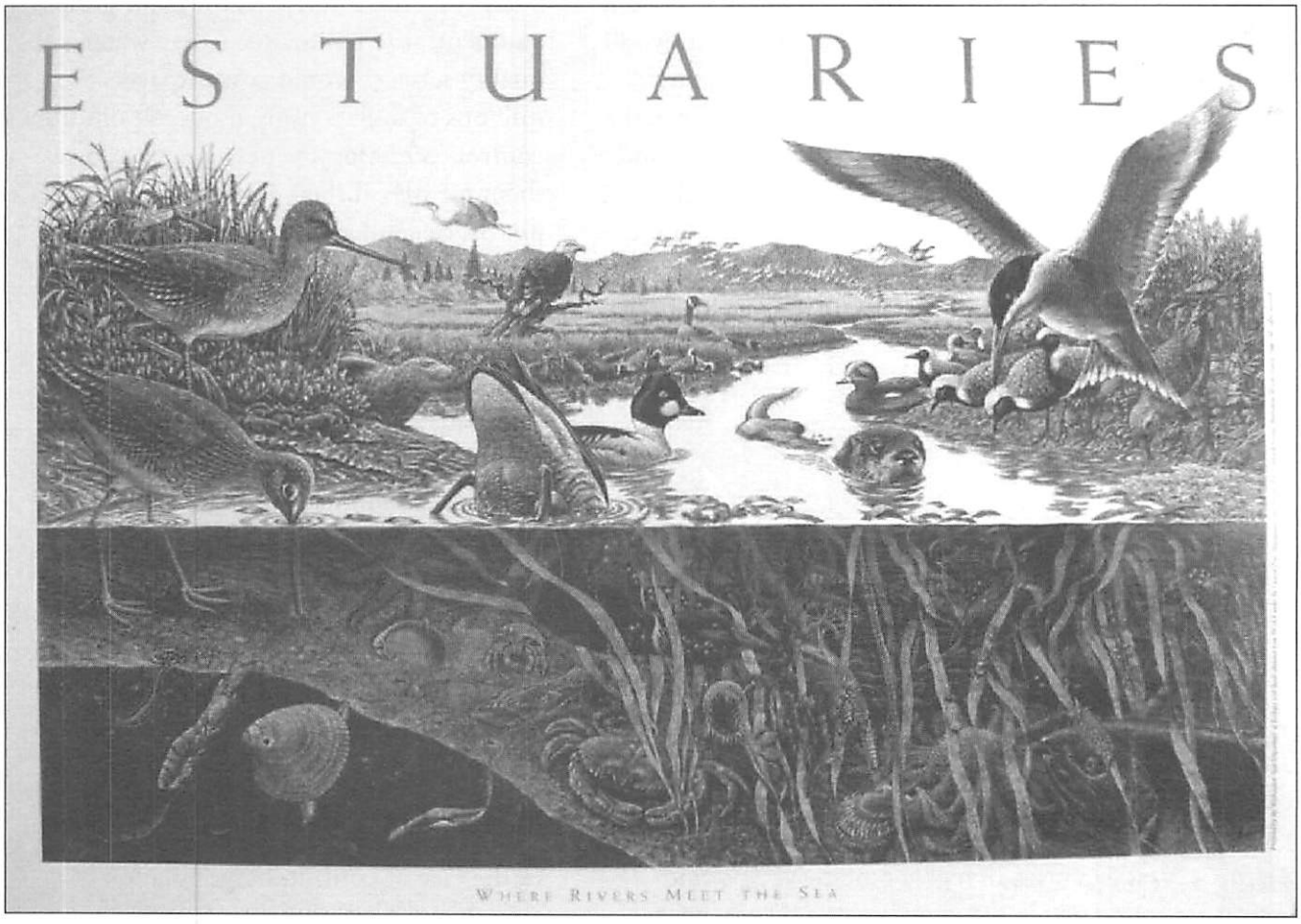

Figure 1. Pacific Northwest estuaries support a great diversity of plants and animals (artwork by Larry Duke, courtesy of the Washington State Department of Ecology).

microscopic copepods, molluscs, and other planktonic species.

One reason for the diversity and abundance of animal life in estuaries is their high *primary productivity.* In other words, estuaries grow a prodigious amount of plant material that serves as food. Salt marsh grasses and rushes, eelgrass, kelp, thick beds of filamentous algae, and literally billions of single-celled diatoms and other microscopic plants called *phytoplankton* are all products of the estuary food factory.

Just how productive are estuaries? No one knows for sure, but scientists who study salt marshes provide some hints. For example, smooth cordgrass *(Spartina alterniflora),* the abundant meadow grass along the east and gulf coasts, produces about six tons of organic carbon per acre (figure 2). On the west coast, scientists found that just one square meter of the abundant marsh species Lyngby's sedge *(Carex lyngbyei)* produces more than eight tons per acre per year.

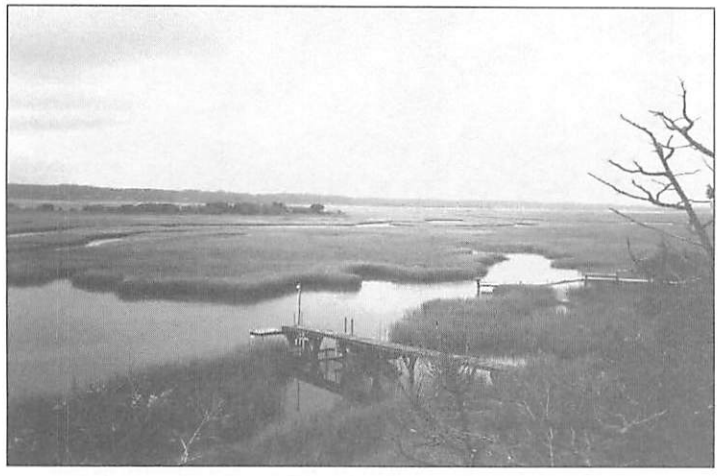

Figure 2. Vast expanses of highly productive *Spartina* marsh are found within estuaries created by east coast barrier islands, such as this one in the outer banks of North Carolina (Sandra Alley photo).

Nearly all of this plant material dies each fall and is recycled within marshes or is transported into adjacent estuarine waters. Microscopic bacteria break down this plant debris, contributing to the rich brew we call *detritus.* Detritus, transported by the tide throughout the estuary and into sloughs and tidal creeks, is the foundation of life in estuarine ecosystems.

Estuaries also help keep water clean. They use excess nutrients for plant growth and neutralize pollutants. These water-quality services would cost taxpayers millions of dollars using modern pollution-control technology, yet estuaries perform them for free, if their assimilative capacity is not overwhelmed. Fringing marshes and other estuarine wetlands, like their upland counterparts, also slow flood waters and stabilize the shore to prevent erosion.

Finally, estuaries are vital for the economic and recreational services they provide—transportation, commerce, commercial and recreational fishing, clamming, waterfowl hunting, birding, boating, sailing, sightseeing, and simple enjoyment of nature. Among the goods and services estuaries provide, these are the most visible and probably the most valuable in dollar terms.

What Can We Do?

In the face of continuing population growth and development pressures, how can we sustain or even increase the flow of estuarine goods and services for ourselves

and future generations? There are no simple answers, the task is not small, and no one can do it alone. Sustaining healthy estuaries over the long term requires an understanding of existing problems and challenges, clear goals and the means to achieve them, the ability to learn from the past and look to the future, and the will to make decisions. For America's estuaries, we need to do the following:

- Protect and conserve the remaining critical estuarine habitat
- Restore former or degraded estuarine habitats where feasible
- Link estuarine restoration actions to upland and upstream restoration and enhancement efforts for a whole-watershed approach
- Monitor water quality, clean up existing pollution, and prevent new pollution that cannot be readily assimilated.
- Avoid the inadvertent introduction of harmful plants and animals
- Work simultaneously from the bottom up (the community level) and the top down (through state and federal assistance) to make sure our efforts are feasible and effective, both locally and regionally
- Incorporate both local knowledge and the best available scientific information into our planning, decision making, and projects
- Conduct necessary research to improve understanding of estuarine ecosystems and their relationships to marine and freshwater systems

A Primer on Estuaries

Estuaries are among the most productive ecosystems on earth, but also one of the most dynamic and stressful to organisms there. The twice-daily ebb and flood of the tide results in sometimes dramatic changes in temperature and salinity at any given location, alternately drowns and exposes habitats and creatures living in different niches, and moves food resources from one area to another. How do we describe these complex ecosystems and classify their diverse habitats and functions? Scientists have devised a number of classification schemes for estuaries and their habitats, based on geomorphology, mixing and circulation, and salinity. Each of these systems is useful and helps us understand how habitats—channels, flats, and marshes—are differentiated. Because tides, salinity regimes, and related features of estuaries are so important in designing plans for restoration of whole estuaries and individual sites, a brief primer on these topics follows. For details on estuarywide and site planning, see chapter 7, "Planning for Watershed Improvement," for details.

Tides and tidal currents

What causes tides? What kinds of tides do we experience along the coasts of the United States? What happens when the tide enters a bay or estuary? The answers to these questions are critical to understanding how waters mix and circulate in estuaries, how and where different types of habitats develop, and how damaged or degraded estuaries might be restored.

Tides actually are very long period waves, with 12 hours and 25 minutes between successive crests (high tide) or troughs (low tide). The wave length of the tide is equal to one-half the earth's circumference.

Many celestial bodies influence tides by their gravitational pull on the fluid ocean surface, but the moon and sun are by far the most important. Tides are strongest and the daily tidal range is greatest when the moon and sun align either on the same side of the earth (at the new moon) or on opposite sides of the earth (at the full moon). We call these *spring tides.* At the quarter moon, between new and full moons, tides are weaker, with smaller differences between the highs and lows. These we call *neap tides.* Over the course of a lunar month, there are two periods of spring tides (new and full moon) and two of neap tides (quarter moons).

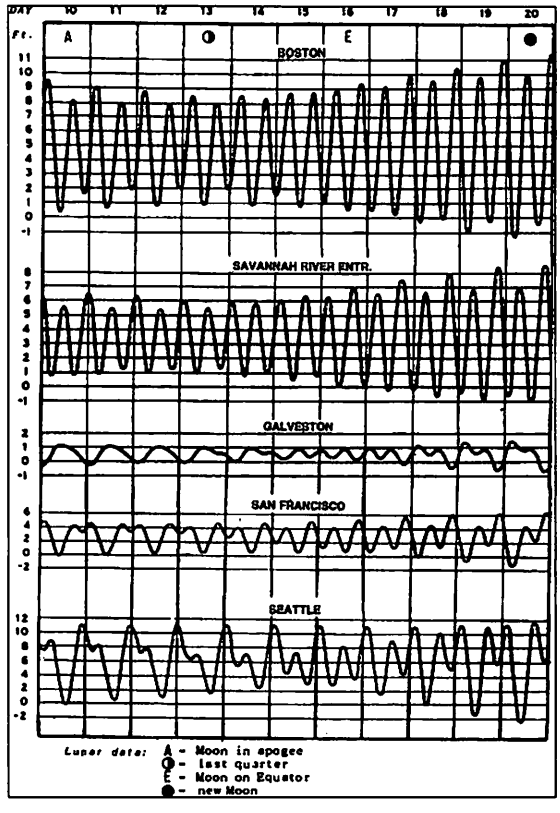

Figure 3. Examples of different kinds of tidal cycles along U.S. coasts. Note that most tides are *semidiurnal* (two highs and two lows a day), except along some areas of the gulf coast, such as Galveston. On the west coast, tides are *mixed*, with the two highs and lows of unequal height and duration).

Each day along the coasts of the United States, there are two high tides and two low tides (figure 3). On the east and gulf coasts, these twice-daily tides, or *semidiurnal tides,* are roughly the same height. On the west coast, we have tides of unequal height and duration—mixed *semidiurnal tide* is the technical term for this kind of tide. In a few areas, such as Galveston, Texas (figure 3), there is just one high and one low tide each day—this is called a *diurnal* or *daily tide.*

The outgoing (receding) tide is called an *ebb tide.* The incoming (rising) tide is called the *flood tide.*

The *datum,* or "zero mark," for measuring tidal elevations on the east and gulf coasts is the *mean lower water,* or the average of all low tides over many years. On the west coast and Alaska, the datum, or zero mark, for tides is *mean lower low water,* or the average of the lowest of the two daily low tides over many years.

The *mean tidal range* is the difference in elevation between the average of all low tides and the average of all high tides. The

mean tidal range varies widely around the United States—it is 30 feet or more in some areas of Alaska and in the Bay of Fundy in Maine but just a few feet along the gulf coast. In most areas, mean tidal range is between 5 and 10 feet. Extreme tides, however, may be much greater.

Mean high water, the average of all observed high tides, sets the boundary in most states between state-owned tideland and privately owned land. Most high salt marshes are above mean high water and thus are privately owned, although they still are part of the estuary and subject to state and federal regulation and planning. This topic is discussed further under "Human uses and management of estuaries."

Tidal currents are horizontal movements of water associated with the rise and fall of the ocean surface. For most estuaries, these currents are strongest on the ebb tide as bay and river water that was backed up by the incoming tide moves out on the ebb. In bay barrier estuaries along the east and gulf coasts with relatively little tidal exchange, flood currents may be as strong as ebb currents. See "Physical classification of estuaries," below, for descriptions of these different types of estuaries. The shape of an estuary, especially its channel constrictions, also affects current velocity.

The timing of the strongest currents varies by estuary, but generally they occur about midtide, when the "tide is running." Slack water—when there is no tidal current—generally occurs soon after low tide or high tide.

How the tide affects an estuary depends on four main factors.

- The range of the tide at the ocean entrance (difference in height between high and low tide)
- The shape of the estuary basin, which determines timing and elevations of the tide at any given location as it moves in or out of the estuary
- The size of the estuary's opening at its mouth, which determines how much water can enter and exit during the tidal cycle
- The amount and variability of freshwater inflow

As tides ebb and flow, they provide huge amounts of energy to estuaries. They mix and circulate dissolved plant nutrients and they redistribute organic detritus—the tiny bits and pieces of plants, bacteria, decomposing plankton, and other debris that small animals eat. Tides and tidal currents also strongly influence the development, structure, and function of estuarine habitats through their influence on temperature, inundation time, sunlight and heat exposure, and wind and wave energy.

Physical classification of estuaries

Although each estuary is unique, a number of classification systems have been developed to help sort out similarities and differences in form and function. Some of the most useful are explained below.

Geomorphology-based classification

Geomorphology relates to the origins and development of the landscape. From a geomorphic perspective, most of the

estuaries in the United States are classified as drowned river mouth estuaries, fjords, or bay-barrier estuaries.

Drowned river mouth estuaries formed as ancient river valleys were flooded by the rising sea at the end of the last ice age. These estuaries often have large watersheds. They are dominated by freshwater (river) when runoff is high, but by salt water in the dryer seasons. The large estuaries along the east coast are good examples—Chesapeake Bay, Delaware Bay, and the Hudson River estuary (figure 4). On the west coast, the Columbia River estuary is a good example.

Fjords were formed in areas covered by ice sheets in the last ice age. The pressure of overlying ice widened and deepened the preexisting river valleys but in some places left shallow rock sills, which tend to restrict the exchange of water with the sea. In the United States, examples of fjords can be found in Alaska and Washington State's Puget Sound.

Bay-barrier or *bar-built estuaries* are partially enclosed by barrier islands or long sand spits, with one or more ocean inlets. They are relatively shallow, have comparatively smaller watersheds, and less freshwater input than drowned river mouth estuaries, and given limited connections to the sea, are often weakly influenced by tides and seawater. One of the best examples of this weak tidal effect is within the Albemarle-Pamlico Sound complex in North Carolina. Other examples of barrier island-created estuaries include Great Egg Harbor Bay in New Jersey and Laguna Madre in Texas. Bar-built estuaries can also be found on the west coast. Tillamook Bay in Oregon and Willapa Bay in Washington are good examples, but given the relatively large tidal range in this region, both are strongly influenced by tides.

Mixing and circulation-based classification

Characteristic patterns of salt water and freshwater mixing and circulation also are used to classify estuaries. Mixing and circulation types include stratified, partially mixed, and well mixed.

Stratified, or "salt-wedge," conditions occur when both river flow and tides are strong. Seawater intrudes into the estuary along the bottom because it is slightly heavier than the freshwater coming downstream. At the boundary between the freshwater and salt water layers, high shear forces allow only limited mixing between the two. In cross-section, the salt water looks like an intruding wedge along the bottom. The Hudson River in New York has a salt wedge that extends upriver all the way to Poughkeepsie.

Partially mixed conditions occur when tidal inflow is similar to or greater than freshwater outflow. In such estuaries, there is continuous mixing between seawater and freshwater because of the efficient exchange between the river and the ocean. There will be some stratification, with surface waters fresher than bottom waters, but only in the upper estuary will undiluted freshwater be found.

Well-mixed estuarine conditions occur when river flows are low and tides are

moderate to weak. This situation occurs in many estuaries along the west coast during summer and early fall before wetter winter conditions set in. Well-mixed, diluted seawater can be found far upstream in coastal rivers at these times.

The same estuary may exhibit different mixing patterns at different times of the year, depending on river flow and the strength of the tide. Generally, however, estuaries that drain large river basins (for example, Chesapeake Bay, Delaware Bay, the Columbia River estuary) more frequently exhibit stratified or partially mixed conditions than do smaller estuaries with smaller drainages. Smaller estuaries typically are well mixed.

Mixing and circulation characteristics are important because they strongly influence an estuary's ecological functioning and thus the goods and services it provides. For example, mixing and circulation help determine where the best food resources are located and thus where predator and prey interact. Mixing and circulation patterns also determine how pollution concentrates or disperses and how long it takes to flush the system of wastes. Estuaries are tuned to these and other physical factors.

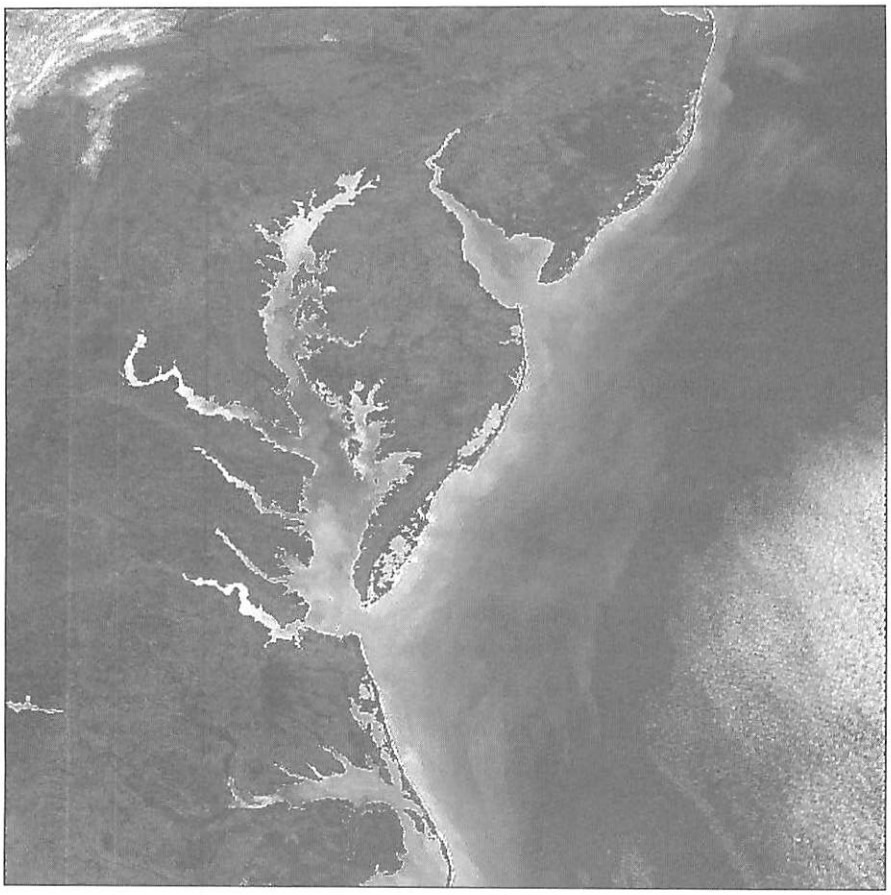

Figure 4. Delaware and Chesapeake Bays on the east coast are classic examples of drowned river mouth estuaries. Similarly, the estuaries formed by barrier islands along the ocean coasts of New Jersey, Delaware, Virginia, and North Carolina are good examples of bar-built estuaries.

Salinity zone-based classification

Differences in salinity have a major influence on

the biology of estuaries. Estuaries are divided into four distinct geomorphic salinity zones. The actual boundaries of these zones shift back and forth with tidal cycles and changes in river discharge.

The *marine-estuarine interface zone* is located immediately outside the mouth of an estuary. This zone is characterized by a mixture of seawater and freshwater in the range of 33 to 25 psu (practical salinity units). Where the volume of river discharge is high, as in the Mississippi or the Columbia, for example, this zone can extend far out into the ocean. Where river discharge volume is relatively low, the marine-estuarine interface zone is confined to the area immediately offshore from the river mouth and is strongly influenced by the ebb and flood of the tides.

The *marine-dominated lower estuary zone* is located just inside the mouth of the estuary and is characterized by high variability in salinity (30 to 18 psu). Bottom sediments in this zone are mainly fine sands of marine origin.

The *middle estuary mixing zone* is located farther up the estuary. Salinities in this zone range from 18 to 5 psu, and bottom sediments are a mixture of fine sands of marine origin, riverine sediments from the watershed, silt, and organic matter.

The *upper estuary riverine zone* extends from the mixing zone upriver to the head of tide. Salinity ranges from 5 to 0.5 psu—virtually freshwater at certain times of the year. Bottom sediments are fine sand, silt, clays, and other materials derived mainly from the watershed.

Estuarine habitats

Habitat is the portion of the natural environment used by an organism. It is where plants and animals find shelter, food, water, reproductive mates, and other resources they need to live and reproduce. Some habitats, such as salt marshes, are by nature more productive than others.

Some types of plants and animals have very specific habitat requirements, whereas others tolerate a wide range of conditions, such as those found in estuaries. Many species, such as crab, shrimp, and salmon, depend on different habitats at different stages of their life.

Although we may "deconstruct" estuaries into various habitat types, they, like other ecosystems, function as a whole. If any part of an estuarine habitat is lost or degraded, the whole ecosystem is degraded.

A number of classification systems have been developed to differentiate estuarine habitats. One example is the Cowardin classification system, which is used in the National Wetlands Inventory and is described in chapter 13, "Restoring Wetlands in Your Watershed." Many of these habitats and the organisms found in estuaries are illustrated in figure 5 and described below.

Subtidal habitats

Subtidal estuarine habitats include *channel bottoms, slope bottoms,* and the *open water* above them. Plants and animals found

in these habitats are influenced by the gradient of salinity, the availability of light, and the type of bottom sediments.

Bottom sediments range from coarse gravel and marine sands near an estuary's mouth to fine sands and silts of both marine and terrestrial origins farther up the estuary. Hard-bottom areas also are common, most often near the ocean entrance or within deep channels. Ebb and flood tidal currents are strongest in channels. Here they mix fine sediments and organic detritus within the water column, scour hard-bottom areas, move sandy sediments along the bottom, and process and redistribute food resources up and down the estuary.

Channels are the migratory routes for upstream-bound striped bass, shad, salmon, and other fish, while juvenile fishes frequent the shallows. Large clams that make their home in the sediments of slopes and deep channels may serve as seed stock for colonizers of the shallower tidal flats.

Water column productivity reaches its maximum in the channel, where salt water and freshwater mixing is greatest. This dynamic mixing zone, which moves upstream and downstream with the tide, is called the *turbidity maximum.* Predator and prey alike are attracted to this region, and here the physical, chemical, and biological transformations that make estuaries unique reach a crescendo.

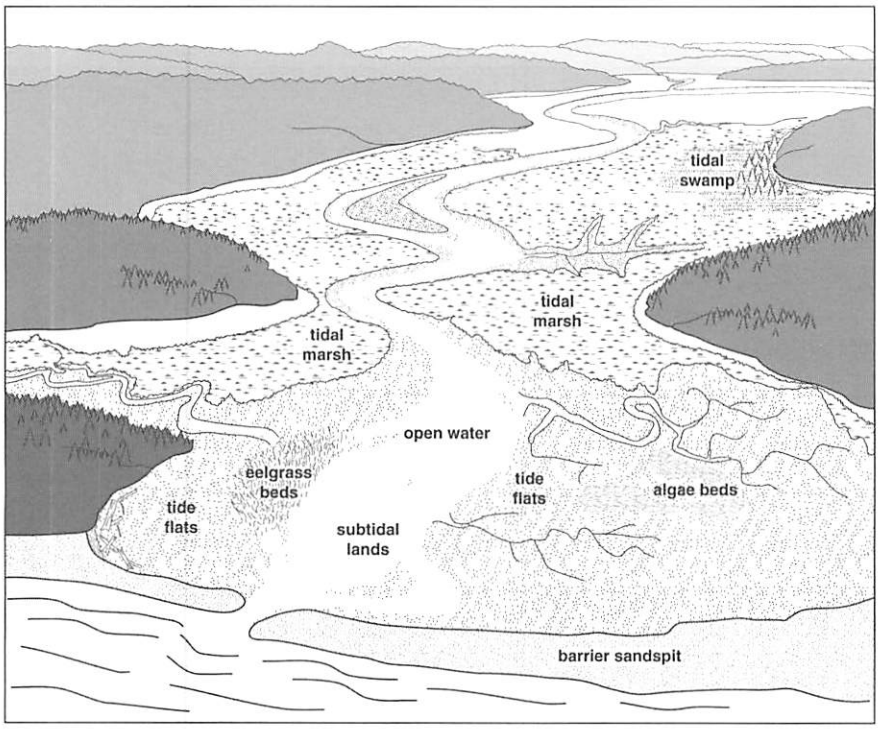

Figure 5. Different estuarine habitats support an abundance of plant and animal life (drawing modified from the *Oregon Estuary Plan Book,* 1987).

Eelgrass beds are another key estuarine habitat found along shallow subtidal slopes where sunlight can penetrate. Eelgrass beds are discussed below under "Tidal flat habitats."

Tidal flat habitats

Between the extreme low-water mark and the mean

tide level are *tidal flats.* East and gulf coast estuaries, which have broad expanses of salt marshes, have relatively small areas of tidal flats, whereas on the west coast, tidal flats have nearly twice the area of salt marshes in most estuaries. Tidal flats dominate backwater sloughs, shallow marginal embayments, and low-tide islands in estuaries (figure 6).

Tidal flat sediments vary, ranging from coarse sand toward an estuary's mouth to fine sand, silt, and mud farther up the bay. The finer substrates often are referred to as soft-bottom habitats because they typically have a high water content and are stirred constantly by bottom-dwelling organisms.

Soft-bottom habitat can be recognized by anyone who has gone clamming in an estuary—perhaps it is where they left a boot behind. Bottom-dwelling organisms include a wide variety of clams, worms, fiddler crab, shrimp, amphipods, and other animals that burrow below the surface. They feed on rich, detritus-laden tidal waters that they pump into their burrows, or on deposits of microscopic diatoms, bacteria, and organic detritus that form a slurry on the surface.

Tidal flats also are prime habitat for oysters, such as the American oyster *(Crassostrea virginica).* Large oyster reefs can be found on the mudflats and edges of tidal creeks in South Atlantic estuaries (figure 7). Many other commercially important shellfish are abundant in mudflats, including the soft-shell clam *(Mya arenaria)* and the hard clam or quahog *(Mercenaria mercenaria).*

Native sea grasses such as eelgrass *(Zostera marina)* are found along the lower fringes of tidal flats and the

Figure 6. Tidal flats habitats support abundant clam, shrimp, and crab populations, as well as a great diversity and biomass of microscopic animals and plants (Jim Good photo).

shallow subtidal slopes they border. Like other rooted sea grass species, eelgrass' major life functions, including flowering and pollination, occur under water. Eelgrass beds serve a number of critical functions. They provide spawning substrate for herring; food for migrating black brant geese; and hiding places for young salmon, crab, bay scallop, and many other species. At low tide, blades of eelgrass lie across the exposed surface, protecting bottom-dwelling organisms from the hot summer sun. Eelgrass root systems also help stabilize the channels they border. Widgeon grass *(Ruppia maritima)* is another common sea grass found in both temperate and subtropical latitudes. Besides widgeon grass, sea grass beds south of the Carolinas may include turtlegrass *(Thalassia testudinum),* manatee grass *(Syringodium filiforme),* and shoal grass *(Halodule wrightii).* All play vital roles in the ecology of estuaries.

Highly productive algae beds also grow on tidal flats, particularly in the salty parts of an estuary. Sea lettuce *(Ulva),* filamentous algae *(Enteromorpha),* and mat-forming species *(Chaetomorpha)* are common. These species also help keep bottom-dwelling animals from drying out at low tide. Excessive algae growth, however, may be an indicator of too much nitrogen or other nutrients.

Tidal marsh and swamp habitats

At the upper edge of tidal flats, there is a distinct transition from soft-bottom, algae, and sea grass-dominated tidal flats to more uplandlike environments dominated by rooted, flowering grasses, rushes, sedges, mangroves, and other shrubs and trees. These are the estuary's tidal marsh and swamp habitats. The types of habitat and plant communities present are controlled mostly by elevation (which determines the tidal inundation period) and salinity. The tidal flooding of marshes and swamps in the upper reaches of an estuary is due in part to the "holdup" effect of the incoming tide on river flow. But even at low river flow, the tide may reach well upstream.

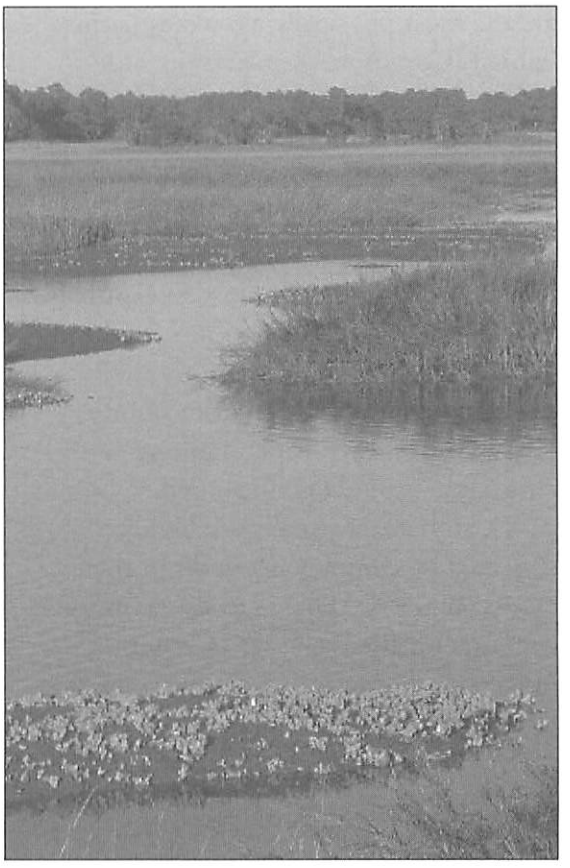

Figure 7. Oysters and other bivalves are common on sandbars and mudflats of the southeast.

Because of their higher elevation and location relative to uplands, tidal marshes

are the most physically altered estuarine habitat. Common alterations include filling for port and industrial development and transportation corridors, diking and draining for agriculture, and ditching for mosquito control. Because many of these alterations are relatively minor, altered marshes are among the most susceptible to restoration—removing dikes, installing or enlarging culverts to improve tidal circulation, and filling in of mosquito ditches to restore normal drainage patterns are some methods used.

Tidal marshes usually are highly dissected by complex networks of tidal creeks (figure 8). These creeks serve as conduits for the exchange of water, nutrients, and detritus, as well as low-tide refugia for small fish such as juvenile salmon. At high tide, these fish spread out across the marsh, feeding on estuarine invertebrates, aquatic insects, and even terrestrial insects wafting in from nearby riparian areas.

Figure 8. Tidal marshes are dissected by complex networks of tidal creeks that serve as conduits for exchange of water, nutrients, and detritus.

Salt marshes occur in the lower or middle estuary, where salinities are relatively high. Salt marshes are dominated by grasses and rushes, but there is significant variation around the country. The dominant plant along the Atlantic coast is smooth cordgrass *(Spartina alterniflora),* found between mean low and mean high water. Smooth cordgrass exhibits varied growth forms—tall, medium, and short—depending on the frequency and duration of tidal flooding. Above mean high water, more diverse species are found and vary with latitude. Along the North Atlantic coasts, for example, saltmeadow cordgrass *(Spartina patens)* and salt grass *(Distichlis spicata)* dominate the high marsh, with black grass *(Juncus gerardi)* at the highest elevations. Moving south along the Atlantic coast, black needlerush dominates the high marsh. Along the gulf coast, *Juncus* species dominate to the east and smooth cordgrass to the west. West coast marshes are more diverse, with Pacific cordgrass *(Spartina foliosa)* common in California marshes and in the Pacific Northwest, Lyngby's sedge *(Carex lyngbyei),* arrowgrass *(Triglochin maritimum),* pickleweed *(Salicornia virginica),* threesquare bullrush *(Scirpus americanus),* and tufted hairgrass *(Deschampsia caespitosa).*

As estuarine waters become brackish and then fresh farther upstream, the flora and fauna of tidal marshes gradually change. Some of the plant species in *tidal freshwater*

marshes are the same as those in salt marshes, but freshwater wetland plants begin to dominate. These marshes, like the salt marshes farther downstream, may be highly dissected with tidal creeks. Tidal freshwater marshes are most extensive along the Atlantic coast between Georgia and New England, in the northeastern Gulf of Mexico, and in the Pacific Northwest (for example, in the Columbia River estuary), where freshwater runoff dominates the larger systems. The diverse vegetation of these freshwater wetlands provides many niches for equally diverse animal life—larval and adult insects, amphipods, isopods, worms, mollusks, and a wide variety of mostly freshwater fishes and juveniles of anadromous species like salmon.

Mangrove swamps comprise woody trees and shrubs and are found in tropical and subtropical areas—southwest Florida, Louisiana, Texas, Hawaii, and some of the island territories like Guam and the Northern Marianas (figure 9). Three species dominate, forming distinct zones, or bands, depending on tidal elevation. In southwest Florida, the red mangrove *(Rhizophora mangle)* is the most seaward species, tolerating flooding well. Moving higher in the intertidal, the black mangrove (*Avicennia nitida)* is found, and still further up, the white mangrove *(Laguncularia racemosa).* Mangrove trees form the structure for a complex mangrove forest ecosystem, contributing detritus as leaves drop and decompose, serving as substrate for algae; habitat for copepods, amphipods, and insect larvae; and hiding places for juvenile fish and shellfish—red drum, spotted sea trout, tarpon, and shrimp. Roots of the mangrove are often covered with mangrove oysters, and fiddler crabs construct borrows among the roots. There is also a rich assemblage of birds and predators, including raccoon, alligator, and the endangered American crocodile.

In the Pacific Northwest, brackish and freshwater tidal swamps of Sitka spruce *(Picea sitchensis)* and red cedar *(Thuja plicata)*, with understories of red alder *(Alnus rubra),* willows *(Salix spp.),* and emergent marsh species once were common, but now are rare. Some good examples of remnant tidal swamps are found along the lower Columbia River. Most of this habitat was logged, cleared, and diked for

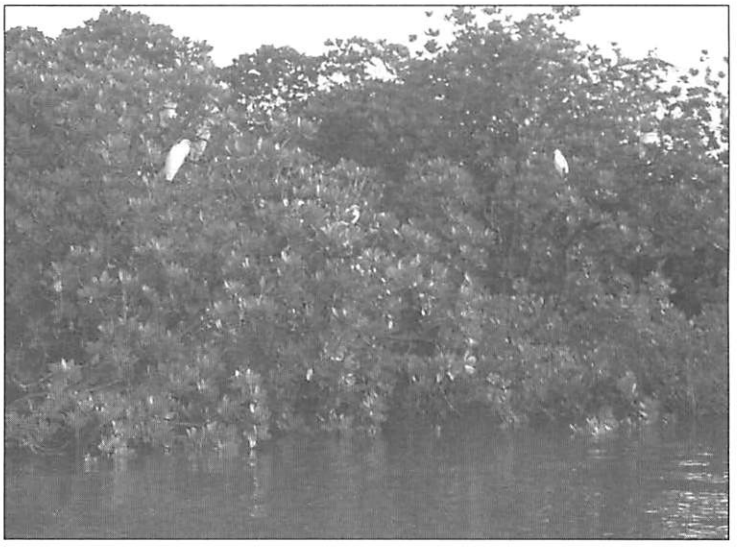

Figure 9. Mangrove swamps comprise woody trees and shrubs and are found in tropical and subtropical areas—southwest Florida, Louisiana, Texas, Hawaii, and some of the island territories like Guam and the Northern Marianas (Jim Good photo).

agricultural use in the late nineteenth century.

Connections to the watershed

The condition and quality of a watershed's aquatic and upland ecosystems have an enormous influence on its estuarine habitats. Activities such as road construction; forestry; agriculture; and urban, suburban, and rural development all have an effect. The resulting runoff pollution and changes in the quantity and timing of water inflow are particularly important. Assessment and management of upland and riparian habitats are described in other chapters.

