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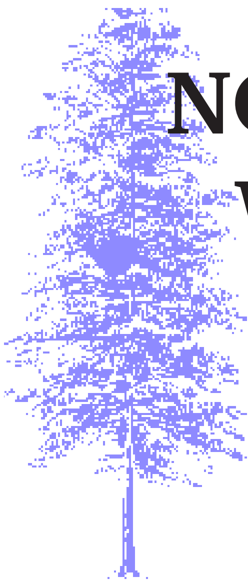

NCSR SPECIAL TOPICS II – WATERSHEDS, SOILS AND ORNITHOLOGY

NORTHWEST CENTER FOR SUSTAINABLE RESOURCES (NCSR)
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NCSR Special Topics II - Watersheds, Soils and Ornithology

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NCSR Special Topics II is a compilation of natural resources exercises selected from course materials developed at Grays Harbor College in Aberdeen, Washington, Shasta College in Redding, California and Feather River College in Quincy, California. Titles of courses from which these materials were selected include *Watershed Ecosystems I* **and** *II, Introduction to Soils* **and** *Ornithology*. **Materials were tested and revised at Mt. Hood Community College, in Gresham, Oregon, Blue Mountain Community College in Pendleton, Oregon and Itasca Community College in Grand Rapids, Minnesota.**

Technology programs in which these materials are incorporated are described fully in the Center's report entitled, "Visions for Natural Resource Education and Ecosystem Science for the 21st Century." Copies are available free of charge.

Course materials are also posted on our website:
www.ncsr.org

Please feel free to comment or provide input.

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INTRODUCTION

Modern natural resource management recognizes that valuable commodities such as fish, trees, wildlife and soils exist as components of functioning ecosystems. None of these components operate in isolation and an understanding of the structure, composition and processes that allow the ecosystem to function is required to effectively manage them. The components are intricately connected, often in unexpected ways. This document provides instructors with a variety of field, laboratory and classroom activities that can be used to introduce students to the concept of ecosystem-based natural resource management.

NCSR Special Topics II is divided into three, unequal sections - Watershed Ecosystems, Soils and Ornithology. The first section - Watershed Ecosystems - focuses on aquatic natural resources with an emphasis on salmon-bearing streams in the Pacific Northwest. Taking a watershed-level approach, these activities focus on the complex interactions between streams, their riparian communities and upland plant communities. Students are introduced to a number of field methods and information sources that can be used to evaluate watershed health. The second section examines the importance of soils in natural resource management. The long-term productivity of soils is a critical consideration in the management of forest and agricultural resources. Additionally, soil erosion that originates from farms, roads and harvested forests can have a negative impact on aquatic resources. The maintenance of natural biological diversity is often a primary goal of ecosystem-based natural resource management. Consequently, methods must be devised to assess existing levels of biodiversity and monitor any changes over time. The final section provides and example of how one group - the birds - can be evaluated in such a program.

INTRODUCTION TO WATERSHED ECOSYSTEMS

The following activities were derived from a two-course capstone series (*Watershed Ecosystems I* and *II*) that focuses on ecosystem concepts, and an exploration of ecosystem and watershed components, functions, variability, processes, and integrity. Students are introduced to the functions of ecosystems and watersheds, the recovery processes after a disturbance and comparisons of ecosystem and watershed management on local, regional and landscape scales. Students evaluate watersheds by collecting data from selected field sites to explore the relationship between ecosystem processes and the impact of disturbance. Students develop the writing skills necessary to communicate technical information, the ability to integrate and contextualize the principles of natural resource management and an understanding of the importance of proper ecological functioning in maintaining healthy watershed systems.

Introduction to Study Design

INTRODUCTION

We all use scientific methods to answer questions about our lives and the world. Farmers study their fields, confer with agronomists, and conduct tests to learn why a certain crop is producing low yields. Consumers select among brands of shampoo by reading labels, talking with friends, listening to commercials, and testing products. All of these actions are guided by questions such as, "Why are my crops failing?" or "Which shampoo should I buy?".

Scientists use questions to guide their research as well. How scientists answer questions depends on current understandings, available resources, and the nature of the questions themselves. There is no one scientific method. Nonetheless, investigations are often guided by a series of questions:

- What is the question we are trying to answer?
- What do we know that is related to this question?
- What are the procedures to answer this question?
- What are the results of the investigation?
- What conclusions can we draw?
- What is the value of these conclusions?
- Can these conclusions be used to answer the question?

This process facilitates thorough, organized investigations. The questions need not be followed in sequential order. Sometimes researchers first recall what they know about the problem, or they make a prediction (a hypothesis), and then test it.

Even when these questions are used to guide an investigation, the problem may not be solved, or more questions may arise. Results may be erroneous. The farmer may not learn why crop yields are low. The consumer may find that his choice of shampoo causes frizzy hair. Similarly, scientists must test and retest hypotheses.

As they learn, people (and scientists) continue to ask questions. Thus, investigations into problems are ongoing.

PROCEDURE

We will start our own study design by determining what we know and the questions we might have about the subject of our study - the streamside environment.

1. Form small groups of 3 to 4 students each.
2. In your group, brainstorm about the following, using one person as a recorder who writes all ideas on a flip chart:

What do we know about the streamside environment?

3. When you have recorded all the ideas about what you and your group knows, brain storm about the following (as before), using one person as recorder and writing all ideas on the flip chart:

What questions do you have about the streamside environment?

Consider, for example, interactions between the physical and biological components of the environment, ecological requirements of different plants and animals, which plants and animals are present and why.

4. Now you will need to narrow your group focus to select a question (or series of questions) that you will try to answer by designing your own research study. It is important to remember that you will be following through and attempting to answer these questions, so "simple" is better than "complex" at this stage. After your group has selected the question(s) to be investigated, you are ready for the next step.

5. Make a list of what you will need to know (e.g., amounts of rainfall, types of soils, types of plants) in order to answer the question(s) your group has posed.

6. The next step is the development of procedures. The objective of these procedures is to provide the knowledge or information that you can then use to answer the question. Develop a list of procedures and steps to achieve those procedures in order to answer the questions you developed in #4. As you develop this list be sure that the procedures will help you answer all or part of your questions.

7. Review your procedures and discuss in your group. This is an important step to try to assess how effectively this form of investigation will address the question.

8. Write a research proposal that includes the following:

   - The goal of your investigation
   - How the investigation is to be carried out
   - A sequential list of detailed procedures
   - A step-by-step accounting for time to be spent on each activity
   - Field location
   - Equipment
   - Personnel
   - A glossary of terms

It will be helpful to review other research studies and discuss other groups' ideas.

NOTES FOR INSTRUCTORS
The primary objective of this activity is for students to be able to design a research study by:

1. Finding and using current available knowledge.

2. Determining questions that have yet to be answered.

3. Deciding on a single question to be the focus of study.

4. Deciding what information needs to be collected in order to answer the question.

5. Developing a field procedure that will produce data to answer the question.

6. Writing a plan for the research proposal.

7. Reviewing procedures and discussing them in a group setting. Assessing how effectively this form of investigation will address the question.

8. Writing a research proposal.

Instructors may introduce this activity by discussing the “scientific method”. For example:

1. State the problem; ask a question
2. Hypothesize about what the answer or conclusion will be
3. Test hypotheses
4. Analyze results
5. Draw conclusions from the results
6. Develop a theory based on well-tested hypotheses

MATERIALS

Flip charts
Marker pens
Examples of research studies

Soils and Land Use

INTRODUCTION

Knowledge of soils and where to go to get further information about soils is an important basic skill for professionals in natural resources fields. In this exercise, students will develop skills in accessing information about soils and applying knowledge to a real-world situation.

Specifically, you will create a subdivision of homes and recreation areas in a specified area with a number of different soil types. Soil capabilities and other characteristics must be taken into account in order to develop a successful project.

PROCEDURE

Form small groups of 3-4 students.

Consider the following scenario:

You have just graduated from college and have landed your first job in your town's planning department. Your first function is to participate as a member of a team to design a suburb. The area to be developed is outlined on the map you have been given. Discuss with members of your team and be sure everyone understands how to read the information supplied on the map (contour lines, soil types and other features).

As a team, you must decide where to locate a subdivision of homes (including streets and roads), a shopping area, one or more parks, walking trails, and any other features you think would be appropriate in this development. Use your knowledge of soils, soil conservation practices and what people are looking for in their suburb to make your land use decisions. Use your county's Soil Survey to determine the characteristics and capabilities of the soils in your area, and their limitations.

Along with the design, you must supply the types of soil conservation practices that can be used during construction to prevent soil loss. Draw your design and list of practices on your map and on an overhead transparency.

After you have completed your design and proposed activities, you must present your work in written form and at a meeting with other designers (other teams within the class) who have been working on the same project. At this presentation, you will explain the reasons for the location of the features in this new suburb. The design that is most environmentally sound will win a major contract which will mean you will be rich beyond your wildest dreams.

NOTES FOR INSTRUCTORS

The primary purpose of this activity is to introduce students to the Soil Survey as an analysis tool that can be used to determine land use potential. Students use the Soil Survey to determine soil types from soil survey maps, use indexes and tables to find individual soil characteristics of specific soils, and evaluate soil characteristics to determine suitability for designated land use. They then synthesize information about different characteristics of different soils and make recommendations about land use and watershed-scale issues.

This exercise can be modified for different geographical areas of the country. The Soil Survey for your county is available from your local USDA Natural Resources Conservation Service. It contains all the information required about each soil to perform this task (soil types, the different capacities of different soils, etc). The Soil Survey is organized in a clear manner that allows general audiences ("beginner scientists") to research physical characteristics of individual soil types, as well as presenting general geographical characteristics such as slope.

