Wetlands
A Living Filter

Table of Contents

Introduction

What is a Wetland?

Wetlands are among the most fascinating places on the planet. Wetlands include places such as cattail marshes, tropical mangroves, cypress swamps and bayous, salt marshes at the ocean, and even the muddy area along your favorite stream. Although these places may differ greatly in their habitat types and species composition, each can be considered a true wetland if it meets three basic criteria: presence of wetland hydrology, hydric soils, and hydrophytic vegetation.

Hydrology is the study of the properties, distribution, and effects of water and is the driving force behind wetland formation. In a wetland, the critical hydrologic feature is the amount of moisture present in the soil over a given time. There are many specific definitions for this attribute but the inclusive scientific definition states that the substrate is saturated or covered by shallow water at some time during the growing season of each year (Cowardin et al. 1979). Such saturation occurs because the underlying substrate of a wetland is impermeable or semi-impermeable to water. Water, from either a temporary or permanent source, collects above the impermeable layer, eventually resulting in the formation of a wetland (Figure 1).

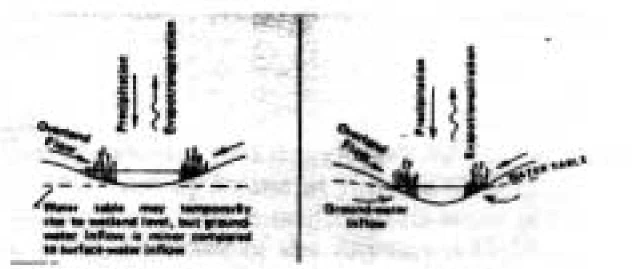


Figure 1. Basic hydrologic characteristics of wetland sites pertaining to surface and ground water. (Adapted by permission from Majumdar et al., 1989).

2

The second characteristic of wetlands is hydric soil. *Hydric soils* are those soils which are saturated long enough during the growing season to develop anaerobic conditions in the upper part of the soil substrate (Federal Manual for Identifying and Delineating Jurisdictional Wetlands, 1989.) These soils may be either organic or mineral in nature. In mineral hydric soils, (which we will encounter in this exercise), two distinctive biochemical processes occur - gleying and mottle formation. Gleying occurs as a result of the chemical reduction of iron (Fe^{3+} to Fe^{2+}) and creates a gray, blue-gray, or greenish soil color. Mottle formation occurs when soils alternate between wet and dry conditions, causing the oxidation of iron (orange/reddish - brown spots) or manganese (dark red/brownish-black spots) (Mitsch and Gosselink 1993). We can quickly assess soil coloration in the field by using a Munsell soil color chart (figure. 2). Unless strongly gleyed, mineral hydric soils are relatively dark and yellow-red in hue.

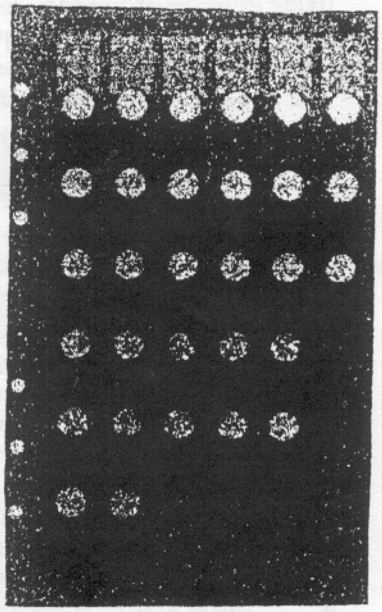


Figure 2. A Munsell soil color chart (like the one shown at the right–only in color not black and white) is used to identify hydric soils based on the soil color; soils will have an associated color hue and shade depending on the composition, moisture, and weight.. The value on the vertical scale is based on soil lightness, while the chroma is based on the color strength or purity.