Human Uses and Management of Estuaries

People have been attracted to estuaries for millennia. Native peoples built their villages along the shore, harvested the abundant salmon, oysters, and other fish and shellfish, and used the estuaries as transportation and trading routes. Early Euro-American settlers were attracted to estuaries, too—for transportation convenience, vast natural resources, and surrounding flat lands they could use for industry and port development. The twentieth century saw the growth of existing and new settlements, improvements in ports and navigation, industrial and commercial development, and commercial and recreational exploitation of oysters, salmon, and other living resources. In recent decades, residential and recreational development has boomed along estuary shorelines, bringing demands for more public access and amenities. With all of this development has come a plethora of unwanted by-products—pollution, conversion of valuable wetlands to other uses, decline of native fisheries, invasion of estuaries by nonnative nuisance species, and crowding of highways and recreational facilities.

These historical and more recent changes are discussed later in this chapter.

Who owns our nation's estuaries?

Each state, as trustee for its citizens, owns and manages most of the land beneath tidal and commercially navigable waters, up to mean or ordinary high water (figure 10). The original 13 states and each state thereafter, when admitted to the Union, received title to these submerged and submersible lands from the federal government. Five states—Maine, Massachusetts, Pennsylvania, Delaware, and Alaska—extend private ownership to mean or ordinary low water. However, public trust rights and easements (described below) remain for those privately held lands up to mean high water.

Through their state lands authorities, many states sold or leased some of these tidelands for port development, oyster farming, or other uses, and still can do so today. However, the state may not relinquish its responsibility to protect certain public rights to these lands. Collectively termed the "public trust doctrine," these rights permit the public to navigate on and over the water; to harvest fish, shellfish, and waterfowl; and

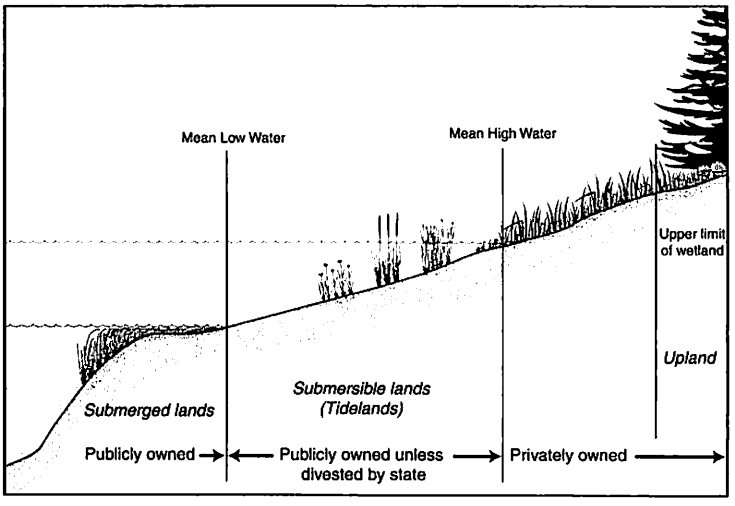

Figure 10. Typical public-private ownership patterns in estuaries. Many state-owned tidelands were sold off in the nineteenth and early twentieth centuries, but public trust rights were not extinguished in most cases.

to use the water as a highway of commerce. Court decisions in the 1980s expanded public trust rights to include recreational and aesthetic values as well.

Today, protection of public trust rights is a fundamental principle used by states in leasing and regulating uses of state waterways and wetlands, including estuaries. Even the areas of submerged land in estuaries that were sold to private parties nearly a century ago are subject to the public trust doctrine.

Although most states own tidelands up to mean high water, the extensive high tidal marshes that fringe estuaries are mostly in private ownership. This situation makes it essential to involve many landowners when considering restoration and enhancement activities in estuaries.

Estuary changes—prehistory, early white settlement, and development to 1970

Our nation's estuaries are affected by both natural and human disturbances. Major forest fires that predate Euro-American settlement of the region are an example of natural disturbances that likely had significant estuary impacts because of the large pulses of wood, debris, and sediment that followed. Climate variability and long-term climate change likely affect estuarine ecology in more subtle ways that are little understood. However, a number of recent studies do illustrate potentially dramatic loss of tidal wetlands as sea level rises as a result of global warming.

Native peoples used estuaries and tidal wetlands for hunting, fishing, and shoreline settlement for millennia, but their use likely had little adverse effect on the health and functioning of these ecosystems. Over the course of Euro-American settlement and expansion, physical alterations designed to improve navigation and provide land for growing ports, cities, and small farms changed the estuarine landscape but degraded its natural functions.

Most apparent are the direct physical changes. Examples include

- Stabilization of river mouths with jetties

- Dredging to deepen or stabilize river channels and construct turning basins and marinas
- Stabilization of shorelines with rock or bulkheads
- Diking and draining of tidal marshes for agriculture
- Ditching and draining for mosquito control
- Filling for industry, ports, marinas, highways, and similar development

Despite huge changes in America's estuaries, large areas of intact tidal marshes, flats, sea grass beds, and other productive, healthy habitat remain today or are being restored in many estuaries. But none can be restored to the relatively pristine conditions of presettlement days. At the very least, dams, forestry operations, agriculture, and human settlement have changed the volume and timing of water inflow and inputs of sediment and other runoff pollution.

Other less visible changes also have occurred, including some that have greatly influenced the ecological character and functions of our estuaries. Examples include

- Massive harvesting and decline of native species, such as oyster, shrimp, and salmon
- Purposeful introduction of nonnative species
- Accidental introduction of dozens of nonnative species from other parts of the world, many through the discharge of ballast water by ships from foreign ports
- Changes in the timing of freshwater inflow and sedimentation caused by farming, logging, and other soil-disturbing activities
- Changes in the quantity of available freshwater associated with the damming of rivers for power production and municipal and industrial water supply

Estuary changes and threats—1970 to present

In the late 1960s, the degraded health of America's estuaries caught the attention of the U.S. Congress, leading to the National Estuarine Pollution Study (1966), the Stratton Commission report (*Our Nation and the Sea,* published in 1969), and the National Estuary Study (1970). These reports documented a precipitous decline in fisheries, shellfish harvest closures, habitat loss, and inadequate governmental control over harmful activities affecting our estuaries. The result was a plethora of new federal and state programs designed to correct these problems. In 1972, two vital national estuarine protection measures passed and signed into law were the federal Coastal Zone Management Act and amendments to the Clean Water Act. Since then, these laws have been strengthened and new ones passed to control dredging and dredged material disposal, land filling, and pollution discharge; to plan for wise development of estuarine shorelines; to protect, acquire, and preserve critical habitat for fish and wildlife species; and to restore and rehabilitate degraded areas. Despite these advances, population growth and

coastal development continue to threaten the health and integrity of our nation's estuaries.

Estuary planning—balancing protection and development

Nearly every coastal state from Maine to California has used land- and water-use planning as tools for protecting estuaries and coastal wetlands. North Carolina, California, Oregon, and other states, require local governments to prepare land-use plans that include protection for estuarine wetlands. For example, Oregon's estuary plans protect 94 percent of remaining estuarine wetlands through zoning.

Rhode Island and many other states rely on special area-management plans to protect estuarine wetlands. In the process of developing these plans, researchers study specific problems; others identify alternative solutions to problems; and local, state, federal, and other stakeholders negotiate and trade off as needed to build consensus. The Salt Ponds Special Area Management Plan, encompassing seven small estuaries on the southwestern shore, is a good example of this process and has resulted in reduction of polluted runoff and improved estuarine fisheries.

Regulating dredge and fill in estuaries

Dredging, filling, in-water construction, and other activities are regulated nationally by the Army Corps of Engineers in estuarine wetlands and deep-water habitats, as described in chapter 13, "Restoring Wetlands in your Watershed." Generally, within estuaries, permits for these activities are not issued unless

- Proposed uses are water dependent.
- A public need is served.
- There are no alternative upland sites that could accomplish the same purpose.
- Unavoidable impacts are minimized and compensated for by habitat mitigation.

Acquisition for preservation and conservation

Acquisition by purchase or easement for preservation and conservation purposes is one of the best ways to protect estuarine areas, particularly privately held high marshes above the state ownership line. At the federal level, the U.S. Fish and Wildlife Service system of national wildlife refuges protects tens of thousands of acres of estuarine wetlands around the United States that are vital to migrating and resident waterfowl and shorebirds. The U.S. Park Service also has significant estuarine wetlands area under its protective jurisdiction as part of National Seashores. There are 25 National Estuarine Research Reserves between 1,000 to 20,000 acres in size, a program that was established as part of the nation's coastal management program. Thousands of acres of other estuarine lands are protected and managed at the state level and by private nonprofit organizations such as The Nature Conservancy, The Trust for Public Lands, and local land trusts.

Pollution and pollution control

Located as they are at the "bottom" of watersheds, estuaries collect a variety of pollutants—introduced nutrients and organic matter, toxic metals, pesticides, herbicides, pathogenic bacteria and viruses, oil and other hydrocarbons, sediment, radioactive waste, plastic debris, and other trash.

Pipeline discharges—known as *point sources*—are responsible for some of these pollutants. Typical point sources in our region include municipal sewage treatment plants, power generation facilities, seafood processing plants, and pulp and paper mills.

Less obvious and more difficult to detect and control are pollutants from dispersed land runoff—*nonpoint sources.* Eroded soil, fertilizer, pesticides, and herbicides that run off from cropland, pastures, and forest land are major sources of pollution (figure 11). So are septic tank wastes that drain or leach into coastal waters. Urban runoff is another example. Storm water laden with oil, grease, fertilizer, pesticides, herbicides, and toxic metals washes into streams and rivers and eventually into estuaries and nearshore waters.

Other pollution threats to estuaries include rare but potentially devastating oil spills, such as the 1989 *Exxon Valdez* oil spill in Alaska and the 1999 *New Carissa* oil spill near Coos Bay, Oregon.

Nonnative aquatic nuisance species represent a growing and significant form of biological pollution that enters estuaries through point and nonpoint sources. Biological pollutants present a special cleanup challenge because, once released, they reproduce and spread on their own. Other nuisance species, such as the common reed *(Phragmites australis),* may be native, but spread invasively when physical conditions, such as tidal flow, are changed.

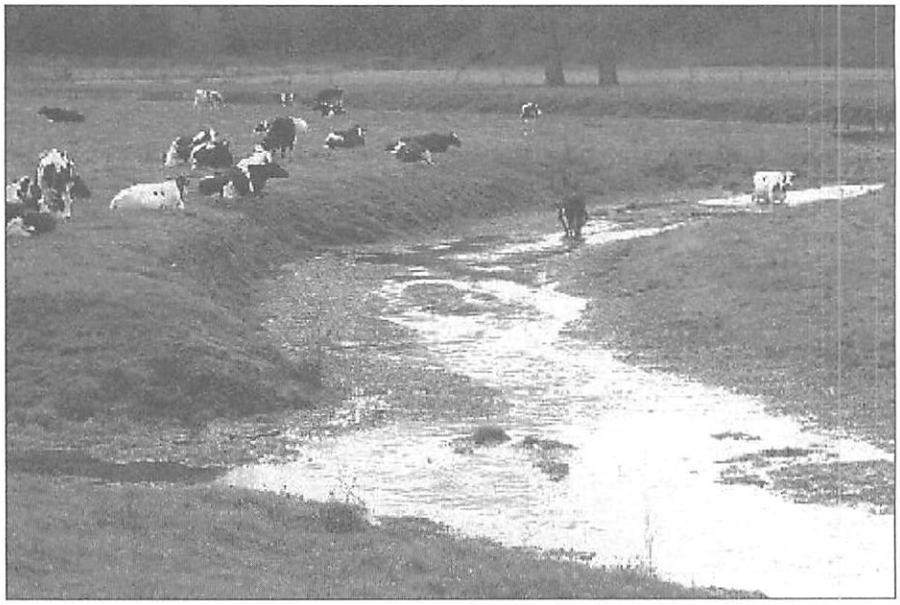

Figure 11. Runoff from agricultural land transports animal wastes, soil, fertilizer, herbicides, and pesticides into streams, rivers, and eventually to estuaries.

Phragmites, a major problem along much of the east coast of the United States, where it has crowded out a more diverse flora to form huge stands with limited habitat value, is the target of numerous eradication efforts, such as prescribed burning and increased tidal circulation.

Estuaries and coastal waters can assimilate certain kinds and levels of pollutants, but their capacity sometimes is overwhelmed, stressing ecosystems and the organisms that live there. In an effort to limit pollution, the U.S. Congress and most state legislatures have passed laws to regulate point source discharges, manage runoff pollution, and help prevent and respond to spills of oil and other hazardous waste. Literally billions of dollars have been spent to upgrade municipal sewage treatment facilities throughout the U.S. in the past three decades, and billions of dollars more have been invested by private business to reduce and treat industrial wastes.

What laws and agencies are designed to limit water pollution? Government uses a combination of "carrot and stick" approaches. At the federal level, the principal law for controlling point and nonpoint sources of pollution is the *Clean Water Act* (formerly the Federal Water Pollution Control Act). The U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers have key responsibilities for implementing the Clean Water Act.

Many key provisions of the Clean Water Act, however, are delegated to state water-quality agencies. These agencies administer Section 402 of the Clean Water Act—the National Pollutant Discharge Elimination System, the permit program for regulating pipeline discharges. State pollution-control agencies are also responsible for nonpoint source pollution control programs (for example, the Clean Water Act, Section 319), as well as for certifying that permits for wetland or waterway alterations issued by the Army Corps of Engineers meet state and federal water-quality standards (Clean Water Act, Section 401).

Another important coastal pollution control law is the Ocean Dumping Act. The Army Corps of Engineers administers the Ocean Dumping Act's Section 103 permit program, which regulates the transportation and dumping of wastes into coastal or offshore waters. Industrial waste dumping no longer is permitted in U.S. waters, so Ocean Dumping Act permits today are mainly for disposal of clean sand dredged from coastal navigation projects. The Environmental Protection Agency must approve offshore dumping sites.

Another provision of the Clean Water Act set up the National Estuary Program in 1987. With 28 "national estuaries" designated, this program has been very successful in bringing together all governmental levels with local communities to address estuarine pollution and related issues from a regional perspective. In addition to focused research, National Estuary Programs each prepare a comprehensive conservation and management plan which is then implemented through local, state, federal, and private-sector partnerships.

The National Estuary Program

The National Estuary Program (NEP) was established in 1987 by amendments to the Clean Water Act to identify, restore, and protect nationally significant estuaries of the United States. Unlike traditional regulatory approaches to environmental protection, the NEP targets a broad range of issues and engages local communities in the process. The program focuses not just on improving water quality in an estuary, but on maintaining the integrity of the whole system—its chemical, physical, and biological properties, as well as its economic, recreational, and aesthetic values.

The NEP is designed to encourage local communities to take responsibility for managing their own estuaries. Each NEP is made up of representatives from federal, state, and local government agencies responsible for managing the estuary's resources, as well as members of the community—citizens, business leaders, educators, and researchers. These stakeholders work together to identify problems in the estuary, develop specific actions to address those problems, and create and implement a formal management plan to restore and protect the estuary.

The Environmental Protection Agency administers the NEP, but program decisions and activities are carried out by committees of local government officials, private citizens, and representatives from other federal agencies, academic institutions, industry, and estuary user groups. Estuaries are selected for inclusion in the NEP through a nomination process led by state governors.

Once selected for inclusion in the national program, each NEP must create decision-making committees made up of relevant stakeholders to identify and prioritize the problems in the estuary. Most NEPs choose a management framework that includes a management committee to oversee routine operation of the program; a policy committee made up of high-level representatives from federal, state, and local government agencies; a technical advisory committee to guide technical decisions; and a citizens advisory committee to represent the interests of estuary user groups and the public. Together, the committees develop a comprehensive conservation and management plan for protecting the estuary and its resources.

The objective of each NEP is to create and implement a coordinated conservation and management plan that addresses the whole range of environmental problems facing the estuary, as well as the economic and social values of the estuary. By providing grants and technical assistance, the Environmental Protection Agency helps state and local governments achieve these goals. The Environmental Protection Agency also shares lessons learned among all the individual estuary programs as well as other coastal communities.

Twenty-eight estuary programs are currently working to safeguard the health of some of our nation's most important coastal waters. One of these areas is Long Island Sound.

Long Island Sound NEP

The Long Island Sound Study was one of the first NEPs designated. The sound, which is bounded by New York and Connecticut, has more than 8 million people living within its watershed (figure 12). It is approximately 110 miles long (east to west) and about 21 miles across at its widest point. Research commissioned by the Long Island Sound Study estimated that more than $5 billion is generated annually in the regional economy from boating, commercial and sportfishing, swimming, and beachgoing.

The Long Island Sound Comprehensive Conservation and Management Plan is the result of a strong partnership between EPA regions 1 and 2 and the states of Connecticut and New York. The comprehensive conservation and management plan was approved by the Environmental Protection Agency Administrator Carol Browner and the governors of Connecticut and New York in September 1994. The plan identifies seven issues meriting special attention, including (1) low oxygen conditions (hypoxia), (2) toxic contamination, (3) pathogen contamination, (4) floatable debris, (5) the impact of these water-quality conditions and habitat degradation and loss on living marine resources, (6) land use, and (7) public involvement and education.

The top priority of the Long Island Sound Study is reducing nitrogen loads that contribute to the low levels of oxygen affecting substantial areas of western Long Island Sound in late summer. Other implementation priorities are habitat restoration, watershed management, disposal of dredged materials, and public education and involvement on Long Island Sound issues.

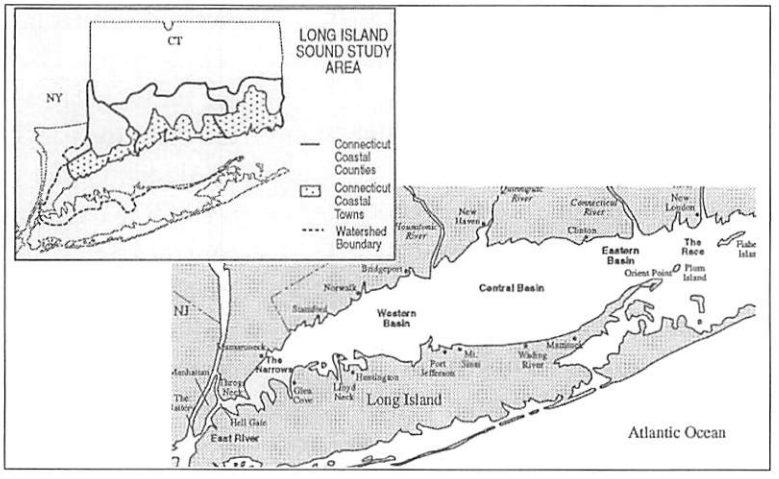

Figure 12. Long Island Sound was one of the first estuaries in the EPA's National Estuary Program.

The Long Island Sound Habitat Restoration

Initiative involves more than a dozen governmental and nongovernmental partners and has identified more than 400 sites for possible restoration. Tidal and freshwater wetlands, beaches and dunes, coastal grasslands, intertidal flats, shellfish reefs, and submerged aquatic vegetation are examples. Overall goals, established in 1998, are to restore the ecological functions of degraded and lost habitats; restore at least 2,000 acres and 1,200 river miles of natural habitat over the next 10 years; and use partnerships to accomplish the restoration objectives and to leverage limited state, local, and federal funds.

Through 2000, the states of New York and Connecticut have made significant progress toward their goals, restoring more than 300 acres of tidal wetlands and 36 miles of riverside habitat. Some 1,400 areas of lands were purchased outright for conservation and development rights purchased on more than 400 acres.

Despite years of planning and voluntary programs, nonpoint source pollution problems have persisted or worsened over the past several decades. Congress responded in 1990 with Section 6217 of the Coastal Zone Act Reauthorization Amendments. The 6217 program attempts to link *enforceable* state coastal zone management policies with *voluntary* nonpoint source pollution control efforts promoted by state water-quality agencies.

In theory, this program makes good sense because poor land management is a major cause of nonpoint source pollution, and pollution reduction programs require changed land-use and management practices. For example, restoration and enhancement projects can create streamside filter strips to intercept runoff pollution that otherwise would go directly into streams and estuaries. The Section 6217 program has yet to achieve its objectives, however, in part because it is an ambitious, long-term undertaking and in part because funding has been sparse.

Oil spill prevention, contingency planning, response, and recovery are addressed under the national Oil Pollution Act and similar laws passed by many coastal states. The most recent version of the national law was passed in the wake of the disastrous 1989 *Exxon Valdez* oil spill in Alaska. Under this and most state laws, the U.S. Coast Guard, the state pollution control agency, and the ship's agent all have major responsibilities for response and recovery, with the ship's owner assuming principal financial responsibility. State and federal settlements for oil spill environmental damages have funded a number of estuarine restoration projects in the Pacific Northwest and elsewhere.

Nonnative species introductions

Some nonnative species introduced to estuaries generally are not considered problems. On the west coast, examples include the eastern soft-shell clam *(Mya arenaria),* striped bass *(Roccus saxatilis),* American shad *(Alosa sapidissima),* and Japanese oyster *(Crassostrea gigas).* These species, in fact, are highly valued for their contributions to recreational and commercial fisheries and provide economic incentives for keeping estuarine waters clean.

Other introduced species are not so welcome. The Asian whelk *(Rapana venosa)* was first seen in Chesapeake Bay in 1998 and is now a well-established population. It preys on bivalves. The European green crab *(Carcinus maenas),* long established on the east coast, was discovered in San Francisco Bay in 1989 and apparently has migrated north to northern California and Oregon. Biologists and the fishing industry are concerned that this voracious, predatory, and highly adaptable species will affect native and commercial shellfish populations.

The Chinese mitten crab *(Eriocheir sinensis)* is another threat to west coast estuaries and upstream freshwater systems. It has become well established in San Francisco Bay, spreading as far as 200 miles up into the delta region, burrowing into and damaging levees, and fouling fishing gear. This species may have been introduced illegally for harvest or accidentally via shipping.

Dozens, perhaps hundreds, of less prominent plant and animal species have invaded America's estuaries, including microscopic and disease-causing organisms. Not all are nuisances, but they certainly have changed estuaries and will continue to do so, sometimes for the worse.

Note that the difference between "nonnative" species and "nuisance" species basically is a value judgment. The two definitions are gray and shifting, depending on the interests at stake. Even some native species are considered a "nuisance" by some people. Examples are burrowing mud shrimp and ghost shrimp in oyster-growing areas and harbor seals that feed on returning adult salmon at the mouths of estuaries.

The pathways for aquatic nuisance species introductions are many. Some individuals may be attached to seaweed that serves as packing material for oysters; others hitchhike on the bottoms of ships, fishing vessels, or recreational boats from other regions. By far, however, the most significant source of aquatic nuisance species today is ballast water discharged by ships calling at U.S. ports from locations throughout the world.

Ballast water, carried in compartments or tanks inside a ship and used to adjust a vessel's trim (its level or position with respect to the water), is a virtual witch's brew of unwanted organisms, mainly microscopic plankton and larval forms of larger species (figure 13). Scientists sampling ballast water from more than 160 ships visiting Coos Bay, Oregon, found more than 400 species of living nonnative organisms that ultimately were pumped into the bay.

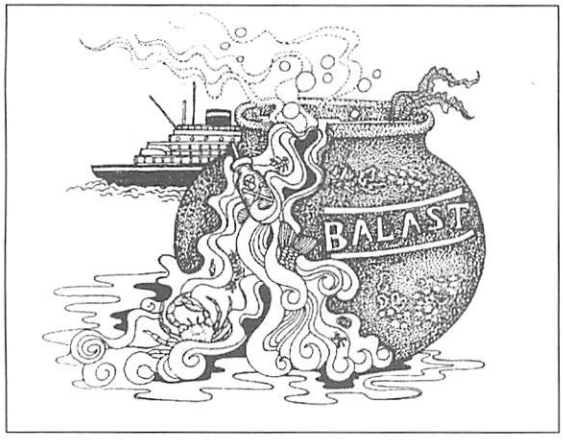

Figure 13. Discharge of ballast water from ships visiting United States ports is the source of many new species introductions (Sharon Torvik drawing, courtesy of South Slough National Estuarine Research Reserve).

Once established, aquatic nuisance species are difficult, if not impossible, to eradicate. The best solution to aquatic nuisance species problems is to avoid introductions in the first place. One preventive measure being promoted is voluntary ballast water exchange in the deep ocean after ships leave foreign ports. Shippers argue, however, that some ships are not equipped to exchange ballast water at sea and to do so would jeopardize vessel stability and safety. Other solutions, such as ballast water treatment prior to release, are technologically feasible, but may be too expensive. Education and management safeguards can reduce inadvertent introductions from the many other "nonpoint" sources of aquatic nuisance species.

America's Estuaries—Regional Overview of Restoration Needs

Two early national studies—the National Estuarine Pollution Study in 1966 and the National Estuary Study in 1970—shone a bright light on the degraded and worsening condition of our nation's valuable, productive estuarine ecosystems. These studies were partly responsible for the passage of landmark national environmental legislation in the early 1970s, including amendments to the Clean Water Act and the Coastal Zone Management Act. Since then, estuaries have been a major focus of research, planning, protection, and management efforts. Examples include state coastal management plans, all of which address estuary protection, protected area programs (for example, National Estuarine Research Reserves), resource inventories (for example, NOAA's 1985 National Estuarine Inventory and the U.S. Fish and Wildlife Service National Wetlands Inventory), and pollution cleanup efforts (the National Estuary Program, for example).

Beginning in the 1990s, a new focus was added to estuary programs in the United States—restoration and rehabilitation of damaged or degraded estuarine environments. Restoration continues to attract more and more interest. State and federal agencies are major players in this movement, directly through acquisition, protection, and both regulatory and

nonregulatory restoration, but also indirectly through incentive and technical assistance programs. An example of the former is extensive restoration undertaken by state and federal agencies in the Mississippi delta region through the Coastal Wetlands Planning, Protection, and Restoration Act. More than 170 restoration projects have been completed or are underway in Louisiana tidal wetlands. An example of the community-focused program is the National Marine Fisheries Service's Community-Based Restoration Program. Another example is the Estuary Restoration Act of 2000, a law that promotes estuary habitat restoration, establishes public-private partnerships, and provides matching funds for restoration activities. These and other programs are aimed at local community and watershed groups—the other major player in restoration. Today, the community-based restoration movement is strong and growing rapidly. Watershed associations or councils are one of the primary vehicles for community participation.

Restoring America's estuaries is the theme of a recent, comprehensive review of the status of estuarine restoration in the United States and its territories. The report is part of a national strategy for restoring coastal habitats, developed by the nongovernmental organization Restore America's Estuaries, which is an alliance of 11 regional, coastal, community-based environmental organizations with a combined membership of more than 250,000. The strategy addresses restoration needs and planning for six major regions of the United States—Northeast Atlantic, Southeast Atlantic and Caribbean, gulf coast, California and Pacific Islands, and the Pacific Northwest and Alaska. It lays out regional and estuary planning guidelines and principles and includes regional summaries of restoration and planning needs. Highlights of estuarine resources and restoration needs in each area are summarized below.

Estuaries of the Northeast Atlantic

The Northeast Atlantic region is defined as the estuarine areas of the states of Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, and the District of Columbia. This region includes 103 estuarine and coastal drainage areas and covers more than 70,000 square miles. The estuaries of the Northeast are home to some of the most densely developed and populated metropolitan areas in the United States, such as New York City, Boston, Providence, Baltimore, and Washington, D.C.

Northeast estuaries support diverse and highly productive habitats, including tidal salt marshes, sea grass beds, shellfish reefs, intertidal flats, estuarine embayments, beaches and dunes, and rocky shores. These ecologically significant habitats provide food, shelter, and nursery areas for a variety of plants, invertebrates, fish, reptiles, birds, and mammals. The estuaries of the Northeast are also home to many species that are endangered, threatened, or of

concern, including bald eagle, piping plover, roseate tern, and diamondback terrapin.

Because of their location in or near major metropolitan areas, Northeast estuaries are centers of residential, recreational, commercial, agricultural, and industrial activities. Historically, estuaries have been preferred as human habitat, and today they are linked inextricably to our economy and our quality of life. Habitat-dependent activities such as fishing, tourism, shipping, energy production, and agriculture have affected the very resources on which they depend. Throughout the Northeast, these activities have resulted in the loss and degradation of vital habitat.

A significant portion of the coastal habitats within the Northeast have been altered, degraded, or destroyed. By the late 1930s, about 90 percent of the marshes of the northeast U.S. coast had been extensively ditched to control mosquitoes. Dams block the migration of diadromous fish (for example, striped bass, shad, sturgeon, American eel). Many shellfish areas are occasionally restricted for harvest because of public health threats from bacterial or viral contamination. Urban storm-water runoff, effluent from sewage treatment plants, agricultural runoff, and increased boating activity are the primary causes of harvest restrictions.

From the Gulf of Maine south to Chesapeake Bay, planning and restoration efforts are under way to restore the health of the estuaries of the Northeast Atlantic. Although there are geographic and ecologic differences among Northeast estuaries, common themes have emerged for important habitats, planning efforts, and information needs essential for the effective restoration of estuary structure and function.

A variety of federal, regional, and state plans have been developed to address habitat restoration issues in the Northeast. Local entities, including city and county governments, nonprofit conservation organizations, and other community groups, are also participating in many successful restoration planning efforts. Some planning has been done through state coastal zone management programs, with restoration goals set at the estuary or watershed level. This work focuses on restoration of natural marsh hydrology to address invasive species like Phragmites, or reduction of nonpoint source pollution to reduce algal growth in favor of natural sea grasses. However, only a limited number of plans set measurable objectives, outline specific action plans, or set priorities for potential restoration projects. Among this limited number are some excellent examples that cover large geographic areas (for example, the Long Island Sound Habitat Restoration Initiative, the New York/New Jersey Harbor Estuary Program, the Chesapeake Bay Program, and the Gulf of Maine Alliance). These plans serve as models for smaller watershed and estuary areas in need of additional planning.

Estuaries of the Southeast Atlantic

For the purposes of this report, the Southeastern United States region is defined as the coastal and estuarine zones of the states of North Carolina, South Carolina, Georgia, the eastern coast of Florida, the Florida Keys, and the U.S. Virgin Islands and Puerto Rico. The Southeast Atlantic estuarine region is one of the largest, most diverse and most productive coastal areas in the United States. It is characterized by 18 major estuaries totaling almost 56,000 square miles of drainage area. The Southeast represents the second highest U.S. region in wetlands coverage area and contains 3.9 million acres (18 percent of the national total) of shellfish beds, ranking third in the total acreage of classified shellfish waters, according to NOAA.

Great habitat diversity is a characteristic of the estuarine and coastal ecosystems of the Southeast Atlantic region—the sawgrass marshes, mangrove forests, and pine lands of south Florida; the carnivorous plant wetlands, bald cypress swamps, live oak maritime forests, longleaf pine savannas, and the barrier island complexes of the Coastal Plain.

Traditionally, forested lands have been the dominant land use within the estuarine/coastal watersheds of the Southeastern U.S. region, accounting for nearly one-third of all land within the estuarine drainage areas. These forests represent a significant percentage of the nation's commercial forest industry lands.

The Southeast region is the least densely populated coastal region in the United States. Land use in the region is about 30 percent forested, 22 percent agricultural, and 4 percent urban. The Albemarle/Pamlico and North Florida areas remain largely agricultural and forested, while other areas are rapidly urbanizing. Rapid population growth is occurring in this region, and the population is projected to increase by 24 percent from 1988 to 2010. Agriculture is also a major land use in the region, accounting for 22 percent of the lands within the estuarine drainage areas.

About 250 million pounds of seafood, representing a catch value of nearly $170 million, were landed at South Atlantic ports in 1989. Over 50 percent of this catch comprised estuarine-dependent species, including blue crabs, Atlantic croaker, Atlantic menhaden, and penaeid shrimp. The region also supplies important estuarine-dependent recreational fisheries, including red drum. Many ecologically valuable species are dependent upon the Southeastern estuaries. Examples are killifish and anchovies, which provide critical links within the estuarine food chain. In addition to finfish, the South Atlantic region accounts for nearly one-fifth of all classified shellfish-growing waters in all regions.

Within the Southeast U.S. region, there are several major themes of estuarine and coastal habitat loss or degradation, including loss of old-growth forest because of logging, agriculture, and development, and loss or conversions of wetlands and bottomland forests because of hydrological alteration

and conversion to agriculture or development. Within private or public land, pristine areas and rare habitats in the Southeast have suffered heavy losses, and human effects have permeated the region, rather than encroaching into the region along one or even several fronts.

Within the Southeast region, restoration programs and plans are primarily being implemented as state-level strategies. The level of planning for restoration varies widely and few plans exist with an emphasis on regional planning. An analysis of the region's restoration planning efforts indicates that duplication of significant efforts (and associated resources) exists within the federal programs and among the state-level programs. Several planning efforts exist, however, with a regional focus. Examples include National Estuary Programs in North Carolina and Florida, Partners in Flight, the North American Waterfowl Plan, and NOAA's Critical Habitat Plan for the Southeast Atlantic. Nevertheless, significant gaps exist in regional planning and implementation of successful restoration efforts.

Estuaries of the Gulf of Mexico

The Gulf of Mexico region is defined here as the coasts of Texas, Louisiana, Mississippi, Alabama, and western Florida, excluding the Everglades, Florida Keys, and Florida Bay. This region includes 28 estuaries, covers 30,000 square kilometers (12,000 square miles), and drains approximately 60 percent of the land area of the continental United States. These estuaries contain more than half the nation's tidal wetlands, as well as large urban areas like Corpus Christi, Houston, New Orleans, Mobile, and Tampa.

Gulf estuaries support diverse and highly productive habitats, including marshes, mangroves, sea grass beds, oyster reefs, tidal flats, shallow open water, swamps, bogs, prairies, barrier islands, and forests. These ecologically significant habitats provide food, shelter, and nursery areas for a variety of fish, invertebrates, birds, reptiles, and mammals. The estuaries of the gulf coast are also home to many protected species, including Kemp's Ridley sea turtles, piping plover, brown pelican, West Indian manatee, diamondback terrapin, Texas pipefish, and bald eagle.

Gulf coast estuaries are centers of residential, recreational, commercial, agricultural, and industrial activities. Oil and gas production is one of the major activities in gulf coast estuaries that are uncommon elsewhere. In addition, fishing, tourism, shipping, and agriculture are important economic endeavors that have affected estuaries in the region and the resources on which they depend.

Throughout the gulf, development, land subsidence owing to regional tectonics and withdrawal of groundwater and oil deposits, and erosion have resulted in the direct loss of critical estuarine habitat. Although there are geographic and ecologic differences among gulf estuaries, similar natural and anthropogenic processes have resulted in the

loss of habitat throughout the region, with impacts being the greatest where development and industrial activity is greatest.

For example, Louisiana has lost more than 1,500 square miles of marsh since 1930 (figure 14), and approximately 80 percent of the sea grass beds have disappeared from Tampa Bay in the past 100 years. Water quality, essential for healthy habitat, has also been degraded and has led to the restriction of more than 50 percent of shellfish harvesting areas in the region.

From Laguna Madre, Texas, to Charlotte Harbor, Florida, planning and restoration efforts are under way to restore the health of gulf estuaries. A variety of federal, regional, and state plans address habitat restoration issues. For example, there are seven National Estuary Programs in the region. Local entities, including governments and conservation organizations, are participating in many successful restoration-planning efforts. Current restoration priorities for the gulf include enhancing marshes, sea grass beds, barrier islands, and other habitats, as well as controlling invasive species, restoring hydrology, and improving water quality.

Estuaries of California and the Pacific Islands

The California and Pacific Islands region is defined here as the northern and southern coasts of California, Hawaii, and the Pacific Island/U.S. protectorates. Covering huge and diverse areas of the earth, estuaries in the region not only are distinct from each other ecologically and politically, but as a whole are geologically and ecologically distinct from the California coast.