Prior to class, the instructor should outline different land areas on the Soil Survey maps. Groups of students will present their subdivision plans within boundaries on each of these maps.

To make the task more challenging for students, instructors can choose an area of a soil map with a variety of soils with different characteristics – for example, one with a high water table (unsuitable for housing), another which is very gravelly, and so on. You could even add a waterway to the map to add more variety. This will encourage discussion and more decision-making among the group members.

MATERIALS

Local Soil Survey with individual soils map with specific area outlined
Sheets of clear acetate to place over the map
Marking pens that will draw on the acetate sheet

Changes in the Macroinvertebrate Community in a Watershed

INTRODUCTION

The benthic macroinvertebrate community in a stream can be used as a biological indicator of stream health and water quality. Benthic macroinvertebrates include larvae of true flies, beetles, caddisflies, stoneflies, mayflies, dragonflies and true bugs, all of which represent important links in the food web as recyclers of nutrients and food for higher trophic levels, including fish. Gradual changes that occur in a stream from headwaters to mouth affect the habitat structure and food base of the stream. As environmental factors change, so does the proportion of different groups of macroinvertebrates. While fish can swim away from at least some pollution problems, more sedentary benthic macroinvertebrates often become “a pollutant’s captive audience.” Thus, sometimes affected by even subtle levels of degradation, they can be good indicators of stream health and are often superior to many technological tools, because regular chemical tests of the water column may fail to detect transitory events.

In this field exercise, you will sample the macroinvertebrate population to gauge the general health of the stream. This is a standard procedure used in any macroinvertebrate analysis, and sampling is designed so organisms can be released back into the stream. The procedure is qualitative, which means it does not analyze numbers of macroinvertebrates, but instead, it takes into account the presence or absence of different species. Nevertheless, it is sufficiently detailed to diagnose the overall health of a stream.

PROCEDURE

This is a two-session field exercise. Work in groups of two to three students. Invertebrate fauna will be sampled and analyzed at two points in a watershed, at upper and lower stream reaches (Site 1 and Site 2). Following the sampling exercise, data will be compared and discussed in the classroom.

Approach the riffle of your sample site from downstream and place a net at the downstream edge of the area you wish to sample. You will sample organisms from a total stream bottom area of 1 square yard.

1. Pick up rocks from the sample area in front of the net that are over 2 inches in diameter. Hold them in front of the net below the water surface. Gently, but thoroughly, rub the organisms from the rock surfaces so they flow into the net. Place the clean rocks outside the sample area. Continue until all rocks in the sample area have been rubbed.

2. After rocks and debris have been rubbed, step inside the sample area and disturb the streambed by kicking.

3. Remove net with a forward scooping motion.

4. Wash all organisms into sieve bucket.

5. Transfer sample from sieve to shallow white tray. Add enough stream water to cover the sample.

6. Use the dichotomous key in *The Streamkeepers' Field Guide* (pp. 148-163) and the list provided to divide the invertebrates into major groups. After identifying macroinvertebrates with a hand lens, divide them by groups into separate cells of the ice cube tray.

The major taxonomic groups include:

Mayflies, Stoneflies, Caddisflies, Dobsonflies, Alderflies, Fishflies, Dragonflies, Damselflies, True Flies, Beetles, Crustaceans, Snails/Clams, Worms/Leeches

This field method is designed to examine the number of different taxa, not to count the total number of invertebrates by species. Thus, you will identify organisms by major groups (mostly orders), and sort them more specifically by looking at morphological differences.

7. Use the data sheet provided in *The Streamkeepers Field Guide* (page 139) to record the number of district taxa that fall within each major group. Use the dichotomous key or the mayfly/stonefly/caddisfly picture key in *The Streamkeepers Field Guide* to determine the feeding strategy of each taxon.

NOTE: See the handout provided for "functional feeding strategies."

8. For each major group, record the number of taxa that are:
   - Shredders
   - Scrapers
   - Gathering collectors
   - Filtering collectors
   - Predators

ANALYSIS

The total number of taxa you have collected provides important information regarding the diversity of the invertebrate population in this stream. In general, streams with higher diversity of invertebrates are considered healthier than those with lower diversity. Pollution often causes a decline in diversity by favoring pollution-tolerant taxa, which then out-compete the more sensitive types.

Excess nutrients or sediments cause low dissolved oxygen conditions. Pollution tolerance of many common invertebrates has been determined. In general, mayflies, stoneflies and caddisflies have the lowest tolerance to pollution, while midges, aquatic worms, leeches and blackflies have the highest. Beetles, craneflies and crustaceans tend to be moderately tolerant.

EPT Richness

The number of mayfly (Order Ephemeroptera), stonefly (Order Plecoptera) and caddisfly (Order Trichoptera) taxa are important as these groups are some of the most sensitive to pollution. EPT (Ephemeroptera, Plecoptera and Trichoptera) richness usually declines with pollution. Many species of midges, black flies, crustaceans, aquatic worms, leeches and snails tend to move into niches vacated by mayflies, stoneflies and caddisflies when areas become polluted since they are more tolerant of these conditions. This shift may simplify and destabilize the structure of the invertebrate community and thus reduce the biotic integrity of the stream ecosystem. In general, between 8-12 EPT suggests good water quality.

Calculate EPT richness of macroinvertebrates at each site.

QUESTIONS

These questions should be answered after the two sessions are complete.

1. Compare your results at the two different sites. How are they similar, or different?

2. What was the EPT richness of macroinvertebrates at each site?

3. What might have affected the survival of the invertebrate populations at your sampling sites?

4. What types of errors in sampling or analysis might be occurring? How could you minimize these errors?

5. Evaluate the overall health of the stream according to the data you have collected.

6. What would be your next step(s) in evaluating the health of the aquatic ecosystems in this watershed?

MATERIALS

Sampling net
Sieve bucket
Small buckets
Waterproof boots or waders
Waterproof, insulated, elbow-length gloves
Large shallow white trays (9 inches by 13 inches or larger, 1-3 inches deep)
Small, shallow white plastic containers (like meat trays)
White ice-cube trays, pre-labeled
Forceps (for hard-bodied bugs)
White plastic spoons (for more fragile bugs)
Clear plastic pipettes (for small and fast bugs)
Small paint brushes (well suited for mayflies)
Hand lenses
Data sheet (reference manual page 139)
Macroinvertebrate keys (reference manual page 148)
Pencils
Clipboard

REFERENCES

Murdoch, T., M. Cheo and K. O'Laughlin. 1996. Streamkeepers Field Guide. Published by the Adopt a Stream Foundation. 600 128th St. SE, Everett WA 98208. (425) 316-8592 Pages 139-163.

For Internet information, including identification keys and sensitivities to pollution:

www.ncsu.edu/sciencejunction/depot/experiments/water/lessons/macro/

www.iso.gmu.edu/~avia/intro.htm

www.people.virginia.edu/~sos-iwla/Stream-Study/Key/Key1.HTML

FUNCTIONAL FEEDING GROUPS OF MACROINVERTEBRATES

Macroinvertebrates have developed a variety of adaptations, which maximize the effectiveness of their preferred feeding strategy. Macroinvertebrates are classified by their feeding habits into four functional feeding groups.

Shredders possess chewing mouthparts, which allow them to feed on large pieces of decaying organic matter, such as leaves and twigs, which fall into the stream from trees and other plants in a riparian zone. Some have strong enough mouthparts to chew dead animals and/or living plant material when detritus is in short supply. Shredders tend to inhabit headwater streams and other areas with a higher percentage of canopy cover. They play an important role in processing coarse organic matter into finer particles, which can in turn be used by other macroinvertebrates.

Scrapers or **Grazers** remove attached algae from rock and wood surfaces in the current. They are found in areas where sunlight is able to reach the stream bottom, because without sunlight, algae cannot grow. Because these conditions often occur in larger, wider streams, many scrapers have developed adaptations for "hanging on" in relatively swift currents, such as flat streamlined bodies or suction disks. Scrapers are more common in the middle reaches of a watershed where sunlight is able to reach the stream bottom, and thus algae are able to grow.

Collectors depend on fine particles of organic matter. Filtering collectors are adapted for capturing these particles from flowing water. Some caddisfly larvae spin nets for this purpose. For example, black fly larvae attach themselves to the substrate and filter particles using sticky hair-like fans. Collectors tend to be common in all reaches, because fine particles are present in all stream types to some degree. However, they make up a greater proportion of the macroinvertebrate population in the lower reaches of a system where fine sediments tend to accumulate – where the habitat becomes unsuitable for shredders or scrapers.

Predators consume other macroinvertebrates; they have behavioral and anatomical adaptations for capturing prey. Many have extensible mouthparts or raptorial forelegs adapted for grasping prey, and strong opposable mouthparts for biting and chewing. Some predators pierce their prey and suck fluids with tube-like mouthparts. Predators are found in all habitat types. Because it takes many other macroinvertebrates to supply their food, predators are usually found in small proportions relative to other feeding types.

NOTES FOR INSTRUCTORS

The primary purpose of this activity is for students to develop the ability to perform a benthic macroinvertebrate analysis from two stream habitats by:

1. Performing sampling procedure properly.

2. Using a dichotomous key properly to divide invertebrates into their major groups.

3. Recording the number of taxa in each group on data sheet.

4. Determining feeding strategy of each taxa.

5. Calculating EPT Richness.

6. Making comparisons between results at different watershed sites.

This field exercise will require two lab times to complete. Sampling will be performed at two sites in the designated watershed, and results will be documented and compared.