Another characteristic of wetland soils is that their anaerobic condition inhibits microbial decomposition of organic matter. In extreme situations (such as cool temperatures and low pH water and soil), decomposition stops and peat forms. On rare occasions, biological specimens can be found perfectly preserved in peat bogs. Much of our understanding of prehistoric climates and vegetation patterns is derived from the study of ancient pollen which has been excavated from bogs.

The third distinctive characteristic of wetlands is the presence of *Hydrophytic plants* - those plants which have adapted to the wet anaerobic soils typical of wetlands. Most terrestrial plants gather oxygen in their roots from the surrounding soil. However, through evolution, wetland plants have adapted to the anaerobic soils by developing air spaces in their roots and stems. These spaces allow oxygen to diffuse to the roots from the leaves and stems. A consequence of this transport is the oxidation of the*rhizosphere* (root zone) around wetland vegetation, which leads to the formation of iron oxide deposits around the roots.

The three above factors - wetland hydrology, hydric soils, and hydrophytic vegetation are found in all true wetlands and are independent of the specific wetland habitat type.

The Benefits of Wetlands

One way to measure the value of any ecosystem is to examine the primary productivity of that system. Primary productivity is the rate at which plants in an ecosystem produce biomass, or plant matter, such as roots, leaves, and stems. With a few exceptions, wetlands are among the most productive ecosystems in the world, rivaling coral reefs and tropical forests. As a consequence of this high productivity, wetlands supply critical habitats for a multitude of species, including microscopic bacteria and protozoans, algae and vascular plants, fish, reptiles, amphibians, birds, and mammals. This variety of living organisms, refereed to as biodiversity, often reaches it highest levels in wetlands. For example, over 80% of America's breeding birds rely on wetlands. Wetlands are also significant to the survival of endangered species. As many as 43% of the threatened and endangered species in the United States depend on wetlands.

In addition to providing important habitats, wetlands serve a variety of other purposes, such as flood control. One acre of wetland, flooded two inches deep, will hold over 54,000 gallons of water. One study showed that losing 8,422 acres of wetlands in the Charles River Basin in Massachusetts would produce flood damage over $17 million annually. Other wetland values include water supply (ground water recharge), shoreline stabilization, and reduction in coastal storm water runoff.

Yet another value of wetlands, and the focus of this module, is water purification. Water sources may carry varying amounts of pollutants, silt, and organic debris into wetlands. Upon entering, the water velocity decreases and organic debris settles to the bottom where it is decomposed by microorganisms. Silt also settles to the bottom and is incorporated into the sediments. Certain pollutants act as nutrients and are taken up by the plants. Pollutants may also be bound by the sediments or pass unaffected through the wetland. As a consequence of these processes, the water leaving a wetland tends to be cleaner than the water entering the wetland. This water cleansing property makes wetlands commercially useful. Constructed wetlands, those not occurring naturally, are used to store and treat a variety of waste waters, including storm water runoff, acid mine drainage, agricultural runoff, and sewage effluent. It is estimated that a municipal water treatment plant would spend $75,000 to clean the same amount of water as is cleaned by one acre of tidal estuary. If the production of commercial fish is added, that one acre wetland is now worth $83,000 in the services that it provides. Because of their productivity, the fishing industry relies extensively on wetlands. The United States commercial fisheries annual harvest is valued at more than $10 billion. In the Southeast, 96% of the commercial catch and 50% of the recreational harvest comes from fish and shellfish populations dependent on estuary and coastal wetlands.

Disappearing Wetlands

Despite the many products and ecological services that wetlands provide, thousands of acres of wetlands have been destroyed to develop the land for crop production, ponds and lakes, housing projects, coastal impoundments, and navigation channels. Other wetlands have also been mined for their peat or simply degraded by pollution. In Pennsylvania, between 1956 and 1979, there was a net loss of nearly 28,000 acres of inland vegetated wetlands. The major cause of wetland loss during this time period was pond construction. Since 1890, over 100 million acres have been drained for farmland. Overall, the U.S. has lost over 1/2 of its wetland habitats in the lower 48 states.