Because of the region's geomorphology, estuaries generally have small water-surface areas. Although most of the estuaries are quite small on a national scale, the largest

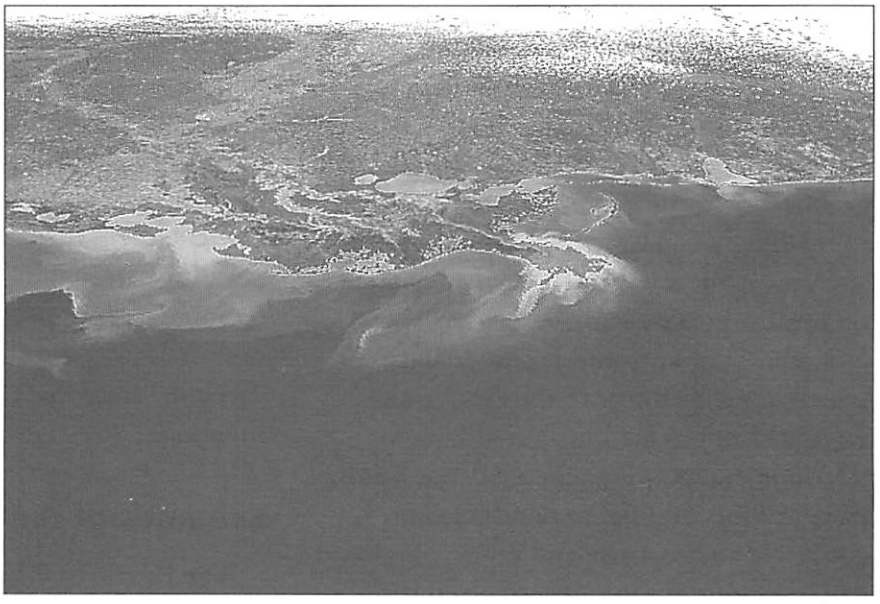

Figure 14. Rising sea level, land subsidence, water and oil withdrawal, and erosion along channels all contribute to significant land loss in the Mississippi delta region (NASA photo).

estuary, San Francisco Bay, has a water surface area of approximately 450 square miles. Habitats within the region include salt, brackish, and freshwater marsh; open water lagoon; seasonal wetland; tidal mudflat; beach/dune; upland and riparian; salt ponds; Hawaiian fish ponds; and others. The estuaries of the Pacific southwest provide important habitat for a host of shore birds and wading birds, fish-eating birds, waterfowl, and raptors. Estuaries also provide essential habitat for numerous insects, reptiles, and mammals. Many of these species are also listed as threatened or endangered, for instance, sea otter; green sea turtle, Hawaiian stilt; salt marsh harvest mouse; frogs, lizards, and turtles; and salt marsh wandering skipper, butterflies, and beetles.

Estuaries of California and the Pacific Islands are centers of residential, recreational, commercial, agricultural, and industrial activity. Indeed, estuaries have historically been preferred as human habitat because of their abundance of fish and shellfish, proximity to freshwater, and access to inland areas. The region also supports a fisheries economy that is directly dependent on healthy estuary habitat.

In the California and Pacific Islands region, a major threat to the estuary and wetland habitats is filling and diking for development. San Francisco Bay has had 82 percent of its original wetland filled or converted to other wetland types. This trend has now been put into reverse. In the Commonwealth of the Northern Mariana Islands, filling has resulted in a loss of 64 percent of Saipan's wetlands. In addition to development, sedimentation and erosion, point and nonpoint source pollution, and oil spills have been identified as threats. In the Pacific Islands especially, introduction of nonindigenous nuisance species is a major concern because of the islands' unique and largely endemic populations.

From northern California to the Northern Mariana Islands, planning and restoration efforts are under way to restore the health of this region's estuaries. Although there are geographic and ecologic differences among estuaries, common themes emerge for the habitat, planning, and information needs essential for effective restoration of estuary structure and function. Throughout California and the Pacific Islands, similar natural and anthropogenic processes have resulted in the loss of habitat, with impacts being the greatest where development is greatest, such as in southern California from Santa Barbara to San Diego. Current restoration priorities for the Pacific southwest focus primarily on increasing and preserving the quality and diversity of habitat and living resources within the estuaries. Estuaries, particularly in the Pacific Island subregions, perform critical biological functions and take on more importance because if these areas are destroyed or compromised, there are no "backup" areas that can perform these functions.

Estuaries of the Pacific Northwest

The Pacific Northwest region is defined here as the coasts of Alaska, Washington (including the Puget Sound), and Oregon. This region has more than 100 estuaries,

contains more than 3,300 square miles of tidal wetlands, and receives freshwater flow from approximately 25 percent of the land area of the United States—much of it from the Columbia River basin. The surface area of Alaska's estuaries makes up more than half of the total estuarine area in the United States

Pacific Northwest estuaries support more than 75 percent of the nation's harvest of wild and hatchery-raised salmon and many other important commercial species, including juvenile rockfish, crab, herring, oysters, and other shellfish. Communities in coastal Oregon and Washington, the greater Seattle area in Puget Sound, and in southeast Alaska, including Anchorage, are growing rapidly in response to recreational and tourism activities.

Pacific Northwest estuaries encompass diverse and highly productive habitats, including open water, kelp forests and eelgrass beds, rocky reefs, sand and gravel beaches, oyster and shellfish beds, mud and sand flats, marshes, swamps, and riparian forests. These ecologically significant habitats provide food, shelter, and nursery areas for a variety of fish, invertebrates, birds, reptiles, and mammals. The estuaries of the Pacific Northwest are also home to many protected species, including coho and chinook salmon, steelhead and bull trout, marbled murrelet, and bald eagle.

As in other regions of the country, Pacific Northwest estuaries are centers for residential, recreational, commercial, agricultural, and industrial activities, although there has been significant transition toward recreation and tourism-related business in recent years. Habitat-dependent activities such as fishing, tourism, shipping, energy production, forestry, and agriculture have all affected habitat quantity and quality in the region.

On the coasts of Washington and Oregon, estuarine habitat loss has been associated with the diking and draining of tidal marshes, dredging and filling for navigation and port improvements, and other development. For example, more than 70 percent of the tidal wetlands have been destroyed in the Columbia River estuary since 1870, and historic anadromous fish stocks are at 10 percent of their original population levels. In Oregon's remaining estuaries, two-thirds of tidal wetlands have been lost. Puget Sound has lost more than 70 percent of its tidal wetlands in the past century, and more than 800 miles (one-third) of its marine shorelines have been modified by development. In the Alaskan subregion, the major cause of estuary habitat degradation has been the *Exxon Valdez* oil spill. In 1989, the *Exxon Valdez* spill contaminated about 1,500 miles of Alaska's coastline. On the bright side, less than 1 percent of Alaska's estuarine wetlands have been lost to direct development, mostly in Anchorage and other developed areas.

From the Gulf of Alaska to southern Oregon, planning and restoration efforts are beginning to restore the health of Pacific Northwest estuaries. Much of this effort has focused on the restoration of diked tidal marshes, which are easily restored by breaching or removing dikes. Current

restoration priorities for the Pacific Northwest include restoring natural hydrology to areas cut off from tidal circulation; removing dikes and tidegates to restore mudflats, marshes, and eelgrass beds; replanting riparian vegetation; controlling invasive species such as green crab; and improving water quality.

A variety of federal, regional, and state plans address habitat restoration issues for the Pacific Northwest. Local entities, including governments and nonprofit conservation organizations, are participating in these planning efforts. For most estuaries in Oregon and Washington and a few in Alaska, planning for protection has been done at the coastal management level. Restoration planning for estuaries is being undertaken by local watershed councils, through National Estuary Projects (for example, Puget Sound, the Columbia River estuary, and Tillamook Bay), and as part of the research efforts of National Estuarine Research Reserves.

Principles for Estuarine Restoration

The Estuarine Research Federation, a professional association of estuarine scientists and managers, in collaboration with Restore America's Estuaries, developed a set of principles, or best practices, to guide restoration activities. These principles should be used to guide all types of restoration activities: research projects, community-based restoration projects, mitigation projects driven by regulatory requirements, and projects funded by federal, state, and local government. They represent a step toward best management practices for estuarine habitat restoration and provide useful guidance for restoration activities.

The principles are divided into four categories: context, planning, design, and implementation, built around the existing state of knowledge.

Context principles

Principle 1: Preservation of existing habitat is critical to the success of estuarine restoration.

- Annual loss of healthy estuarine habitat far outstrips the rate at which degraded habitat can be restored.
- Preservation of existing habitat must be the starting point for efforts to achieve a net gain in healthy, functioning estuarine habitat.
- Preservation activities must be combined with an aggressive restoration program to achieve national estuarine restoration goals.

Principle 2: Estuaries can be restored only by using a long-term stewardship approach and developing the constituencies, policies, and funding needed to support this.

- Restoration of estuarine habitats requires time and vigilance to allow the cumulative effects of smaller projects to emerge and larger-scale natural processes to reestablish themselves.
- A balanced approach to environmental stewardship and sustainable economic

growth in the coastal zone should be sought that recognizes the needs of humans as well as other species that inhabit estuarine watersheds.

- As pressures on estuaries increase, sustained efforts will be needed to maintain this balance between human and ecological needs.

Principle 3. The size, scale, and amount of restoration activity must increase substantially to have a significant effect on overall estuarine functioning and health.

- Restoration efforts must move from demonstration projects to larger-scale activities that restore more acreage and achieve economies of scale. Scientists and practitioners should collaborate closely on this to be sure we apply what we have learned to date in designing these larger projects.
- New methods and technologies are needed to make restoration as cost-effective as possible.
- Approval requirements need to be streamlined to allow projects to move forward efficiently.

Principle 4: Greater public awareness, understanding, and involvement in estuarine habitat restoration are necessary to the success of individual projects and to achieve national restoration goals.

- Successful restoration efforts require an informed public ready to support the policies, funding, and changes in lifestyle needed to restore and maintain estuaries as healthy and productive ecosystems.
- The public must be involved in direct and meaningful ways in all aspects of the restoration process—design, implementation, and monitoring—so they understand what is possible and what is at stake and can see progress along the way.
- Connections must be made between habitat restoration and other social and economic goals.
- The scientific, advocacy, and regulatory communities need to have a continuing exchange with the public about general progress and problems in habitat restoration and about the results of specific restoration projects, to provide information and accountability.

Planning principles

Principle 5: Restoration plans should be developed at the estuary and watershed levels to set a broad vision, articulate clear goals, and integrate an ecosystem perspective.

- Estuarywide restoration plans are needed to provide a framework for restoration efforts. They should be based on sound ecological principles and incorporate the realities of public preferences and funding.
- The plans should be used to set restoration priorities within an estuary, using scientific criteria, such as the presence of certain hydrology to build on, and socioeconomic factors, such as cultural and aesthetic values and community and economic interests.
- Restoration priorities should not be rigid. Estuaries are dynamic, conditions will

change, and priorities may need to change in response.

- It is important to stay open to community priorities that arise outside the plan and can engage people in ways that provide benefits beyond those of a specific project.

Principle 6: Estuarine restoration plans should be developed through open regional processes that incorporate all key stakeholders and the best scientific thinking available.

- Restoration planning should involve as many stakeholders as possible to build ownership in the plan and its implementation.
- Core planning teams should include scientists, agency representatives, policymakers, and representatives of organizations with an interest in the future of the estuary.
- Property owners and other members of the public should be kept up to date on the process and given frequent opportunities to participate.
- The planning process should have the benefit of quality information provided from all available sources.
- Restoration plans should be designed as catalysts for restoration activity, not as ends in themselves. Everyone involved in developing the plans should be charged with implementing them to ensure that plans are practical, are scientifically sound, and lead directly to action.

Design principles

Principle 7: Project goals should be clearly stated, site specific, measurable, and long term—in many cases greater than 20 years.

- Goals should be set for individual restoration projects as well as for larger-scale estuary restoration plans.
- Goals should be measurable and realistic for the site selected. They should build on favorable habitat conditions and residual values or functions where they exist.
- Opportunities to form partnerships with neighboring landowners to expand the size and scale of restoration projects should be explored.
- Given the uncertainties involved in restoration, goals should be expressed in terms of a scientifically developed range of acceptable outcomes based on appropriate reference habitats.
- Project time frames need to allow sufficient time for natural processes to be reestablished and function restored. Interim goals and progress points need to be identified to make sure a project is moving in the right direction and sustaining public interest and support along the way.

Principle 8: Success criteria for projects need to include both functional and structural elements and be linked to suitable, local reference habitats.

- Success criteria should be identified that relate in a meaningful way to the functioning of the habitat(s) being restored and include such things as vegetation, hydrology, the presence or

absence of key biotic components, nutrient cycling, energy flow, and production.

- The criteria should be linked to the scientifically determined set of goals or end points identified for the project.
- Success criteria must be measurable, widely accepted, and able to be translated into terms the public can understand so they can follow the progress being made.

Principle 9: Site plans need to address off-site considerations, such as potential flooding and saltwater intrusion into wells, to be sure projects do not have negative impacts on nearby people and property.

- Habitat restoration projects should be designed to prevent any negative effects on other property in the vicinity.
- Project neighbors should be provided with information about the project and answers to questions and concerns about potential impacts.

Principle 10: Scientifically based monitoring is essential to the improvement of restoration techniques and overall estuarine restoration.

- All restoration projects and programs need a well-thought-out, scientifically based monitoring component as part of their design. Monitoring is necessary to evaluate the success or failure of a project or program and provide a basis for making adaptive changes.
- Key indicators need to be identified that are linked to restoration goals and can serve as the foundation of the monitoring program. Monitoring protocols should be kept as simple and replicable as possible to minimize costs.
- Monitoring costs need to be built in up front to be certain this critical part of the restoration project or program is carried out.
- As the number and size of restoration projects or programs grows, the need for monitoring will grow and require increased collaboration among scientists, citizens, and advocacy organizations. Monitoring results from today's projects and programs can be used to improve the quality of design of future efforts, creating an ongoing dynamic partnership between the science and practice of restoration.

Implementation principles

Principle 11: Ecological engineering practices should be applied in implementing restoration projects, using all available ecological knowledge and maximizing the use of natural processes to achieve goals.

- Ecological engineering practices built on ecological knowledge are more likely to be successful in restoring functional habitat and more cost effective over the long term than more traditional engineering practices.
- Historical data and appropriate reference sites can be used to design ecologically appropriate interventions.
- The best way to accomplish full restoration is to remove barriers to natural functioning, such as dams, ditches and other manmade structures, and allow

natural hydrology and drainage patterns to reestablish themselves.

- The benefits of ecological engineering should be shared widely with all agencies and organizations engaged in habitat restoration activities.

Principle 12: Adaptive management should be employed at as many restored sites as possible, so they continue to move toward desired end points and self-sustainability.

- Because estuaries are dynamic systems, restoration involves a great deal of uncertainty. Restoration activities must be evaluated and changed through adaptive management if they do not appear to be moving the site toward desired habitat conditions.
- A well-designed monitoring program serves as the basis for this evaluation and adjustment process.
- The ultimate goal of all restoration efforts is self-sustainability, but this might not be possible in situations where human impacts continue to affect the site and long-term adaptive management might be required.

Principle 13: Long-term site protection is essential to effective estuarine habitat restoration.

- Restored sites should be placed under long-term protection whenever possible to prevent future actions or development from reversing the restoration process.
- There are many different ways to protect restoration sites, including land acquisition, conservation easements, and other land-use controls, as well as maintaining the necessary water-quality requirements of restored sites.
- Efforts to protect restored sites long term will require cooperation between landowners, governments, and nonprofit organizations committed to the protection of these resources.

Principle 14: Public access to restoration sites should be encouraged wherever appropriate, but designed to minimize impacts on the ecological functioning of the site.

- Providing public access to restoration sites is a way of increasing public awareness of the value of these estuarine areas. Allowing appropriate recreational uses such as hiking and wildlife observations and use by schools are ways to enhance the value people place on these sites, increasing the likelihood they will continue to support ongoing preservation and restoration activities.
- At some locations public access might not be appropriate or possible, but it is important to look for ways to allow access in as many cases as possible.

Prognosis for America's Estuaries—Decline or Rehabilitation?

What is the outlook for estuarine ecosystem health in the United States? Many factors need to be considered. Population growth, demand for fresh water, coastal economic trends, efforts to control pollution and aquatic nuisance species, the integrity of

plans designed to provide habitat protection, and restoration and enhancement efforts all play a role.

The United States' population in 2000 was 282 million, of which approximately 40 percent live in coastal counties. During peak tourist season, coastal population doubles or triples in many regions as people flock to the sea to recreate. The permanent coastal population also will grow as baby boomers retire on the coast.

Given this projected growth, what changes might we expect for America's estuaries over the next 20 to 50 years? While predictions can be risky, they are useful if taken with a grain of salt (pun intended). Recent trends suggest the following:

- Estuaries will continue to support a diversity of uses and activities, among them deep-water shipping, home ports for fishing fleets, recreational fishing and marinas, charter fishing, sailing, aquaculture, waterfowl hunting, birding, and other nature activities.
- Special coastal zone management protective designations may prevent major new dredging or filling for development.
- Increased withdrawals of freshwater by urban and rural users will change freshwater inflow to estuaries, which, in turn, will change mixing and circulation patterns, estuarine habitats, and biology.
- Fish and shellfish resources may decline because of increased harvest pressure, particularly from recreational users.
- Our understanding of the impacts of runoff pollution will increase, as will our ability to pinpoint sources and provide control technologies. Political considerations and costs will determine whether problems persist, increase, or diminish.
- The adverse impacts of introduced species will become better known as scientists continue to study their distribution, spread, and ecological interactions.
- Estuarine habitat restoration activities will continue to expand, as former marsh areas are restored, eelgrass is planted, and other projects are undertaken. This trend may lead to improved ecosystem health and increase the supply of fish and wildlife habitat, offsetting other losses.
- Estuary-related tourism and recreation will continue to increase as more people call the coast home for at least part of the year.
- Competition for limited shoreline and estuarine surface area likely will increase, with residential developers, marinas, tourist businesses, and recreational users challenging traditional users such as ports, fish processors, oyster farmers, and commercial clammers.
- Natural resource industries that use the estuary, despite decline in recent decades, still will be important economically and culturally.
- Public access to estuaries, particularly in urban areas where waterfront revitalization plans are being developed and implemented, will continue to

improve, further enhancing recreational and tourism uses.

- Urban shoreline changes will have ramifications for ecosystem protection and restoration by increasing both the pressure to expand urban growth boundaries along the shoreline and the awareness of the need and opportunities for ecosystem restoration.

Summary

Estuaries are transition ecosystems characterized by sheltered wetlands, tidal flats, strong tidal mixing of salt water and freshwater, and an assemblage of plants and animals adapted to highly variable conditions.

Estuaries provide a variety of valued goods and services—fish and wildlife habitat; food production that supports the estuarine food chain; water-quality maintenance; moderation of floodwater flows; shoreline stabilization; and a variety of economic, recreational, and educational benefits.

Restoration projects and activities of all kinds will benefit from application of 14 principles or best management practices.

To maintain and increase the benefits estuaries provide to people and the environment, we need to

- Protect the critical remaining estuarine habitat
- Restore former or degraded estuarine habitat where feasible
- Link estuarine restoration actions to upland and upstream restoration and enhancement efforts for a whole-watershed approach
- Monitor water quality, clean up existing pollution problems, and prevent new pollution that cannot be readily assimilated
- Avoid introduction of harmful, nonnative plants and animals
- Incorporate both local knowledge and the best available scientific information into our planning, decision making, and projects
- Support research to improve understanding of estuarine ecosystems and their relationships to marine and freshwater systems

Resources

Federal agencies

Federal Emergency Management Agency (FEMA)

FEMA Mitigation, Environmental Program

http://www.fema.gov/mit/ep/overview.htm

Ensures that FEMA addresses all applicable environmental laws and Executive Orders; provides guidance, tools, and support in the integration of environmental concerns into disaster preparedness, mitigation, response, and recovery decisions.

U.S. Army Corps of Engineers

U.S. Army Corps of Engineers, Waterways Experiment Station, Engineer Research and Development Center (ERDC)

http://www.erdc.usace.army.mil/

ERDC research provides support in mapping and terrain analysis; infrastructure design, construction, operations, and maintenance; structural engineering; cold regions and ice engineering; coastal and hydraulics engineering; environmental quality; geotechnical engineering; and high performance computing and information technology.

U.S. Army Corps of Engineers, Environmental Laboratory, Research and Development

http://www.wes.army.mil/el/el_r&d.html

Research supports the U.S. Army Corps of Engineers' mandate for environmental cleanup and restoration as well as technology development in support of ecosystem conservation.

U.S. Department of Agriculture (USDA)

USDA, Natural Resources Conservation Service

http://www.nrcs.usda.gov

Provides leadership in a partnership with the American people to conserve, improve, and sustain our natural resources and environment.

USDA, Wetland Science Institute

http://www.pwrc.usgs.gov/wli/

Provides a cadre of technical experts to anticipate and fulfill the diverse needs of Natural Resources Conservation Service (NRCS) field personnel, program managers, and decision makers and is a tangible demonstration of NRCS' commitment to wetland conservation.

U.S. Environmental Protection Agency (EPA)

U.S. EPA, Office of Water

http://www.epa.gov/owow/

Promotes a watershed approach to manage, protect, and restore the water resources and aquatic ecosystems of our marine and fresh waters.

U.S. EPA, Office of Water, River Corridor and Wetland Restoration

http://www.epa.gov/owow/wetlands/restore/

Defines various restoration principles, explains the benefits of restoration, describes projects, lists links to partners and access to related documents.

U.S. EPA, Office of Water, National Estuary Program

http://www.epa.gov/owow/estuaries/

Describes the National Estuary Program and includes background information about estuaries and common threats. Also includes funding mechanisms and legislation.

U.S. EPA, A Phase I Inventory of Current EPA Efforts to Protect Ecosystems.

http://www.epa.gov/ecoplaces/

This inventory includes summaries of projects that involve EPA and its partners in place-based management and ecosystem protection.

U.S. Department of the Interior (DOI)

DOI, Natural Resource Damage Assessment and Restoration Program

http://restoration.doi.gov/

Restores natural resources injured as the result of oil spills or hazardous substance releases; assesses the damages and injuries to natural resources entrusted to the Department of the Interior and negotiates legal settlements or takes other legal actions against the responsible polluting parties.

DOI, U.S. Fish and Wildlife Service, Division of Habitat Conservation

http://www.fws.gov/conwh.html

Principal federal agency for conserving, protecting, and enhancing fish, wildlife, plants, and their habitats for the continuing benefit of the American public.

DOI, U.S. Geological Survey (USGS), National Wetlands Research Center

http://www.nwrc.usgs.gov/

Develops and disseminates scientific information needed for understanding the ecology and values of our nation's wetlands and for managing and restoring wetland habitats and associated plant and animal communities.

DOI, USGS, Science in Your Watershed

http://water.usgs.gov/wsc/

Scientific information organized on a watershed basis. This information, coupled with observations and measurements made by the watershed groups, provides a powerful foundation for characterizing, assessing, analyzing, and maintaining the status and health of a watershed.

DOI, National Park Service, Water Resources Division Wetland Program

http://www.nature.nps.gov/wrd/wrdwetl.htm

Preserves and protects NPS water resources and water-dependent environments through a watershed management program based on needs at

the park, cluster, regional, and national levels.

Department of Commerce, National Oceanic and Atmospheric Administration (NOAA)

National Ocean Service (NOS) Home Page

http://www.nos.noaa.gov/

The NOS Web site is a comprehensive presentation of the many facets of NOS, including links to several NOS offices and projects. It is continually growing, with new offerings appearing regularly.

National Ocean Service (NOS), Coastal Services Center (CSC)

http://www.csc.noaa.gov

Fosters and sustains the environmental and economic well being of the nation's coast by linking people, information, and technology.

NOS, CSC, Habitat Characterizations

http://www3.csc.noaa.gov/CSCweb/genericPage.asp?bin=8

Provides services in habitat characterization and habitat restoration

NOS, CSC, Coastal Management Techniques Database

http://www.csc.noaa.gov/techniques/htm/techniques.html

Searchable database of methods, strategies, and policies for addressing various coastal issues, including habitat protection and watershed/water quality.

NOS, National Centers for Coastal Ocean Science (NCCOS)

http://www.nccos.noaa.gov

The National Centers for Coastal Ocean Science (NCCOS) conducts and supports monitoring, research, assessment, and technical assistance for the range of NOAA's coastal stewardship responsibilities.

NOS, NCCOS, Center for Sponsored Coastal Ocean Research, Coastal Ocean Program

http://www.cop.noaa.gov

Provides scientific information to assist decision makers in meeting the challenges of managing our nation's coastal resources; targets critical issues that exist in the nation's estuaries, coastal waters, and Great Lakes; translates its findings into accessible information for coastal managers, planners, lawmakers, and the public; aims to create near-term and continuous improvements in environmental decisions affecting the coastal ocean and its resources.

NOS, National Estuarine Research Reserve System

http://www.ocrm.nos.noaa.gov/nerr

Protects and studies estuarine areas through a network of 25 reserves.

NOS, National Marine Sanctuaries

http://www.sanctuaries.nos.noaa.gov

Information about our nation's marine sanctuaries: how they were established, how they're managed, their scientific and educational programs, and the many exciting events that occur in them throughout the year.

NOS, Office of Response and Restoration

http://response.restoration.noaa.gov

Responds to dozens of spills of oil and other hazardous materials each year, helps emergency planners prepare for potential accidents, creates software, databases, and other tools to help people respond to hazardous materials accidents, works to find remedies for environmental damage caused by hazardous waste sites in coastal areas, assesses injury to coastal resources from releases of oil and other hazardous materials, and pursues restoration from those responsible for the harm.

NOS, Office of Ocean and Coastal Resource Management

http://www.ocrm.nos.noaa.gov

Responsible for administering the Coastal Zone Management Act and a leader on the nation's coastal, estuarine, and ocean management issues.

National Marine Fisheries Service, Office of Habitat Conservation

http://www.nmfs.noaa.gov/habitat

Interacts with the NOAA-Fisheries Regional Offices to manage, conserve, and enhance habitats for fishery resources, protected species, and other living marine resources; oversees the Habitat Protection Division, Watershed Division, NOAA Restoration Center, and NOAA Chesapeake Bay Program.

Office of Oceanic and Atmospheric Research, National Sea Grant Program

http://www.oar.noaa.gov/oceans/ocean_nsgo.html#start

Conducts research, education, and outreach to help the nation wisely use and conserve its coastal, ocean, and Great Lakes resources for a better economy and environment.

Federal partnerships

Bureau of Reclamation, Stream Corridor Restoration

http://www.usda.gov/agency/stream_restoration/

Cooperative effort among 15 federal agencies and partners to produce a common reference on stream corridor restoration.

Coastal America

http://www.coastalamerica.gov

Joins the efforts of federal agencies with those of state, local, and private alliances to collaboratively address environmental problems along our nation's coasts.

Lake Superior Binational Program, Habitat Committee

http://www.d.umn.edu/~pcollins/lsbp/home.htm

Works to protect and maintain existing high-quality habitat sites in the Lake Superior basin and the ecosystem processes that sustain them, and to restore degraded plant and animal habitat in the Lake Superior basin.

Nonprofit organizations

American Bird Conservancy

http://www.abcbirds.org/

Dedicated to conserving wild birds and their habitats throughout the Americas.

The American Littoral Society

http://www.americanlittoralsoc.org/

A national, not-for-profit, membership organization, dedicated to the environmental well-being of coastal habitat.

American Oceans Campaign

http://www.americanoceans.org/index.htm

Environmental organization working to revitalize the nation's oceans and coastal waters.

Association of State Wetland Managers, Inc.

http://www.aswm.org/

A nonprofit organization dedicated to the protection and restoration of our nation's wetlands.

Ballona Wetlands

http://www.ballona.org

Dedicated to the restoration and preservation of the Ballona Wetlands in Los Angeles, California.

Carolina Estuarine Reserve Foundation

http://www.ncnerr.org/cerf/

Promotes state acquisition and protection of a diverse system of coastal natural areas to advance research, education, and partnerships.

Center for Marine Conservation

http://www.cmc-ocean.org/

Environmental organization committed to protecting ocean environments and conserving the global abundance and diversity of marine life.

The Chesapeake Bay Foundation

http://www.cbf.org/

Environmental nonprofit dedicated to creating solutions for Bay problems.

Coalition to Restore Coastal Louisiana

http://www.crcl.org/

Environmental nonprofit incorporated to address and advocate for the restoration and preservation of the Mississippi River Delta.

Coastal States Organization

http://www.sso.org/cso/

An advocate for improved management of the nation's coasts, oceans, and Great Lakes, representing the governors of U.S. coastal states, territories, and commonwealths.

Conservation Law Foundation

http://www.clf.org

The largest regional environmental advocacy organization in the United States.

Delaware Center for the Inland Bays

http://www.udel.edu/CIB/

Oversees the implementation of the Inland Bays Comprehensive Conservation and Management Plan and facilitates a long-term approach for the

wise use and enhancement of the Inland Bays watershed by conducting public outreach and education, developing and implementing conservation projects, and establishing a long-term process for the preservation of the inland bays watershed.

Ducks Unlimited

http://www.ducks.org/

A wetland conservation organization that seeks to secure the future of waterfowl and wetlands.

Elkhorn Slough Foundation

http://www.elkhornslough.org/

Dedicated to the conservation of coastal wetlands in Elkhorn Slough and the Monterey Bay area of California.

Estuarine Research Federation.

http://www.erf.org

An international organization whose purpose is to promote research in estuarine and coastal waters.

Galveston Bay Foundation

http://www.galvbay.org/ [under construction]

Dedicated to preserving and enhancing Galveston Bay, Texas.

Global Rivers Environmental Education Network

http://www.earthforce.org/green/

Seeks to improve the quality of watersheds and rivers.

Gulf of Maine Council on the Marine Environment

http://www.gulfofmaine.org

Fosters cooperative actions within the Gulf of Maine watershed to preserve our common heritage and encourage sustainable resource use for present and future generations.

Long Island Friends of the Bay

http://www.friendsofthebay.org/

Organization committed to the protection of the Oyster Bay-Cold Spring Harbor estuary and its surrounding upland communities.

Long Island Soundkeeper Fund

http://www.soundkeeper.org/

Dedicated to the protection and enhancement of the Long Island Sound and its watershed.

National Audubon Society

http://www.audubon.org/

Fights to conserve and restore natural ecosystems, focusing on the birds and wildlife in these areas.

National Environmental Trust

http://environet.policy.net/

A nonprofit, nonpartisan membership group established to inform citizens about environmental problems and how they affect our health and quality of life.

National Wildlife Federation

http://www.nwf.org

Protects wildlife by aiding in the restoration of their areas.

Natural Resources Defense Council

http://www.nrdc.org

Preserves and restores our lakes, wetlands, and coastal waters.

The Nature Conservancy

http://nature.org/

Works to preserve the plants, animals, and natural communities of the lands and waters worldwide.

New Jersey Marine Sciences Consortium

http://www.njmsc.org

A cooperative center for the study of marine and environmental science.

North Carolina Coastal Federation

http://www.nccoast.org/

Works to develop a healthy coastal environment in the state of North Carolina.

Northwest Straits Commission

http://www.nwstraits.org/nsc.html

Works to restore the overall health of the Northwest Straits marine ecosystem.

People for Puget Sound

http://www.pugetsound.org/

Dedicated to educating and involving people in protecting and restoring the land and waters of Puget Sound and the Northwest Straits.

Restore America's Estuaries

http://www.estuaries.org/

An alliance of 11 regional, coastal, community-based environmental organizations with the mission to restore and protect America's estuaries and coastal heritage.

San Francisco Bay Joint Venture

http://www.sfbayjv.org

Works to restore and protect the San Francisco Bay Watersheds.

Save San Francisco Bay Association

http://www.savesfbay.org/

Seeks to preserve, restore, and protect the Bay and Sacramento/San Joaquin Delta Estuary.

Save The Bay, People for Narragansett Bay

http://www.savebay.org/

Focuses on restoring the area surrounding Narragansett Bay.

Save the Sound

http://www.savethesound.org

Dedicated to the restoration, protection, and appreciation of Long Island Sound and its watershed.

Tampa BayWatch

http://www.tampabaywatch.org/

Dedicated to protecting and restoring the marine and wetland environments of the Tampa Bay Estuary (Florida).

Tip of the Mitt Watershed Council

http://watershedcouncil.org/

Protects the waters of northern Michigan.

Wildlife Habitat Council

http://www.wildlifehc.org/

A group of corporations, conservation organizations, and individuals dedicated to protecting and enhancing wildlife habitat.

State agencies

Alabama

Department of Conservation and Natural Resources, Marine Resources Division,

Artificial Reef Program-Restoring Mobile Bay

http://www.dcnr.state.al.us/mr/page2.htm

Largest artificial reef program in the U.S., a product of a cooperative agreement between the U.S. Army Corps of Engineers and the Marine Resources Division of the Alabama Department of Conservation and Natural Resources.

California

California Coastal Conservancy

http://www.coastalconservancy.ca.gov

Acts with other agencies to preserve and restore the resources of the California coast

California Department of Water Resources, Suisun Marsh Program, Suisun Ecological Workgroup

http://iep.water.ca.gov/suisun

SEW is an ad-hoc multiagency/organization work group whose goal is to review the scientific basis for the current salinity standards in Suisun Marsh and make recommendations for comprehensive brackish marsh standards.

California Environmental Resources Evaluation System, California Wetlands Information System

http://www.ceres.ca.gov/wetlands/

http://ceres.ca.gov/wetlands/projects/restor_map_index.html

Compilation of public and private sector information, maps, environmental documents, agency roles in wetlands management, restoration and mitigation activities, regulatory permitting, and wetland policies; designed to provide comprehensive wetlands information to the general public, the educational community, and government agencies.

California Resources Agency

http://www.ceres.ca.gov/cra/

Responsible for the conservation, enhancement, and management of California's natural and cultural resources, including land, water, wildlife, parks, minerals, and historic sites.

Sacramento River Conservation Area Program

http://www.SacramentoRiver.ca.gov

Working to ensure that riparian habitat management along the river addresses the dynamics of the riparian ecosystem and the reality of the local agricultural economy; its goals are to preserve remaining riparian habitat and to reestablish a continuous riparian ecosystem along the river.

San Francisco Bay Conservation and Development Commission (BCDC)

http://www.bcdc.ca.gov

Agency created by the state legislature to protect and enhance San Francisco Bay and to encourage the responsible use of its resources.

Southern California Wetlands Recovery Project—Point Conception and the International border with Mexico.

http://www.coastalconservancy.ca.gov/scwrp/index.html

Partnership of public agencies working cooperatively to acquire, restore, and

enhance coastal wetlands and watersheds between Point Conception and the international border with Mexico.

Connecticut

Connecticut Department of Environmental Protection, Inland Wetlands Management

http://dep.state.ct.us/wtr/wetlands/inland.htm

Oversees implementation of the law (particularly, the Inland Wetlands and Watercourses Act) designed to protect Connecticut's 450,000 acres of inland wetlands and 85,000 acres of freshwater watercourses.

Connecticut Department of Environmental Protection, Office of Long Island Sound Programs

http://dep.state.ct.us/olisp/index.htm

Administers and coordinates programs within the Department of Environmental Protection that have an impact on Long Island Sound and related coastal lands and waters; undertakes long-range planning for Long Island Sound and is directly responsible for the implementation, oversight, and enforcement of the state's coastal management and coastal permit authorities; provides technical and financial assistance to state and local government agencies.

Delaware

Delaware Department of Natural Resources and Environmental Control (DNREC)

http://www.dnrec.state.de.us/dnrec2000/

Protects and manages the state's vital natural resources, protects public health and safety, provides quality outdoor recreation, and serves and educates the citizens of the First State about the wise use, conservation, and enhancement of Delaware's environment.

Florida

Florida Department of Environmental Protection, Everglades Ecosystem Restoration

http://www.dep.state.fl.us/secretary/everglades/default.htm

Restores the natural hydrology, enhancement, and recovery of native habitats and species, and revitalizes urban core areas.

Florida Water Programs, Wetlands

http://www.dep.state.fl.us/water/wetlands/index.htm

Directory of program links: mangroves, mitigation banking, wetland evaluation and delineation section (DEP), etc.

Georgia

Georgia Soil and Water Conservation Commission

http://www.gaswcc.org

Protects and conserves soil and water resources in Georgia.

Hawaii

Hawaii Department of Land and Natural Resources, Commission on Water Resource Management

http://www.state.hi.us/dlnr/cwrm

Administers the 1987 State Water Code; works to protect and enhance the water resources of the state of Hawaii through wise and responsible management.

The Kaho'olawe Island Reserve

http://www.state.hi.us/kirc/main/home.htm#Restoration

Established in 1993, consists of the island and its surrounding ocean waters in a two-mile radius from the shore; by state law, can be used only for Native Hawaiian cultural, spiritual, and subsistence purposes; fishing; environmental restoration; historic preservation; and education.

Illinois

Illinois Department of Natural Resources, Office of Resource Conservation Wetlands Program

http://dnr.state.il.us/wetlands/index.htm

Works to promote the protection, management, restoration, and creation of wetlands to ensure a high quality of life for present and future generations.

Louisiana

Louisiana Department of Natural Resources (DNR), Coastal Management Divisions, Gulf Ecological Management Site (GEMS)

http://www.dnr.state.la.us/crm/coastmgt/gems/cmdgems.ssi

GEMS Program is an initiative of the Gulf of Mexico Program (GMP) and the five Gulf of Mexico states that provide a regional framework for ecologically important Gulf habitats; will coordinate and use existing federal, state, local, and private programs, resources, and mechanisms to identify GEMS in each state, build an informational database, and foster cooperative use of GEMS to further GMP goals.

Louisiana DNR, Office of Coastal Restoration and Management, Save Louisiana Wetlands

http://www.savelawetlands.org

Responsible for the construction of projects aimed at creating, protecting, and restoring the state's wetlands, many funded through the Coastal Wetlands Planning, Protection, and Restoration Act.

Louisiana DNR, Office of Coastal Restoration and Management, Save Louisiana Wetlands, Coastal Restoration Division

http://www.savelawetlands.org/site/crdpage.html

Develops, implements, and monitors coastal vegetated wetland restoration, creation, and conservation measures; performs engineering, planning, and monitoring functions essential to successful development and implementation of wetland conservation and restoration plans and projects as directed by the Coastal Wetlands Conservation and Restoration Plan.