STREAM MACROINVERTEBRATES

There are many different types of stream macroinvertebrates. Each type has a specific set of requirements, which the stream must provide for the organism to survive.

Stream macroinvertebrates differ in their type of development. Some, such as true flies, beetles and caddisflies, undergo a complete metamorphosis that includes four stages: egg, larvae, pupa and adult. Many of these organisms are aquatic in the egg and larval stages, but not in the adult stages. Incomplete metamorphosis has three stages: egg, nymph and adult. Organisms that undergo incomplete metamorphosis include stoneflies, mayflies, dragonflies and true bugs. Many of these organisms, such as dragonflies, do not live in an aquatic ecosystem as adults. Other species, such as true bugs, including the backswimmers, water scorpions and the water striders, are examples of macroinvertebrates that spend their entire lives in the water.

Alterations to the stream can have great impacts on the abundance and distribution of different macroinvertebrate types. Some are intolerant of pollution. Their presence in the stream, like a canary in a mineshaft, suggests healthy conditions. Yet some macroinvertebrates are quite tolerant of pollution. Taken together, the presence or absence of tolerant and intolerant types can indicate the overall health of the stream.

Many macroinvertebrates (especially those that are insects), tend to have short life cycles, usually one season or less in length. Most aquatic insects spend the greater part of their lives as larvae. It is this larval stage that we most frequently encounter in stream surveys. The length of the life cycle of a macroinvertebrate can vary from less than 2 weeks for some midges and mosquitoes to two years or longer for some stoneflies, dragonflies and dobsonflies. The larvae of some insects can remain in the water for more than a year, while others hatch into their adult forms after a shorter growth period. The whole duration of aquatic insect life cycles ranges from less than two weeks to four or five years, depending on the species. For any particular species, life cycle events can also vary, depending temperature, dissolved oxygen levels, day length, water availability, and other climatic and environmental conditions.

Macroinvertebrates are easy to collect and sampling equipment is fairly inexpensive. These organisms are generally easier to identify than algae, which also have pollution tolerant and intolerant groups.

Trophic relationships among macroinvertebrates change with location in the watershed. Some general characteristics of stream regions (reaches) follow:

Upper reaches

- Classified as first order and second order streams
- Very little sun to stream
- Plant material in the stream comes from outside the stream. Supports primary consumers

Middle reaches

- Riparian canopy no longer covers whole stream
- Some sunlight and photosynthetic algae grow forming part of food base. Composition of food base changes

Lower reaches

- Most of the water is un-shaded
- Turbidity often prevents sunlight from reaching the bottom
- Fine particles replace organic debris and algae as the food source for primary consumator

Ecosystem Management

INTRODUCTION

"Everything is connected to everything else in ecosystems; it is impossible to take only one action without causing a chain of other reactions."

Jerry F. Franklin, *Defining Sustainable Forestry*, 1993

Ecosystem management is management that is guided by the concept of the ecosystem. This means focusing on whole ecosystems rather than on single species or commercial products. Scientists have found that management for single commodities on a short-term basis (e.g., patch clearcutting and networks of roads) can lead to undesirable landscape dysfunction (i.e., erosion, sedimentation, and habitat loss). Thus, new approaches focus on planning at larger spatial and temporal scales and thinking about the collective effects of activities on the landscape.

Consider the forest ecosystem: it includes the organism complex of all biota (not just trees), and the physical environment that supports it. Ecosystem management does not mean management of all organisms in these communities, but rather the consideration of the effects management has on these communities and environments (e.g., harvesting timber, construct hiking trails, building roads, bridges, or structures).

Management Planning

A management plan that does not have an ecosystem focus will be different than one that has a more holistic emphasis. For example, it may focus on the products that can be harvested, rather than the processes that are occurring to ensure sustainable product harvest. We have the ability to manipulate ecosystems – we can, for example, manage landscapes to grow more wood, produce more water, or provide more edge for game species. But we also must understand that such alterations might produce large-scale and cumulative negative effects on other resource values (i.e., impacting the hydrological cycle or providing habitat for forest-dwelling organisms).

While traditional management has emphasized single species, commercial products, economic returns and human uses, ecosystem management focuses on:

- Holistic view
- Ecological viability
- Sensitivity to ecosystem integrity
- Economic feasibility
- Socially and politically acceptable goals
- Managing on time scales more appropriate for the ecosystem
- Diversity of resource uses and values of native plant and animal species
- Diverse land uses within the watershed
- Relationships among various forest conditions, natural events and processes, human uses of the forest, changing values of forests to people over time

OBJECTIVES

Upon successful completion of this exercise, students should be able to:

- identify ecosystems in a watershed
- recognize the interrelationships in these ecosystems
- identify the components of the watershed we value
- identify potential goals for a management plan
- list the different elements of a traditional management plan

PROCEDURE

A watershed is a functioning unit with interacting biological, physical, chemical and human components. It is a dynamic and unique place. If our goal is to manage the watershed, we need to first develop an understanding of it. The final result of this exercise is a report, which characterizes the watershed, details management goals and describes how these will be achieved.

Our resources for this exercise include a variety of maps of the watershed (e.g., soils, vegetative cover, topography) as well as, the watershed itself.

Form small groups to accomplish the following tasks:

1. Using available resources, characterize the watershed by listing or describing:
    - the different ecosystems that you recognize in the watershed.
    - the soils, wetlands, vegetation categories, waterways (including tributaries).
    - any zoning designations.
    - plant and animal associations.
    - current land uses in the watershed (create a Land Use Map of the watershed).
    - ownership of land within the watershed (private, public, tribal, etc.)

Is this watershed part of another larger one?

2. Visit your watershed to conduct a “ground truthing”. This is a vital step to check the validity of the information you have derived from maps.

3. Hypothesize about the interrelationships within and between the ecosystems you catalogued. What connects them?

4. If we could manage the watershed as a class, based on its special characteristics that we have researched, what goals would we as managers have for the watershed? In considering goals we need to consider the biological, chemical, physical and human components of the watershed. Brainstorm and list the goals your group has developed.

5. Create lists of potential “uses” for the various components of our watershed. Consider the following:
   - What values do we recognize there?
   - What characteristics are critical to maintaining watershed health?
   - Do we want the public to visit the watershed?
   - What experience do we want them to have?
   - What experience do they hope to have?

The following example of a forested watershed may help you get started. When looking at the forest elements in a watershed, consider the following as some potential “uses” or “goals”:

- forests can be considered a natural factory for many renewable resources (wood, water, medicinal plants and animals, foods and materials for shelter and clothing)
- forests hold soil, clean water, maintain atmospheric balances
- forests are playgrounds
- forests are sources of livelihood and personal identity
- forests are places for inspiration and communion with nature

6. Put together all of these elements (1-5) in a report, which covers the evaluation of the watershed, and management guidelines, based on ecosystems. Divide your report into sections, which describe the components of the watershed. In your report, describe the differences between a management plan encompassing all the elements above, and a management plan that focuses on a single resource.

NOTES FOR INSTRUCTORS

A field site (watershed) should be selected by the instructor that is close enough so that the students are able to visit several times. A combination of map-use and field verification is required to characterize a watershed. Partnering with a local resource agency that has Geographic Information Systems (GIS) layers of many of these characteristics (e.g. zoning, waterways, vegetation, etc.) would be invaluable.

MATERIALS

Maps of different physical and biological characteristics of a selected watershed
Field notebooks
Pencils

Watershed Research on the Internet

INTRODUCTION

There are many organizations that have been established to manage, protect or investigate watersheds. We are about to explore some of these, using the Internet, which provides easy access to these organizations.

The purpose of this activity is for students to survey information provided on these sites – with particular emphasis on watersheds and salmon. Government agencies, educational institutions, local environmental groups, and national organizations host the sites.

PROCEDURE

Working individually, visit each of the websites listed below and write a short report based on the questions below.

1. Northwest Indian Fisheries Commission www.nwifc.wa.gov/

   The Northwest Indian Fisheries Commission was created in 1974 by the treaty Indian tribes in western Washington as a result of the *U.S. v. Washington* litigation that affirmed fishing rights reserved by the tribes in treaties signed with the federal government in the 1850s.

   The commission's role is to assist the tribes in conducting biologically-sound fisheries practices and to provide member tribes with a single, unified voice on fisheries management and conservation issues. Member tribes are Nisqually, Squaxin Island, Puyallup, Jamestown S'Klallam, Port Gamble S'Klallam, Lower Elwha Klallam, Skokomish, Swinomish, Sauk-Suiattle, Upper Skagit, Tulalip, Makah, Stillaguamish, Muckleshoot, Suquamish, Nooksack, Lummi, Quinault and Quileute.

   Examine the structure and function of this commission, and describe the monitoring protocols that have been developed. Why is this monitoring being done?

2. International Rivers Network www.irn.org

   IRN supports local communities working to protect their rivers and watersheds. We work to halt destructive river development projects, and to encourage equitable and sustainable methods of meeting needs for water, energy and flood management.

   Determine the structure and purpose for this environmental action group. How might information help those interested in researching or getting involved in issues on local streams and watersheds?

3. The Nature Conservancy http://nature.org/

   The mission of The Nature Conservancy is to preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive.

   The Nature Conservancy, a nonprofit organization founded in 1951, is the world's largest private international conservation group. Working with communities, businesses and people like you, we protect millions of acres of valuable lands and waters worldwide.

   What are major goals and projects of TNC? What does this organization hope to achieve? Describe how the group is going about doing this, and how is this unique?