Research Design

Research Objective

The objective of this field exercise is to determine if the constructed wetland at Fouse's Crossing functions as a water purification system, and if so, to what degree. We will investigate the effect of the wetland on water quality by examining the following factors : pH, nitrates and dissolved oxygen.

Water Quality Factors

pH: pH is a measure of the concentration of hydrogen ions in a solution and thus expresses the intensity of an acid or base. The normal range of pH for Pennsylvania streams and other aquatic ecosystems is between 6 and 8. An increase in acidity results in a lower pH, whereas an increase in alkalinity (base) raises the pH. The greater the deviation from the normal range, the less life the water can support. Maintaining a stable, moderate pH is very important for wetlands because they serve as fish and amphibian breeding grounds. (Figure 2)

Keppy INSERT: FIGURE ON pH LIMITING VALUES

Keep in mind that pH is measured on a logarithmic scale. For each unit of change in pH, the acidity changes by a factor of 10. Therefore, a change from pH 4 to pH 3 is 10 times more acidic. A pH of 3 is 100 times more acidic than a pH of 5.

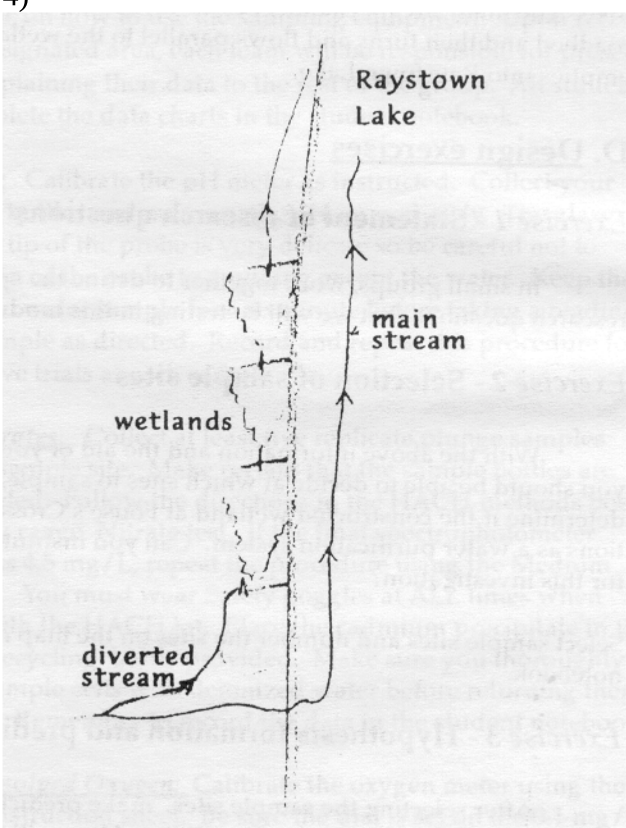
Nitrates: Nitrates, in low concentration, are important nutrients for wetland plants. However, in high concentrations, nitrates are considered to be a pollutant. (Figure 3) High nitrate levels, such as those caused by sewage, support high bacteria concentrations which consume oxygen from the water. This oxygen depletion results in the loss of many of the fish and macro-invertebrates.

Keppy INSERT: FIGURE ON NITRATE LEVELS

Dissolved Oxygen: Oxygen is required by animals and plants for respiration and is given off by plants in photosynthesis. Effective atmospheric mixing and/or high photosynthetic activity will yield high oxygen levels. However, this increased oxygen level is usually balanced by respiration, oxidation of the sediments by plants, diffusion of oxygen to the atmosphere, and decomposition activities in the wetland.