Louisiana Coastal Restoration Web Site

http://www.lacoast.gov/

Contains information and links relating to coastal restoration projects in Louisiana.

Maine

Maine Department of Environmental Protection, Division of Remediation

http://www.state.me.us/dep/rwm/rem/homepage.htm

Administers the investigation, cleanup, monitoring, and closure of Maine's uncontrolled hazardous substance sites.

Maine Bureau of Land and Water Quality, Marine Coastal Habitat

http://www.state.me.us/dep/blwq/doccoast/coastal3.htm

Information on the many different coastal, wetland, tidal, and subtidal habitats in Maine.

Maryland

Maryland Department of the Environment, Wetlands and Waterways Program

http://www.mde.state.md.us/wetlands/index.html

Seeks to conserve valuable aquatic systems; providing for the environmental, economic, and resource needs of Maryland.

Maryland Department of the Environment, Maryland Wetlands Restoration

http://www.mde.state.md.us/wetlands/restoration.html

Maryland Integrated Watershed Information System-"Surf Your Watershed"

http://www.dnr.state.md.us/watersheds/surf/

Cooperative effort involving the Maryland Departments of the Environment and Natural Resources to "catalog" important environmental, socioeconomic, and programmatic information on a watershed basis.

Maryland Conservation, Restoration, and Monitoring Projects

http://www.dnr.state.md.us/watersheds/surf/proj/proj.html

Massachusetts

Massachusetts Environmental Affairs, Coastal Zone Management, Coastal Wetlands Ecosystem Protection Project

http://www.state.ma.us/czm/waCWEPP.HTM

Develop, test, and refine a transferable approach for wetlands evaluation to determine the impacts of adjacent land uses and nonpoint sources of pollution on the ecological integrity of Massachusetts coastal aquatic resources.

Massachusetts Environmental Affairs, Watershed Initiative

http://www.state.ma.us/envir/watersheds.htm

Broad partnership of state and federal agencies, conservation organizations, businesses, municipal officials, and individuals that protects and restores natural resources and ecosystems on a watershed basis.

Michigan

Michigan Department of Environmental Quality, Watershed Homepage

http://www.deq.state.mi.us/swq/watershd/links.htm

Links to Michigan watersheds, Michigan watershed Information, watershed general information, non-Michigan watersheds.

North Carolina

North Carolina Division of Coastal Management, Wetlands Program

http://dcm2.enr.state.nc.us/Wetlands/wetlands.htm

New Hampshire

New Hampshire Department of Environmental Services, Wetlands Bureau

http://www.des.state.nh.us/wetlands

Protect, maintain, and enhance the environmental quality in New Hampshire through the powers set forth in RSA 482-A to regulate impacts to those areas "wherever the tide ebbs and flows" or "freshwater flows or stands."

New Hampshire Fish and Game

http://www.wildlife.state.nh.us/

As the guardian of the state's fish, wildlife, and marine resources, works in partnership with the public to conserve, manage, and protect these resources and their habitats.

New York

New York Department of Environmental Conservation, Estuary Management Programs

http://www.dec.state.ny.us/website/dfwmr/marine/estmgmt.htm

Cooperatively manages several estuaries of New York's Marine District with other state, local, and federal government agencies, the scientific community, and direct input from private citizens. Provides links to national estuary programs for Long Island Sound, Peconic Estuary, Hudson River, and New York/New Jersey Harbor.

New York Department of Environmental Conservation, Rivers and Estuaries on the Hudson

http://www.dec.state.ny.us/website/hudson/hrep.html

Proposed institute will foster a deep understanding of how rivers and estuaries function, describe how the ecosystem processes of rivers and estuaries interact with humans, and develop tools for river and estuary conservation.

Hudson River Estuary Management Action Plan

http://www.nysl.nysed.gov/edocs/encon/hud_plan.htm

Fifteen-year management plan for protecting and improving the health of the Hudson River estuary while ensuring compatible human uses within the river's ecosystem.

Oregon

South Slough National Estuarine Research Reserve

http://www.southsloughestuary.com/restore.html

A research reserve in Charleston, Oregon, devoted to restoring the estuarine wetlands in the Coos estuary.

Oregon Coastal Management Program, Oregon Department of Land Conservation and Development

http://www.lcd.state.or.us/coast/estuaries.html

Goal 16, Estuarine Resources, establishes detailed requirements for planning and managing Oregon's estuaries, with the overall objective of recognizing, protecting, developing, and restoring the unique, long-term environmental, socioeconomic values, diversity, and benefits of each estuary and associated wetlands.

Plan for Restoring and Protecting Oregon's Salmon and Watersheds

http://www.oregon-plan.org

Represents the state's unprecedented undertaking to restore Oregon's salmon and trout populations and fisheries to productive and sustainable levels that will provide substantial environmental, cultural, and economic benefits.

Rhode Island

Rhode Island Department of Environmental Management, Office of Water Resources, Narrangansett Bay Estuary Program

http://www.nbep.org

Protects and preserves Narragansett Bay through partnerships that conserve and restore natural resources, enhance water quality, and promote community involvement.

Rhode Island Department of Environmental Management,Wetlands Restoration

http://www.state.ri.us/dem/programs/benviron/water/wetlands/index.htm

Works to see that wetlands are protected and rehabilitated to provide wildlife habitat, reduce floods, and improve water quality.

Rhode Island Department of Environmental Management, Rhode Island Watershed Partnership

http://www.state.ri.us/dem/programs/bpoladm/stratpp/partnership/index.htm

Works to preserve, protect, and restore Rhode Island's environment by bringing additional resources, expertise, and different perspectives to the table to identify, prioritize, and solve complex environmental issues; aims to coordinate what have traditionally been separate government programs to use existing resources more effectively.

Texas

Texas Coastal Bend Bays and Estuaries Program

http://tarpon.tamucc.edu

Works to protect, restore, or enhance the quality of water, sediments, and living resources found within the 600-square-mile estuarine portion of the study area.

Texas General Land Office, Texas Coastal Wetlands

http://www.glo.state.tx.us/wetnet/

Manages state lands and mineral-right properties totaling 20.3 million acres,

including the beaches, bays, estuaries, and other "submerged" lands out to 10.3 miles in the Gulf of Mexico; wetland restoration, enhancement, and creation.

Texas Parks and Wildlife

http://www.tpwd.state.tx.us/

Works to manage and conserve the natural and cultural resources of Texas for the use and enjoyment of present and future generations; investigates fish and wildlife kills, and hazardous waste spills; engages in aquatic vegetation management.

Virginia

Virginia Department of Environmental Quality, Chesapeake Bay Program

http://www.deq.state.va.us/bay

Unique regional partnership directing and conducting the restoration of the Chesapeake Bay since the 1983 Chesapeake Bay Agreement; partners include Maryland, Pennsylvania, Virginia, the District of Columbia, the Chesapeake Bay Commission, the Environmental Protection Agency, and participating advisory groups.

Virginia Coastal Resources Management Program

http://www.deq.state.va.us/coastal

A network of state laws and policies through which the Commonwealth and its coastal localities manage wetlands, point and nonpoint source water pollution, coastal wildlife habitats, etc.

Virginia, Elizabeth River Watershed Action Plan

http://www.deq.state.va.us/bay/eliz.html

Developed by DEQ in cooperation with the Elizabeth River Project, a private partnership of citizens, businesses, and local governments.

Wisconsin

Wisconsin Department of Natural Resources, Wisconsin Great Lakes Protection Fund

http://www.dnr.state.wi.us/org/water/wm/glwsp/greatlakes/glpf.html

Provides support for projects that protect or restore the unique qualities of the Great Lakes Ecosystem.

Universities

Great Lakes Region

State University of New York College, College of Environmental Science and Forestry, Great Lakes Consortium

http://www.esf.edu/glrc/

Works to improve the understanding of the Great Lakes ecosystem, including the physical, biological, and chemical processes that shape it, as well as the social and political forces that affect human impact on the lakes and their associated economic resources through research, instruction, and public service.

College of Environmental Science and Forestry, Randolph G. Pack Environmental Institute

http://www.esf.edu/es/pack.htm

Works to enhance the faculty's ability to create and disseminate knowledge about environmental concerns of high public interest.

University of Michigan, School of Natural Resources and Environment, Ecosystem Management Initiative (EMI) Research, Ecological Restoration

http://www.snre.umich.edu/ecomgt/restoration.htm

EMI is an integrated program of ecosystem-based teaching, research, and outreach focused on imagining, evaluating, and promoting sustainable natural-resource management.

Mid-Atlantic Region

Old Dominion University, Center for Coastal Physical Oceanography

http://www.ccpo.odu.edu/

Works to promote research on the physical oceanography of the coastal ocean and related oceanographic processes, particularly in the innovative coupling of realistic physical models to ecosystems models.

University of Maryland, Center for Environmental and Estuarine Studies (CEES)

http://www.co.cees.edu

400 scientists, engineers, and economists from around the globe working together to advance knowledge through scientific discovery of the environment in Maryland, across the nation, and throughout the world.

University of Maryland, Chesapeake Bay Environmental Effects Committee

http://www.mdsg.umd.edu/CBEEC/index.html

Oversees systemwide research on the Chesapeake Bay; research funded by NOAA Chesapeake Bay Office and through the Sea Grant programs of Maryland and Virginia.

University of South Carolina, Belle W. Baruch Institute for Marine Biology and Coastal Research

http://inlet.geol.sc.edu

Conducts basic and applied research in marine and coastal environments that addresses the critical need for knowledge and improved understanding of these essential ecosystems.

Northeast Region

Brown University, Center for Environmental Studies, Wood-Pawcatuck Watershed Project

http://watershed.envstudies.brown.edu/

Seeks to assist the protection of the water resources in southern Rhode Island and nearby southeastern Connecticut.

University of New Hampshire, Institute for the Study of Earth, Oceans, and Space

http://www.eos.sr.unh.edu/index.html

Multidisciplinary research institute devoted to the study of the planet Earth

and its space environment; provides graduate education with a particular emphasis on interdisciplinary studies that contribute to understanding the global integrated behavior of the Earth and Earth-Sun system.

University of New Hampshire, Cooperative Institute for Coastal and Estuarine Environmental Technology

http://ciceet.unh.edu

Fosters collaboration between academia, government, and the private sector; develops and applies new environmental technologies and techniques.

University of New Hampshire, Center for Marine Biology, Jackson Estuarine Laboratory

http://marine.unh.edu/jel/jel.html

Using a diversity of specialties and larger interdisciplinary programs, engages in basic scientific research focused on applying scientific expertise to environmental issues of regional significance.

University of Rhode Island, Graduate School of Oceanography, Coastal Physical Oceanography

http://espo.gso.uri.edu/coastal

Conducts research in the coastal areas of Narragansett Bay, Coddington Cove, and Narrow River.

Yale University, Yale School of Forestry and Environmental Studies, Center for Coastal Watershed Systems

http://www.yale.edu/ccws/

Promotes interdisciplinary science and policy studies of watersheds and adjacent coastal waters; works to develop linkages and foster collaboration on watershed research, education, habitat preservation, and ecological restoration.

Pacific Region

University of Alaska, School of Fisheries and Ocean Services, North Specific Marine Research Program

http://www.sfos.uaf.edu/npmr/dsands.html

"A History: Dinkum Sands"

Oregon State University, Oregon Sea Grant Program, Watershed Stewardship Education Program

http://www.upstreamconnection.com/WSEP/index.cfm

Southeastern Atlantic and Gulf of Mexico Region

Florida Atlantic University, Riverwood Field Lab-Restoration of Kissimmee River and greater Everglades Watershed

http://riverwoods.ces.fau.edu

Supports research and educational activities related to the restoration of the Kissimmee River and the greater Everglades watershed.

Florida State University, Center for Environmental Studies

http://www.ces.fau.edu/projects

Acts as a facilitator and coordinator of research and training related to the environment and as a locus for

environmental information; encompasses global tropical and subtropical environments, especially the issues and problems of water dominated ecosystems; grounds its activities in the Florida subtropical environment.

Louisiana State University, Center of Coastal, Energy and Environmental Resources

http://chaos.cceer.lsu.edu

College-level academic and research unit that exists to provide knowledge, technology, and human resources for successful management of natural resources and resolution of environmental issues important to Louisiana, the Gulf of Mexico region, and comparable areas throughout the nation and the world.

Louisiana State University, Department of Oceanography and Coastal Sciences

http://www.oceanography.lsu.edu/research.htm

Conducts research within four institutes: Coastal Ecology, Coastal Fisheries, Coastal Studies, and Wetland Biogeography.

Louisiana State University, Wetland Biochemistry Institute

http://www.wetlandbiogeochemistry.lsu.edu/

Established to conduct investigations of wetland soils and sediment in fresh, brackish, and salt marsh environments. Soil-plant relations, their responses to stresses, and the production of greenhouse gases from natural and agricultural wetlands are major research areas.

Texas Water Resources Institute, Texas Waternet

http://twri.tamu.edu/

Serves as a focal point for water-related research at Texas universities, often encouraging discussion of statewide issues through meetings and conferences and stimulating multi-university studies.

University of Georgia Marine Institute

http://www.uga.edu/ugami/

Center of nearshore ecological and geological research; works to understand the processes which affect the health of the salt marshes and coastline and to identify the role of the nearshore environment in the maintenance of our coastal resources.

University of Miami, Rosenstiel School of Marine and Atmospheric Science

http://www.rsmas.miami.edu/groups/coastal-studies.html

Engages in education and research emphasizing in situ and remote sensing and numerical and statistical modeling; numerous disciplines involved include physical oceanography, meteorology, applied marine physics, marine chemistry, atmospheric chemistry, marine geology, marine geophysics, marine biology, fisheries science, marine resource economics and law, and coastal policy; research is often conducted in a multidisciplinary fashion and on an international basis.

University of New Orleans, College of Engineering

http://www.uno.edu/~engr/research.html

Research centers include Advanced Marine Technology Center, Maritime Environmental Resource Information Center, Gulf Coast Region Maritime Technology Center, and Pontchartrain Ecosystem Research and Education Project.

University of Southern Mississippi, College of Marine Science, Gulf Coast Research Laboratory

http://www.cms.usm.edu/research.htm

Engages in research in aquaculture, biodiversity, coastal ecology, environmental fate/effects, and fisheries science.

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Case Study

Eelgrass Restoration in Little Egg Harbor, New Jersey

The Problem

Since the turn of the century, submerged aquatic vegetation (SAV) has undergone dramatic declines worldwide from both natural and anthropogenic sources. This loss is especially detrimental to coastal systems because of the many ecological roles it serves. As essential fish habitat, it functions as a nursery for many commercially and recreationally important fish species, as well as for crustaceans (see photo). It also serves as a recruitment site for a variety of shellfish, especially bay scallops. Eelgrass *(Zostera marina)* plays an important role in coastal systems because it dampens wave energy, which protects shorelines from erosion, and stabilizes sediments that can cloud water and bury bottom-organisms, such as oysters. SAV also plays an environmental role by removing excess nutrients, such as nitrogen and phosphorus, that could fuel unwanted growth of algae in surrounding waters. Studies over the past 25 years have shown a decline in SAV in Barnegat Bay, New Jersey. Dramatic losses have also occurred in Little Egg Harbor because of an abundance of algae that often smother SAV and prevent light from reaching the plants. When the amount of light is too low, plants are unable to photosynthesize and produce enough food to grow.

Eelgrass habitat is essential fish habitat, serving as a nursery for many commercially and recreationally important finfish species and shellfish, including crab and lobster.

What is Being Done

In an effort to restore *Zostera* habitat in Little Egg Harbor, the Marine Field Station at Rutgers University is working with the FishAmerica Foundation and the NOAA Restoration Center to establish a methodology for long-term restoration and monitoring of eelgrass beds. Using a variety of

techniques, researchers are restoring the beds, monitoring each technique to determine its overall effectiveness. The first technique involves the collection of *Zostera* seed shoots from floating wrack that will be sorted and allowed to mature until they release seeds. Volunteers from the Jacques Cousteau National Estuarine Research Reserve, the Alliance for a Living Ocean, and Rutgers University staff then will place seeds in biodegradable containers that will be inserted at planting sites at varying distances. This will determine the best spacing arrangement for optimal planting units that would produce the best results. A second technique involves the collection of live *Zostera* from the field that will be transplanted to recipient sites at restoration patches planted at two spatial scales. This technique would provide information about plant unit spacing and plot area for future restoration activities. The third technique will collect live shoots to be held in flowing seawater at the Marine Field Station, where sediments will be rinsed from the rhizomes and shoots in preparation to be planted by hand.

Outcomes

Although it is still too early to quantify results, this project not only will benefit aquatic resources in Egg Harbor, but will also provide valuable information for future SAV restoration activities in this region and elsewhere. Project partners include the Jacques Cousteau National Estuarine Research Reserve, the Alliance for a Living Ocean Organization, and the American Littoral Society.

Case Study

Salt Marsh Restoration in the Salmon River Estuary, Oregon

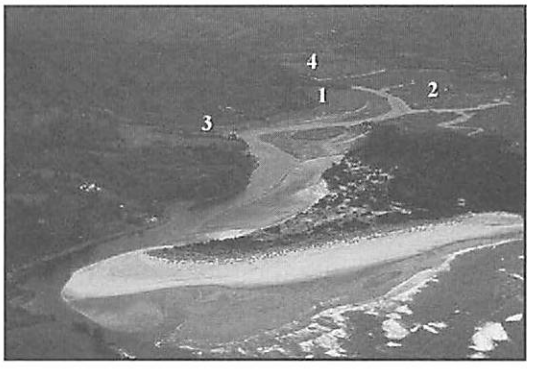
The Problem

When Congress established the Cascade Head Scenic Research Area in 1974, one goal was the restoration of the Salmon River estuary just south of the massive headland. The tidal marshes along the estuary had been used for years for hay production and grazing. About 75 percent were diked and drained during the 1950s and 1960s to improve agricultural productivity and create pasture. Another marsh was dredged for a marina that never materialized. The rerouting and shortening of U.S. Highway 101 with a filled causeway and bridge across the estuary in 1961 caused additional major hydrologic changes to the estuary and its tributary creek system.

What Was Done

Salt marsh restoration projects began in 1978 with removal of a tide gate and the breaching of 17-year old dikes on the 52-acre "Mitchell" marsh parcel on the north shore (see photo). Scientists from Oregon State University surveyed the site prior to breaching and set up a long-term monitoring program to evaluate the restoration process, especially vegetation reestablishment.

In 1988, the entire dike was removed at the Mitchell site to allow more natural tidal flow and drainage across the site. At the same time, the 200-acre "Y" marsh on the south side



Location, size, and date of dike removal for salt marsh restoration sites in the Salmon River estuary: (1) Mitchell marsh, 51 acres, 1978; (2) "Y" marsh, 200 acres, 1988; (3) Knight Creek marsh, 1.5 acres, 1996; (4) Salmon Creek marsh, 52 acres, 1996.

of the estuary was restored by breaching and removing dikes and a tide gate at Rowdy Creek. Other restoration projects followed, including the 2-acre Knight Park marsh and the 55-acre Salmon Creek marsh in 1996.

Outcomes

Generally, restored marshes took several years to pass through a succession of species and develop full wetland plant cover. After 5 to 10 years, Lyngby's sedge—a common low-salt and brackish marsh species—dominates much of the restored area. Restored tidal marsh vegetation seems to reach a relatively stable community about 10 to 20 years after dike removal, although vegetation does continue to change after that time.

Tidal creeks, made shallow and wide from years of grazing and the absence of tidal exchange, have deepened and narrowed. In the more mature project areas, these restored tidal creeks now resemble those in control marshes that never were altered.

In 1997, monitoring expanded to include fish use of restored areas, particularly by juvenile salmon. This work is still in progress, but has shown thus far that juvenile coho salmon use restored tidal creeks and marshes extensively, hiding from predators and feeding on aquatic insects and other invertebrates.

Salmon River estuary restoration sites have also served as a field laboratory for students from surrounding universities and for informal training of wetland professionals in Oregon and elsewhere.

Case Study

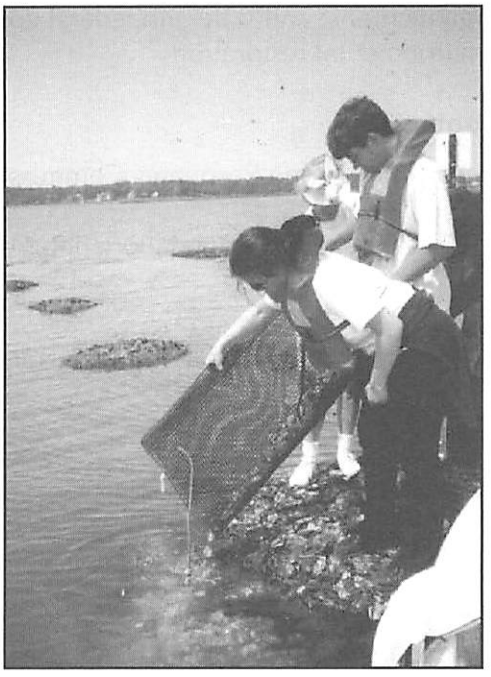
Oyster Reef Restoration in the Western Branch of the Elizabeth River, Virginia

The Problem

Oyster reefs play an important ecological role throughout the Chesapeake Bay region. They provide essential habitat in their three-dimensional shape for the bay's oysters, finfish, and crabs. They are especially beneficial to oysters because they maximize spawning efficiency by putting male and female oysters in close proximity to one another. They also provide protection for the young of the year (spat) from predation. Much of the oyster reefs within the Chesapeake Bay have been lost to harvesting pressures, silting, oyster diseases, and pollution. This has had a large impact on the oyster populations within the bay, which is currently thought to support only 1 percent of its historic stocks.

What Was Done

Since 1993, the Conservation and Replenishment Division of the Virginia Marine Resources Commission has completed more than 14 oyster reef restoration projects throughout the Virginia portion of the Chesapeake Bay. The NOAA Restoration Center has joined with the Virginia Marine Resources Commission and the Virginia Institute of Marine Science to continue Virginia's successful oyster reef restoration program in the Elizabeth River. The western branch of the Elizabeth was once completely closed off from the taking of shellfish for human consumption. An oyster industry once flourished in this area, and live oyster beds are still present. Though the



Local marine contractors have helped volunteers plant oysters on reconstructed reefs in the Elizabeth River estuary (photo from Chesapeake Bay Program).

western branch of the Elizabeth River is relatively clean, with little industry activity and limited development, its restoration can have positive impacts on a much larger part of the surrounding river area.

Outcomes

The restoration effort was implemented by volunteers from the Chesapeake Bay Foundation, citizens in the Hampton Roads area, and the Virginia Marine Resources Commission, with funding provided by NOAA and the Virginia Chesapeake Bay Restoration Fund. Oyster shells were used to rebuild an oyster reef on a historic footprint adjacent to a natural oyster bar. Local middle and high school students grew more than 100,000 bushels of hatchery-produced seed oysters in floating cages. At the end of the academic year, local marine contractors planted the oysters on the reconstructed reef (see photo). The effort was a unique approach to the restoration of oysters and has encouraged similar projects in other parts of Virginia. Its educational and ecological benefits make it a model for establishing partnerships between communities, conservation organizations, and state and federal government agencies for achieving environmental restoration.

Contacts

Virginia Marine Resources Commission: http://www.state.va.us/mrc/homepage.htm

Chesapeake Bay Foundation: http://www.cbf.org

Case Study

Winchester Tidelands Restoration
South Slough National Estuarine Research Reserve, Coos Bay, Oregon

The Problem

After diking for agricultural or other uses, high marshes subside up to a foot or more because of organic matter oxidation, shrinkage, and compression from grazing cows. Tidal creeks widen and shallow as cows break down edges and deep areas fill in. Typically, when these areas are restored, the kinds of habitats created are different from those that were present before diking. This raises questions about how much site manipulation may be in order to achieve a fully functioning, restored wetland ecosystem. For example, should subsided, diked areas be filled before dike removal to regain former tidal elevations and thus get back high marsh as opposed to low marsh or tidal flats?

What Was Done

In the South Slough National Estuarine Research Reserve (SSNERR)—the south arm of Coos Bay-a unique experiment in integrated upland-floodplain—estuary restoration is underway. Scientists from the SSNERR, with advice from an interdisciplinary team of specialists, are restoring fresh- and saltwater marshes, eelgrass beds, tidal creeks, and channels; reconnecting historical floodplains to creeks; passively restoring long-abandoned roads and decommissioning others; and planting a mixture of native trees—fir, hemlock, cedar, alder, and maple—along slopes that have been logged as many as three times since early settlement.

The Winchester Tidelands Restoration Project (WTRP) is the coastal wetland component of the project (figure 1). It includes a variety of passive and active tidal wetland restoration projects along Winchester Creek.

At Kunz Marsh, which subsided several feet after diking at the turn of the century, an experiment is underway to determine whether manipulation of site elevation can accelerate recovery of different types of wetlands. Five experimental cells were established, and soil from the dike was redistributed within the cells to establish different base elevations.

Figure 1. *Winchester Creek marsh restoration sites: (1) Kunz marsh, with different research cells (a-e); (2) Dalton Creek marsh; (3) Fredrickson marsh; (4) Cox Creek canyon marsh; (5) Tracy marsh (photo courtesy of Craig Cornu, South Slough National Estuarine Research Reserve).*

Figure 2. *Beavers have served as restoration project assistants at the Cox Canyon marsh, Winchester tidelands restoration (Jim Good photo).*

Outcomes

After three years of sampling, this project illustrates that site manipulation does result in the development of different vegetative cover and drainage. Several more years of monitoring will be necessary to more fully document site development and evolution and to draw definitive conclusions. Active or passive restoration of other wetlands along the tidal creek is proceeding. One site—Cox Canyon Marsh—is getting significant help from beavers that have recolonized the area (figure 2).

Lessons learned at South Slough are proving extremely valuable to local watershed groups and others seeking to restore estuarine marshes. It has also been used extensively for university research (the University of Oregon Institute for Marine Biology is a few miles distant), as well as field trips and projects for secondary and middle school students in the area.

PART THREE

Best Management Practices

Introduction to Best Management Practices

by Robert Kent

Nonpoint source pollution occurs when rainfall, snowmelt, or irrigation flows over or through the ground, picks up pollutants, and delivers them into rivers, lakes, coastal waters, or groundwater. Imagine the path taken by a drop of rain from the time it hits the ground to when it reaches a river, groundwater, or the ocean. Any pollutant it picks up on its journey can ultimately affect natural habitats and the living organisms they sustain. Nonpoint source pollution is sometimes called *contaminated runoff.* It is widespread and can occur any time activities disturb the land.

Tremendous advances have been made in cleaning up the aquatic environment by controlling pollution from point sources such as industries and sewage treatment plants. Unfortunately, we have not done enough to control runoff from diffuse, or nonpoint, sources. Today, nonpoint source pollution, or contaminated runoff, remains our largest cause of poor water quality. It is the main reason that approximately 40 percent of our rivers, lakes, and estuaries are not clean enough to allow basic uses such as fishing or swimming.

The most common nonpoint source pollutants are sediment and nutrients. These contaminants wash into water bodies from lawns, roads, construction sites, and other areas of disturbance. Runoff pollutants include fertilizers, pesticides, pathogens (bacteria and viruses), salts, oil, grease, toxic chemicals, and heavy metals. Beach closures, degraded habitat, unsafe drinking water, fish kills, and many other severe environmental, economic, and human health problems result from these widespread pollutants. Each year, polluted runoff threatens community vitality.

A *watershed* is the area of land that contributes drainage to a particular body of water. Land features such as slope, permeability, elevation, and contour determine which way the water flows. We can identify the drainage area for water bodies as small as a backyard stream or as large as an entire estuary. Watersheds represent the natural boundaries within which nonpoint source pollution is best managed. They enable us to know the origins and route that runoff travels before flowing into a receiving water body. Watershed boundaries are independent of governmental boundaries. Therefore, effective protection and restoration of our waterways often necessitates multijurisdictional partnerships and collaboration.

The following chapters look at a variety of land-use types (agricultural, forested, rural, and urban lands) and discuss what are called *best management practices* to protect water quality from nonpoint source pollution. Best management practices are often referred to as

BMPs. People, industries, and governments in any area can implement appropriate BMPs to protect water quality. BMPs to control nonpoint source pollution and to restore ecosystem health can be applied around the home, on farms, in forestry practices, during road construction, and on government owned and managed land. Reducing nonpoint source pollution or contaminated runoff is a major challenge and priority nationwide.

In the chapters that follow, examples of BMPs are given for a variety of settings. They provide examples of what can be done to stimulate individuals and communities to adopt and implement their own BMPs. There are many places to turn to for help and to find out more about BMPs. These sources are listed at the end of each chapter. No one set of BMPs fits every occasion. What works at one site may be inappropriate at another. What is "best" for a situation depends on the site conditions there.

The chapter "Best Management Practices to Protect and Restore Wildlife Habitat and Resources" looks at ways communities and landowners can help restore living resources. Keeping pollutants out of the water is only one of many things that can be done. The chapter "Best Management Practices—Invasive Species" explores the issue of how such species disrupt ecosystems. The spread of invasive species is causing concern nationwide.

CHAPTER FIFTEEN

Best Management Practices in Agricultural Settings

by Garry Stephenson and Robert Kent

In this chapter you'll learn

- What the chief pollutants are that damage ecosystems in agricultural settings
- What best management practices are and how they contribute to habitat restoration
- What some farmers are doing to implement best management practices

The effects of agriculture on the environment must be addressed by every land grant college in the country," said Cornell University's dean of the College of Agriculture and Life Sciences, who has made the environment one of the main focuses of the college. "We have farms and suburbs existing side by side. We have huge urban populations whose water supplies come from watersheds that are vulnerable to agricultural pollution. It's an incredibly important issue" ("Animal Nutrient Plan," 1999, p. 20).

With industrial pollution significantly reduced, the U.S. Environmental Protection Agency is turning its attention to agricultural activities. As a result, nutrient pollution is of primary concern to farmers and natural resource managers ("Animal Nutrient Plan," 1999). For example, in New York State, agriculture ranks as the third most common primary source of nonpoint pollution out of 12 primary sources. In that state, agriculture affects 182 water bodies covering over 76,636 acres of surface waters and rivers. Agriculture is responsible for 12 percent of the total water-quality impacts in the state (*Agricultural Management Practices Catalogue,* p. A-4).

Of the 1.9 million acres of U.S. land, excluding Alaska, approximately 907 million acres are cropland, pasture, or rangeland. The management of these agricultural lands can affect the quality of ecosystems and the condition of natural resources over a significant portion of the U.S. land base. For this reason, farmers and ranchers should be encouraged to control sediment carried in runoff from farms and ranches, use environmentally sound pest and nutrient management techniques, reduce consumption of nonrenewable energy, and take other actions that would preserve the health of ecosystems and conserve natural resources (*Sustainable America,* 1996). This form of agriculture is referred to as integrated farming systems (that is, systems that integrate pollution prevention and natural resource conservation into agricultural production).

Environmental Problems

The types of land management practices that contribute to agricultural nonpoint source pollution include overgrazing, uncontrolled barnyard runoff, livestock in streams, riparian vegetation removal, inappropriate manure storage and spreading, inappropriate fertilizer and pesticide application, lack of crop rotation, and overirrigation.

Essentially, environmental problems common to agriculture fall into three main categories, each with associated pollutants:

1. Surface water pollution
   - Soil sediments
   - Dissolved or soil-bound nutrients and pesticides
2. Groundwater pollution
   - Nitrates
   - Pesticides
3. Soil erosion
   - Wind
   - Sheet and rill
   - Concentrated flow

Surface water and groundwater

Surface water pollution by nutrients and pesticides can occur by nonpoint and point source actions.

Nonpoint source pollution is the subtle loss of a pollutant from a wide geographic area. It is the major cause of pesticide presence in surface water. It most often occurs as runoff from fields during storms. Nutrients and pesticides can run off dissolved in water or attached to soil particles. Runoff can move small amounts of these materials from many farms. They collect and are concentrated in larger and larger waterways and can be transported great distances.

Point source pollution is the direct introduction of a pollutant into surface water from a specific source. Although it is more common from factories or sewage treatment plants, it can occur on the farm from improper chemical mixing, loading and disposal, or misapplication to water bodies. Some consider runoff from concentrated livestock activities as point source rather than nonpoint source pollution.

There are two primary ways nutrients and pesticides enter groundwater—run-in and leaching. *Run-in* is the movement of nutrients or pesticides into groundwater by direct routes, such as irrigation or domestic wells, abandoned wells, or sinkholes. Run-in occurs when nutrients or pesticides are applied, spilled, or run off into or near such sites. Back siphoning of chemicals when sprayer tanks are being filled is another example of run-in. *Leaching* occurs when materials are carried with precipitation or irrigation water downward to groundwater. Some chemicals and soils are more susceptible to leaching than others.

Erosion

Wind erosion occurs to unprotected fields with a dry soil surface that is smooth, loose, and finely granulated. Erosion can occur with wind speeds as low as 13 mph.

The rate of erosion more than triples as wind speed increases from 20 to 30 mph.

Water erosion is the natural process of soil movement from higher areas to lower areas by the action of flowing water. It can be separated into different forms, based on how water is moving over the surface. *Sheet erosion* occurs as soil is moved by water in a thin film over the surface. *Rill erosion* occurs as water begins to concentrate into small channels or rills. Sediments from sheet and rill erosion will be finer textured and will contain higher proportions of nutrients and other pollutants attached to soil particles than soil as a whole. *Concentrated flow erosion* occurs as channels become larger. Unchecked, concentrated flow erosion can form gullies.

Nutrients and pesticides

Nutrients are added to soil to allow plants to have adequate growth and to reach production goals. A number of nutrient sources are used in agriculture:

- Commercial fertilizers (synthetic and organic)
- Manure and sludge
- Compost
  - — Crop residues
  - — Irrigation water
  - — Soil reserves

Pesticides are materials used to prevent diseases, control insects and weeds, and so on. Pesticides have a broad range of applications, from those approved for certified organic agriculture to those used in conventional agriculture. They also have differing properties that make them more prone or less prone to moving in or with soil.

Before a nutrient or a pesticide can become a pollutant or an environmental problem, it must be available for movement in the environment. Many best management practices (BMPs) attempt to reduce the availability of nutrients and pesticides for environmental losses.

Once nutrients and pesticides are applied to the soil, their movement is usually determined by the movement of water. Some nutrients and most pesticides move off the farm while dissolved in water. Other nutrients and some pesticides are tightly bound to soil particles and are moved off the farm with soil particles from water or wind erosion.

Agricultural BMPs strive to prevent or reduce the availability, release, or transport of substances that adversely affect ground and surface waters. Most BMPs focus on conserving soil, using fertilizers and pesticides at appropriate times and amounts, and buffering waterways and other sensitive areas from potential runoff.

Using BMPs can increase efficiency and profits, increase property values (a farm with little soil has little value), benefit local communities by reducing nonpoint source pollution and erosion, and sustain soil and water resources on the farm, allowing it to be kept in the family for generations.

Table 1. Conventional agricultural best management practices.

Conventional Agricultural Best Management Practices Having Moderate to Significant Effects on Common Pollution/Degradation							
	Surface Water			Groundwater		Erosion	
	Sediments	Nutrients and Pesticides	Nitrates	Pesticides	Wind	Sheet	Concentrate Flow
Crop rotation	×				×	×	×
Cover crop/green manure	×	×	×		×	×	
Composting	×	×	×				
Realistic yield goals		×	×				
Soil testing/plant analysis		×	×				
Nitrogen timing and rates			×				
Pasture management: Management intensive Short-duration grazing	×	×			×	×	×
Barnyard runoff management	×	×	×				
Fencing	×	×					
Manure management		×	×				
IPM		×		×			
Sprayer maintenance and calibration		×		×			
Pesticide application–timing, methods, and rates		×		×			
Irrigation management	×	×	×	×			
Harvest management	×				×	×	×
Buffer zones	×	×	×	×			
Minimum- /no-till	×	×			×	×	×
Windbreaks					×		
Contour farming, strip cropping, terraces	×	×				×	
Grass waterways							×
Vegetative filter strips	×	×				×	
Riparian/wetland protection	×	×	×	×			

Best Management Practices

Following are descriptions of some best management practices used in agricultural settings to protect and restore habitats.

Barnyard runoff management system

Barnyard runoff management systems intercept, collect, and safely dispose of runoff water from a barnyard or concentrated livestock area. The goals are to keep clean water from entering the barnyard and to reduce the transport of pollutants

from the barnyard or concentrated livestock area to streams and ponds. This system might include a variety of structural and vegetative practices. Examples include installing waste storage facilities, managing roof runoff, protecting the area from heavy use, fencing, using diversions, and using filter strips to treat runoff. Properly installed barnyard runoff management systems have been found to reduce both nutrient levels and bacteria leaving the barnyard.

Conservation tillage

Conservation tillage practices seek to reduce the transport of sediments and solid-phase nutrients from agricultural lands. Two types of conservation tillage are *minimum tillage* and *no-tillage.* Minimum till leaves a minimum of 30 percent of the solid surface covered with plant residue after the tillage or planting operation. No-tillage is the placing of a crop seed into the solid surface by a device that opens a trench or slot through the sod or pervious crop residue. Conservation tillage can reduce soil loss by 50 percent or more compared to conventional tillage.