4. The Conservation Technology Information Center. www.ctic.purdue.edu

   We all live in a watershed. Watersheds are the places we call home, where we work and where we play. Everyone relies on water and other natural resources to exist. What you and others do on the land impacts the quality and quantity of water and our other natural resources.

   Managing the water and other natural resources is an effective and efficient way to sustain the local economy and environmental health. Scientists and leaders now recognize the best way to protect the vital natural resources is to understand and manage them on a watershed basis. Everything that is done in a watershed affects the watershed's system.

   Describe this organization's "Know Your Watershed" program. How is this site an excellent clearinghouse source of watershed information?

5. Visit the following sites and write a brief summary of the information that is available at these sites:

   • California's ERWIG/Watershed Times www.applecreek.com/erwig/home.html

Eel River Watershed Improvement Group (E.R.W.I.G.) is a newly-formed group of active community members who are interested in pulling together in order to restore and enhance salmonid habitat in the Eel River sub-basins. Our roots go back to 1985.

The primary goal of ERWIG is to provide organizational and technical assistance to landowners and managers - that they may organize and implement specific watershed action plans in their particular watersheds, from the ridgetops to the streams. Our efforts will help owners, managers, and restorationists positively address the needs of their specific sub-basins in the areas of project organization, fund-raising, implementation, and evaluation.

• EPA's Surf Your Watershed www.epa.gov/surf/

Surf Your Watershed contains databases and watershed groups from around the nation. You can search for a group in your area either by state, zip code, group name, keywords or even stream name. Currently over 3000 groups are indexed. Sites and groups are voluntarily submitted.

• EPA's Watershed Tools Directory www.epa.gov/OWOW/watershed/tools

This Watershed Tools Directory describes several hundred methods, models, data sources and other approaches that states and communities can use in managing watersheds to improve or maintain water quality for human health and ecological purposes. The Directory was prepared under the guidance of the Environmental Protection Agency's (EPA) Assistant Administrator for Water to promote the Watershed Approach by facilitating the exchange of information on technical protection measures.

• U.S. Geological Survey: Water Resources of the USA http://water.usgs.gov/

Compiled by the USGS Geologic Inquiries Group with links to frequently asked questions about pesticides and mine drainage, general interest publications on acid rain and radon, publications for educators and much more! Maps of the major aquifers in the Nation and introductory information on groundwater. Includes USGS fact sheets with information about natural resources, hazards, environment and information management.

• Oregon Sea Grant http://seagrant.oregonstate.edu/links/salmsites.html

Includes Oregon State University Sea Grant and comprehensive salmon sites, such as BC Salmon Page, a comprehensive and well-organized set of links to salmon pages, mostly British Columbia-related; StreamNet, the Northwest Aquatic Resource Information Network, which is a collaborative effort among NW fish and wildlife agencies and tribes; and Watershed Education Resources on the Internet, which includes a large selection of links compiled by the Global Rivers Environmental Education Network (GREEN)

NOTES FOR INSTRUCTORS

This activity is designed to familiarize students with watershed-related information that is available on the Internet. Students should be able to use a computer to search the Internet, summarize pertinent information from Internet sites and find links to additional sites for associated information.

A Community Profile – Line Intercept Technique

INTRODUCTION

Quantitative methods are commonly used in the field to evaluate vegetative cover. The objective of this exercise is to determine species composition in a given habitat. A **line intercept method** is used in which plants lying on a straight line cutting across the community are counted and recorded. This is a time-efficient method of quantifying plant cover when setting up individual plots may be too time consuming.

PROCEDURE

1. Form groups of 3-4 students
2. Locate two randomly selected points in the community to be studied
3. Extend the transect between the two points marked. This is your sampling line.
4. Mark off one-meter intervals on the line. Each interval will be treated as a separate sampling unit along the transect.
5. Begin counting at one end of the line, and record all plants that are within 1 cm of the line for each interval. Plants whose aerial foliage overlies the transect are also included. Every plant must be identified and counted.

6. In this method of plant sampling known as line-intercept sampling, the measurement of intercept length is used to estimate coverage. This length is that portion of the transect length intercepted by the plant measured at or near the base of the plant, or by a perpendicular projection of its foliage intercepted by the line (Figure 1).

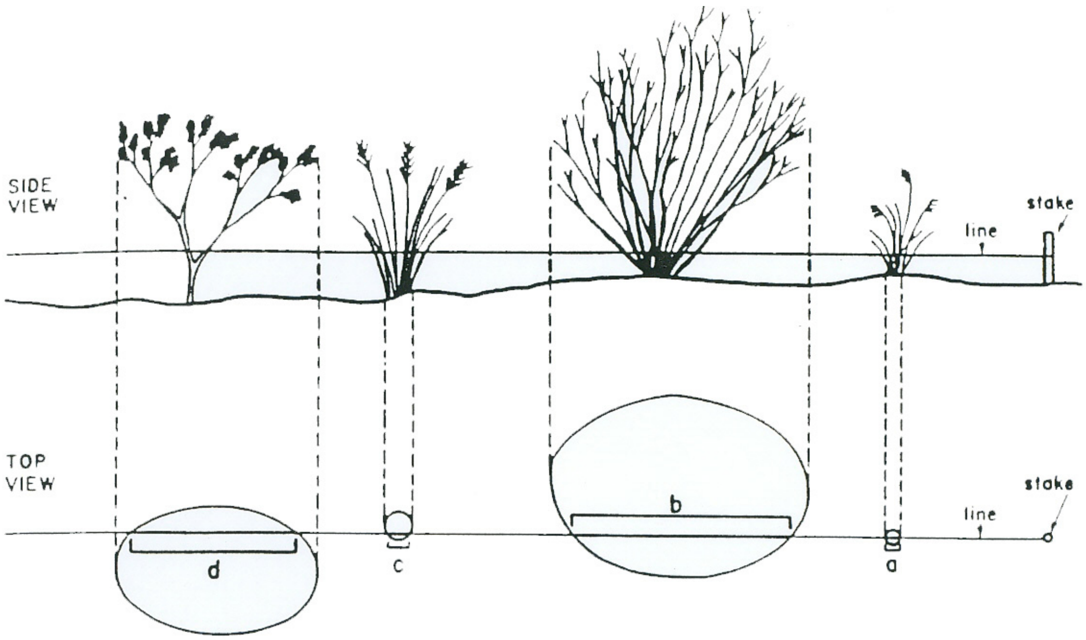


Figure 1. The intercept length (brackets) is that portion of a line intercepted by a plant (or clump of plants, as the basal intercept length for plants a and c) or by a perpendicular projection of the foliage to the line (as the aerial intercept length for plants b and d).

7. For each plant counted, measure the intercept length and record the values on Data Sheet 1.

8. When sampling is complete data should be summarized on Data Sheet 2.

9. Use Data sheet 3 to determine the following quantities:

Linear density index

$$\text{Linear Density Index (ID)} = \frac{\text{Total number of individuals of particular species}}{\text{Total length of all transects sampled}}$$

Relative density

$$\text{Relative density (RD)} = \frac{\text{Total number of individuals of a particular species}}{\text{Total number of individuals counted for all species}}$$

Linear coverage index (for each species)

$$\text{Linear Coverage Index (IC)} = \frac{\text{Sum of the intercept lengths for particular species}}{\text{Total length of all transects sampled}}$$

Relative coverage of species

$$\text{Relative Coverage of Species (RC)} = \frac{\text{Sum of the intercept lengths for a particular species}}{\text{Sum of the intercept lengths for all species}}$$

Frequency of species

$$\text{Frequency of Species (F)} = \frac{\text{Number of line intercept intervals containing a particular species}}{\text{Total number of intervals on the transects}}$$

Relative frequency of species

$$\text{Relative Frequency of Species (RF)} = \frac{\text{Frequency of a particular species}}{\text{Sum of the frequencies of all species}}$$

Importance Value

$$\text{Importance Value} = \text{RD} + \text{RC} + \text{RF}$$

Data Sheet #1 - Tabulation of Raw Data from Line-Intercept Plant Sampling

Date ____________ Observers: ____

Habitat: ______________________________ Location: ______________________________

Transect Identification ______________________________ Length of Transect: ______________________

Plant Number	Species:	Species:	Species:	Species:	Species:
	Intercept length (1)	Intercept length (1)	Intercept length (1)	Intercept length (1)	Intercept length (1)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Data Sheet #2 - Summary of Data from Line-Intercept Plant Sampling

Date: ____________ Observers: ____

Habitat: _________________________________ Location: __________________________________

Species (i)	Unit *	Intercept Interval										Total for Species
		1	2	3	4	5	6	7	8	9	10	

Data Sheet #3 - Class Summary of Data from Line-Intercept Plant Sampling

Date: ____________ Observers: ______________________________

Habitat: ______________________ Location: ______________________

Total Transect Length (L) ______________ Total Number of Transect Intervals ______________

Species (i)	Number of individuals (n_i)	Linear Density Index (ID_i)	Relative density (RD_i)	Present in how many transect intervals? (j_i)	Frequency (f_i)	Relative frequency (Rf_i)	Intercept length (I_i)	Linear coverage index (IC_i)	Relative coverage (RC_i)	Impor-tance Value (IV_i)
Totals	$\sum n =$	$\sum RD =$	$\sum RD = 1.0$		$\sum f =$	$\sum Rf = 1.0$	$\sum I =$	$\sum IC =$	$\sum RC = 1.0$	

NOTES FOR INSTRUCTORS

Students should be familiar with the following concepts before field sampling begins:

Density

Most studies of populations begin with an estimate of the **abundance** or the number of individuals of a particular species in a given area. **Density** is the number of individuals in a given area, expressed as “number per unit area” or, for aquatic species, “number per unit volume”.

$$\text{Density (D)} = \frac{\text{Total number of individuals counted of species in question}}{\text{Total length of all transects sampled}}$$

Relative Density is the number of individuals of a given species as a proportion of the total number of individuals of *all* species.

$$\text{Relative Density (RD)} = \frac{\text{Total numbers of individuals of species in question sampled}}{\text{Total numbers of individuals counted for all species}}$$

For example:

If there are 50 trees in a given area and 30 of them are sugar maple, then the relative density of sugar maple is 30/50.