Study Site

The Fouse's Crossing Wetland was originally a wetland that was converted to cropland by the previous owner. Last farmed in 1988, the area is now managed by the Pennsylvania Game Commission, as part of a Wildlife Mitigation Project. The project is designed to recover some of the 3,000 acres of wetland habitat which was flooded when the Army Corps of Engineers constructed the Raystown Lake Dam in 1970-71. (Figure 4)



The wetland was constructed along an abandoned railroad bed. The bed serves as a dike and provides the eastern boundary for the wetland. Smaller dikes were constructed perpendicular to the railroad bed, creating several small impoundments in a line along the bed. An overflow pipe between each impoundment allows water to pass from one impoundment to another, and eventually into Raystown Lake. The Fouse's Crossing Wetland now consists of a series of four small wetlands (constructed in 1991) and one large wetland cell (constructed for wildlife propagation in 1990.) The water for the wetland is diverted from a small stream which initially flows perpendicular to the railroad bed dike. The main stream channel passes beneath the abandoned roadbed and then turns and flows parallel to the wetlands, and empties into Raystown Lake.

Design Exercises

Exercise 1- Statement of Research Questions

In small groups, work together to define the specific research questions that we will be testing in this module.

Exercise 2 - Selection of Sample Sites

With the above information and the aid of your instructor you should be able to decide at which sites to sample, in order to determine if the constructed wetland at Fouse's Crossing functions as a water purification system. Can you institute a control for this investigation? Select sample sites and number the sites on the map in the student notebook.

Exercise 3 - Hypothesis Formation & Predictions

After selecting the sample sites, make predictions about the effectiveness of the wetland as a filter. How will the wetland affect the pH ? Will the nitrate levels change and if so, how? How will the dissolved oxygen levels in the water differ at each sample site? Make your predictions and record them in the form of a research hypotheses in the student notebook. Be certain to specify the null hypothesis.

Data Collection

Excercise 1 - Characterizing the Wetland

Working in small groups, use a hand spade to dig a shallow hole (12 inches will suffice). Examine the soil and associated plant roots and record your observations in your student note book. Use a Munsel soil chart to characterize the soil. Note any mottling or gleying. Carefully examine the plant roots. Note the presence of reddish - orange deposits on the roots. What is this compound?

Using your wetland field guide, identify any common plants or animals that you encounter and record your observations.

Exercise 2 - Field Testing Your Hypothesis

Approach: The data collection will be done in three teams. Each team will be assigned a test parameter that they will be responsible for at all sample sites. Each test parameter will require at least 5 replicate samples. Your teachers will provide you with instructions on how to use the sampling equipment. Upon returning to a designated area, each team will be responsible for presenting and explaining their data to the rest of the group. All students must complete the data charts in the student notebook.

pH: Calibrate the pH meter as instructed. Collect your samples in bottles and measure the pH immediately. The glass bulb at the tip of the probe is very delicate so be careful not to touch the tip of the probe to anything except the water. Keep the probe in the water sample for one minute before taking a reading. Test the sample as directed. Record and repeat this procedure for a total of five trials at each sample site.

Nitrates: Collect at least five replicate plunge samples from each sample site. Make certain that the sample bottles are clearly labeled. Follow the directions in the HACH methods book for the <u>Low</u> range Nitrate test. If the final spectrophotometer value blinks 4.5 mg/L, repeat the procedure using the Medium Range test. You must wear Safety goggles at ALL times when working with the HACH kit. Place the cadmium precipitate in the cadmium recycling bottle provided. Make sure you thoroughly rinse the sample cells with deionized water before returning them to the case. Remember to record the data in the student notebook.

Dissolved Oxygen: Calibrate the oxygen meter using the provided instruction sheet. Be sure the dial is set on the 0.1mg/L setting (if the reading is too low, then switch the knob to 0.01mg/L.) The membrane at the tip of the probe is fragile, so be careful not to touch the probe to anything other than the water. Immerse the lower four inches of the probe into the water and slowly agitate the probe while the reading stabilizes. Keep the probe in the water for one minute before taking a measurement. Record and repeat the procedure for five trials at each sample site.

Data Analysis and Follow-up

When you have finished collecting data, return to the meeting area. We will demonstrate how to analyze your data using a statistical software package. A follow-up handbook and data analysis assistance will be provided by your instructor.

References