Contour farming

Contour farming is the alignment and operation of all farm tillage, planting, and harvesting practices as close to the true contour as possible. The goal is to reduce erosion and surface runoff and thus the transport of nutrients and pesticides from the field. When water retention is increased during rainstorms, contoured rows increase infiltration and thus reduce runoff.

Cover and green manure crop

Cover and green manure crops are crops of close-growing grasses, legumes, or small grains grown primarily for temporary, seasonal soil protection and improvement except where there is permanent cover, as in orchards and vineyards. Green manure crops are plowed under and incorporated into the soil. The goals are to control erosion, add organic matter and nutrients, suppress weeds, remove surplus nitrogen remaining in the ground after harvest, and reduce the need for nitrogen fertilizers. The impact of these practices depends on the type of cover crop selected, the date of cover crop seeding, and the amount and extent of cover crop growth.

Critical area protection: stream bank and shoreline protection

Stream bank and shoreline protection involves the use of vegetation, structures, bioengineering, or management techniques to stabilize and protect stream banks and shorelines. The goal is to reduce sediment and nutrients entering water bodies from eroding stream banks and shorelines. Vegetatively stabilized stream banks and shorelines can provide wildlife cover. Mature woody vegetation lowers stream temperature by shading streams, which in turn improves fishery habitat.

Crop rotation

Crop rotation is a planned sequence of annual or perennial crops. The goal is to reduce erosion and improve water quality.

The practice improves or maintains good physical, chemical, and biological conditions of the soil and breaks the reproductive cycles of plant pests. Reducing plant pests and weeds leads to decreased use of pesticides.

Integrated pest management

Integrated pest management, or IPM, is an ecologically based, integrated pest control strategy designed to keep pest populations below economically injurious levels using a variety of control tactics. The goals are to reduce pesticide use and the movement of pesticides into the environment. IPM uses monitoring, pest forecasting, scouting, and economic thresholds to determine the appropriate use of control tactics. A pest population must reach a particular level or action threshold before controls are used. Control options include biological control agents, cultural practices such as crop rotation, the use of trap crops, destruction of pest breeding and refuge sites, ecosystem diversification, scouting, resistant crop varieties, mechanical weed control, timing of planting and harvesting, and the selection and use of least-toxic pesticides. Factors affecting the choice of IPM options include crop and pest growth stage, days to harvest, crop yield, and environmental values. IPM philosophy calls for pesticide use when all other management methods have been used and have been found to be insufficient.

Trickle, or drip, irrigation

Trickle irrigation systems apply water directly to the root zone of plants by drip, subsurface, or spray systems operating under low volume and low pressure. This system maintains soil moisture without excessive water loss, erosion, or reduction in water quality. It reduces surface runoff and resulting sediment, nutrient, and pesticide losses from agricultural fields. It is typically used in high-value vegetable crops, vineyards, orchards, small fruits, and ornamentals that require irrigation.

Nutrient/sediment control system

The nutrient/sediment control system is a system of structural and vegetated component practices installed downhill from concentrated farm operations. The goal is to reduce pollutants found in agricultural runoff water. The pollutants controlled include nutrients, ammonia, sediments, pesticides, bacteria, and organic matter. Components can include a sediment basin to trap and detain large-sediment particles, a grassed filter strip designed to receive runoff (typically planted in cool-season grasses), and a constructed freshwater wetland to absorb pollutants.

Pasture management: short-duration, or management-intensive, grazing systems

Most of the pollution associated with livestock on pasture results from a reduction in ground cover brought about by overgrazing. Reduced grazing pressure increases the quality and quantity of pasture vegetation. Short-duration grazing systems typically use 10 or more paddocks for a

grazing season, rotating the paddocks in sequence to allow for forage regrowth. Livestock graze for less than a week before they are rotated to another paddock. The goals are to prevent soil erosion, reduce surface runoff, and improve forage cover while properly utilizing animal manures. The size and number of paddocks depend on the level of pasture productivity, the stocking rate of livestock, and the desired speed of rotation.

Pesticide management: proper timing of pesticide application

The goal of this pesticide management procedure is to apply pesticides only when they are most effective for pest control and pose the least risk of contaminating surface or groundwaters. Proper timing of pesticide application involves the use of scouting to detect pest infestations so that pesticides are used only when needed, the use of weather forecasting to detect rain and wind speed so that pesticide applications can be avoided during adverse weather, and the use of irrigation scheduling to control the rate, amount, and timing of irrigation water to reduce or eliminate the leaching potential of pesticides to ground or surface waters.

Riparian forest buffer

Riparian forest buffers are areas of trees, shrubs, and grasses located adjacent to water bodies. The goal is for the buffer zone to intercept surface runoff, wastewater, subsurface flow, and groundwater flow from agricultural upland sources. The pollutants controlled include nutrients, sediment, and organic matter. They are used at the margins of lakes, ponds, and streams. Riparian forest buffers will be most effective when used as a component of a sound land management system, including nutrient management and runoff and sediment and erosion control practices.

Agriculture in the Twenty-First Century

Two current trends in agriculture bear mentioning. Both promote protecting water quality and the environment. One depends on high technology, the other on low inputs and striving for integration. The two share a sense that best management practices must fit the specific needs of a farm or an area of a farm and will vary from farm to farm.

Precision agriculture

Following the recent explosion of technology, *precision agriculture* has emerged as a method for protecting soil and water quality while attaining production efficiency. Precision agriculture allows site-specific management of areas within fields rather than entire fields, as is conventionally practiced. It integrates crop management inputs to match the actual crop needs for specific small areas within a field.

Precision agriculture consists of the use of a number of tools—some technological, some good farming practices. The goal is to gather and use information effectively. This is accomplished through the use of global

positioning systems (GPS) receivers, yield monitors, remote sensing, geographic information systems (GIS), crop scouting, and more. These tools allow farmers to more effectively use crop inputs such as fertilizers, pesticides, tillage, and irrigation.

Sustainable agriculture

Sustainable agriculture refers to an agricultural production and distribution system that works to minimize adverse impact on water quality and the environment by integrating natural biological cycles and controls, protecting soil fertility, reducing the use of nonrenewable resources, and providing an adequate and dependable farm income while promoting family farming and farm communities.

Sustainable agriculture does not refer to a prescribed set of practices. Instead, it promotes looking at agriculture from an ecological perspective—in terms of nutrient and energy dynamics and interactions among plants, animals, insects, and other organisms in agroecosystems—and then balancing it with profit, community, and consumer needs. Farming methods that improve the sustainability of one farm might not be appropriate for a different farm or region. Each practice must be evaluated in a given farming system for its ability to achieve a set of economic, environmental, and social goals.

Summary

The management of agricultural lands, which cover a significant portion of the United States' landscape, can affect the quality of aquatic and coastal ecosystems. Farmers and ranchers can play a major role in protecting these sources by implementing what are commonly called best management practices (BMPs). The goals of BMPS are to reduce the amount of pollution leaving farms and ranches and to improve the environmental quality on them. The focus of most agricultural BMPs is on reducing soil erosion (soil particles washing off farm land can carry pollutants with them) and on the careful use of fertilizers and pesticides (potential pollutants).

Pollution that is caused by soil and water leaving farms and ranches is called nonpoint source pollution. Examples of contributors to nonpoint source pollution are overgrazing, barnyard runoff, livestock in streams, riparian vegetation removal, and inappropriate fertilizer and pesticide application.

There are many types of BMPs farmers and ranches can install and try. The first step is to analyze a farm or ranch for potential pollution problems and then to rank their seriousness. The next step is to consider which BMPs will best address and correct the problem. Technical and financial assistance is available from several sources. Installing or implementing BMPs—and monitoring their success—is the last step.

The steps taken by each farmer or rancher to be a good steward of his or her property add up to make a major contribution to restoring and protecting our aquatic and coastal resources.

Resources

Agricultural Management Practices Catalogue for Nonpoint Source Pollution Prevention and Water Quality Protection in New York State (NYS Department of Environmental Conservation, Division of Water, Bureau of Water Quality Management, November 1992).

"Animal Nutrient Plan Protects Environment," by Mike Powers. *Cornell Focus* 8(1):20 (1999).

Best Management Practices for Colorado Agriculture, by Reagan M. Waskom. Bulletin number XCM-171 (Fort Collins: Colorado State University Cooperative Extension, 1994). http://www.colostate.edu/

Best Management Practices for Wheat: A Guide to Profitable and Environmentally Sound Production, edited by Steve Watson (Washington, D.C.: National Association of Wheat Growers Foundation and USDA Cooperative Extension System, 1994).

*Farm*A*Syst: Farmstead Assessment System* (Madison, WI: University of Wisconsin Extension, 1991). Order from Farm*A*Syst, B142 Steenbock Library, 550 Babcock Drive, Madison, WI 53706-1293. Phone 608-262-0024. http://www.wisc.edu/farmasyst.

Livestock Management in Grazed Watersheds, by Mel George. Publication 3381 (Davis, CA: University of California Agricultural Issues Center, 1996).

Managing Cover Crops Profitably, 3rd edition (Beltsville, MD: Sustainable Agriculture Network, 2001).

National Handbook of Conservation Practices (Washington, D.C.: USDA Natural Resource Conservation Service).

Pacific Northwest Conservation Tillage Handbook (Pullman, WA: Pacific Northwest Solutions to Environmental and Economic Problems, Washington State University, Oregon State University, and University of Idaho, n.d.). http://pnwsteep.wsu.edu/Tillage_Handbook/contents.html

Precision Agriculture in the 21st Century: Geospacial and Information Technologies in Crop Management, Board on Agriculture—National Research Council (Washington, D.C.: National Academy Press, 1998)

Precision Agriculture: An introduction, by Glenn Davis, William Casady, and Ray Massey. Water Quality Initiative publication WQ450 (Columbia: University of Missouri, 1998).

Soybean Management and the Land: A Best Management Practices Handbook for Growers (St. Louis: American Soybean Association, n.d.).

Steel in the Field: A Farmer's Guide to Weed Management Tools, edited by Greg Bowman (Beltsville, MD: Sustainable Agriculture Network, 1997).

Sustainable Agriculture Research and Education Program. http://www.sare.org/

The Real Dirt: Farmers Tell about Organic and Low-Input Practices in the Northeast, edited by Miranda Smith et al. (Beltville, MD: Sustainable Agriculture Network, 1998).

Case Study

Beaver Creek Riparian Project, Oregon

Pacific Northwest states are undergoing efforts to restore salmonid populations through improvements in stream habitat and water quality. Livestock grazers have been identified as an important audience to assist with making these improvements. Improper grazing, hoof impacts, and the deposit of livestock wastes into streams damage water quality. The accompanying loss of vegetation can lead to an increase in stream temperatures and in stream sedimentation through erosion. Added livestock wastes can lead to excess nutrients and pathogens in water.

Starting in 1995, a portion of an operating ranch located near Oregon's central coast was developed as a research and demonstration project to examine the effectiveness of a variety of management practices and to expose area livestock owners to these practices in order to enhance adoption. Specific objectives were controlling livestock access to the creek to prevent stream bank deterioration, planting riparian vegetation and allowing natural plant regeneration to stabilize erosion problems, and more.

Methods employed included fencing a portion of the creek and planting red alder in varying degrees of density for shade production. Soon after the project was implemented, the stream bank stabilized from heavy grass regrowth and the appearance of a variety of native shrubs. Stabilization continues. Shading has been steadily enhanced by the fast growth of red alder. Limited-duration cattle grazing within the fenced buffer strip began in 2001.

Numerous tours and presentations have exposed other area livestock producers to the methods and results of the project. Some producers have begun to use techniques demonstrated in this project. Efforts to disseminate the information continue.

(Courtesy of Bill Rogers, Oregon State University Extension Service, Lincoln County, Oregon)

Case Study

Improving Water Quality Through Accurate Fertilizer Recommendations for Winter Wheat

Nitrogen fertilizer recommendations for winter wheat in western Oregon have improved in accuracy with the addition of a soil test for mineralizable nitrogen. The application of excess nitrogen to wheat and other crops can affect water quality through leaching and runoff. Using more nitrogen than the crop needs also wastes financial resources.

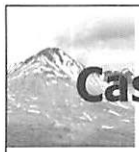
Recent research in Oregon has revealed that by measuring the amount of nitrogen that is likely to be released by the soil during the growing season, the farmer can more precisely calculate supplementary nitrogen applications to meet crop need and no more. The addition of a soil test for mineralizable nitrogen is the answer.

Mineralization is the microbe-driven release of plant-available nitrogen from crop residues and soil organic matter. Mineralization is one part of the nitrogen cycle. Research from other parts of the U.S. and world suggests that mineralizable nitrogen test values cannot routinely be used to predict fertilizer nitrogen needs. But work in western Oregon indicates that the test can be used for winter wheat and possibly other cool-season crops grown under the unique environmental conditions of the region—wet, mild winters.

Comparisons of traditional predicted nitrogen rates with rates based on the mineralizable nitrogen soil test indicate that predicted rates were overestimated by about 10 percent. Clearly, with this technique, there is potential for a significant reduction in excess nitrogen in surface and groundwater in the region and an increase in profitability for growers.

This technique is easy to use. Currently, field representatives for fertilizer dealers in western Oregon are using it. To date, the test has improved the accuracy of fertilizer recommendations on several thousand acres of winter wheat grown in the southern Willamette Valley.

(Courtesy of Russ Karow, Dost Baloch, Ernie Marx, Neil Christensen, Maqsood Qureshi, and John Hart, Department of Crop and Soil Science, Oregon State University)



Case Study

Long Island Vineyards

The Problem

Growing grapes for wine is a relatively new industry on Long Island, New York. Once one pioneering grower showed that it was possible to grow grapes on Long Island and to produce high-quality wine, many other people followed. Eastern Long Island is now a major wine-growing area, with tourists flocking to the region to taste and buy wine, as well as other agricultural products. Vineyards typically replaced potato farms. Wealthy investors replaced family farmers as owners of the land. Because it was a new industry, there was much to learn. Grapes are grown in straight lines. At first, growers kept the soil between the rows bare, fearing that any vegetation growing between the rows of grapes would compete with the grapes for water and nutrients. Because some of the vineyards are on land that slopes, soil erosion soon became a problem. Eroding soil can find its way into the nearby coastal waters and can carry with it fertilizers and pesticides. Many of the vineyards are located between Peconic Bay and Long Island Sound, both part of the National Estuary Program. The goals of each of these estuary programs is to keep pollutants such as soil particles, fertilizers, and pesticides out of the water.

What Was Done

The district conservationist of the United States Department of Agriculture Natural Resource Conservation Service became concerned about the soil erosion problems on vineyards. He proposed planting grass (perennial rye grass and creeping red fescue) between the rows of grapes. An experiment was established on one vineyard where the grass mixture was planted between the rows. During the trial period, researchers monitored the pruning weight of the vines, the harvest weight of the fruit, and the clipping of the grass. Planting grass between the rows was found to have neither a negative nor a positive effect on the growth of the vines or the harvest of the fruit.

Outcomes

Growing grass between rows of grapes is now standard practice in all Long Island vineyards, providing a permanent, year-round cover. The grass must be mowed two to three times a year. The grass has stopped soil erosion and kept potential pollutants from reaching coastal waters. Growers enjoy a second benefit: Because the grass provides a foundation to drive on, growers are able to move their agricultural equipment through the vineyards much more frequently and easily. Previously, when bare soil was wet after rainfalls, equipment could not be driven over it, sometimes for several days.

Case Study

Farm*A*Syst

Farm*A*Syst is a national program designed to support the voluntary efforts of farmers and ranchers to protect the quality of the environment. It does this by

- Building awareness of the pollution risks posed by farm activities, as well as the importance of water quality and environmental protection
- Identifying sources of technical, educational, and financial assistance
- Aiding in developing personal, voluntary action plans to prevent pollution
- Empowering individuals and communities to protect water resources

Farm*A*Syst is a jointly funded and sponsored program of the U.S. Department of Agriculture Cooperative State Research Education and Extension Service, the U.S. Department of Agriculture Natural Resources Conservation Service, and the U.S. Environmental Protection Agency. The Farm*A*Syst formula of education, self-assessment, and action plans motivates farmers and ranchers to take voluntary action. Fact sheets pull together legal and technical requirements into a format that nonexperts can understand. Step-by-step work sheets enable individuals to apply site-specific management practices to their own property. The work sheets assess pollution risks from activities such as livestock waste disposal and pesticide management. Program materials help landowners locate the technical resources and financial assistance needed to implement action plans or best management practices.

Fact sheets help farmers and ranchers assess their water pollution potential. The topics are

- Drinking water well condition
- Pesticide storage and handling
- Fertilizer storage and handling
- Petroleum product storage
- Hazardous waste management
- Household wastewater treatment
- Livestock waste storage
- Livestock yards management
- Silage storage

- Milking center wastewater treatment
- Nutrient management practices.

Nutrient Management Practices: A Farm*A*Syst Example

Soil nutrients need to be properly managed to meet the fertility requirement of crops without adversely affecting the environment. The soil nutrients of greatest concern for protecting water quality are nitrogen (particularly for the marine environment) and phosphorus (particularly for fresh water). Water quality can be harmed by the addition of nutrients. Erosion and runoff from fertilized cropland to lakes, ponds, streams, and bays can stimulate excessive growth of aquatic weeds and algae.

Nutrient management practices for minimizing water-quality impacts vary widely and are dependent on the soil, cropping, topography, weather, and economic conditions. For example, careful management of nitrogen should be a priority on sandy soils to control nitrate leaching to groundwater; minimizing runoff and erosion should be a primary goal on sloping cropland fields.

Each of the Farm*A*Syst fact sheets has landowners rate their own land and farming practices. Following are examples of self rating from the *Nutrient Management Practices* fact sheet. Low risk is rated as 4, low to moderate as 3, moderate high as 2, and high as 1. A 4 ranking is ideal and should be your goal; a 3 ranking provides reasonable protection of water quality; a ranking of 2 provides inadequate protection of water quality in most circumstances; and a 1 ranking indicates a high potential for degrading water quality. Although this example is specific to Wisconsin, it provides a feel for the program.

Nutrient Application Rates

4. Nutrient application rates do not exceed land-grant university recommendations.
3. Nutrient application rates exceed land-grant university recommendations by 10–25 percent.
2. Nutrient application rates exceed land-grant university recommendations by 25–50 percent.
1. Nutrient application rates exceed land-grant university recommendations by greater than 50 percent.

Slope

4. Manure is applied to fields with slopes of 0–2 percent.
3. Manure is applied to fields with slopes of 2–6 percent.
2. Manure is applied to fields with slopes of greater than 12 percent.
1. Manure is applied to fields with slopes less than 12 percent.

Cover Crops

4. Cover crops are established in the fall after the primary crop is harvested on all fields.
3. Fall cover crops are established on the majority of fields.
2. Fall cover crops are established on the minority of fields.
1. Fall cover crops are not used.

When the user is finished ranking, the next step is to make an action plan. Below is an example of the form used in the Farm*A*Syst program.

HIGH-RISK ACTIVITIES

A listing of individual activities or structures that ranked "1" on your Farm*A*Syst work sheets

After completing each of the 10 assessments appropriate to your farmstead, list any individual activities or structures that you ranked as "1" (high risk). Fill in the work sheet number, the work sheet name and the individual activity of concern. Don't fill in the blanks to the right of the double line. You'll do that later, when you're completing Work sheet #12.

Work - sheet number	Worksheet name	Individual activity identified as being high risk (1)		Response Options (check one)		
				Immediate action possible (change in practice only; cost not a factor)	Further planning required (required major structural improvement or relocation involves major effort or high cost)	Taking Action (proposed first step to address concern)

From 63536-12W and 13W—*Overall Farmstead Assessment* and *Assessing the Risk of Water Contamination from Nutrient Management Practices,* respectively—by Farm-A-Syst Farmstead Assessment System, © 1991. Copyright Board of Regents of the University of Wisconsin System, doing business as Division of Cooperative Extension of the University of Wisconsin-Extension.

Complete information about this program is available from the Farm*A*Syst Program, B142 Steenbock Library, 550 Babcock Drive, Madison, WI 53706-1293, phone 608-262-0024. Most county Extension offices or Natural Resources Conservation Service offices should also be able to help with this program. All forms are kept confidential. No information is passed on to others regarding any individual farm or its ratings or practices.

CHAPTER SIXTEEN

Preventing Nonpoint Source Pollution from Forestry

by Mike Cloughesy and Robert Kent

Unlike some European countries, the United States has no federal law that directly regulates forest practices on private land. Federal environmental laws such as the Clean Water Act and the Endangered Species Act indirectly regulate activity on private land, but direct regulation has been left to state and local governments.

The Federal Water Pollution Control Act Amendments of 1972 and 1987 (Clean Water Act) required states to limit nonpoint source pollution from forestry operations. Best management practices (BMPs) were required by the Clean Water Act, but the form and process of enforcement were left up to the states. Most states rely on voluntary BMPs, accompanied by educational and incentive programs for landowners. Forest management activities on state and private lands in 10 states are regulated by state forest practices rules. Forest practices rules were written to establish and enforce BMPs to control nonpoint source pollution from forestry activities as required by the federal Clean Water Act of 1972.

This chapter first describes what forestry BMPs are and then highlights two different ways that forestry BMPs are put into practice on the ground. We discuss the New York *Silviculture Management Practices Catalogue* and the Oregon forest practices rules in detail. We conclude with a case example demonstrating sediment prevention through forest road maintenance and then give you some ideas for your next steps.

In this chapter you'll learn

- What the best practices are in forestry management
- How to manage harvest operations to protect water quality
- How to protect forest riparian zones to protect water quality
- How to manage watercourse crossings and access routes to protect water quality
- How to manage hazardous material to protect water quality

Forestry Best Management Practices

Nonpoint source pollution is caused by runoff from rainfall and snowmelt, which moves over the ground and picks up pollutants, including sediment, finally

depositing them into our rivers, lakes, and groundwater. This type of pollution is called *nonpoint source pollution* because it comes from many diffuse sources and not from a single point (such as a pipe).

Foresters, loggers, and landowners can reduce forestry nonpoint source pollution by implementing a combination of BMPs or management measures, listed below.

Preharvesting planning

Protect water quality and control erosion and sedimentation by performing advance planning for efficient forest harvesting, site preparation, and road systems.

Streamside management areas

Establish and maintain a streamside management area along surface waters to buffer against detrimental changes in the temperature regime of the water body, to provide bank stability, and to withstand wind damage.

Road construction and reconstruction

Minimize delivery of sediment from road construction by following the preharvest plan layouts and designs for the road system, incorporating adequate drainage structures, and properly installing stream crossings.

Road management

Maintain road stability and utility and minimize sedimentation and associated pollution by inspecting and maintaining roads as needed.

Timber harvesting

Preserve roads, lower equipment maintenance costs, and protect water and soil quality by conducting harvesting, yarding, and hauling activities in accordance with preharvest planning.

Site preparation and forest regeneration

Protect water quality and improve soil quality and productivity by selecting site preparation and regeneration methods that reduce soil exposure, displacement, and compaction.

Fire management

Guard against excessive sedimentation from prescribed fire and reduce potential nonpoint source pollution during wildfire suppression and rehabilitation.

Revegetation

Reduce erosion and sedimentation by rapid revegetation of areas disturbed by harvesting operations or road construction.

Forest chemical management

Minimize the use and maximize the benefits of chemicals through skilled and appropriate management and application.

Wetlands forest

Protect the functions of forested wetlands by tailoring forestry practices to reduce or minimize impacts to this unique environment.

The New York Silviculture Management Practices Catalogue

The New York *Silviculture Management Practices Catalogue* was developed by the Silviculture Management Practices Subcommittee of the New York State Nonpoint Source Management Task Force. It is intended to be used by those involved with educating and providing technical assistance to forest owners, loggers, and equipment operators. The catalogue addresses nonpoint source pollution problems from various forms of silvicultural activity, but its primary focus is on controlling disturbances associated with logging.

BMPs are selected from the catalogue, based on the application of professional judgment to solve a particular nonpoint source problem for a specific harvest operation or for a wider watershed area. The catalogue is neither a regulatory tool nor a design manual.

The catalogue includes summary sheets for the following management practices: planned harvest operations, riparian buffer protection, planned watercourse crossings, planned access routes, road water management, sediment barriers, vegetation establishment, and hazardous material management.

A brief description of each of the BMPs is given below. However, to get the full details, readers should obtain a copy of the catalogue.

Planned harvest operations

Proper planning of harvest operations involves the thorough collection and use of information about the harvest area. The plan integrates the harvest needs of the managed forest with the need to protect water resources. It incorporates soil, slope, and water resource information with the silvicultural aspects of the harvest. The type of equipment to be used, the operation's timing, the spatial limits, and the intensity of the harvest are adjusted on the basis of the need to minimize soil disturbances and watercourse crossings in a particular harvest area. The needs for other management practices are also identified.

Riparian buffer protection

Riparian buffer protection involves identifying and preserving corridors along streams and other water bodies. Riparian buffer areas are identified early during harvest planning. Aerial photos, topographic maps, soil surveys, forest-type maps, stream classification maps, and field reconnaissance are used. Standard buffer distances are often designated for different types of silvicultural activities. Distances may vary according to soil type, slope, cover, and season.

Planned watercourse crossing

Planned watercourse crossings may be bridges, culverts, or fords installed for use by skidders, trucks, and other logging vehicles. Fords are used only where the substrate is hard and stable, where low flow conditions exist, and where light use is expected. Crossings are perpendicular to the watercourse, and the approaches are as straight as possible for 50 feet on each side of the crossing.

Planned access routes

Access routes are planned by determining the size, location, and future use of the area to be harvested. Critical site features are identified, including places to avoid and places to use. Existing roads and trails are used where feasible and are adequately modified. Road grades, lengths, curves, cuts, fills, and surfaces are planned to minimize erosion and to avoid drainage problems.

Road water management

Road water management involves the properly integrated use of component measures such as drainage dips, skid turnups, waterbars, cross-drain culverts, road ditches, and road grading. The proper design and integration of the components provide control of water movement and stabilization of soils on access routes.

Sediment barriers

Sediment barriers normally consist of silt fences or straw bale dikes. Silt fences are constructed of geotextile fabric supported with steel or wooden posts, and sometimes wire fence. Straw bale dikes consist of bound bales of straw or hay that are tightly abutted to each other. Sediment barriers are installed as close to the contour as possible. They serve to reduce the velocity of sheet flow, thereby limiting its capacity to transport sediment.

Vegetation establishment

Establishing vegetation involves roughly grading and mulching exposed forest soils and applying lime, fertilizer, and seed to them. Site preparation may involve smoothing ruts, removing logging debris, scarification, and installing water control devices. Mixtures of legumes and cool-season grasses are normally seeded by hand or with a cyclone seeder on smaller sites and with a hydroseeder or other commercial equipment on larger sites.

Hazardous material management

Managing hazardous material involves the control of pesticides, fertilizers, petroleum products, road salt, and other potential pollutants. These products are used only when deemed necessary and only according to the label. Less hazardous products or procedures are substituted whenever possible. Equipment is maintained and materials are stored in locations distant from water bodies where flooding is unlikely, soils are well drained, and surface runoff is controlled. Spill contingency plans are in place.

The Oregon Forest Practices Rules

The Oregon forest practices rules regulate commercial forest activities on nonfederal forest land in Oregon. The goal of the rules is to encourage forest production on private forest land while protecting forest soil, water, air, fish, and wildlife. The Oregon forest practices rules are administered by the Oregon Department of Forestry. The rules apply to commercial forest operations. The activities that must comply with the rules include, but are not limited to,

- Harvesting trees. (The rules apply to all timber harvesting activities, including precommercial thinning and commercial firewood harvesting. Special emphasis is given to keeping soil from sliding or washing into streams, lakes, and wetlands.)
- Operating around streams, lakes, bogs, swamps, and other wetlands. (Examples include limiting ground disturbance, leaving trees in riparian management areas, and limiting chemical use on buffer strips.)
- Constructing, reconstructing, or maintaining roads, landings, skid trails, and fire trails (including surface mining of rock for road construction, constructing ditch systems, and disposing of excess soil)
- Reforestation (numbers of trees to plant, timelines to meet, and getting the new forest going ahead of brush competition)
- Applying chemicals (for example, herbicides to slow brush growth and tree-growth-enhancing fertilizers)
- Disposing of slash (treating timber debris left after harvest to limit fire hazard and make planting possible)

The forest practices rules often don't require specific *practices*; they more often require *results*. For example, not only must you replant a harvested area, but you must also ensure that a minimum number of new trees survive and outgrow competing vegetation.

The forest practices rules and water quality

Most activities associated with growing and harvesting trees can affect water quality. The forest practices rules are designed to encourage growing and harvesting of timber while protecting aquatic and wildlife habitat and water quality.

The rules focus on minimizing *nonpoint source pollution.* Since 1979, the forest practices rules have been recognized by the Oregon Department of Environmental Quality and the U.S. Environmental Protection Agency as BMPs for forest nonpoint source pollution control to meet the requirements of the federal Clean Water Act.

The rules require forest operators to do the following to protect water quality:

- Keep chemicals out of water
- Keep soil from eroding into streams, lakes, and other waters
- Retain near-natural water drainage paths around roads, landings, skid trails, and fire trails to maintain slope stability

- Retain vegetative ground cover to stabilize soils and prevent erosive overland water flows
- Retain trees and other vegetation around stream channels, lakes, and wetlands
- Protect stream banks and beds from disturbance by activity and equipment
- Limit soil disturbance and compaction
- Stabilize exposed soil surfaces by seeding, mulching, or riprapping
- Fell trees away from streams
- Maintain a stable road surface and ditches or other drainage systems
- Carefully control forest management activities in riparian management areas above high-water marks of streams
- Keep organic debris out of road and landing fills
- Build roads and landings so they are not a source of erosion into waters

Table 1. Stream types and riparian management area widths.

	Type F	Type D	Type N
Large	100 feet	70 feet	70 feet
Medium	70 feet	50 feet	50 feet
Small	50 feet	20 feet	None

The water protection rules of the Oregon forest practice rules were strengthened in 1994. The revised rules require growing and maintaining vegetation, especially large conifers, along streams in order to establish mature forest conditions in streamside stands. Riparian management areas are the areas along each side of a stream where trees, snags, and understory vegetation must be protected. The rules allow limited timber harvesting, stream crossing, and reforestation inside the riparian management areas.

The requirements for the riparian management areas vary, depending on stream size and use. Stream size is classified as small, medium, or large, based on *average annual streamflow*. Average flow estimates are based on the size of the drainage area and on rainfall measurements from several places within the drainage area. Most stream sizes already have been determined by the Department of Forestry.

Streams are further classified by use:

- *Type F streams* are used by fish, or by fish and for domestic (household) use
- *Type D streams* don't have fish but do have domestic (household) use
- *Type N streams* have neither fish nor domestic (household) use

Maps showing classification of most streams on state and private forestland in Oregon are maintained by the Oregon Department of Forestry. A visit to a local Oregon Department of Forestry office is all that is necessary to find out the classification of a reach of stream.

The required riparian management area for different types and sizes of streams is shown in table 1.

Table 2. Requirements for live conifers in riparian management areas (per 1,000 feet of stream).

	Type F	Type D	Type N
Large	40	30	30
Medium	30	10	10
Small	no minimum	no minimum	no minimum

Within the riparian management area, the following general requirements apply:

a. Except for yarding corridors (areas where logs are yarded across streams by cable logging systems) or stream crossings, leave
   1. All trees within 20 feet of the stream
   2. All trees that lean over the stream
   3. All understory plants within 10 feet of the stream
   4. All snags (dead trees) and down wood in the channel and riparian management area. (Trees that pose a safety or fire hazard may be felled, but can't be removed.)

b. Leave a minimum number of live conifers in the riparian management area. Minimum numbers per 1,000 feet of stream are shown in table 2.

c. Leave a minimum amount of live conifer basal area (cross-sectional area of trees in square feet) in the riparian management area. The minimum basal area and minimum diameter requirement of trees retained varies with stocking level, stream classification, and geographic region.

You can obtain more specific information on the forest practices rules from any local office of the Oregon Department of Forestry. On-the-ground technical assistance and rule enforcement are available from the Oregon Department of Forestry forest practices foresters.

Summary

Using BMPs is a way to limit nonpoint source pollution during forestry operations. Two ways of carrying out BMPs are through state-sponsored assistance, as in New York, or as state-mandated regulation, as in Oregon. In either system, the control of nonpoint source pollution comes down to proper implementation of properly selected BMPs by landowners, foresters, and operators. With proper use of BMPs, it is possible to conduct a full range of forestry operations while protecting our precious soil and water resources.

Publications

Best Management Practices for Water Quality (New York State Forestry, 2000). A best management practices field guide.

The following publications are published by Cornell Cooperative Extension. They are available from

Media Services Resource Center
7 Cornell Business & Technology Park
Cornell University
Ithaca, NY 14850
Telephone: 607-255-2080
Fax: 607-255-9946

Assistance for New York Forest Owners (1993). A guide to the major public and private organizations that help forest owners manage their lands efficiently. Covers harvesting for timber, Christmas trees, and maple production. 14 pp. 147V18#3. $2.00.

Biodiversity for Forests and Farms (1996). Useful to anyone who wants to protect and enhance habitat for fish and wildlife and the many ecological services upon which we all depend. Introduces the technologies of GAP analysis and geographic information systems. 28 min. Video. 147VBFFF. $24.95.

*Forest*A*Syst,* by Rick Hamilton (Raleigh, NC: North Carolina State University). A self-assessment guide for managing your forest for timber production, wildlife, recreation and aesthetics, and water quality.

Forestry Handbook, Part II (1981). Basic information on the practice of forestry, including thinning, girdling, building forest roads for logging, harvesting timber, logging safety, taking measurements, mapping, and milling. Includes tables to help you estimate cords of wood per average tree. 24 pp. 147NE21. $2.00.

A Guide to Logging Aesthetics: Practical Tips for Loggers, Foresters, and Landowners (1993). Fifty color photographs and text describe cost-effective and proven practices that minimize negative impacts during and immediately after the harvest while enhancing the wildlife, recreational, and aesthetic qualities of the woodlot. 27 pp. 123NRAES60. $7.00.

Managing Small Woodlands for Firewood (1987). Helps you get the most economic value from your woodlot. Includes the harvest plan, actual harvesting methods, legal considerations, and valuable information about the wood itself. 32 pp. 1471B208. $6.75.

Timber Management for Small Woodlands (revised 1995). This popular publication explains and illustrates basic silvicultural and forestry techniques. It is of interest to owners and caretakers of

noncommercial forestland who want to give nature a hand in producing marketable timber and wood products. 57 pp. 1471B180. $5.50.

The following publications are published by the Oregon State University Extension Service, Corvallis, Oregon. They are available from

Extension and Experiment Station Communications
422 Kerr Administration Building
Oregon State University
Corvallis, OR 97331-2119
Telephone: 541-737-2513
Fax: 541-737-0817

Many of these publications are also available on the Internet at http://eesc.orst.edu/agcomwebfile/edmat.

Logging Woodland Properties (1993), by J. J. Garland. EC 956. 4 pp. $0.75.

Maintaining Woodland Roads (1997), by P. W. Adams. EC 1139. 8 pp. $1.50.

Oregon's Forest Practices Rules (1996), by P. W. Adams. EC 1194. 12 pp. $1.00.

Planning Woodland Roads (1996), by J. J. Garland and D. J. Jackson. EC 1118. 8 pp. $1.00.

Soil and Water Conservation: An Introduction for Woodland Owners (1993), by P. W. Adams. EC 1143. 4 pp. $0.75.

Soil Compaction on Woodland Properties (1993), by P. W. Adams. EC 1109. 6 pp. $1.00.

T*imber Harvesting Option* (1997), by J. J. Garland. EC 858. 2 pp. No charge.

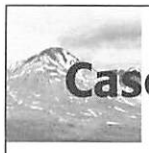
Available from other sources:

Oregon Forest Practices Rules and Statutes (Salem, OR: Oregon Department of Forestry). Oregon Department of Forestry, 2600 State Street, Salem, OR 97310.

Silviculture Management Practices Catalogue for Nonpoint Source Pollution Prevention and Water Quality Protection in New York State (Albany, NY: New York State Nonpoint Source Management Practices Task Force, 1993).

For more information on nonpoint source pollution and BMPs contact:

U.S. Environmental Protection Agency
Nonpoint Source Control Branch (4503-F)
401 M Street, SW,
Washington, DC 20460



Case Study

Preventing Sedimentation through Forest Road Maintenance: A Case Example

The Problem

Sediment losses from unpaved forest roads during the rainy season can be a major source of nonpoint source pollution from forestry. Bare soil on overly steep and unstable cutbanks is subject to erosion and slumping into road ditches. Ditches and culvert inlets can become clogged with soil and debris slumped in from cutbanks and ditch walls. Wheel ruts can collect and channel water on the road surface. Debris and sediment can collect in culverts, thus reducing their flow capacity. Soil below culverts can be washed away by culvert water.