Frequency

Frequency is the number of times a given event occurs. In our study, frequency indicates the number of samples in which a particular species occurs. This is expressed as the proportion of the total number of samples taken that contains the species in question.

For example:

If a species were found in 7 out of 10 samples, it would have a frequency of 7/10.

$$\text{Frequency} = \frac{\text{Number of intervals in which a species occurs}}{\text{Total number of intervals sampled}}$$

Relative frequency of a species is the frequency of that species divided by the sum of the frequencies of *all* species in the community. Relative frequencies can be considered to be the chance of finding a given species in a sample as a proportion of the total of the frequencies for all species.

$$\text{Relative frequency (Rf)} = \frac{\text{Frequency of a species}}{\text{Sum of frequencies for all species}}$$

Coverage

Coverage is the proportion of the ground occupied by a perpendicular projection to the ground from the outline of the aerial parts of the plants being sampled. You can visualize this as expressing the proportion of ground covered by the species, as the habitat is viewed from above. Coverage is in general calculated as the area covered by the species divided by the total area.

$$\text{Coverage (C)} = \frac{\text{Sum of intercept lengths for species in question}}{\text{Total length of all transects sampled}}$$

Relative Coverage is the proportion of a certain species coverage (intercept length) compared to that of all species in the community.

$$\text{Relative Coverage (RC)} = \frac{\text{Sum of the intercept lengths for the species in question}}{\text{Sum of the intercept lengths for all species}}$$

Importance Value

The **importance value** gives an overall estimate of the influence or importance of a plant species in the community. This measure takes into account all three of the previous parameters:

$$\text{Importance Value} = \text{Relative Density} + \text{Relative Frequency} + \text{Relative Coverage}$$

$$IV = RD + Rf + RC$$

Some considerations on sampling

Quantitative assessments of ecosystems usually require the measurement of certain parameters that are used to describe the dominant plant communities. Measurements of “density”, “frequency” and “coverage” are among the most frequently used. Although it is seldom possible to count every individual in a population, a representative portion, or **sample**, of the entire population can be measured. Inferences about the whole population can then be made from this sample. It is important to recognize that when a sample is used to make inferences about entire populations, some error is to be expected.

In the line-intercept method, for example, the probability of being sampled is dependent on the size of the plant. A large rare plant is more likely to be detected than a small rare plant. Large dense species will appear more frequently than small dense species.

Frequency is dependent on the length of the transect line. If the transect is very long, you might find all the species in every transect. If the transect line is too short, then the same species will seldom be encountered in more than one transect.

MATERIALS

Tape measure
Plant identification book
Data sheets

Stream Monitoring Protocols

The following watershed ecosystem activities ("Stream Segment Identification" and "Reference Point Establishment") are based on a series of monitoring protocols developed by the Northwest Indian Fisheries Commission (NWIFC). These protocols are designed to evaluate salmon habitat in the Pacific Northwest and are based on the Timber, Fish and Wildlife Monitoring Program for the state of Washington. The program is a cooperative, inter-agency effort initiated in 1989 to fill the need for monitoring information. It focuses on assessing and monitoring habitat conditions in salmon-bearing streams on state and private forest land in Washington State, and evaluating the effectiveness of forest practices in meeting habitat and water quality goals.

The two activities described here are included as examples of these protocols. Additional protocols include "Habitat Unit Surveys", "Large Woody Debris Surveys", "Stream Discharge Surveys" and "Stream Reach Surveys" and are available in the manual (cited below) or at the NWIFC website (www.nwifc.wa.gov).

These activities focus on the assessment and monitoring of watershed ecosystems. Students learn the purposes and roles of monitoring and assessment, qualitative and quantitative criteria and methodologies of assessment. Students then use these data to assess stream channel and habitat conditions, to examine the impacts of upland practices on these habitats, and to estimate salmonid habitat carrying capacity and limiting factors. The importance of a study design that defines clear objectives and selects appropriate parameters for measurement is emphasized. Students compare data collection methods for accuracy, consistency, and repeatability; and analyze raw data to determine trends over time. Students compare and critique current methodologies for data collection in an effort to minimize bias and sampling variability.

REFERENCE

Pleus, A.E. and D. Schuett-Hames. 1998. TFW Monitoring Program method manual for stream segment identification. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-98-001. DNR #103. May.

Manuals are available by contacting:

Northwest Indian Fisheries Commission
TFW Monitoring Program
6730 Martin Way E.
Olympia, WA 98506
(360) 438-1180

OR

Washington Department of Natural Resources
Forest Practices Division - CMER Documents
(360)902-1400

Stream Segment Identification

INTRODUCTION

Stream segmenting is the first step in a monitoring exercise. It organizes and stratifies stream systems, according to certain criteria (flow rate/tributaries, gradient and confinement), effectively making a filing system for the watershed. It provides us a way to break up the landscape into similar areas, for certain types of habitat.

PROCEDURE

Teams of 2 to 4 students should work together on the following activities in the laboratory or classroom.

Tributary Confluences

1. Identify the watershed in which the stream survey will take place.

    - Obtain the appropriate USGS 7.5 minute topographical maps for survey area.
    - Obtain a working map copy and label this map as “Tributary Confluences”.
    - Identify location of target stream.
    - Delineate surrounding watershed of interest and indicate boundaries with colored pencil line.

2. Determine the stream order of all stream channels in the watershed using the Strahler Method (described below).

    - Mark with a number 1 on the map with colored pencil all small headwater streams which have no tributaries (the first order streams).
    - Mark with a number 2 on the map with colored pencil where 2 first order streams meet the second order streams).
    - Mark with a number 3 on the map where 2 second order streams join (the third order streams).

3. Note all tributary junctions where the stream order is the same, or the next smaller order, as the main channel. Mark these on the map.

    - Review labeled streams in watershed for labeled stream order.
    - Mark with colored pencil the appropriate junctions after differentiating between orders of streams.

4. Note all smaller tributary junctions where there may be changes in factors such as sediment load, channel width or channel morphology

   • Review available materials for information regarding sediment load, channel width and morphology.
   • Mark on the map where these situations occur.

Stream Gradient

1. Highlight the stream channel of focus and indicate with a colored pencil where each contour line crosses the main stream channel.

   • Obtain working map copy and label as "Stream Gradient".
   • Locate main stream channel.
   • Highlight main stream channel.
   • Identify contour lines.
   • Determine contour interval.
   • Mark with colored pencil all intersections of contour lines and main stream.

2. Determine the gradient of the stream segments by dividing the difference in elevation between the contour lines (rise) by the stream channel distance between those contour lines (run).

   • Identify contour interval.
   • Measure channel distance between contour line-stream channel intersections by map wheel or template.
   • Divide elevation difference (one contour interval) by channel distance within this contour interval (the rise over run calculation).

3. Mark the percentage gradient and labels the boundaries between the gradient categories on the topographical map.

   • Calculate rise over run as a percentage elevation gradient.
   • Mark in colored pencil on map the percentage gradient within each contour interval-stream channel intersection.

Channel Confinement

1. Estimate channel confinement (the ratio between the width of the valley floodplain and the bankfull channel width) based on interpretation of the relevant topographical map, and personal knowledge of the river system and surrounding landscape.

   • Obtain working map copy and label as "Channel Confinement."
   • Identify contour lines.

- Determine contour interval.
- Examine contour lines running parallel or near parallel to the main stream that indicate elevation increases near stream.
- Estimate and compare proximity of contour lines to each other and to the main stream.
- Knows criteria for levels of confinement (unconfined, moderately confined and confined).
- Designate levels of confinement along the main stream according to topographic features indicated by contour line proximity.
- Label as one of the three categories: unconfined, moderately confined and confined.

2. Mark and label on the map the estimated break-points between the channel confinement categories (unconfined, moderately confined and confined).

   - Review categories of confinement and designates boundaries between each of the categories (where one type ends and another begins).
   - Mark these boundaries with colored pencil.

Synthesis

Examine and compare category breaks for all criteria combined. Mark in final stream segments based on the type of functional habitat each area provides.

- Obtain working map copy and labels as "Final Segments"
- Review tributary confluence break-points.
- Review stream gradient break-points.
- Review channel confinement break-points.
- Discuss with team members the type of functional habitat on the main stream according to the information in these categories.
- Lump or split marked areas to create areas of expected similar habitat type according to the categories under consideration.
- Mark final segment breaks.
- Label segments sequentially from 1 (1 being the furthermost downstream segment).

LAB PRODUCT

After you have completed the activity, answer the following questions:

1. Describe the Strahler Method of stream stratification.
2. Why do we subdivide stream habitat according to the number of tributaries? Describe the effect of additional tributaries on the stream.
3. What does a contour line illustrate?
4. Where is the highest gradient of a stream – at the headwaters or near the mouth?
5. Describe in your own words and demonstrate on a map how you determine confinement of a stream.
6. What is the formula for determining gradient?