What Can Be Done

Key activities for maintaining forest roads include

- Grading roads to smooth ruts and direct water off the road surface
- Cleaning ditches and culverts to efficiently remove road drainage to stable areas
- Adding fresh surface gravel when earlier applications become worn by traffic
- Monitoring road conditions during large storms so that clogged ditches and culverts can be taken care of to prevent serious problems such as gullies, washouts, or landslides

In areas where sedimentation is a major concern, it may be wise to reduce or suspend traffic from unpaved roads during wet weather and to schedule timber harvesting and log hauling during the summer to reduce sedimentation from forest roads.

Outcomes

Well-maintained roads have stable cutbanks with good plant cover that does not impair visibility and drying of road surface. Open culverts and clear ditches have good capacity to carry runoff. Water drains freely from a well-graded road to the ditch. Rock riprap or half rounds protect fill slope from culvert water.

(Source: *Maintaining Woodland Roads,* Extension Circular 1139 [Corvallis, OR: Oregon State University Extension Service, 1997])

CHAPTER SEVENTEEN

Protecting Watershed Health: Management Practices for Small Acreage Landowners

by Garry Stephenson and Linda J. Brewer

Living on a small acreage offers you the opportunity to have a large garden, a few livestock, and other benefits of a little extra space. The property you live on, no matter its size, is part of a larger mosaic of properties. Water drains over and through this land into streams, rivers, lakes, and eventually the ocean. Even if there are no streams on your property, water eventually makes its way to these bodies of water from your land. Thus, the quality of water before and after it leaves your property is critical for human consumption, fish habitat, and many other uses.

It might seem that small properties couldn't contaminate water resources or do much to improve water quality. But the combined impact of many rural homes and small acreages can represent a significant source of pollution or clean water, depending on how well the land is managed. Your property is an important part of the watershed processes.

The kind of pollution we're concerned with in this instance is *nonpoint source pollution.* This kind of pollution comes from many sources, some quite small. These sources might not be easy to identify, but added together they're a major contributor to water contamination. *Point source pollution,* on the other hand, comes from easily identified sources such as factories or sewage plants.

This chapter discusses several key sources of water-quality contamination on rural homesites and small farms and suggests ways to reduce water-quality problems. The "Resources" section at the end of this chapter includes additional materials with more in-depth coverage of these topics.

In this chapter you'll learn

- The role of soil in water quality
- How to manage home landscapes and gardens to protect water quality
- How to manage your domestic well and septic system to protect water quality
- How to manage livestock pastures to protect water quality
- How to manage manure and compost piles to protect water quality

Managing Your Landscape and Garden to Protect Water Quality

Home landscapes and gardens can be a source of water contamination in the form of eroding topsoil and excess fertilizers and pesticides. Pounding rain and runoff carry away soil particles, organic matter, plant nutrients, and soil contaminants. This mix of water, soil, and chemicals can make water turbid or cloudy, stimulate excess algal growth, and contaminate aquatic life and drinking water. Quantities of these pollutants from a single property might be small, but when you add up the pollutants from many similar properties, the total can be significant.

Fortunately, you can minimize erosion and runoff with some fairly basic land-management practices. The key is to minimize the amount of contaminated water that runs off your property by using fertilizers and pesticides correctly. Do not overapply any fertilizer or pesticide to your lawn, garden, or landscape.

Home landscape design and materials

The design of your landscape and the materials you use can have a major impact on how water behaves on your property. Water leaving a site as runoff is more likely to carry pollutants than water that has soaked through the soil and leaves as groundwater. When water soaks through the soil, the soil filters the water to a greater extent than when the water just runs off.

In general, more than 90 percent of the rain that falls on pavement runs off. Lawns have about 25-percent runoff, and dense forests have about 10-percent runoff. Therefore, when designing a landscape, it's best to have fewer hard surfaces and more grass, trees, and natural landscaping.

It's a good idea to select plants that are native or well adapted to your area. Often these plants require less supplemental water and fertilizer and fewer pesticides to remain healthy and attractive. By using fewer of these inputs, you decrease the cost of the landscape as well as the potential for water contamination.

The same is true for lawns. Consider using low-maintenance groundcovers instead of grass, particularly in areas where grass doesn't grow well, such as dense shade.

Always mulch or plant some type of cover crop over bare soil. These techniques protect the soil from erosion and add organic matter.

Managing weeds

Weeds are plants that have a detrimental effect on agriculture, recreation, wildlife, and humans. Weeds cause production losses to agriculture, endanger native plants and animals by encroaching into forest and conservation areas, hamper the use of recreational areas, and can be poisonous or harmful to humans and animals.

Weeds can also be a source of conflict between neighbors when weed control is not practiced. Many states mandate that noxious weeds be controlled on lands managed privately or publicly. Regardless of

The Role of Soil in Water Quality

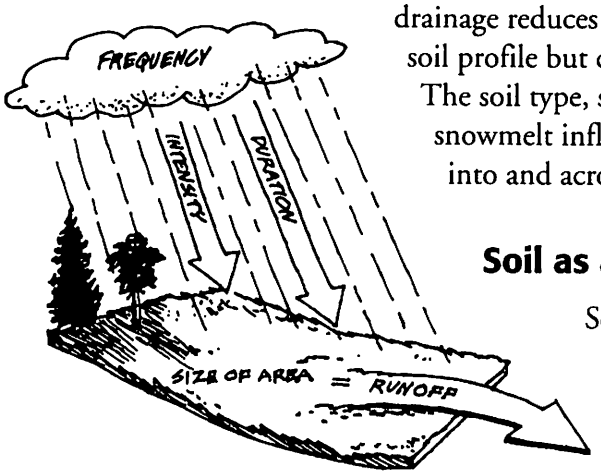
Soil as a filter

Eroding topsoil, fertilizer, petroleum products, and pesticides are some of the sources that can degrade the quality of water that passes through or over soil. The type of soil you have and how you manage it help determine whether these contaminants reach bodies of water.

Activity in soil is a complex interplay of chemical and biological reactions. Most soil has a negative electrical charge that allows it to attract and hold positively charged ions. Many plant nutrients and soil contaminants have a positive charge and so can be held by soil particles. In this case, soil acts as a chemical filter. Soil also contains immense quantities of microorganisms that feed on organic matter and other material in soil. These organisms act as a biological filter when they degrade, alter, or inactivate contaminants.

There are many kinds of soil, and each has characteristic drainage patterns. Sandy soil has large pore spaces that permit water to drain quickly. Clay soil has very small pore spaces, so water moves through it very slowly. The pore sizes of silt loam, silty clay loam, and clay loam lie somewhere between those of sand and clay.

Each of these drainage characteristics has water quality consequences. Soils with quick drainage reduce runoff but permit nutrients and contaminants to travel quickly into and through the soil toward groundwater. Soil with slower drainage reduces the rate of contaminants traveling into the soil profile but causes standing water and surface runoff. The soil type, slope, and rate and amount of rainfall or snowmelt influence the exact amount of water flowing into and across soil.



Rainfall characteristics help to determine amounts of runoff. (Source: *Water Quality Protection Guide,* Oregon Department of Agriculture, 1993)

Soil as a contaminant

Soil suspended in water causes clouding or turbidity. Soil contains organic matter and nutrients that can reduce the oxygen content of water. Fish and other aquatic animals suffer as a result of low or limited dissolved oxygen in the stream.

Clay soil particles, because of their small size, can be carried along in

freshwater streams, keeping them cloudy. Heavier soil particles, such as silt or sand, settle out of flowing water more easily, especially where the flow slows. In these places, they build up, changing the course of the stream over time. Soil deposited on stream bottoms can cover or smother nurturing habitats for fish eggs as well as the insect eggs upon which fingerlings depend.

How organic matter improves soil

Organic matter is an important ingredient in a healthy soil system. It can be supplied as crop residue, dead grass, or animal manure. When applied to the surface, it reduces erosion and the compaction caused by raindrop splash.

Organic matter, like soil, has a negative charge and attracts and holds positively charged plant nutrients and other materials. Thus, organic matter "ties up" nitrogen and pesticides, slowing their leaching into surface water and groundwater.

Organic matter also acts like a sponge, slowing the flow of water through soils. This characteristic is especially beneficial to sandy soils. In clay soils, organic matter creates larger soil pore spaces, increasing the amount of air in the soil and enhancing drainage.

enforcement, it is everyone's responsibility to control noxious weeds.

Several plants can be characterized as "plant barbarians." These plants invade and aggressively spread, dominating other more favorable plants. They can harm humans, poison livestock, and make land unattractive and virtually unusable.

Riparian and wetland areas are susceptible to several very aggressive plants. If these plants are present, manage them so they do not spread, or plan to remove them. For instance, reed canarygrass (*Phalaris arundinacea*) is used as a pasture grass in many wet areas. Proper grazing can keep this plant in check. Efforts should be made to keep it from escaping into riparian or wetland areas, where it is not welcome. In many areas, purple loosestrife (*Lythrum salicaria*) is a threat to wetlands. It should always be removed.

When possible, it's a good idea to allow native plants or plants highly compatible with native plants to dominate the uncultivated areas of your farm. You will find these plants are easy to manage, encourage appropriate wildlife, often assist in preventing weeds, and maintain important natural functions, such as the water-filtering role of wetlands.

Reduce weed problems on your property with these guidelines for weed control:

1. Know the difference between a weed and a benign plant.

2. Weed controls work best when plants are seedlings or are actively growing.
3. Cut or kill weeds before they go to seed.
4. Sow grasses or groundcovers on bare spots to compete with weeds.
5. Don't disturb areas larger than you can reasonably manage when establishing garden sites, landscaping, pastures, and other improvements.
6. Compost manure before spreading to reduce weed seeds.

Using fertilizers correctly

Homeowners usually add fertilizer to their landscapes and gardens to enhance plant growth. However, if you overapply compost, manure, or synthetic fertilizers, water can carry excess nutrients into streams or leach them into groundwater.

A soil test to determine the nutrients available to your plants will help you avoid adding unnecessary fertilizer. Information on how to test soil and the location of analytical labs is available from the local county office of your state's Extension Service. When using fertilizer, use only the amount recommended. In some cases, plants can achieve adequate growth with less than the recommended fertilizer rate.

Time fertilizer applications to match the plants' needs so the nutrients are not lost in runoff or leaching. Plants take up nutrients most vigorously during the active growing season. Don't add any kind of nitrogen during the short, cool days of late autumn and winter, when plant growth slows significantly. Most plants have reduced nutrient demands at this time, and nitrogen is easily leached into groundwater by precipitation.

It's best to fertilize trees and shrubs just before or as new growth begins in the spring. Fertilize grass and flowers when they're actively growing. Use slow-release fertilizers when possible. They release nutrients into the soil in small amounts over time and are less prone to leaching.

Excessive irrigation after a fertilizer application promotes runoff and leaching. Match the application of water to the needs of plants. Install irrigation timers if needed.

Manure can be a valuable fertilizer and soil conditioner, and when applied appropriately, will produce minimum ground- and surface-water contamination. Land application is a logical and time-proven method of disposing of manure. To avoid water contamination, apply manure between periods of intense rainfall, when the ground is neither frozen nor saturated. Because the nitrogen in manure is so water soluble, you should attempt to apply it as the soil warms up and plants are vigorously growing. It's also helpful to incorporate it lightly into the soil. In permanent landscape plantings, apply up to one inch and work it into the surface with a hand rake or similar tool. Cover and compost stockpiled manure to conserve its fertilizer value.

Using pesticides appropriately

Pests in gardens and landscapes fall into three major categories: weeds, insects, and diseases. There is an arsenal of organic, least toxic, and highly toxic pesticides and

methods available to control these problems. As with fertilizer, the tendency is to overuse pesticides. These excess chemicals threaten surface and groundwater quality.

When dealing with a problem in your yard, it's a good practice to begin to solve the problem by using the least-toxic method at your disposal. Then, if the problem continues, you can use more toxic methods until you achieve success. This strategy will decrease your use of more toxic pesticides, minimize your handling of pesticides, protect your family and pets, and limit environmental impacts.

Start by adjusting cultural practices to give your plants optimum growing conditions. A healthy plant is less susceptible to pest attack. Choose plants carefully, based on the conditions of your yard. If you do encounter pest problems, consider using cultural, mechanical, and biological controls first.

Some "pest problems" are not problems at all. Good plant selections for home landscapes tolerate low levels of insect and disease damage. Putting up with some landscape imperfection reduces labor and chemical inputs.

Always use pesticides—organic or synthetic—for their intended purpose. Apply them at the recommended rate and follow label directions. Never dump pesticides into household drains, down storm drains, or on the ground. Instead, either use the pesticide for its intended purpose or take advantage of a pesticide collection event. Your local garbage collection service or landfill can provide information on these collection events. Purchase only the amount of pesticide you'll need for a single growing season. In the case of pesticides, bigger is not necessarily better.

Managing Your Well and Septic System

Domestic wells

Most rural homes get their drinking water or irrigation water from a well. By properly managing your well water system, you can protect groundwater and your drinking water supply. Proper management requires inspection and maintenance of all wells on your property and special attention to any practice that could potentially contaminate groundwater.

The location of your well relative to other farming activities is very important in protecting your drinking water. Common sense dictates that potential contaminants be located as far from a well as possible. For public health reasons, states and counties set minimum distances between well heads and common pollution sources. Frequently regulated structures and activities include

- Septic tanks
- Confined animal feeding or holding operations
- Animal waste holding ponds, lagoons, or other waste storage sites
- Pesticide or fertilizer storage
- Above-ground and buried fuel storage tanks
- Sewage disposal systems such as pit privies or septic system drain fields

Contact your county sanitarian to determine whether there are minimum setback limits regulating the placement of these or other structures in relation to your well.

Inspect your well to see whether it is properly constructed. See figure 1. The well casing should extend 12 to 18 inches above the ground surface, and there should be a concrete or soil pad surrounding and sloping away from the casing. This design protects the wellhead from contamination by surface water. If your wellhead does not extend above the ground surface, a shallow trench around the wellhead is recommended to protect the well from surface water.

Check the sanitary well cap to make sure the bolts are tight and no gaps or cracks are visible in the cap or casing. Replace old and cracked sanitary seals, especially when surface water, as from flooding, can cover your wellhead. Make sure there is a screen covering the vent pipe to prevent insects and mice from entering your well.

It's a good idea to locate all of the wells on your property (figure 2). Wells no longer in use present a high risk of groundwater contamination. These old wells provide a direct conduit for pollutants to reach groundwater. Abandoned wells may be visible only as an unnatural depression left by a hand-dug well, a ring of bricks or rocks, or a pipe sticking out of the ground. Always abandon old wells properly and document their location. Pass this information on to a new property owner.

If your household well is located in a pasture, fence the wellhead to prevent urine and manure from reaching the well. If your soil is sandy (porous), remember that fecal

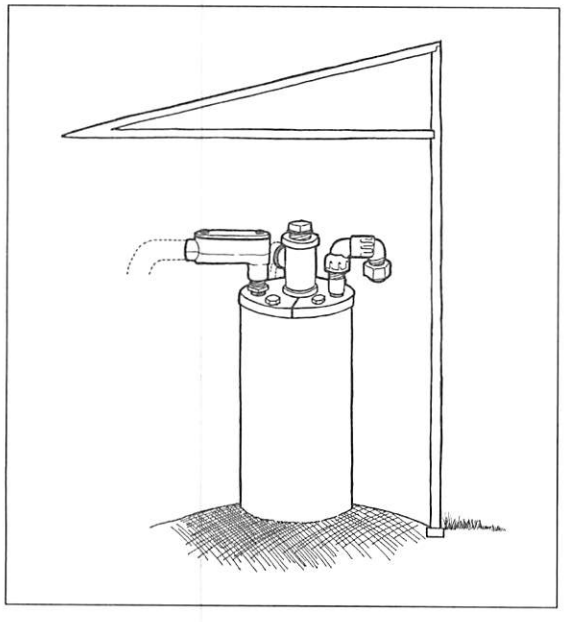


Figure 1. A properly constructed well protects against contaminants entering your drinking water system.

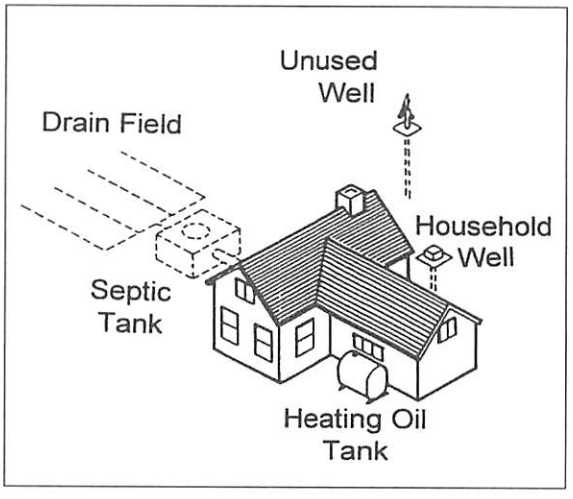


Figure 2. Know the location of all active and abandoned wells on your property.

bacteria can travel in groundwater as well as surface water.

Don't store pesticides and fertilizers in your well house. One spill could contaminate your drinking water. Find a suitable dry location for these materials away from your well.

Install an anti-backflow or anti-backsiphoning device on all outdoor faucets. These devices prevent contaminants from pesticide sprayers, livestock tanks, and so on from being siphoned into your household water system. As an alternative, never put the end of the hose in liquid—always maintain a gap between the end of the hose and any potential contaminant.

Test your water annually for bacteria and nitrate. These two tests serve as an indicator of the health of your well water.

Septic systems

Properly operating septic systems safely process household wastewater and sewage. Failing septic systems are major groundwater and surface water hazards and are sources of odor and bacteria. Through routine inspection and maintenance, you can protect your household water supply as well as the surface water and groundwater in your watershed.

In a properly working septic system, liquids and solids from the household are separated in the septic tank (figure 3). Liquids are passed from the tank into the drain field, where they're leached into the soil. Solids are partially digested by microorganisms, and the remaining solids settle and slowly fill the tank.

Most legally installed septic systems consist of a septic tank and a soil leach field. The proper size depends on the size of the dwelling, expected water use, and leach field soil type. States specify the size of septic tanks in newly constructed systems. The drain field must also be the correct size for the household. You can obtain specific guidelines from your county sanitarian.

Have your septic tank inspected regularly by trained personnel. A properly sized tank should be pumped out every several years to remove accumulated solids. The pumping schedule varies with the size of the

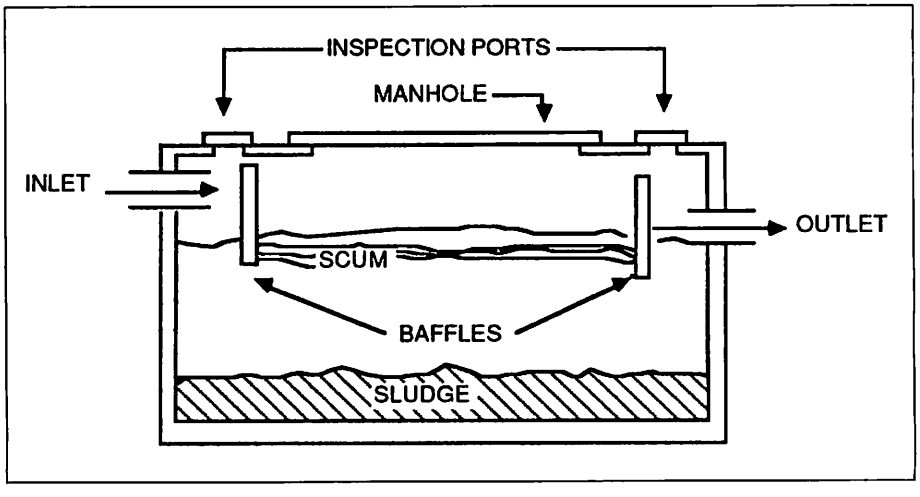


Figure 3. Cross section of a septic tank.

household and the size of the system. An overfilled tank can pass solids to the drain field, thus clogging it and leading to leach field failure and costly repairs.

Don't flush material into your septic system that doesn't decompose readily or that might clog the system or interfere with the decomposing activity. These items include diapers, fats, grease, solvents, oils, paints, or pesticides. Using a garbage disposal also contributes to the accumulation of solids in the tank; more frequent pumping is required when garbage disposals are used. Normal use of household cleaning products and laundry bleach doesn't affect the system.

There is no need to purchase additives to increase the rate of decomposition in your system. Pumping the tank to remove solids is the most important maintenance item you can schedule for your septic system.

Keep runoff from roofs and pavement away from your drain field to avoid saturating the soil. Saturated soil won't accept any more wastewater. Don't allow water that doesn't need treatment to be added to the amount of wastewater in the septic system. Examples are water softener backwash water, basement floor drain sumps, and roof runoff water. Water-saving fixtures and other conservation practices will also reduce the amount of wastewater entering your system.

Plant grass over the drain field. The roots from trees and large shrubs can clog it. Avoid soil compaction over the drain field. Compacted soil can damage the system or interfere with its function. Don't use the area for a parking spot or a road. Don't drive large equipment over it or allow large animals to stand on it, especially when the soil is wet. Don't cover the drain field with plastic, cement, or other impermeable material. These materials reduce the soil's ability to breathe, thus inhibiting proper function of the drain field.

Managing Small Pastures

Owning livestock is often an important benefit of living on a small farm. In areas with sufficient rainfall and soil fertility, pastures can supply large quantities of high-quality feed for animals. Maintaining the quantity and quality of feed in a pasture saves money and promotes healthy animals. The type of management that promotes high-quality pastures also protects water quality.

Here are some basic management recommendations:

- Base the number of animals you keep on the size and productivity of your land.
- Do not overgraze your pasture.
- Cross-fence pastures to provide several paddocks, then rotate grazing.
- Keep animals off saturated pastures.

Each of these recommendations is discussed below.

Base the number of animals you keep on the size and productivity of your land.

One of the challenges of managing livestock on a small acreage is taking care of the needs of the animals in a small area without overusing it. Land has a limit to how much forage it can produce. If the number of livestock is in balance with the

amount of forage produced, your land is considered to be within its carrying capacity. If the number of animals exceeds this amount, pastures are overgrazed, the quantity and quality of forage declines, weeds invade, and the soil becomes compacted from too much animal traffic.

Even within a given region, some land is more productive and can support more animals.

In overgrazed and overused conditions, sediments and pollutants no longer are filtered by a vigorous stand of grass and can run directly into streams. The soil can't absorb excess water and isn't protected with a thick groundcover, so it's more likely to erode. Too many animals produce excess manure and urine—perhaps supplying more nutrients than can be cycled naturally through the pasture.

The amount of pasture required for livestock will vary by region and is dictated by climate, soil type, and other factors. Even within a given region, some land is more productive and can support more animals. Some land has limitations and can't support the recommended number of animals or isn't appropriate for every type of livestock. Some land is so wet that it simply isn't appropriate for livestock use except during the driest time of the year. Contact your local Extension Service office, USDA Natural Resource Conservation Service, or soil and water conservation district for specific information about your land's carrying capacity for livestock.

Do not overgraze your pasture.

Pasture plants, like other plants, require leaves to grow. When the leaves of pasture plants are continuously nipped close to the ground, the plants lose vigor and may die. On the other hand, when plants are grazed and then given time to recover, they remain healthy and vigorous.

In most areas, it is recommended to graze a pasture to about 3 inches in height and then allow it to rest until it regrows to about 6 to 8 inches. The rest period allows the plants to grow and store energy so they can withstand future grazing. The correct grazing height will vary somewhat by region. It is a good idea to contact the Extension office, the Natural Resources Conservation Service, or the soil and water conservation district in your area.

This technique maintains vigorous pasture plants and decreases weeds and bare spots. A vigorous pasture also does a great job of filtering sediments and using nutrients from manure that otherwise might run off into streams.

The plants typically grown in pastures require some additional fertilizer to maintain a productive stand. Manure and urine deposited by grazing stock can contribute to pasture fertility. Periodic harrowing to distribute manure will promote general pasture quality. Legumes included in a pasture mix can also make a contribution to pasture fertility. Often, an additional amount of fertilizer is added to meet the nutrient needs of pasture plants.

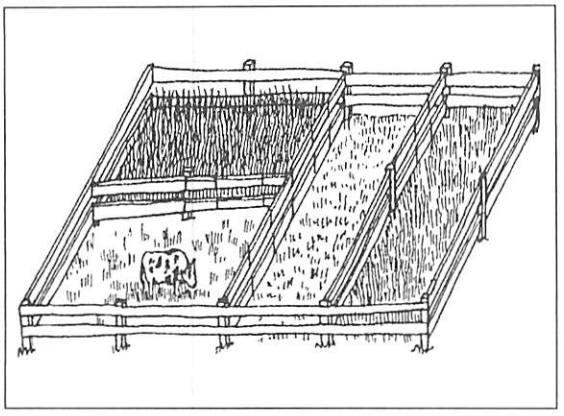


Figure 4. Rotational grazing. (Source: *Water Quality Protection Guide,* Oregon Department of Agriculture, 1993).

Cross-fence pastures and rotate grazing. Dividing or cross-fencing your land into several small pastures allows one part of a pasture to rest while animals are grazing another. You then can rotate animals from one pasture to another. This method not only increases the productivity of pastures, which decreases feed costs, but also protects the soil with a heavy sod and filters runoff.

Pastures can be cross-fenced with permanent fencing or temporary electric fence. Cross-fencing systems should have at least three pastures. Four are recommended; more are even better (figure 4).

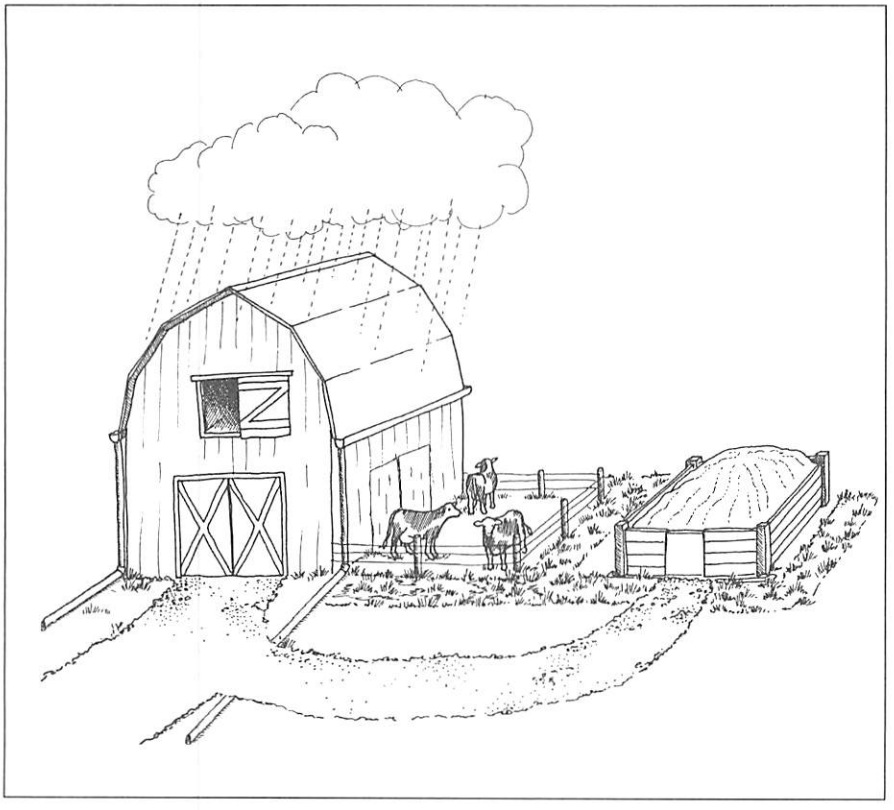


Figure 5. Careful management of grazing, manure storage, and clean water runoff can protect surface and groundwater from contamination during wet weather.

Keep animals off saturated pastures. In areas with cold, wet winters, pastures grow very slowly or stop growing altogether. Pastures in these areas can be saturated with water. This is a good time to move your animals to a well-drained area or an all-weather paddock to avoid damaging the pasture.

When animals stay on wet pastures, they overgraze what little feed there is. They also compact

and damage the soil and generally create a muddy mess. Pastures that have livestock on them all winter usually don't support a good stand of grass the following year, cause stress for animals, and are a source of sediment in streams.

On small farms, a good investment is to construct an all-weather paddock for animals to stay on until pastures are ready to graze in the spring (figure 5). In addition to saving your pasture, these well-drained areas keep animals and their feet drier and provide a convenient area for winter feeding. If they're large enough, they also can be used as an exercise area or arena.

When large animals routinely use streams for watering, they contribute to turbidity and bacterial levels and degrade the stream banks. Animals use riparian areas to access water and shade. Providing both water and shade away from the stream reduces stream impacts.

Managing Compost and Manure Piles to Protect Water Quality

Composting waste materials from the household, barn, and garden is a popular and effective way to generate fertilizer and organic matter to add to soil. Although composting is a good method of recycling nutrients, it can be a source of sediments, excess nutrients, and bacteria in streams when managed incorrectly.

Any accumulating mass of organic waste can threaten water quality. Common sources are large amounts of fresh manure and urine-soaked bedding generated from horse barns and other small livestock farms. These wastes contain both nutrients and potential disease-causing organisms.

The following suggestions, each discussed below, can help you minimize the possibility that waste will contaminate surface water or groundwater:

- Site waste piles properly.
- Use buffer strips to trap flowing contaminants.
- Apply manure and compost when and where plants can use it.

Site waste piles properly.

It's important to control the flow of water through compost and manure piles. Covering piles is an effective way to do this (figure 6). It also enhances the composting process and prevents the loss of nitrogen from water percolating through the pile.

If you keep horses or other livestock in a confined area during the winter, you'll need to store manure in piles so you can spread it on pastures later. When choosing a spot for long-term organic waste storage,

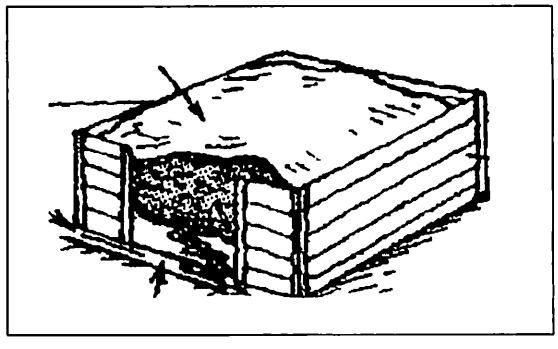


Figure 6. Covered manure storage. (Source: *Water Quality Protection Guide,* Oregon Department of Agriculture, 1993).

consider the soil types on your property. Sandy soil, with its large pore spaces, permits nutrients to travel quickly with rain or irrigation water through the soil to groundwater. Water moves more slowly through clay soil, which has small pore spaces. However, clay soil may allow more surface runoff. Other soils, such as silt loams, sandy clay loams, and so on, are between sandy and clay soils in their particle size and drainage characteristics.

Also consider the flow of surface water before siting a waste pile. Don't locate piles in low spots where drainage water flows. If necessary, divert surface water to prevent it from moving through the pile. Site the pile downslope from your well. A 200-foot separation ensures maximum well-water protection.

Consider using a roofed, concrete pad for storage of large amounts of waste. Such structures should have gutters that divert clean rainwater downslope from stored materials. Curbs, to further divert surface flows away from the pad, go a long way toward protecting water quality and manure nutrient content. Smaller amounts of waste can be stored on the ground, provided they are covered by weighted tarps during the rainy season. Be sure all waste is above the floodplain so it won't be carried downstream during floods.

Adequate manure storage space, correctly sited, can reduce the pressure to dispose of manure by winter's end. The number and type of animals and the bedding used will all be factors in the amount of space needed for manure storage. Assuming a pile five feet high, the following table can be used to estimate the area needed per animal for six months:

Animal	Sq. ft./animal/six months
Horse	72
Cattle	72
Sheep	6
Pig	12
Goat	6
Llama	12

Use buffer strips to trap flowing contaminants.

Protect streams by maintaining a buffer strip between manure piles and sacrifice areas, and streams. Buffer strips are areas planted with grasses and ground covers (figure 7). They enhance water quality by slowing runoff, promoting infiltration, and reducing the transport of pollutants. They serve as water filters and reduce amounts of sediment, nutrients, and microorganisms reaching the stream.

These vegetated strips will take up dissolved nutrients before they reach the stream. Deeply rooted plants are able to recover nutrients that have been washed to lower soil levels.

Buffer strips must be protected from grazing and compaction by animal hooves, especially during wet weather. If you want to mow a buffer strip, do so only during the dry season. Set the mower high to promote lush, vigorous growth of grasses.

As a property's slope increases, the width of the buffer strip also must increase. A wider buffer provides increased filtration on sites where the volume and rate of water flow is high. For a 0–3 percent slope,

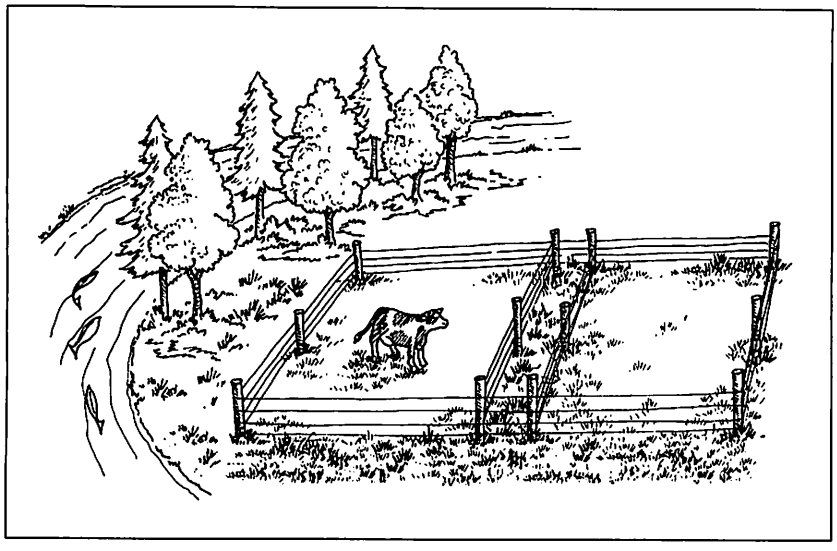


Figure 7. Use vegetated filter strips to slow runoff, increase infiltration, and filter pollutants from runoff water.

provide 25–50 feet of buffer. For a 3–8 percent slope, 50–100 feet of buffer is necessary for effective filtration. These are minimum recommendations. Steeper slopes require even greater widths to protect streams from contamination.

Apply manure and compost when and where plants can use it.

Spread manure and compost only when actively growing plants can take up their nutrients. The safest times of year to apply manure to soils are

- Just before planting, provided the soil isn't frozen or waterlogged
- When crops or pasture are actively growing

Summary

The quality of water before and after it leaves your property is critical for human consumption and fish habitat and other uses. The combined impact of many rural homes and small acreages can represent a significant source of pollution or clean water, depending on how well the land is managed.

Soil has an important role in maintaining water quality. It can act as a filter of pollutants or, if eroding, it can act as a pollutant. The organisms that live in soil and organic matter help digest and tie up pollutants. The plants growing on the soil, such as grass buffer strips, use excess nutrients. These functions prevent pollutants from reaching bodies of water.

Soil, if not protected by a groundcover, can become a pollutant. Soil suspended in water causes clouding or turbidity. Soil contains organic matter and nutrients that can reduce the oxygen content of water. Fish and other aquatic animals suffer as a result of low or limited dissolved oxygen in the stream.

Home landscapes and gardens can be a source of water contamination in the form of eroding topsoil and excess fertilizers and pesticides. Landscapes should be designed to reduce water runoff. Use pesticides and fertilizers only when needed and according to directions.

Manage household wells and septic systems to prevent contamination of

household water and groundwater. Protect household wells from sources of pollution, and have water tested routinely for nitrate and coliform bacteria. Septic systems should be regularly pumped and inspected by a trained person.

Base the number of livestock you keep on the size and productivity of the pasture. Provide adequate fertility for plants used in pastures to maintain a good stand, and manage livestock to prevent overgrazing. Minimize mud by avoiding use of pastures during the rainy season and by providing an all-weather paddock or sacrifice area.

Cover manure and compost piles to prevent leaching. Apply compost only when plants are actively growing. Maintain grass buffers to prevent sediments and excess nutrients from reaching bodies of water.

Resources

Printed materials

Gardening and Water Quality Protection: Using Nitrogen Fertilizers Wisely, by G. Glick. EC 1493 (Corvallis, OR: Oregon State University Extension Service, 1998).

Home Fruit, Vegetable, and Ornamental Garden Fertilizer Guide, by J. Hart and R. McNeilan. FG 66 (Corvallis, OR: Oregon State University Extension Service, 1995).

*Home*A*Syst/Farm*A*Syst Assessment System* Home*A*Syst is a set of 20 publications dealing with protecting the groundwater that supplies drinking water. It is a voluntary, self-assessment system to assist homeowners in identifying and reducing environmental hazards. Home*A*Syst and Farm*A*Syst (a similar program for farmers) are national programs supported by the USDA Cooperative State Research Education and Extension Service, USDA Natural Resources Conservation Service, and U.S. Environmental Protection Agency. The national office provides guidelines and educational support to states. Nearly every state currently operates or is developing a Home*A*Syst/ Farm*A*Syst program.

Manure Management in Small Farm Livestock Operations: Protecting Surface and Groundwater, by D. Godwin and J. A. Moore. EM 8649 (Corvallis, OR: Oregon State University Extension Service, 1997).

Septic Tank Maintenance, EC 1343, by J. A. Moore (Corvallis, OR: Oregon State University Extension Service, Corvallis, 1997).

Twelve Simple Things You Can Do to Protect Your Well Water, by G. Glick. EM 8651 (Corvallis, OR: Oregon State University Extension Service, Corvallis, 1995).

Your Yard and Water Quality: Simple Things Gardeners Can Do to Prevent Water Contamination, by V. Bobbitt et al. EB 1744 (Pullman, WA: Washington State University Cooperative Extension, revised 1994).

Web sites

Assessing Your Pastureland to Protect Water Quality (University of the Virgin Islands Cooperative Extension Service). http://rps.uvi.edu/CES/pastmgt.assess.htm

Fact Sheets: Functions and Values of Riparian Areas (Massachusetts Department of Fisheries and Wildlife). http://www.magnet.state.ma.us/dfwele/river/rivfstoc.htm

*Home*a*Syst/Farm*a*Syst* (University of Wisconsin). http://www.wisc.edu/farmasyst/index.html

Septic Tank Maintenance (Ohio State University Extension Service). http://www.ag.ohio-state.edu/~ohioline/aex-fact/0740.html

*Stream*A*Syst: A Tool to Help You Examine Stream Conditions on Your Property* (Oregon State University Extension Service). http://eesc.orst.edu/agcomwebfile/edmat/em8761.pdf

Surf Your Watershed (U.S. Environmental Protection Agency). http://www.epa.gov/surf/

Water Quality Information Center (National Agriculture Library). http://www.nal.usda.gov/wqic/

Oregon Small Farms—Water/Soil Quality Page (Oregon State University). http://smallfarms.orst.edu/water.htm/

Small Acreage Conservation Toolbox—20 fact sheets (Natural Resources Conservation Service) http://www.or.nrcs.usda.gov/pas/factsheet.htm/

CHAPTER EIGHTEEN

Best Management Practices for Marinas

by Robert Kent

Keeping contaminants out of the water should be the concern of all people, whether they are homeowners, farmers, foresters, or marina operators. The environmental quality of our coastal and inland waters cannot be restored if pollutants continue to enter them. Best management practices are simply anything marina operators can do to help prevent or reduce the amount of pollution coming from their facilities. Which BMPs are really best for a particular facility depends on the marina.

In this chapter you'll learn

- The chief sources of potential pollutants from marinas
- Examples of BMPs for controlling sources of pollution (source-control BMPs)
- Examples of BMPs for treating storm-water runoff (storm-water BMPs)

For marinas, runoff can be a concern, particularly in areas used for boat hull maintenance, because of the materials used on boats to control fouling and corrosion and for repairs. The wastes generated by sanding, scraping, painting, varnishing, and fiberglassing can contain contaminants such as metals, solvents, and hydrocarbons. If materials are not handled properly and are allowed to get into the water, they can be toxic to marine and aquatic organisms, even at very low levels. These levels are so low that their harmful concentration is often measured in terms of parts per billion. Materials washed into the water from hull maintenance areas can also contaminate sediments in the marina basin, posing problems for dredging and the disposal of dredged material. Allowing pollutants to seep into the ground can eventually contaminate the site itself, posing problems if the marina is ever to be sold.

BMPs are often categorized into two types, commonly known as *source-control BMPs* and *storm-water-treatment BMPs.* Source-control BMPs focus on keeping storm water from coming into contact with pollutants. Storm-water-treatment BMPs usually involve building structures or installing devices to treat or manage contaminated runoff. Source-control BMPs are generally preferred because they usually

This chapter is adapted from *Stormwater Runoff Best Management Practices for Marinas: A Guide for Operators*, by Jay Tanski (Stony Brook, NY: New York Sea Grant Extension Program, 1998).

cost less and keep most, if not all, of the pollutants out of the water.

Boat Maintenance Area Source-Control BMPs

Moving boat maintenance and repair work indoors or under a roof where it is not exposed to rainfall is one of the most effective ways to reduce contaminated storm-water runoff. For marinas with enough room, temporary work enclosures can be a relatively inexpensive way to protect maintenance areas from rain. The enclosures are prefabricated structures made of heavy-gauge polypropylene plastic stretched over a tubular metal frame. Moving certain types of work, like painting, indoors or into enclosed areas might require the use of special ventilation equipment, protective clothing and respirators, and safety equipment to meet Occupational Safety and Health Administration, Clean Air Act, and local fire safety requirements and regulations. Typical costs for temporary work enclosures run between $3 and $5 a square foot for materials. This does not include labor.

When work is done outdoors, it should be done over dry land in specially designated areas designed for that purpose. These areas should be clearly marked with signs. Customers and staff should be discouraged from performing maintenance work outside these areas. Maintenance areas should be located as far away from the boat basin as possible to prevent contaminants from getting into the water.

Maintenance areas should have a hard, impermeable surface that can be easily vacuumed or swept to remove contaminants. Waste should be disposed of properly. Care should be taken to ensure that storm-water runoff from other parts of the marina does not flow over the maintenance area. This can be done by proper siting or by using berms, curbs, or other BMP devices. If the maintenance area cannot be properly cleaned, rainwater falling on it should be directed to a storm-water treatment device before being allowed to run into the marina basin.

Maintenance areas should be located away from storm drains. If storm drains are nearby, they should be covered when work is being done to prevent material from being carried into the marina water.

Storm-Water-Treatment BMPs

Storm-water-treatment BMPs are structural devices used to manage and treat runoff contaminated with pollutants. They work by capturing runoff and allowing it to filter into the ground (infiltration) or hold the runoff long enough for pollutants to settle out (detention/retention) or a combination of both. In general, marinas should try to reduce the total amount of runoff coming from the entire facility by using permeable material such as gravel or shell wherever possible outside of maintenance areas. Following are some examples of storm-water-treatment BMPs that can be installed in marinas. These same BMPs are used in other settings as well. They serve as

examples; each marina operator will need to determine what is best or needed at his or her facility. More technical details on the planning and technical considerations for these BMPs are described in the Sea Grant publication *Stormwater Runoff Best Management Practices for Marinas,* listed in the reference section.

Vegetated filter strips are planted areas that act as a buffer along the water's edge to filter storm-water runoff and remove contaminants and soil particles before they reach surface areas. Nutrients or chemicals in the runoff might be taken up by the vegetation rather than going into the surface water. Creatively landscaped strips can provide aesthetic and recreational amenities. Filter strips must be a minimum of 20 feet wide to be effective.

An infiltration trench is a shallow trench, usually three to eight feet deep, filled with stone to create an underground reservoir that holds runoff, allowing it to slowly percolate through the bottom into the surrounding soil. Runoff carrying pollutants is diverted to the trench before it reaches surface waters. The storm-water slowly filters through the soil below, where pollutants are removed by adsorption, straining, and decomposition by bacteria in the soil. Trenches are feasible only where soils are well drained (sandy). They are used for areas less than five acres or where the slope is less than 5 percent.

A *dry well* is an excavated pit that is filled with clean stone typically 3 to 12 feet deep. The dry well is usually designed to collect and store storm water from rooftops or other relatively "clean" runoff. The water entering the dry well infiltrates down through the subsoil rather than running over the land. Because dry wells normally collect relatively clean water, they can provide good-quality groundwater recharge.

A *vegetated swale* is a vegetated channel that looks similar to but is wider than a ditch, with a gentle slope designed to transport and treat storm-water runoff. A vegetated swale is also sometimes called a "biofilter" swale and is commonly used as a substitute for a curb-and-gutter system. Surface water is directed to a vegetated channel where gentle slopes and dense vegetation slow water flow. The reduced flow, in combination with the vegetation, provides moderate to high removal rates of particulate pollutants from runoff by trapping, filtering, and infiltration into the soil.

Creatively landscaped strips can provide aesthetic and recreational amenities.

A *catch basin* is an underground retention system designed to remove trash, debris, and a portion of the sediment and oil and grease from storm-water runoff. Runoff is directed into the top of an underground chamber, which contains a permanent pool of water. Oil and grease float on the surface of the water and eventually attach to the sediment trapped in the chamber, which settles to the bottom. A discharge outlet carries cleaned water out of the catch basin. Catch basins should be used only when the drainage area is less than one acre of impervious cover. Because they provide limited pollutant removal, they are

recommended as pretreatment devices for other runoff treatment practices. At a minimum, catch basins should be inspected monthly and cleaned four times a year.

Summary

Marinas, like many other uses of the land, are a potential source of pollutants to the marine and aquatic environments. Because they are so near the water, they often receive special notice by the general public and concerned citizens' groups. Of special concern are materials used on boats to control fouling and corrosion and to make repairs. The wastes generated by sanding, scraping, painting, varnishing, and fiberglassing can contain contaminants such as metals, solvents, and hydrocarbons.

Source-control BMPs focus on keeping storm water from coming into contact with pollutants. Storm-water-treatment BMPs involve building structures or installing devices to treat or manage runoff. There is no one-size-fits-all set of BMPs for all marinas. Each marina must carefully analyze its own operations to identify potential pollution problems and to take corrective action.

Resources

Marina Operations for Existing Facilities (New York: New York State Department of Environmental Conservation). New York State Department of Environmental Conservation, 50 Wolf Road, Albany, NY 12233-0001. Telephone: 518-457-5400.

Stormwater Runoff Best Management Practices for Marinas: A Guide for Operators (Stony Brook, NY: New York Sea Grant). New York Sea Grant, 146 Suffolk Hall, State University of New York, 146 Suffolk Hall, Stony Brook, New York 11794-5002. Telephone: 516-632-8730.

CHAPTER NINETEEN

Best Management Practices—Invasive Species Planning

by Robert Kent

According to the U.S. Department of the Interior, invasive species cost our nation an estimated $123 billion annually and are second only to habitat destruction in threatening the extinction of native species. Invasive plants and weeds ("invasive plant" is often used interchangeably with "weed") are spreading on federal lands at a rate of 4,600 acres a day (U.S. Department of the Interior 1999). Invasive species causing harm include plants such as purple loosestrife, which chokes wetlands; miconia, which might destroy the Hawaiian rain forest; and melaleuca trees, now expanding across the Everglades ("Invasive Alien Species" 1998, p. 15). Animals also cause problems: the zebra mussel, for example, is altering freshwater ecosystems.

Invasive plants and animals are disrupting the ecology of natural ecosystems, displacing native plant and animal species, and degrading our nation's unique and diverse biological resources (NCPI 1999). Aggressive invaders reduce the amount of light, water, nutrients, and space available to native species and alter hydrological patterns, soil chemistry, moisture-holding capacity, erodibility, and fire regimes (Randall and Marinelli 1996).

In this chapter you'll learn

- What invasive species are and what their characteristics are
- What impacts invasive species are having on ecosystems
- How agencies and people are working to control invasive species
- How you and your organization can help with the problem of invasive species

President Clinton, when signing an executive order that directs federal agencies to expand their effort to control the introduction and spread of plants and animals not native to the United States, stated: "Many Americans are all too familiar with gypsy moths and other nonnative insects that devour our gardens and trees. Few realize, however, that countless other nonnative plants and animals are upsetting nature's balance, squeezing out native species, causing severe economic damage, and transforming our landscape."

Definition of Terms

Invasive species have many names: "nonnative," "exotic," "alien," "foreign," "introduced," or "nonindigenous." Organisms are considered *nonnative* when they occur artificially in locations beyond their known historical natural ranges. Species nonnative to the United States have come from all over the world. Invasive species can also include species brought from one region of the United States to another. When nonnative plants establish themselves in new environments (reproduce on their own), they are considered to be *naturalized.*

An *invasive* species is one that displays rapid growth and spread, allowing it to establish over large areas. Most invasive plants are nonnative. However, not all nonnative plants are invasive or a problem. An invasive exotic species, therefore, is a nonnative plant, animal, or pathogen that causes ecological or economic harm to an ecosystem in the place where it is introduced ("Invasive Alien Species" 1998, p. 9).

Species *native,* or *indigenous,* to the United States are commonly thought of as those that occurred here before European settlement. Invasive exotic species did not. Therefore, they tend to have no natural enemies to limit their reproduction and spread. Invasive species have characteristics that make them successful at spreading:

- They mature very early.
- They reproduce profusely.
- They have varied and effective dispersal methods (by wind, water currents, birds, and so on).
- They might produce great quantities of seeds that can lie dormant for years until conditions are right.
- They might have extensive root or underground stem systems that enable them to spread easily.
- In their new country, they might face none of the predators, parasites, or pathogens that kept them in check in their native habitats.

Invasive species tend to do well in habitats that have been disturbed, either by humans or nature. Road building, forest clearing, and ditching of marshes for mosquito control are examples of human disturbances that may allow invasives to colonize an area. Natural disturbances, which might predispose a site to exotic invasion, include fires, floods, and landslides.

Examples of Exotic Invasive Species and the Problems They Have Caused

Japanese knotweed (*Polygonum cuspidatum)* is an herbaceous perennial that can grow to over 10 feet high. Japanese knotweed spreads quickly to form dense thickets that exclude native vegetation. It is a major problem along riparian areas. This plant is now found throughout most of the United States.

Melaleuca *(Melaleuca quinquenervia),* native to Australia, is an aggressive invader that spreads rapidly, converting native plant communities such as sawgrass marshes, wet prairies, and aquatic sloughs into impenetrable thickets. It is a great threat to the Everglades.

Purple loosestrife *(Lythrum salicaria)* is a European perennial plant often used for ornamental purposes. It has spread throughout the United States, invading wetlands. It replaces native plants that are higher in wildlife value.

Eurasian watermilfoil (*Myriophyllum spicatum)* is an aquatic plant. It forms large, floating mats of vegetation on the surface of lakes and rivers, blocking out the light needed by other plants and making navigation difficult.

Common reed (*Phragmites australis)* is common in brackish environments. Once thought to be nonnative, it is now considered native (although an invasive strain might be nonnative—research is ongoing to determine this). Filling and construction activities that alter an area's hydrology promote the growth of this plant. It forms dense monocultures.

The **Japanese shore crab** *(Hemigrapsus sanguineus)* was released from ballast water in New Jersey around 1987. It has extended its range north into Massachusetts and south into North Carolina. An omnivore, it eats young clams, scallops, oysters, algae, and fish larvae. It is upsetting natural ecosystems in the regions to which it has spread.

The **European green crab** (*Carcinus maenas)* is a shore crab (adults measure about three inches across) whose native distribution is along the coasts of the North and Baltic Seas. Although the crab is known by the common name of green crab, the color of its shell (carapace) can vary from dark, mottled green to orange or red, with yellow patches on the dorsal carapace. The crab is an able and effective forager, capable of learning and improving upon its food-gathering skills. Studies have shown that the green crab is quicker and more dexterous than most crabs and can open bivalve shells in more ways than other crabs. One adult crab reportedly can eat 40 half-inch clams each day and can devour crabs as large as itself. Green crabs also prey on numerous other organisms, making these crabs potential competitors for the food sources of native fish and bird species.

The green crab has already invaded numerous coastal communities outside of its native range, including South Africa, Australia, and both coasts of North America. An able colonizer and efficient predator, this small shore crab has the potential to significantly alter any ecosystem it invades. It has been blamed for the collapse of the soft-shell clam industry in Maine.

Zebra mussels *(Dreissena polymorpha)* are fingernail-sized, freshwater mollusks accidentally introduced to North America via ballast water from a transoceanic vessel. Since their introduction in the mid-1980s, they have spread rapidly to all of the Great

Lakes and an increasing number of inland waterways in the United States and Canada. Zebra mussels colonize surfaces such as docks, boat hulls, commercial fishing nets, water intake pipes and valves, native mollusks, and other zebra mussels. Their only known predators—some diving ducks, freshwater drum, carp, and sturgeon—are not numerous enough to have a significant effect on them. Zebra mussels have had a significant impact on the Great Lakes ecosystem and economy.

The **spiny water flea** (*Bythotrephes cederstroemi),* a small planktivorous crustacean, has an average length slightly larger than one centimeter (0.4 inches) of which 70 percent is a long, sharp, barbed tail spine. First introduced into the Great Lakes ecosystem in 1984 via ballast water that was discharged into Lake Huron, spiny water fleas had spread to all of the Great Lakes by 1987 and currently infect inland lakes in Michigan and southern Ontario. Their rapid reproduction, general lack of predators, and direct competition with young fish for food gives them the potential to alter the food web of the Great Lakes.

Combating Invasive Exotic Species

Prevention and education

The problem of invasive species is one that many Americans do not know much about. National focus on the issue is recent. President Clinton's executive order of 1999 established the Invasive Species Council, which, among other actions, will develop a National Invasive Species Management Plan. The Federal Interagency Committee for the Management of Noxious and Exotic Weeds notes that preventing the spread of invasive plants in the United States is a monumental task that depends on public awareness, support, and participation.

The Invasive Plant Council of New York State was recently organized, with representatives from a number of environmental organizations, educational institutions, commercial nurseries, and government agencies. One of their major missions will be education. This group has developed a draft list of the 20 most important invasive plants in New York State. When the list is finalized, the group will launch an educational program aimed at a diverse audience.

Sea Grant, on the national level, has been quite active in educating the public about aquatic invasive species, particularly the zebra mussel. While in some cases it might be very difficult to completely stop the spread of an invasive species, it might be possible to slow it down.

Involving volunteers in the removal of invasive species and the planting of native species is one effective way to educate people about the issue. For example, in Utah, a Scotch Thistle Day is held. For the past six years, 300 public school students have been bused to wildland locations heavily infested with Scotch thistle. They cut and dig out the invasive plants. As word has spread about the program, other groups have joined in. Scotch thistle has been significantly reduced

in the students' work area over the six-year period.

Control of Invasive Plants

Manual control

Pulling out invasive species, as in the Scotch Thistle Day example above, is one option. However, you must have a thorough understanding of the biology of the plant before embarking on manual control. Some plants have underground root or stem systems that are difficult to remove and that enable them to grow back quickly. Others have seed banks that lie dormant for years in the soil. Disturbing the soil might enable the seeds to sprout.

Chemical control

Herbicides can control some invasive exotic species. However, when the plants have invaded vast areas, herbicides might not be an option. Using herbicides near aquatic habitats raises special concerns. A good source of information about herbicides, their effectiveness and their environmental impacts is the Cooperative Extension Education Center, located in most counties of the country.

Biological control

Many invasive exotic pests and plants have few or no biological controls in this country to keep them in check. Scientists sometimes attempt to find a biological control from the plant's native habitat that can be brought to this country to control the pest species. Bringing another organism into this country has additional risks because it is not easy to predict how the organism brought over to control one pest might act once set free in this country. Concern exists that the new imported biological control could become a problem itself, affecting native plants and animals as well as the target species. The federal government has a rigorous testing program in place for biological controls. In some cases, biological controls are being tried in the field and are beginning to work. Note, for instance, the example of purple loosestrife in this chapter, in which insects are being released to fight the invasion of the plant.

What can communities do?

Communities can begin by learning about the invasive exotic species in their locality. Public education campaigns are a good place to start. The Native Plant Conservation Initiative is a consortium of 10 federal agencies and over 110 nonfederal cooperators. A public-private partnership, the Initiative serves as a forum for the exchange of ideas, expertise, and information between public and private entities engaged in habitat restoration and preservation. The Alien Plant Working Group of the Native Plant Conservation Initiative makes the following suggestions to prevent the introduction or spread of invasive exotic plants into natural areas and to help restore native flora and fauna:

- Avoid disturbing natural areas, including clearing native vegetation, planting nonnative plants, and dumping yard wastes.

- Do not purchase or use invasive species in landscaping or for land restoration or erosion control projects.
- For landscaping, use plants that are native to the local region as much as possible or those that are known not to be invasive.
- If you're unsure whether a plant is invasive, take it to a local office of the Extension Service, an arboretum, a local nature center, or a native plant society. To be on the safe side, if you don't know it, don't grow it.
- Control invasive plants in the home landscape, either by removing them entirely or by managing them to prevent their spread outside of property lines. This might include pruning to prevent flowering and seed dispersal, cutting or mowing the plant, or using herbicides to prevent vegetative spread.
- Discuss concerns about invasive plants with nurseries and garden shops and ask for noninvading alternatives instead.
- Notify land managers of invasive plant occurrences.
- Offer to assist in plant removal projects.

Sea Grant offers these tips to prevent the spread of aquatic invasive exotic species:

- If you fish, be sure not to release bait, fish, shellfish—or the materials in which they are stored or shipped—into new environments. Always empty your bait bucket on land and discard unused bait in trash.
- If you boat, be sure to remove any plants and animals from your boat, trailer, and other equipment. Drain all the water from the motor, live well, bilge, and transom well away from the lake or river. Wash your boat, tackle, trailer, and other equipment with 104°F water, a high-pressure spray, or, at the very least, tap water. Then allow everything to dry for at least five days to make sure that none of the exotics have survived.
- If you have an aquarium, don't dump fish or plants into a waterway. Dispose of them in the trash.

The case examples in this chapter highlight what is being done to combat a number of invasive species and to encourage the return of native ones. They serve as illustrations of techniques that might be options for your community. Learning about invasive species and getting to know the people and agencies concerned with the issue is a good starting place to getting involved. Volunteers can play an important role in helping with projects designed to reduce invasive species populations in a particular area. They can help in the removal of the invasive species, in the planting of native or noninvasive species, and in the long-term maintenance of projects to ensure that invasive species do not return.

Summary

Plants and animals are considered to be nonnative when they occur in locations beyond their historical natural ranges. Not all exotic or nonnative plants and animals are invasive, but some are. As trade and travel around the world continues to grow, the problem of invasive species gets worse. Invasive species degrade natural habitats and

upset the ecology of these areas. Invasive pest species cause problems for agriculture and crop production. Aquatic environments are also negatively affected by invasive species.

Controlling or eliminating invasive species once they enter a habitat is not easy. Public education is critical in helping to slow down the spread of these problem plants and animals. Options for fighting invasive species include manual control, chemical control, and biological control. In many regions of the country, habitat restoration projects involve removing invasive species and reestablishing the native vegetation that once grew there. Volunteers and community groups can play a major role in such habitat restoration projects. Homeowners should become educated consumers and be sure not to plant invasive species. Boaters and anglers should be careful not to spread invasive species from one body of water to another.

Resources

Notes

"Invasive alien species: a summary of a public dialogue exploring new solutions to an old persistent problem." *Yale Forest Forum* 1(2):15 (1998).

Randall, J., and J. Marinelli. 1996. *Invasive Plants: Weeds of the Global Garden.* Handbook no. 149. (NY: Brooklyn Botanic Garden Club).

U.S. Department of the Interior. 1999. *Invasive Species Fact Sheet.*

Native Plant Conservation Initiative (NPCI). 1999. *Weeds Gone Wild.* Native Plant Conservation Initiative.

Publications

Biological Pollution: The Control and Impact of Invasive Exotic Species, ed. by Bill N. McKnight (Indianapolis: Indiana Academy of Science, 1993).

Harmful Non-Indigenous Species in the United States. U.S. Congress, Office of Technology Assessment, OTA-F-565 (Washington, D.C.: U.S. Government Printing Office, 1993).

Roadside Use of Native Plants, by the Water and Ecosystems Team (Washington, D.C.: Office of Natural Environment, Federal Highway Administration, 1999).

Web

The Alien Plant Working Group: http://www.nps.gov/plants/alien

Invasive Plant Council of NYS: http://www.nysm.nysed.gov/ipcnys

MIT Sea Grant's exotic species Web pages: http://massbay.mit.edu/exoticspecies

National Sea Grant Program's nonindigenous species research and outreach: http://www.mdsg.umd.edu/NSGO/research/nonindigenous

National Aquatic Nuisance Species Clearinghouse: http://www.cce.cornell.edu/aquaticinvaders

Sea Grant nonindigenous species site: http://www.ansc.purdue.edu/sgnis

Case Study

Controlling Purple Loosestrife, an Invasive, Exotic Plant

The Problem

Purple loosestrife (*Lythrum salicaria L. [Lythraceae]*) is a plant of European origin. The plant was introduced in the early nineteenth century as a medicinal herb and, incidentally, from ballast in ships. It can now be found in temperate North American wetlands throughout the United States (all states but Florida) and in Canada. Purple loosestrife is a herbaceous wetland perennial. Established plants can reach heights of two meters with 30 to 50 stems forming wide-topped crowns that dominate the herbaceous canopy. One mature plant can produce more than 2 million seeds annually. Seeds are easily dispersed by water and in mud adhered to aquatic wildlife, livestock, and people.

The invasion of purple loosestrife into a wetland can result in the suppression of the resident plant community and the eventual alteration of the wetland's structure and function. Native foods and cover for some wildlife species are lost in the process.

What Was Done

Purple loosestrife is difficult to control in large stands. Some control techniques include water-level manipulation, mowing or cutting, burning, and herbicide application. These control methods are costly and require continued long-term maintenance. Herbicides are nonselective and environmentally degrading and are, therefore, not a good management option.

The plant was introduced to America without any of its natural enemies from Europe. The goal of the Purple Loosestrife Project at Cornell University and other locations is to establish a biological control. The U.S. Department of Agriculture has approved four host-specific insect species from Europe for release in the United States. These species are *Hylobius transversovittatus,* a root-mining weevil; *Galerucella calmariensis* and *Galerucella pusilla,* two leaf-eating beetles; and *Nanophyes marmoratus,* a flower-feeding beetle. The strategy of releasing these insects is long-term control, not complete eradication, through provision of a simple, yet diverse, collection of natural enemies.

Outcomes

The released insects are having an impact on purple loosestrife populations. *Hylobius transversovittatus* larval feeding can be very destructive, reducing shoot growth, seed output, and shoot and root biomass and ultimately increasing plant mortality. Larval feeding of *Galerucella calmariensis L.* and *Galerucella pusilla Duft* can strip the photosynthetic leaves of individual plants, and entire purple loosestrife populations can be defoliated, causing increased plant mortality. Adult and larval feeding of *Nanophyes marmoraturs Goeze* causes flower-bud abortion, thus reducing the seed output of purple loosestrife.

How to Get Involved

Detailed instructions are available on how to release insects and how to monitor their impact. Cornell University is one source of information and might be able to help you locate more local assistance. Contact Dr. Bernd Blossey, Director, Biological Control of Non-Indigenous Plant Species Program, Department of Natural Resources, Fernow Hall, Cornell University, Ithaca, NY 14853. Telephone 607-255-5314. E-mail bb22@cornell.edu. Web page http://www.dnr.cornell.edu/bcontrol/purple.htm

Case Study

Controlling *Phragmites australis*

The Problem

Common reed *(Phragmites australis)* is indigenous in the Northeast United States. It is aggressively invading many salt marshes in the region. Some scientists now believe that an aggressive form of the plant is a genetically different stock native to Europe and that it was probably transported to North America in ship ballast. The question of whether the aggressive form is native is still being studied. Reproduction by this species is primarily vegetative. *Phragmites* shades out other indigenous species considered to have greater ecological value. In many areas, resource managers are attempting to reduce common reed stands while bringing back other salt marsh plants. *Phragmites* can survive brackish water but is not tolerant of higher salinity. It thrives where drainage patterns have been altered and disturbed. In the past, salt marsh drainage was often altered in an effort to dry the marshes for mosquito control. Road construction and railroad construction along the coast also altered the drainage of many salt marshes.

What Was Done

Long Cove in Guilford, Connecticut, is a case example from many years ago. In an attempt to control mosquito breeding, a tide gate was installed. The gate was closed in the summer to drain the marshes and opened again in the fall after the first frost. Over time, *Phragmites* replaced most of the typical salt marsh vegetation. A culvert under a road also changed the drainage patterns.

In the 1980s, the tide gate fell off, which reestablished year-round tidal flushing. In the area of the cove where tidal flushing was reestablished, the *Phragmites* was replaced over time by salt marsh plants. The road culvert had become clogged with sediment. When it was reopened, tidal flow to Long Island Sound was reestablished. This permitted a larger area to experience natural tidal flooding.

Outcomes

Eight years after the work was done, nearly all of the *Phragmites* has been replaced by other native salt marsh vegetation. Long Cove illustrates successful restoration of a marsh when normal tidal cycles and salinities are restored.

(Source: Adapted from *Tide Marshes of Long Island Sound,* Bulletin #33 [New London, CT: Connecticut College Arboretum, 1995])

CHAPTER TWENTY

Best Management Practices to Protect and Restore Wildlife Habitat and Living Resources

by Robert Kent, Kami Ellingson, and W. Daniel Edge

An important reason to restore coastal habitats, and the habitats in any watershed, is to restore the wildlife and living resources of the area. *Living resources* is a term that includes plants and many species, such as plankton or insects, that are not usually thought of as wildlife, as well as those that traditionally are. Estuaries are often areas rich in wildlife and living resources. For example, the Peconic Estuary in Eastern Long Island, New York, is home to 111 endangered, threatened, rare, or "of special concern" terrestrial and freshwater species. Some species—such as bay scallops, hard clams, and many finfish species—are commercially valuable. Often, their populations have declined, and communities are interested in restoring populations of these desirable species to higher levels. Then there are the common species, which we often overlook until they are no longer common. Wildlife populations and the living resources of an area can become degraded or threatened by a number of causes. Reversing the trend is not easy and takes a lot of planning, cooperation, and community support.

In this chapter you'll learn

- The basic concepts of wildlife management and wildlife ecology
- Why wildlife populations are suffering in many areas
- How restoring coastal and riparian and other habitats can lead to protection and resurgence in wildlife populations
- What some communities are doing to help restore wildlife
- How landowners in rural and suburban-urban areas can help restore wildlife

Causes of Decline

The Peconic Estuary Program identified a number of causes for declines in living resources. These causes can often be identified in estuaries around the country. *Physical alteration* of the landscape is a primary cause. Historically, low-lying marshes and swamps have been ditched and

drained for mosquito control or filled for construction or agriculture. Bulkheads used to stabilize waterfront property alter shorelines. Upland areas have been cleared, historically for agriculture, and more recently for housing. Natural areas affected by development include wetlands, beaches, grasslands, forests, and coastal ponds.

All animals need a minimum amount of area within which they carry out their daily and lifetime activities.

Chemical contamination can have a variety of effects, both acute and chronic, on living resources. There is concern that some toxic materials may affect the reproductive health of wild species and cause other health problems.

Invasive species, described in chapter 20, often disrupt natural ecosystems. Native species can become displaced by invasive exotic ones or be affected by new pests and diseases brought in from other parts of the world.

Some Important Definitions

Before moving on to see what steps can be taken to protect and restore living resources, it is useful to define and explain some wildlife management and ecological terms.

Habitats are the surroundings in which organisms carry out their life functions. Different species have different habitat requirements. A species' habitat requirements might change during its lifetime. It might need one type of habitat when young and another during reproduction periods. It might require one type of habitat in the summer and another in the winter. The basic components of habitat are food, cover, water, and space. Each species has different food needs, and these needs might change throughout the year and over the lifetime of the organism. Cover includes hiding cover and thermal cover. Hiding cover or escape cover provides security from predators. Thermal cover protects a species from extreme temperatures. All animals need a minimum amount of area within which they carry out their daily and lifetime activities. Animals employ spacing to avoid competition and predation.

Habitat fragmentation occurs when areas of habitat are broken up into smaller pieces, usually by human land-use activities such as urban development, agriculture, or forestry. When habitat pieces become too small, they may fail to provide for the needs of the species that live there.

Habitat edges or *ecotones* are boundary zones at the border of two different plant communities. Examples are the edge between riparian habitats and upland sites or the edge between a recent clear-cut and an adjacent timber stand. As habitats become fragmented, the amount of edge habitat increases. Species that like edge habitats are often different from those that live in the interior of larger pieces of habitats. Fragmenting habitats will change the composition of species that live there.

For reasons not entirely understood, some species won't use small tracts of seemingly suitable habitat. The goal of some wildlife restoration projects is to prevent further habitat fragmentation or to increase the size of small patches of isolated habitats. Patches of habitat can be linked by corridors between them.

The main point to remember is that we cannot manage wildlife populations without thinking about their habitat needs. Without suitable habitat, a species cannot exist in an area.

Improving Wildlife Habitat

Each property differs in what it contributes to the living resources and wildlife values of a watershed, so there are no hard and fast rules for improving wildlife habitat. To begin to think about how an individual piece of property fits into a larger watershed perspective, consider these questions.

- Does the property contain habitats that are uncommon in the watershed or region? For example, does it contain rare plant communities or rare and endangered wildlife species?
- Can these habitats be managed to maintain or increase their occurrence? In some cases, protection will suffice; in others, participants might need to take a creative approach.
- Can habitat fragmentation be reduced? Is there a way to connect similar habitats or to make small patches of habitat larger?
- Does the property contain logical corridors or riparian management zones that connect one uncommon habitat to another? Maintaining the widest strip of habitat possible may allow animals to move among patches as well as provide habitat itself.

Before beginning a wildlife habitat improvement project, you must ask, "What do we want to accomplish?" Setting objectives may be the most difficult step. Being realistic about one's capabilities and limitations in both time and resources is needed. Wildlife enhancement means to cause an increase in the number or quality of animals or habitats. A good way to start thinking about wildlife enhancement is to think about habitat. Habitat provides basic life requirements, including food, protection from enemies and weather, and a place to rear young. Each species has specific habitat requirements that are different from those of other species. The question, "How do we enhance wildlife?" is met primarily by the response, "How do we enhance habitat?" The best approach to wildlife enhancement is to design habitat improvement projects.

Learning how to recognize habitats is a good place to start a wildlife enhancement project. In Oregon, for example, there are 30 classified types of wildlife habitat. The Peconic Estuary Program has identified a list of habitats it wishes to restore (submerged aquatic vegetation, nontidal freshwater wetlands, tidal wetlands, beaches and dunes, intertidal flats, estuarine embayments, riverine habitat and migratory corridors, coastal forests, and coastal grasslands). It is important to try to learn something about which species of wildlife are found in each habitat type.

Table 1 provides examples of the habitat requirements of various wildlife species' in Oregon. Similar types of information should be available for other states, from state or federal wildlife agencies or local universities.

A next step is to identify the types of habitats found on a piece of property and to make a sketch or map of habitat types. Spending time observing the land will help you discover which wildlife species use the area. On the basis of an assessment of habitats and wildlife populations, you can see how well actual conditions match desired conditions. If the match isn't good, you must decide whether to manipulate the habitat to increase either species diversity or the total number of animals or both. No piece of property is too small for wildlife enhancement. City dwellers have been known to plant flowers attractive to butterflies that help butterflies find food as they migrate through an urban area.

Getting Help

Help with wildlife improvement projects is available from many sources. Federal and state wildlife agencies provide technical advice, and sometimes financial incentives, to landowners. Cooperative Extension and Sea Grant offices are also good sources of information. Land grant colleges usually have departments of natural resources that publish helpful bulletins for wildlife enhancement projects. The National Audubon Society and the Nature Conservancy and their local chapters are another good source of information and help.

Monitoring Projects

Monitoring will ensure long-term project success. By evaluating a wildlife enhancement project, you can modify your activities if needed. Without proper monitoring, a project's success cannot be measured. Monitoring can pinpoint specific changes required to make a project a success.

The New York-New Jersey Harbor Estuary Program has been developing monitoring protocols for their habitat restoration projects. That program believes that a minimum of five years of monitoring should be required of all habitat restoration projects. Monitoring is an excellent opportunity for volunteers to become involved in habitat restoration projects on public lands. A population study should be done before the project begins so that you can compare pre- and postrestoration populations.

In a salt marsh restoration project, some of the items that should be monitored include

- Ribbed mussel populations
- Fiddler crab burrows
- Saltwater-fish-eating bird populations (for example great egret, snowy egret)
- Benthic invertebrate feeding birds (for example little blue heron)
- Winter waterfowl populations

Table 1. Habitat requirements of representative wildlife species.

Wildlife group	Representative species	Required habitats and acreages	Special habitat requirements
Meadow wildlife	California quail Brush rabbit Meadowlark	Open areas with grasses and forbs; some shrubs (15 acres)	Brush piles essential (1 per 2 acres)
Meadow/forest wildlife	Deer Elk	Openings (50 acres); closed canopy (15+ years old); conifers (150 acres)	Migration corridors between seasonal ranges
	Chipmunk	Openings (15 acres); second-growth timber (15 acres)	
	Bluebird Junco	Openings (5 acres); second-growth timber (5 acres)	Snags with nest cavities
Young forest wildlife	Red squirrel	Mixture of 15- to 75-year-old conifer trees; understory of grasses and forbs (100 acres)	Cone-bearing trees for food
	Ruffed grouse	50-50 mixture of conifers and alder (15 acres)	Moist streamside environment
	MacGillvray's warbler	Mixture of 15- to 75-year-old conifers (15 acres)	
Mature forest wildlife	Flying squirrel	75+ year-old conifers (100 acres); understory with forbs and small shrubs	Nest cavities in older (100+ year-old trees)
	Spotted owl	100+ year-old conifers (400 acres)	
	Pileated woodpecker	100+ year-old conifers (100 acres)	Conifer snags; minimum 20" d.b.h. for nest trees
Riparian wildlife	Salamanders Snakes Frogs	Moist, streamside vegetation with closed canopy (¼ to 2 acres); flowing streams	
Large predators	Cougar Bear Coyote Goshawk	Mixtures of closed canopy with openings (300–1,500 acres)	Large (>15" d.b.h.) trees for nesting/denning

Summary

Restoring the living resources and wildlife populations in a watershed or estuary is an important component of most restoration projects. Reasons for the decline of living resources in an area include physical alterations such as dams; conversion of natural areas to other uses; chemical contamination, which may affect the ability of wildlife to survive in an area; and invasion by exotic species, which disrupt natural ecosystems and alter habitats.