REFERENCE

Schuett, D., Pleus, A., Bullchild, L., and S. Hall. 1994. Timber-Fish-Wildlife (TFW) Ambient Monitoring Program (AMP) Manual

MATERIALS

USGS 7.5-minute maps
Photocopied maps for use as working copies
Colored pencils
Map wheel

NOTES FOR INSTRUCTORS

To conduct this exercise with different streams, copy watersheds from different 7.5-minute USGS maps and have small groups of students go through the exercise on different maps. This exercise works particularly well in groups when students can collectively discuss the decisions they are making.

Instructors may find the information on the following pages useful to introduce students to aerial photographs and topographic maps.

An Introduction to Aerial Photos and Topographic Maps

In addition to on-the-ground measurements and analysis, the evaluation of watersheds often requires the examination of images obtained through **remote sensing** in which information is obtained about an object or phenomenon without physical contact. Aerial photographs and satellite images are examples. Since aerial photography has been used since the 1930s, these photos can be used to assess land use changes such as deforestation, urban sprawl and farm encroachment in a watershed over time. Remote sensing has tremendous advantages over on-the-ground data collection. Simple interpretation of aerial photos is quite cost-effective and reduces time required for data collection using ground-based surveys.

Aerial Photographs

Aerial photos are pictures of the earth taken from airplanes. They are normally taken in a sequence, which results in about 60% overlap of the image in successive frames. The view is straight down at the very center of each picture, but all other portions of the landscape are viewed at an angle that is increasingly oblique away from the center of the picture. The **scale** of the photographic image is not uniform – it differs with the distance of the camera lens from the ground. Thus, in photos of flat terrain, the scale is largest at the center of the photo, where the ground is closest to the camera lens, and decreases away from the camera. Also, hilltops and other high points, which are closer to the camera lens, are shown at larger scales than are valley bottoms and other low places, which are farther away from the lens.

The following characteristics are commonly used to identify features in aerial photos:

Shadows
Most aerial photos are shot within two hours of solar noon. Shadows may aid in identification.

Texture
Texture is the function of the size of objects photographed and the scale of the aerial photo. For example, on a large-scale photo (1:2,800), individual tree crowns may be recognized; on a smaller scale (1:24,000), the tree crowns are so small that only a textured appearance results. Also, pasture or farmland presents a smoother texture than rangeland, and these discernable differences appear among other features.

Site Association
Natural and man-made features generally occur in certain locations or near other objects. In nature for example, cottonwoods and willow trees are natural occurrences along flood plains or river sandbars. And in urban landscapes, whereas shopping malls would be located or near major highways, schools are generally located away from main traffic arteries.

Shape

Because we are generally not familiar with a vertical viewpoint (e.g., looking down on objects), the direction of a view often makes the identity of an object difficult to judge. Getting around this includes gaining experience in interpreting aerial photography, and some rules of thumb such as manmade items tending to have straight linear shapes, whereas natural features are more irregularly shaped.

Other

Topographical maps often include features that aid the aerial photo interpreter (e.g., populated areas, power lines, roads, vegetation cover, and topography). Other specialty maps may aid in identifying county roads, soils, stream classification, and other landmarks.

Topographical maps

Topographical maps portray the shape and elevation of the terrain. The most commonly used topographical map series in the U.S. is the 7.5-minute series topographic quadrangles produced by the U.S. Geological Survey (USGS) through its national mapping program. These maps use contour lines to display topographic information.

- Any point on a contour line is located at the same elevation as all the other points on the line
- Contours never cross, divide, or merge
- When a topographic contour crosses a stream, the contour lines produce a "V" that points up stream

Mapping symbols shown on quadrangle maps are divided into a few major categories, each printed in a different color. Generally, colors include:

- Brown = relief information
- Blue = water features
- Black = man-made or cultural symbols
- Green = woodland, grassland
- Red = public land subdivisions, built up areas, and important roads

On a topographic quadrangle map, several items around the margin are related to the description of that particular map. Cardinal directions are presented in a small diagram, and they show the relationships between True North (the location of the North Pole) and Magnetic North (about 1400 miles south of true north).

In the field, directions are measured with a magnetic compass. A compass rosette has 8 point bearings which can be divided into: North (N), South (S), East (E), West (W), Northeast (NE), Southeast (SE), Southwest (SW), Northwest (NW). Eight additional points may be described as intermediates between each of these (e.g., NNE, between N and NE).

Bearings are angles of 90-degree increments measured from either N or S reference directions toward the E or W. An example of a bearing in the NE quadrant would be: N150E. Bearing measurements are never greater than 90°; and "90°" would not generally be used. For example, a bearing of N90°E would simply be "due East" and similarly, a bearing of S90°W would be "due West.".

Azimuths are angles from 0 to 360 degrees measured in a clockwise direction from North. They are an alternative to bearings as a description of direction and are becoming more commonly used than bearings. An azimuth of 182°, for example, would be equivalent to a bearing of S20W. Since only an angle between 0° and 360° is needed to convey an azimuth, it is a simpler value.

Compass declination is the variation between true north and magnetic north; declination is shown in the margins of a topographic. In the U.S., true north and magnetic north are the same only along a line that runs from Florida, through Lake Michigan, and on to the magnetic north pole, which is north of Hudson Bay in Canada.

For any location east of this line, the compass needle points west of the true North Pole location. West of this line, the compass needle points east of the true north line. The angle between the direction the needle points and true north line is called the **magnetic declination**. It varies between 20° West in Northern New England, to 30° East in parts of Alaska. This declination becomes important in the directions you travel in the field. Each degree off from true north results in an error of about 1/60 of the direction traveled. If the declination is 15 degrees W, after traveling 3000 ft you will be 50 ft off for every degree of declination; in this case, 750 feet (50 ft. X 150).

Thus, direction angles taken on a magnetic compass are magnetic angles, and must be converted to true angles by correcting for magnetic declination. Many compasses automatically correct for declination.

A good rule of thumb to correct a compass reading for declination:

If the magnetic declination is West, you must add to the compass reading. If the declination is East, you must subtract from the reading. For example, if the declination is 20°E, with a compass reading of 270°, true north is determined by subtracting 20° from 270°, resulting in a corrected reading of 250°.

The **map scale** is the relation between the size of the map and the size of the piece of ground it portrays. The scale of a map or aerial photo can be expressed in several different ways.

- Scale ratio – 1:20,000
- Fractional scale – 1/20,000
- Equivalent or descriptive scale (i.e., 1 inch = 1,667 feet)

Topographic maps are divided into 6 x 6 mile squares called **townships** by the U.S. Public Land Survey (Rectangular Survey System). Each township is bounded by intersecting township and range lines, which are lines surveyed north-south and east-west at 6-mile intervals.

Townships are further subdivided into one-mile square **sections**, which are numbered consecutively. Sections are further divided into **half sections**, **quarter sections** and **quarter-quarter sections** (which are "forties" of 40-acres each). An example of a legal description for a land parcel using this system:

The "forty in the northwest corner of section 15" could be described as the "NW ¼ NW ¼ S15, T3N, R2W".

Reference Point Establishment

INTRODUCTION

Reference points are a series of permanently marked points established along the edge of the stream channel under study. Reference points translate stream segments into survey reaches in the field. They break up a segment as defined on the map into discrete survey reaches – each of 100 meters. These points are fixed locations, and provide a systematic sampling layout from which habitat characteristics can be measured. Permanent photo points are established here, and bank full width and depth, and canopy closure are also measured from these points.

When measurements are repeated at regular time intervals, changes over time can be documented. Use of reference points also allows sorting of habitat unit and large woody debris data by 100-meter reaches, providing a convenient means of examining variability within stream reaches and a framework for sub-sampling during repeated surveys.

PROCEDURE

Form teams of two to three students.

1. Locate the boundary of a stream segment using information from the map produced during the stream segment identification. If necessary, adjust the boundary to correspond with actual field conditions (marking any changes on the stream segment identification map).

2. Establish the first reference point at the downstream boundary of the stream segment, assigning it reference point of zero.

3. Using a hip chain to measure distance, lay out and number reference points at 100-meter intervals along the center of the bank full channel. Number each point consecutively (0,1,2,3...) until the last point is within 100 meters of the segment boundary.

4. Begin the reference point numbering sequence at the boundary of each successive segment, beginning with the last reference point of the previous segment. This last reference point will have two numbers to reflect the two segment boundaries.

5. Locate a permanent reference point marker at least 3 meters outside the edge of the stream bank at a 90-degree angle from the centerline. This will reduce the possibility of washout or burying by floods and bank erosion.

Stop at 100-meter intervals within a segment to establish a new reference point. Examine the bank area for an appropriate location to attach a permanent marker. Describe in your notes any physical features at this point that may assist you in subsequently finding the location of markers.

6. Permanently mark reference points by either nailing a tag into a tree, pounding a "rebar" rod into the ground and attaching a tag, or affixing a tag to a bedrock canyon wall with masonry nails. Record the type of marker used at each location on your survey form.

7. Identify the program (e.g., "TFW Ambient Monitoring"), the stream segment, and the reference point number on each tag.

Ensure that all necessary information is included at each permanent reference point.

To further ensure the accuracy of each location, take photographs at each reference point from the center of the channel, first looking upstream then downstream. Use the first frame of each roll to photograph a sheet of paper indicating the roll number, segment, date, and survey crew.

Determination of bank full channel width and depth

1. Identify the edges of the bank full channel using these three indicators: floodplain level, bank shape, and changes in vegetation. Temporarily mark edges of bank full channel with flagging.
2. Measure bank full width by anchoring a fiberglass tape at one boundary of the bank full channel and extending it across the channel to the other boundary, keeping tape taut for accurate measurement.
3. Measure the bank full depth by taking vertical measurements with a stadia rod from the tape stretched horizontally between the bank full boundaries to the stream channel bed, at 0.5 meter intervals in channels less than 5 meters in width, at 1 meter intervals in channel between 5 and 15 meters in width, at 2 meter intervals in channels greater than 15 meters.

Answer the following questions:

1. Describe the definition and significance of bank full.
2. What is the difference between bank full and high flow?
3. Describe how you recognize bank full channel indicators.
4. Describe in your own words the default method for determining bank full.

MATERIALS

Hip chain
Fiberglass tape measures
Stadia rod
Densiometer
Steel rods
Nails
Rock nails
Flagging
Hammer
Tags
Camera
Film
Reference Point Survey Forms

REFERENCE

Schuett, D., A. Pleus, L. Bullchild, and S. Hall. 1994. Timber-Fish-Wildlife (TFW) Ambient Monitoring Program (AMP) Manual

NOTES FOR INSTRUCTORS

Students may find it helpful to create their own individualized "memory sheets" to recall details of the reference point protocol such as the list of bank full indicators or measurements that must be taken at the beginning of each 100-meter stream reach. These can be reduced on a photocopier and then laminated to take out into the field. It is worthwhile for the students to go through the entire exercise and take all the photos required. The photos are an important part of the protocol and good photos are unique referencing aids for labeling the location and describing it physically – which otherwise can be surprisingly difficult.

Instructors may find the information on the following pages useful to introduce students to the salmon life cycle and salmon stream characteristics.

Pacific Salmon and Stream Characteristics

Salmon spawning runs begin far out to sea, and the precision with which salmon are able to locate and reach their home stream is often puzzling to scientists. Swimming upstream, upon arrival at their spawning river, a salmon stock will continue to move quickly upstream. Once at their ancestral (original) spawning gravels, females search for suitable egg-laying territories called **redds**. Each species of salmon shows different preferences for optimum spawning habitat. This ensures that available habitat is used efficiently and a minimum of competition exists.

One of the best ways to determine the health of an ecosystem is to examine the life it supports. In Pacific Northwest streams two major groups of animals are used as indicators of stream health: aquatic invertebrates and fish – both are negatively affected by degraded ecosystems. Biologists sample either or both groups to monitor stream health.

Salmon in freshwater face a variety of hazards created largely by human activity. These include improperly designed culverts that can block migration, loss of fry-rearing habitat (clean spawning and rearing gravels), poor water quality, reduced summer flows, high water temperatures, and reduced populations of stream invertebrates (food sources).

Most salmon biologists believe loss of healthy habitat is the primary threat to Pacific salmon. This explains why the species that need freshwater rearing time (coho, chinook, sockeye) are most commonly listed as "threatened" or "endangered" in most of or parts of their range. Degraded habitat also affects the macroinvertebrate community.

Stream Characteristics

Chemistry

The proper chemical balance is crucial to salmon survival in a dynamic stream environment. Salmon require highly oxygenated water – a condition that varies dramatically with flow rates, water temperature and biological activity – and water with a neutral pH, nether acidic nor basic. Phosphate and nitrate concentrations in water affect the entire food web – these compounds cause algae and other plant life to bloom rapidly, setting off a chain of events harmful to salmon as decomposing organic material consumes oxygen. Also, many salmon-bearing streams are particularly vulnerable to storm-water run-off that has collected petroleum and heavy metals from parking lots and highways.

Water temperature

Water temperature affects the rate of growth and development of aquatic organisms. All cold-water fish stop growing at temperatures above 68.5°F. The preferred temperature range for all salmonids is 45-55°F. Upper lethal limits are between 73.4 and 78.4°F.

Salmon species that rear in freshwater during summer months (mainly coho and sea run trout) are susceptible to high water temperatures. Ideal water temp for fry is 45-55ºF. Temperatures above this range have several negative effects on fry health. Higher water temps result in less dissolved oxygen in the stream, reducing the oxygen that is available to the fish and to the macroinvertebrates that are food to the fry. Increased temperature can also increase a young fish's metabolism, causing an increased demand for both oxygen and food. Warm temperatures can also increase susceptibility to disease, and decrease the ability for the juvenile fish to compete for food and avoid predation.

During summer months, deep pools are important as places of refuge when surface temperatures rise. Individual downed logs, undercut banks, and logjams provide shade, and pools created provide cooler water (which naturally sinks).

Turbidity

Turbidity is the measure of water's clarity, or the amount of silt or debris suspended in the water – the greater the turbidity, the "murkier" the water. Turbidity increases as a result of suspended solids in the water that reduce the transmission of light. Suspended solids are varied, ranging from clay, silt, and plankton, to industrial wastes and sewage. At higher levels of turbidity, water loses its ability to support a diversity of aquatic organisms. Water becomes warmer as suspended particles absorb heat from sunlight, causing oxygen levels to fall, as warm water holds less oxygen than colder water. Increased turbidity also decreases total amount of light entering the stream, decreasing photosynthesis of aquatic plants and decreasing oxygen levels – which reduces populations of invertebrates (which feed on plant material). High levels of turbidity may indicate erosion, which greatly impacts stream ecology (roads are often a problem). Along with decreased light and increased temperatures, excessive silt from erosion limits oxygen flow to eggs and salmon fry.

Canopy Cover

The amount of overhead vegetative cover, or canopy, is an important aspect of stream health. In healthy ecosystems, trees shade water from direct sunlight. Where streamside vegetation has been removed or trampled by livestock, water is exposed to direct sunlight, increasing temperature. Canopy also provides nutrients and detritus to the stream in the form of falling leaves and woody debris.

Streamside canopy vegetation also affects the density of insects, the main prey of juvenile salmonids. Also, terrestrial insects enter streams by falling off vegetation. These insects are another important component of the prey base of juvenile salmonids. Thus, reduced or absent canopy can negatively impact both macroinvertebrate and fish populations.

Substrate

Substrate is the material within a streambed. Materials in a river bottom that compose substrate can be bedrock, rocks, gravel, sand, or silt – composition is determined in part by velocity of the stream current and by the underlying geology of the area. Stream gradient and substrate work together to create the substrate at any particular point in a stream. Streams with steeper gradients move water faster, and thus smaller particles from the streambed are washed away downstream.

Healthy salmon habitat generally includes a mixture of substrate sizes, but spawning beds require greater percentages of larger-sized gravels and rocks. Salmon eggs and alevin also need a stable streambed and an adequate supply of water while developing to prevent dehydration, supply oxygen, and carry away metabolic waste. Fine sediment that lodges in the spaces between gravel can slow the rate of water flow, often resulting in oxygen deprivation and the accumulation of toxic metabolic by-products.

Structure

For salmon, the quality of stream habitat is closely related to its structure – the number and arrangement of pools, riffles, side channels and barriers. Pools and riffles are a result of the flow regimes of a stream, substrate composition, channel dimensions, shape, profile and pattern. Changes in land use practices that alter channel processes can subsequently change the pool and riffle environment in the stream.

Pools offer deep water, shade, and protective cover from logs or boulders and reduced current. In pools, fish can find eddies and counter currents that enable them to hold a position facing upstream while minimizing their energy expenditure, conserving energy as they feed. Studies of coho salmon, for example, have shown that their abundance in forest streams is directly related to the presence and volume of pools. Additionally, riffles act as factories for aquatic insects and important sources of oxygen (i.e., mayfly and stonefly nymphs thrive in the rocks in riffles). And side channels, meanders and accessible over-wintering ponds are crucial to juveniles as rich feeding habitat, and as refuges during peak flooding.

Overall, the type and amount of different stream habitats (i.e., pools and riffles) can be used as indicators of a stream's suitability for a particular species or life history stage of salmon.

Large Woody Debris

NOTE: Many watershed scientists prefer the term "Large Downed Wood" due to the somewhat negative connotation of the term "debris" for such a critical ecosystem component. Although this newer terminology is gaining acceptance, "Large Woody Debris" is used here because the TFW protocols use the older terminology.

Large woody debris (LWD) plays an integral role in the formation of stream channel morphology and fish habitat. Channel morphology is affected in several ways – pools often form in association with LWD, due to adjacent scouring or impounding of water behind channel-spanning pieces. These are safe resting places for adult salmon, home for invertebrates that are food for fry, and particularly beneficial for over-wintering salmon. Large woody debris can protect exposed banks from erosion, trap and store sediment, and it has a moderating effect on sediment-transport rates. Large woody debris also retains spawning gravel in high-energy channels.

Habitat Access and Off Channel Habitat

Aquatic species require upstream and downstream access at different stages in their life history. Barriers prevent fish from accessing portions of the stream – a single barrier can cut off miles of productive habitat (i.e., a road culvert, or on a larger scale, a dam). Salmon require off-channel rearing habitat available to them that provides sufficient food sources and enables them to escape from high flows.

Flow

Flow is the volume of water passing a certain point. Flow characteristics of a stream can affect other habitat characteristics – which can, in turn, become limiting factors for salmonids. Low flows make riffles impassable. They can also cause fatally high water temps and leave fry stranded in pools that will dry up. Inadequate water flow is one of the major threats to salmon runs throughout much of their range. On the other hand, high flows can erode spawning beds, flushing eggs out of the gravel and temporarily eliminate aquatic insects from the stream. Very high flows can cause problems in terms of erosion and sediment movement.