Habitats are the surroundings in which organisms carry out their life functions. Food, cover, water, and space are the components of habitat. The breaking up of large areas of habitat into small isolated pieces is called *habitat fragmentation.* This process disrupts the ability of some species to use the remaining smaller patches of habitat that are left.

Wildlife populations cannot be managed without thinking about their habitat needs. Without suitable habitat, a species cannot exist in an area.

It will be important to set priorities on which habitats and wildlife species you are trying to restore. Communities can work together to restore large watersheds, and individuals can help by restoring the land for which they are responsible. Establishing best management practices is one way communities can work to ensure that the living resources in their watershed are protected and restored. No piece of land is too small for some type of wildlife enhancement.

Assistance is available from many agencies and organizations. They can help you learn about the types of habitats and wildlife in an area and can help in the development of wildlife enhancement projects.

It is important to monitor a project for years, perhaps for decades, to see whether the goals and objectives of the project are being met. If they are not, corrective action should be taken.

Resources

Information

Several public agencies and private groups in Oregon can provide assistance with wildlife assessment and enhancement. Oregon State University Extension Service publications describe how to provide special habitat needs, such as nest boxes. The Natural Resources Conservation Service provide help with habitat manipulation. The Audubon Society is an excellent source of information on providing for special needs of songbirds.

Field guides are sold in a variety of bookstores and in garden and specialty shops. Ask a specialist which guide best meets your specific needs.

The National Gap Analysis Program, Biological Resources Division, U.S. Geological Survey, has information on the World Wide Web at http://www.gap.uidaho.edu/gap

The Oregon Department of Fish and Wildlife can provide numerous publications and monitoring protocols for game species. The agency's biologists may be able to provide specific assistance.

The U.S. Fish and Wildlife Service can provide numerous publications and monitoring protocols for nongame species. The agency's biologists may be able to provide specific assistance.

Many publications are available from the World Forestry Foundation, 4033 SW Canyon Rd., Portland, OR 97221; phone: 503-228-1367.

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Wildlife Habitats in Managed Forests: The Blue Mountains of Oregon and Washington, by J. W. Thomas. Agricultural Handbook No. 553 (Washington, DC: U.S. Department of Agriculture, Forest Service, 1979).

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Cornell University Media Technology Services Resource Center
Cornell Business and Technology Park
Ithaca, New York 14853
Telephone: 607-255-7660
Web site: http://freedom.cce.cornell.edu/publications/natural-resources.html

Biodiversity for Forests and Farms (1996). Useful to anyone who wants to protect and enhance habitat for fish and wildlife and the many ecological services upon which we all depend. Introduces the technologies of GAP analysis and geographic information systems. 28 min. Video. 147VBFFF. $24.95.

Enhancement of Wildlife Habitat on Private Lands (Revised 1998). Have you ever wondered what you could do to help wildlife or why you should? An increase in some insect-eating birds around a garden can naturally reduce insect damage to garden produce. Habitat enhancement can increase both the number and variety of wildlife on your property to allow close viewing or study of various birds and mammals. Conversely, do you want to know what kind of habitat attracts unwanted wildlife to your land? This publication shows what types of habitat attract which animals so you can either attract or discourage these creatures. Includes dozens of illustrations and detailed instructions for making 10 habitat projects. Many are applicable for an urban park, suburban backyard, or rural area. 42 pp. 1471B1 $7.50.

Field Guides Made Easy (1991). What to look for in identifying birds, trees, mammals, and others. 19 pp. 147L521 $2.50.

Managing Small Woodlands for Wildlife (1990). Explains the ecological principles of the forest ecosystem and the elements of a wildlife population. Tells how wildlife can be integrated with other woodland uses such as maple syrup and Christmas tree production. 33 pp. 1471B157. $3.

Wildlife and Timber from Private Lands: A Landowner's Guide to Planning (1990). Includes a sample woodland-wildlife management plan and explains how landowners can make a personal plan by using clues from wildlife. 55 pp. 1471B193. $5.50.

Wildlife Discovery (1990). Introduces children to the needs of wildlife and helps them search for wildlife and their signs. Sections include "Animal Tracts," "Attract a Tract," "Owl Pellets," and "Who Lives Here?" 147L519 (packet with 2-page leader guide). $9.25. U147M519. (20-page member guide) $1.25.

Wildlife Habitat Enhancement (1984). Provides a basic understanding of a wildlife habitat, including food, water, space, and cover. Can be used by an adult with youth aged nine and older. Guidelines for field trips point out what to look for and keys to wildlife habitat enhancement. Complements *Enhancement of Wildlife Habitat on Private Lands* (listed above). 23 pp. 147L516. $3.00.

Wildlife in Today's Landscapes (1991). More than 100 illustrations plus concepts in wildlife ecology. For adult use with youth aged 12 and older; contains everything you'll need to choose a habitat patch, map it, make improvements, and maintain it. Habitats range from midtown Manhattan to country woodlots. 63 pp. 147L520 $13.24

Wildlife Notebook. Favorite birds and mammals are sketched and described to bring alive your field trip to the woods or fields (or in your armchair). Comments and vital statistics on each, including preferred habitat and food, size, colors, and breeding cycles. 67 pp. 1471B210. $5.50.

Case Study

Piping Plover Case Example

The Problem

The piping plover (*Charadrius melodus)* is a small bird that breeds on coastal beaches from Newfoundland to North Carolina. Piping plovers winter farther south, some migrating to the Bahamas and West Indies. They were once quite common. Millions were killed through commercial harvest for meat and feathers before the Migratory Bird Treaty Act was signed in 1918. They made a modest comeback but became threatened again when the human population along the coast in the Northeast started to skyrocket in the 1950s. Before World War II, 90 percent of the nation's coastal barrier real estate existed as undeveloped natural areas, largely inaccessible to the public. Today in the Northeast corridor, it is hard to find undeveloped and unused beaches. The piping plover became a protected species under the Endangered Species Act in 1986.

Piping plovers return to their breeding grounds in late March or early April. Their nest is simply a small depression in the sand on the high beach close to the dunes. They are highly vulnerable to disturbance by off-road vehicles and pedestrian traffic. The eggs are so small and inconspicuous that they are easily stepped on or driven over. Excessive disturbance may cause the parents to abandon the nest. Pets, especially dogs, which people take to the beach for walks, harass the birds. Garbage left on the beach attracts predators such as gulls and crows that attack the young. Development has caused many of the suitable breeding grounds to disappear.

What Is Being Done

Protecting the piping plover entails protecting the birds on the remaining breeding grounds. The goal is to keep people and their vehicles and pets away from nesting and rearing areas. Management techniques include fencing and posting nesting sites and excluding vehicles from areas where chicks are present. In heavily used eastern beaches, this is not always easy. Volunteer tern stewards have been trained to educate the public about the plovers and to protect and monitor nesting areas.

Stewards have numerous responsibilities:

- Protecting nesting areas from recreational beach goers with symbolic fencing (typically strands of nylon string on snow fence posts) and signs explaining that these are piping plover nesting areas
- Recording observations of unsanctioned activities, such as driving on the beach and allowing dogs to run unleashed, and reporting them to authorities
- Interacting with the public on the beach and explaining why plovers are endangered and what is being done to facilitate their recovery
- Monitoring and recording the success of plover nests

Stewards work closely with the United States Fish and Wildlife Service, the federal agency responsible for protecting endangered and migratory species. They also work closely with state environmental agencies and the local governments that own and control beach use. As soon as the birds leave the nesting grounds, the fences are taken down to allow public use of the area once again.

Outcomes

Protecting piping plover nesting areas from disturbance from humans has proven to be highly effective in increasing the number of young birds reared and fledged each year. Most of the public, once they are educated on the issue, are willing to cooperate and to leave the plovers alone. Each year the stewards and agency staff must be on the alert for the return of the piping plovers and fence off the areas. The birds use many of the same areas for years, but as conditions change, they move to new breeding areas, which must be protected in turn.

For more information, contact the U.S. Fish and Wildlife Service nearest you.

Case Study

Preserving Wildlife Habitat and Living Resources in New York Harbor

The Problem

New York Harbor sustains a remarkable diversity of habitat types and species within a relatively small area. The harbor, which lies on the Atlantic Flyway, a major pathway for migratory birds, supports a large and flourishing population of aquatic birds. It is also blessed with exceptionally diverse plant life. The harbor continues to support viable recreational and commercial fish populations and provides a major outlet to hundreds of thousands of sportfishers.

Although much remains, much has been lost. Much of the natural habitat has been lost because of such human activities as filling of wetlands and water areas; alterations of shorelines, including construction of piers and platforms; dredging; and coastal development. Loss of natural habitats results in diminished local and regional biodiversity and negatively affects the ecological integrity of the harbor.

What Is Being Done

This case study serves as an example of people and agencies working together to restore and protect living resources. The New York-New Jersey Harbor Estuary Program (HEP) is part of the National Estuary Program. It is a partnership between the U.S. Environmental Protection Agency, the states of New Jersey and New York, and many other local agencies, businesses, and community groups. The overall goal of HEP is to establish and maintain a healthy and productive ecosystem with full beneficial uses.

To reverse some of the past damage and to preserve what is left, NY-NJ HEP established the following goals for itself (those listed below are not the complete list, but a sample of the major ones).

- To restore and maintain an ecosystem that supports an optimum diversity of living resources on a sustained basis
- To preserve and restore ecologically important habitat and open space

- To encourage watershed planning to protect habitat
- To foster public awareness and appreciation of the natural environment
- To minimize human disturbance of natural habitats
- To identify significant coastal habitats warranting enhanced protection
- To develop and implement plans to protect significant coastal habitats and improve water quality

HEP established strategies to achieve its goals. Some of them are listed below to serve as examples.

  — HEP will identify regional and local habitats requiring special protection.

  — The responsible resource management agencies, counties, and municipal governments will identify the most effective means of using their authorities, programs, and expertise to protect habitats and living resources.

  — HEP will conduct regional and watershed workshops and meetings for information exchange.

  — HEP will encourage additional efforts by state, local, and private sponsors to promote public education with regard to reducing human disturbance to sensitive coastal species.

Outcomes

The *New York-New Jersey Harbor Estuary Program Final Comprehensive Conservation and Management Plan* was published in 1996. Recently HEP took stock of its work to see what kind of progress it has made in reaching its goals. Here are some of its accomplishments, which serve as examples of what can be done in other regions:

- HEP identified priority acquisition and restoration sites throughout the estuary and published maps of them. In 1998–2000, nearly $60 million was secured to acquire or restore almost 700 acres of these sites.
- The U.S. Fish and Wildlife Service completed, printed, and distributed an extensive study of the significant habitats of the entire estuary watershed region, which is also made available on a CD-ROM.
- HEP developed "issue maps" highlighting environmental challenges in order to galvanize support for addressing those problems.
- The Brooklyn Botanic Garden has been conducting the Metro Flora Project, which is cataloging every plant species within a 50-mile radius of the center of New York City. The results will be used to develop recommendations for managing plant populations.

- Two organizations documented barriers to anadromous fish-spawning habits. Efforts are underway to fund small pilot projects that will remove impediments to upstream migration of spawning fish.

For more information on NY-NJ HEP, contact Outreach Coordinator, New York Sea Grant, c/o USEPA, 290 Broadway, 24th Floor, New York, New York 10007.

(Adapted from *New York-New Jersey Harbor Estuary Program Final Comprehensive Conservation and Management Plan* and *Successes and Challenges: Highlights of Program Accomplishments and Challenges for the Future.)*

Case Study

Migratory Bird Habitat Restoration

by Mike Liffmann and Pam Blanchard

The Problem

The Nature Conservancy, in conjunction with the Barataria-Terrebonne National Estuary Program, took on the job of restoring lost habitat and food sources for migrating neotropical birds. In a recent survey of bird breeding habitats, it was noted that the number of species breeding within the Barataria-Terrebonne basin declines from north to south, which reflects a decline in habitat diversity. In the same survey, it was also noted that the number of bird migrants increases as one approaches the coast. This reflects the tendency of transgulf migrants to concentrate nearest the coast, as this region reflects the first landfall area for those birds migrating to the north across the Gulf of Mexico.

The live oak trees found on Grand Isle and Cheniere Caminada represent a unique and important habitat during spring migration for birds such as tanagers and warblers returning from wintering grounds in South America. Transgulf, migrant, neotropical birds crossing between the Yucatan peninsula and North America use the oak groves as a landfall during northbound migration or as the final point of departure for southbound birds.

What Was Done

Recognizing the importance of the chenier forests in providing habitat and shelter to migrating birds, more than 75 volunteers gathered in January 2000 to begin restoring one of the lost chenier forests on Grand Isle. These volunteers planted 4,000 oak, hackberry, and mulberry trees on a portion of a 40-acre site on the east end of Grand Isle. The planting site, owned by ExxonMobile, was once a housing development for offshore workers. The site has stood vacant since the development was torn down years ago.

Outcomes

The native tree-planting project represents an ongoing effort that will continue over the next several years with the goal of restoring native tree groves to the 40-

acre Grant Isle site. In addition to the restoration of this barrier island forest, project directors hope that the project will provide suitable habitat and food resources to migrating neotropical birds, as well as raise awareness in the local community of the importance and uniqueness of these barrier island ecosystems.

Contacts

Don McDowell. The Nature Conservancy. Phone: 225-338-1040

Lynn Schoenberg, Barataria-Terrebonne National Estuary Program. Phone: 800-259-0869

CHAPTER TWENTY-ONE

Best Management Practices in Urban Settings

by Robert Kent

Best management practices, or BMPs, in urban settings are particularly important because so much of the land area is developed. BMPs are plans and programs put into place to reduce the amount of pollutants entering the water. The more development in an area, the more storm-water runoff it generates because so little unpaved land exists where nature can absorb water when it rains. Increased storm-water runoff associated with development often begins a chain of events that includes flooding, erosion, stream channel alteration, and ecological damage. Because there is also a greater quantity of manmade pollutants found in urban areas, the potential for degraded habitats increases. Primary pollutants that are responsible for water quality degradation in urban storm-water runoff are toxic substances, pathogens, nutrients, and sediments. In New York State, for example, 21,000 acres of surface freshwater bodies, 88,000 acres of marine waters (bays and oceans), and 295 miles of rivers are affected by urban runoff *(Urban/ Stormwater Runoff Management Practices Catalogue).*

Toxic substances can have adverse impacts on the environment or human health. In addition to direct poisoning, some toxins cause cancer and reproductive harm to living things. Toxic substances found in products from automobiles, including oil, grease, antifreeze, brake-lining particles and fuel, are carried to surface waters in runoff from driveways, roads, and parking lots. Pesticides applied to home lawns and landscapes can be carried to these waters.

Pathogens are disease-causing organisms such as certain bacteria and viruses that result in the closure of beaches and shellfishing areas along the coast because

In this chapter you'll learn

- What the chief pollutants are that damage ecosystems in urban and suburban settings
- What best management practices are (both structural and nonstructural)
- What one community is doing to implement best management practices to restore its bay
- What are some programs and resources to help you start a program in your community

they make people sick. Pet waste is a source of pathogens when it is carried into storm sewers. Faulty septic systems are another potential source of pathogens.

Nutrients stimulate the growth of plants and algae. Excessive growth of aquatic plants and algae upsets an ecosystem's balance, and can lead to low oxygen levels in some waters. Fertilizers, pet waste, and failing septic systems are potential sources of nutrients.

Sediments or soil particles resulting from erosion can affect plants and animals that depend on certain bottom conditions. They can also prevent sunlight from penetrating to depths necessary for plant life.

Sediments or soil particles resulting from erosion can affect plants and animals that depend on certain bottom conditions.

Studies are finding a direct relationship between the intensity of development in an area, as indicated by the amount of impervious surfaces, and the degree of degradation of its streams *(Impacts of Development on Waterways).* Studies suggest that aquatic biological systems begin to degrade at community impervious surface levels of 12 to 15 percent or at even lower levels for particularly sensitive streams. As the percentage of imperviousness climbs above this threshold, degradation tends to increase accordingly.

Impervious manmade surfaces (asphalt, concrete, rooftops) and compacted earth associated with development create a barrier to the percolation of rainfall into the soil, increasing surface runoff and decreasing groundwater infiltration. This disruption of the natural water cycle leads to a number of changes, including

- Increased volume and velocity of runoff
- Increased frequency and severity of flooding
- Peak (storm) flows many times greater than those in natural basins
- Loss of natural runoff storage capacity in vegetation, wetlands, and soil
- Reduced groundwater recharge
- Decreased base flow, the groundwater contributing to streamflow, which can result in streams becoming intermittent or dry

(Source: *Impacts of Development on Waterways*)

Nonstructural and Structural BMPs

Urban storm-water BMPs strive to prevent or reduce the availability, release, or transport of substances that adversely affect ground and surface waters. They might be implemented by a private, commercial, or government entity through voluntary action, financial incentives, or regulatory requirements.

BMPs can be classified as *nonstructural* and *structural.* Some examples of nonstructural BMPS are

- Public educational programs designed to encourage good stewardship and the adoption of BMPS in home settings
- Education of public employees, businesses, and the general public about the hazards associated with illegal discharges and improper disposal of waste
- Passing of new ordinances that regulate the implementation of BMPs
- Development and implementation of a municipal operation and maintenance program to prevent or reduce nonpoint runoff from municipal operations into storm sewer systems
- Employee training on how to incorporate pollution prevention and good housekeeping techniques into municipal operations such as park and open space maintenance, fleet and building maintenance, new construction and land disturbance, and storm sewer maintenance

The following are examples of structural BMPs:

- Catch basins

  Catch basins are storm-water runoff inlets equipped with a small sedimentation sump or grit chamber. They are used to capture and remove sediment and debris from storm-water runoff before it enters a storm-water conveyance system. They are used in parking lots, along streets and roadways, and in other areas. A typical catch basin is made of precast concrete. Storm-water runoff enters the catch basin and drops to the bottom of the sedimentation sump, where sediment and other debris are deposited and accumulate. Catch basins need to be maintained and cleaned out after storm events. New types are beginning to come out with outlet hoods that help retain floatables.

- Concrete grid and modular pavement

  Concrete grid and modular pavement are specifically designed to infiltrate water back into the ground. The supporting subbase materials must be carefully designed and installed to maximize infiltration and withstand wheel load pressures. They consist of strong structural materials with regularly interspersed void areas that are filled with pervious materials such as sod, gravel, or sand. The goal is to reduce or eliminate storm-water runoff from low-volume traffic areas such as parking areas and recreational and pedestrian surfaces. These pavements can be used if the underlying soils allow infiltration of storm-water runoff. These surfaces significantly reduce or eliminate runoff to surface water bodies.

- Filter strips

  Filter strips are strips of perennial grasses, legumes, or shrubs and trees planted across a slope that is adjacent to areas with a high potential to deliver pollutants. These strips remove pollutants during overland flow. They are used to catch and filter out sediment, solid-phase nutrients, organics, some heavy metals, and pathogens. Filter strips are used in riparian zones. Desirable filter strip widths will vary with land slope, type of vegetative cover, watershed area, soil suitability, and type of pollutant to be filtered. Filter strips in

riparian zones have trapped 85–90 percent of the phosphorus leaving surface-disturbed fields.

- Infiltration trenches

  Infiltration trenches are subsurface trenches backfilled with gravel, usually three to eight feet deep. They create underground reservoirs that hold runoff, allowing it to slowly percolate through the bottom into the surrounding soil. Absorption, straining, and decomposition by bacteria in the soil remove pollutants. Infiltration trenches are used economically in small sites and where the soil is permeable.

- Roof runoff system

  Roof runoff systems direct runoff into downspouts and into trenches before it infiltrates permeable soil. They prevent relatively clean roof runoff from becoming contaminated. These systems are used in urban, suburban, and industrial areas where roof runoff contributes significantly to storm-water runoff and in areas where soils are permeable. Downspouts from the roofline feed underground pipes, which lead to infiltration trenches. In some cases, they are linked to municipal storm-water systems but are designed to store the water and to release it slowly. Stamford, Connecticut, has experimented with a rooftop lawn at its government center. It has a drain system beneath the lawn. The grass filters the pollutants, provides a surface for evapotranspiration, and slows the discharge to the municipal storm sewer system.

- Constructed wetlands

  Natural wetlands are well known for their ability to trap pollutants before they enter water bodies such as estuaries. Constructed wetlands are designed to simulate natural wetlands. Typical plants used are cattails, bulrushes, and reeds.

Storm Water Phase II Program

Since the passage of the Clean Water Act, the quality of our nation's waters has improved dramatically. However, according to the U.S. Environmental Protection Agency, approximately 40 percent of surveyed U.S. water bodies are still impaired by pollution and do not meet water-quality standards. A leading source of this impairment is polluted runoff. According to the survey, 13 percent of impaired rivers, 21 percent of impaired lake acres, and 45 percent of impaired estuaries are affected by urban/suburban storm-water runoff. The Phase II Final Rule is part of EPA's effort to preserve, protect, and improve the nation's water resources from polluted storm-water runoff. This rule applies to operators of separate, small municipal storm sewer systems. Municipalities will be required to identify BMPs to improve water quality in

their watersheds. For more information on this program, see the EPA fact sheets listed in the resource section of this chapter.

Summary

Contaminated runoff, also called nonpoint source pollution, is a major problem in most urban areas, where the amount of impervious surface is usually much greater than in rural areas. The result is that storm water washes off these surfaces into storm drains and is carried to nearby surface waters. This storm water carries with it the many pollutants found in urban areas, including toxins, pathogens, nutrients, and sediments.

Best management practices, or BMPs, are steps communities take to reduce the amount of polluted runoff emanating from an area. They can be either structural or nonstructural. Normally a combination of both types of BMPs is used to combat contaminated runoff in highly populated areas. The U.S. Environmental Protection Agency, through its Storm Water Phase II Program, will require many urban communities to implement BMPs to reduce the pollutant load from storm-water runoff.

Many resources and programs are available to help communities learn about nonpoint source pollution and best management practices. One is the NEMO, or Nonpoint Education for Municipal Officials program. Another source is the EPA Storm Water Phase II Final Rule Fact Sheets. Information on these two programs is listed in the "Resources" section.

Resources

Printed materials

Baybook: A Guide to Reducing Water Pollution at Home. Available from Chesapeake Regional Information Service. 1-800-662-CRIS.

BayScapes. Includes eight short fact sheets on environmentally sound landscape management for the Chesapeake Bay. Available from the Alliance for the Chesapeake Bay, PO Box 1981, Richmond, VA 23216; phone 804-775-0951.

Better Backyard: A Citizens Resource Guide to Beneficial Landscaping and Habitat Restoration in the Chesapeake Bay Watershed. Available from the Chesapeake Bay Watershed, Chesapeake Bay Program Office, 410 Severn Avenue, Annapolis, MD 21403, 1-800-Your Bay.

Better Lawns and Gutters: A Homeowner's Guide to Protecting Water Quality. Available from Agricultural Bulletin, Room 245, 30 North Murray Street, Madison, Wisconsin 53715.

Controlling Pollutants in Industrial Storm Water. A fact sheet developed by the city of Portland, Oregon. This fact sheet was presented at the conference "Tools for Urban Water Resource Management and Protection" in Chicago, February 2000.

Designing with Nature: Using Ecological Principles in Garden Design: Inspiration and Information. Available from Waquoit Bay National Estuarine Research Reserve, PO Box 3092, Waquoit, MA 02536; phone 508-457-0495.

EPA Storm Water Phase II Final Rule Fact Sheets

Small MS4 Program

Fact Sheet 2.0—*Small MS4 Storm Water Program Overview* (EPA 833-F-00-002)

Fact Sheet 2.1—*Who's Covered? Designations and Waivers of Regulated Small MS4s.* (EPA 833-F-00-003)

Fact Sheet 2.2—*Urbanized Areas: Definition and Description* (EPA 833-F-00-004)

Minimum Control Measures

Fact Sheet 2.3—*Public Education and Outreach* (EPA 833-F-00-005)

Fact Sheet 2.4—*Public Participation/ Involvement* (EPA 833-F-00-006)

Fact Sheet 2.5—*Illicit Discharge Detection and Elimination* (EPA 833-F-00-007)

Fact Sheet 2.6—*Construction Site Runoff Control* (EPA 833-F-00-08)

Fact Sheet 2.7—*Post-Construction Runoff Control* (EPA 833-F-00-009)

Fact Sheet 2.8—*Pollution Prevention/ Good Housekeeping* (EPA 833-F-00-010)

Permitting

Fact Sheet 2.9—*Permitting and Reporting: The Process and Requirements* (EPA 833-F-00-011)

Fact Sheet 2.10—*Federal and State-Operated MS4s: Program Implementation* (EPA 833-F-00-012)

Construction Program

Fact Sheet 3.0—*Construction Program Overview* (EPA 833-F-00-013)

Fact Sheet 3.1—*Construction Rainfall Erosivity Waiver* (EPA 833-F-00-014)

Industrial "No Exposure"

Fact Sheet 4.0—*Conditional No Exposure Exclusion for Industrial Activity* (EPA 833-F-00-015)

The Estuary Book. Maine Coastal Program, Maine State Planning Office, State House Station 38, Augusta, Maine 04333. Includes chapters on the consequences of development and estuary planning and management.

Florida Yards and Neighbors Handbook: A Guide to Environmentally Friendly Landscaping. Institute of Food and Agricultural Sciences, Bulletin 295, University of Florida.

*Home*A*Syst: An Environmental Risk Assessment Guide for the Home.* Available from Northeast Regional Agricultural Engineering Service, Cooperative Extension, 152 Riley-Robb Hall, Ithaca, NY 14853-5701; phone 607-255-7654.

Impacts of Development on Waterways.

NEMO Fact Sheet no. 3. (See NEMO.)

Landscaping for Water Conservation: A Guide for New Jersey. Publications Distribution Center, Cook College, Rutgers, The State University of New Jersey 08903

Living with an Eye on Water Quality: Fact Sheets 1–8. Available from Connecticut Sea Grant, University of Connecticut, 1084 Shennecossett Road, Groton, CT 06340; phone 860-405-9141.

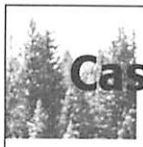
NEMO: Nonpoint Education for Municipal Officials. A series of fact sheets and instruction on how to use geographic information systems to manage nonpoint source pollution. University of Connecticut Cooperative Extension System, 1066 Saybrook Road, Box 70, Haddam, CT 06438-0070; phone 860-345-4511.

Seashore Gardening with Native Plants (East Coast). M. Marilyn Schmidt. Pine Barrens Press, PO Box 305, Barnegat Light, NJ 08006; phone 609-494-3154.

Sound Gardening. A series of 10 fact sheets on the topic of environmentally sound gardening and landscaping. Available from New York Sea Grant, 3059 Sound Avenue, Riverhead, NY 11901; phone 516-727-3910.

Urban/Stormwater Runoff Management Practices Catalogue for Nonpoint Source Pollution Prevention and Water Quality Protection in New York State. NYS Department of Environmental Conservation, Division of Water, Bureau of Water Quality Management, April 1994.

Yards and Neighbors Brochure for California's Central Coastal Morro Bay Area. Available from Friends of the Estuary at Morro Bay, PO Box 1375, Morro Bay, CA 93443.



Case Study

BMPs in an Urban/Suburban Setting

The Problem

In the early 1900s, a bay near New York City was known as the shellfish garden of the city. In the late 1970s, the bay was shut down for shellfish harvesting because of pollution and has remained closed for the past three decades. Low oxygen conditions sometimes lead to fish kills, which result mainly from too much nitrogen entering the bay. Sediments have been building up in the bay and the ponds that drain into it, interfering with environmental quality and navigation. Storm-water runoff is the primary cause of most water pollution problems in the bay.

What Was Done

A committee was formed to examine the bay and its problems and to make a management plan to correct them. There are many local government entities on both sides of the bay. For the first time, local governments have come together to address the bay's problems. The committee includes 11 village governments, one town, and the county. Together, they wrote a water-quality management plan, gained public support for it, and began implementing the plan, step by step.

Outcomes

The parts of the plan listed below serve as an example of the committee's work. Over one million dollars (mainly in the form of grants) has been secured in just under one year to implement pieces of the plan. The committee established five goals for itself:

1. Improve water quality so that swimming and fishing standards are consistently met
2. Improve water quality to allow the harvesting of shellfish for human consumption
3. Restore tidal wetlands so that they can serve to cleanse ecosystems and provide for marine food production, wildlife habitat, and flood and storm control and offer opportunities for open space, education, recreation, and aesthetic appreciation
4. Control and reduce point and nonpoint sources of pollution to the bay

5. Coordinate local coastal efforts to improve water quality

To achieve the goals identified above, the committee identified numerous recommendations for implementation in the watershed, which would lead to a reduction in adverse impacts in the bay caused by storm water. A sample of these recommendations follows:

Objective: Reduce volume of runoff

- Recharge runoff to the groundwater
- Use grass buffer strips, swales, porous pavement, dedicated infiltration
- Use storage basins or percolation trenches
- Create "no mow" zones around sloped lawn areas
- Avoid overwatering of lawns
- Eliminate roof drains that discharge to street gutters
- Use shrubs and trees to promote infiltration
- Use porous pavements for walkways, patios, driveways, and parking lots
- Use vegetative soil berms with gravel or porous trenches
- Use dry wells for parking lot drainage
- Use closed-system, recycling cooling systems
- Create detention-retention ponds
- Divert runoff from paved areas to grass and vegetative areas
- Use constructed wetlands for runoff storage and retention

Objective: Reduce rate of runoff

- Use detention basins to slow the runoff rate
- Use grass swales and filter strips instead of curbs
- Increase tree cover and require approval for cutting trees; replant on a two-to-one ratio
- Replace cut sidewalk trees within a three-month period
- Identify early symptoms of disease in trees and develop a protection plan or a replanting program
- Create cutbacks or buffers for properties that are developed or redeveloped along or adjacent to the bay or along ponds or creeks around the bay

Objective: Reduce bacterial pollution

- Enforce ordinances against feeding waterfowl and requiring pooper-scooping of wastes from pets
- Plant low but dense vegetative barriers around ponds to deter waterfowl entry
- Use biofiltration ponds and constructed wetlands to promote natural die-off of coliform bacteria
- Prepare an inventory of cesspools and septic systems near the bay (or ponds and creeks) in areas of groundwater in elevations less than 10 to 20 feet below the surface of the ground
- Conduct a feasibility study in those areas with larger population densities or within sewered areas to evaluate the need (1) to replace cesspools or septic tanks with private treatment systems that discharge to the groundwater or (2) to connect to a sanitary sewer for treatment at an existing wastewater treatment plant
- Inventory and inspect on a regular basis houseboats used as living quarters, to ensure proper sanitary waste disposal or treatment

Objective: Reduce sediment discharges

- Regularly clean out catch basins, once every two to three years for those discharging directly to the bay and every three to five years for those discharging through pond systems
- Require a storm-water pollution-prevention plan for construction sites
- Trap or remove sediments from construction runoff
- Do not have lawns on moderate to steep slopes that are prone to soil erosion
- Repair deteriorated asphalt, concrete, or gravel driveways on moderate to steep slopes
- Use energy dissipaters or berms to slow down runoff rates that would cause soil erosion
- Sod rather than seed new lawns to avoid soil erosion during wet weather
- Have residential and commercial property owners keep street gutters and any catch basin gratings free of sediment, leaves, and other debris
- Restore and stabilize streambanks with mats, blankets, or vegetation to keep the soil and sediments from eroding into the creek, stream, or pond
- Plant vegetative access barriers along stream banks and shorelines to prevent pedestrian or waterfowl erosion of the soils

- Construct forebays or sediment traps at the entrance of the ponds around the Bay
- Plant vegetative buffers around ponds and along stream banks

Objective: Reduce nitrogen discharges

- Minimize or avoid use of fertilizers
- Decrease lawn sizes and increase shrubs and wooded areas
- Construct and restore wetlands to provide nutrient uptake
- Seed lawns only from mid August to early October
- Prepare an inventory of the number of cesspools and the number of septic tanks located in areas of groundwater elevation of 10 to 20 feet or less

Objective: Reduce pesticides and toxic discharges

- Minimize or avoid use of pesticides and other chemicals
- Use pest-resistant plants
- Use integrated pest management on all public parks and private golf courses
- Use household hazardous waste STOP days for proper disposal (STOP = stop throwing out pollutants)
- Require pollution prevention plans for all industrial facilities and operations under U.S. Environmental Protection Agency regulations

The town will be looking to a variety of funding sources—including federal, state, local, and private—to get the job done. In one year, it has raised one million dollars to control storm water to its bay.

For more information, contact Robert Kent, New York Sea Grant, 3059 Sound Avenue, Riverhead, NY 11901.

Case Study

NEMO

NEMO stands for Nonpoint Education for Municipal Officials. NEMO is the name of a program at the University of Connecticut whose aim is to help local land use decision makers, especially planning and zoning board members, understand the link between land use and water quality. This is accomplished by University of Connecticut staff members' meeting with local officials and presenting information to them about land use and water quality. Supporting these informational presentations are a wide variety of educational fact sheets, videos, and CD-ROMs. The goal of the program is to have local officials make better land use decisions that lead to reducing nonpoint source pollution.

The NEMO program has spread beyond the boundaries of Connecticut. As of this writing, 19 NEMO projects are funded throughout the United States. A national NEMO network has been established to facilitate communication between the various programs. New York Sea Grant recently began a NEMO program that focuses on the Long Island Sound watershed.

The University of Connecticut, which serves as the coordinator of the NEMO network, is the best place to learn more about NEMO. It offers the following services:

- Scoping workshops for those wanting to find out more about NEMO and considering starting a NEMO program in their area
- A Web site that contains NEMO fact sheets and a basic NEMO PowerPoint presentation that can be adapted for local use
- A CD-ROM that includes a wide variety of support materials for those starting a NEMO program

For more information about the NEMO program, contact the University of Connecticut NEMO program at University of Connecticut Cooperative Extension System, 1066 Saybrook Road, Post Office Box 70, Haddam, CT 06438-0070. Telephone 860-345-4511. The Web address is http// nemo.uconn.edu.

Case Study

Americorps on the Bayou

by Mike Liffmann and Pam Blanchard

The Problem

Louisiana is losing more than 20 square miles of its coastal wetlands each year to coastal erosion. In many cases, the only high ground remaining in south Louisiana is along the natural levees of bayous. Bayou Lafourche, once a distributary of the Mississippi River, supports communities along its entire length. The people living in the communities generally make their living from commercial fishing or through oil-field and offshore-related industries. One of the major modes of transportation in this region is boat, and so the water quality and natural beauty of Bayou Lafourche was often taken for granted in past years. Recently, efforts have been made to restore the natural beauty along this waterway near the communities of Golden Meadow and Cutoff, Louisiana. Les Reflections du Bayou, a nonprofit group dedicated to improving, cleaning and beautifying Bayou Lafourche, began working with Americorps workers several years ago to accomplish this goal.

What Was Done

Since this partnership began, Americorps workers have participated in the Great American Cleanup project, picking up litter and using weed eaters along the bayou to help improve the appearance of the area and instill public pride in the towns along the bayou. They have planted flower beds and trees along the bayou to help bring back some of the natural beauty to the area. These young people have also participated in helping restore some of the fragile environments along the Louisiana coast by building sand fences on rapidly eroding barrier islands. In addition, they have participated in marsh grass planting projects sponsored by the United States Department of Agriculture-Natural Resources Conservation Service.

Outcomes

To date, Americorps on the Bayou participants have planted more than 20,000 plants in several restoration projects in the marshes surrounding the Bayou Lafourche area. Americorps volunteers have a hand in monitoring and maintaining 20 restoration sites. Recently, volunteers checked on one of their largest restoration planting areas and were excited to see a wall of giant cutgrass growing in the planting area where originally they had planted small pots of cutgrass about five feet apart. In addition to these restoration and planting duties, Americorps workers also volunteer as speakers in the schools in the areas. Americorps on the Bayou volunteers are particularly imaginative at creating games through which school children learn about our wetlands, coastal environments, litter, and recycling. These young people provide an important service to the area by working in marsh restoration and beautification projects, as well as by serving as volunteer speakers at area schools and meetings of civic groups. The Americorps volunteers learn first hand what the environmental problems are in this region of south Louisiana and have the satisfaction of knowing that they helped make a difference in the community.

Contacts

Peggy Bagala, Les Reflections du Bayou.

Carolyn France, Americorps on the Bayou Director. 14833 West Main Street, P.O. Box 993, Cut Off, LA 70345. Phone/Fax: 985-632-6040.

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References to illustrations are printed in italics.

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