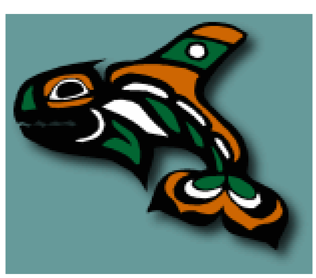
Intact forest ecosystems are highly absorbent, acting like a sponge, absorbing rainfall and surface water. In the western Pacific Northwest, winter rainfall is common, and forests provide cover and rooting that prevent erosion; conversely in this region, during droughty summer months, these natural "sponges" slowly release accumulated winter water back into the system, providing year-round stream flows. With increasing human development, cities and municipal areas reduce plant cover, and non-absorbent areas like streets do not retain water during the winter; water drains directly into streams – causing short-lived high flows, and very low summer flows, adding to pollution problems.

American Indian Perspectives on Salmon

Instructors with an interest in providing students with American-Indian perspectives on stream and fish monitoring efforts of tribes are encouraged to visit the Northwest Indian Fisheries Commission (NWIFC) website (www.nwifc.wa.gov). In addition, the materials on the following pages were developed by NCSR tribal partners and other sources. They are reprinted here with permission.

The NWIFC may also be contacted at:

Northwest Indian Fisheries Commission
6730 Martin Way E.
Olympia, WA 98506
(360) 438-1180



A Letter from Billy Frank, Jr., Chairman, Northwest Indian Fisheries Commission

People need to slow down, and look ahead. While such an approach to life may seem efficient for now, the truth is that it can be wasteful. Many of these drivers end up smacking into other cars and cutting their commutes short in the blink of an eye. More to the point, they don't slow down long enough to enjoy the beauty of the life they've been given. For far too many people, contemporary society is depicted by the man who eats his fast-food breakfast, makes business calls, reads the morning paper, listens to talk radio and shaves his whiskers—as he speedily drives his routine commute to the office.

This commuter depiction can apply to a contemporary farmer as easily as it can to an accountant or even a politician. We are all commuters at least in the sense that we are all traveling from the past to the future, between generations and amid millenniums.

Liken this to the current salmon controversy. People are so preoccupied with their daily business that they are blind to the car crash ahead. They are so tuned into protecting their own lifestyles, even at the other's expense, that they are forgetting to consider the common future.

Uninhibited population growth combined with an insatiable appetite for instant wealth has caused many natural resources to dwindle. Yet the simple application of common sense beyond the next fiscal quarter clearly reveals that future propriety is utterly dependent on healthy natural resources. In short, society has such a fixation on the daily business page that it's indifferent to break lights just ahead.

We Indians traditionally believe that decisions we make today should be based on the impact they will have over the next seven generations. Today's society is so obsessed with its immediate "needs" that it is oblivious to what will happen in the next seven seconds. If this weren't the case, people would embrace the Endangered Species Act, and support its full implementation. They would learn about Indian treaties, and begin to understand that they are actually non-Indian treaties, as well. They would demand that all segments of society be fully accountable to the needs of Salmon, because they'd understand that the future of their families is intertwined with the vitality of the natural world. Salmon are the icon of the Pacific Northwest for a reason. As creatures dependent on all elements of the environment for their survival, they are a keystone species to the human race.

Will the crash be avoided? That remains to be seen. But a positive outcome is clearly dependent on whether or not the commuters in today's society choose to look forward and slow down enough to save their own lives. So don't be surprised if you see tribal fishermen exercising their treaty rights this summer and autumn in the waters of Western Washington.

Superficial news coverage would portray fishing as the primary cause in the decline of many wild salmon populations. That's because fisheries are a highly visible "taking" of the resource.

There is no question, however, that the loss and degradation of good spawning and rearing habitat to urbanization, pollution, dams, improper logging practices, water withdrawals and other less visible manmade cause "take" more salmon than all fishermen ever could.

Tribal fisheries management is based on science, not public perception. If identifiable surpluses of salmon can be harvested in Elliott Bay, the Strait of Juan de Fuca, or anywhere else in western Washington, the tribes will fish. Non-Indians should fish, too. It isn't bad to fish, and it isn't wrong. Fishing is the desirable outcome of good fish management that is consistent with the productivity of salmon populations.
For 1999, treaty Indian tribes have adopted another extremely conservative package of fisheries regulations that will protect weak stocks of wild Chinook and Coho salmon.

Tribal fisheries in the Strait of Juan de Fuca and northern Puget Sound will target only healthy stocks of sockeye and chum salmon, while minimizing incidental harvest of weak wild Chinook and Coho. All other treaty fisheries in terminal areas, such as at the mouths of rivers, will focus on identifiable surpluses of Chinook, Coho, and chum salmon. Mostly, these fisheries will target healthy returns of hatchery salmon.

Tribal fisheries managers have steadily reduced harvests for the past decade in response to declining wild salmon populations. In 1987, for example, treaty Indian fishermen caught nearly 300,000 Chinook. Last year, the tribal harvest was about 115,000 Chinook, a 62% reduction. Coho harvest reductions have been even more dramatic. In 1987, tribal fishermen landed about 1.2 million Coho. Last year, the tribal Coho harvest was about 158,000, a reduction of about 87 percent. Hatchery surpluses comprised most of the tribal harvest of all species last year.

Even the most severe fisheries management actions, such as allowing no fisheries, have failed to restore wild salmon runs. That's because habitat degradation and loss is occurring faster than we can reduce or eliminate fisheries. Even if we were to end all fishing everywhere today, some runs would still become extinct simply because their habitat has been destroyed or degraded to the point that it can no longer sustain them.

Fishing defines the tribes as people. It was the one thing above all else that the tribes wished to retain during treaty negotiations with the federal government 150 years ago. Nothing was more vital to the tribal way of life then, and nothing is more important now.

The tribes didn't trade most of what is now western Washington for the "privilege" of sitting on the beach when the salmon come home to spawn. Tribal fishermen are not responsible for the salmon's decline, yet are continually expected to bear a disproportionate share of the salmon conservation burden.

The proposal earlier this year by the National Marine Fisheries Service to protect Puget Sound Chinook under the Endangered Species Act (ESA) made the Seattle area the largest metropolitan area to ever come under a proposed listing. There is little doubt that Puget Sound Chinook will be listed as "threatened" under the ESA, but it would be wrong if we rely solely on the ESA's species-by-species approach to preventing extinction. The treaty Indian tribes are not interested in any goal other than rebuilding threatened wild salmon runs, and the ecosystems on which they depend, to historic levels that can again sustain harvest. Anything less should be unacceptable to everyone.

The tribes have voluntarily reduced harvests, worked hard to improve and protect salmon habitat, minimized impacts of hatchery salmon on wild stocks and taken many other actions in response to the needs of wild salmon stocks. Unless the state's business and the political leaders commit to protecting and improving the salmon's home, however, all of the harvest reductions and other efforts to save the wild salmon will have been wasted.

Tribal fishermen have no more sacrifices to make. Heaping the conservation burden on tribal harvesters at the end of the line is unfair, unproductive, and won't bring the salmon back.

The tribes have fought too hard for too long to let the salmon and their treaty rights to harvest salmon go extinct. This summer and fall you will see tribal fishermen doing what they have always done: fish! Remember, not all salmon are endangered. Some can still be safely harvested by a people whose very being is defined by the act of fishing.

A Chronology of Treaty Fishing on the Columbia River by Delbert Frank, Sr., Warm Springs Indian Reservation, Warm Springs, Oregon

Time Immemorial. Indian people have lived in the Columbia Basin for thousands of years, using salmon as a staple of life and as a foundation of culture, economy, and a source of religion. According to conservative estimates, the river's annual salmon returns ranged from 11 to 16 million fish before European settlement.

1805. Reaching the Columbia River, Lewis and Clark were amazed by the abundance of salmon.

1855. Treaties with Columbia River tribes were signed. In these treaties, tribes ceded most of their lands, but reserved exclusive rights to fish within their reservations and rights to fish at "all usual and accustomed fishing places…in common with citizens."

1905. In the first major fishing rights case to reach the Supreme Court, *U.S. vs. Winans*, the Justices held that treaty Indians had reserved the right to cross non-Indian lands to fish at "usual and accustomed" places and that treaties are to be interpreted the way the Indians had understood them.

1938. Congress passed the Bonneville Project Act to market power from Bonneville and other federal dams on the Columbia. Dams would eventually inundate such important Indian fishing places as Celilo Falls and block salmon migration to some 2,800 miles of fish habitat. Congress also passed the Mitchell Act, which promised that fish lost because of the dams would be replenished with the help of hatcheries.

1942. The Supreme Court decided in *Tulee vs. Washington*, that because a treaty takes precedence over state law, Indians with tribal treaty rights cannot be required to buy state fishing licenses. However, the court also rules that the state could regulate treaty fisheries for purposes of conservation.

1948. State and federal fish agencies began implementing the Mitchell Act by putting almost all of the hatcheries in the lower river, where mostly non-Indians fish, instead of in the tribes upriver fishing areas where salmon were being destroyed by the dams. Of the 25 Mitchell Act hatcheries eventually built, only two are above The Dalles Dam. The effect is that some 85 percent of the tribes' main stem fishing area does not benefit from the Mitchell Act releases.

1968. Fourteen members of the Yakima tribe filed suit against Oregon's regulation of off-reservation fishing (*Sohappy vs. Smith*). The United States and the Yakima, Warm Springs, Umatilla, and Nez Perce tribes also sued (*U.S. vs. Oregon*). The federal court combined the two cases.

1969. Judge Belloni, in *Sohappy vs. Smith/U.S. vs. Oregon* (the famous "Belloni Decision") held that the tribes were entitled to a "fair share" of the fish runs and the state is limited in its power to regulate treaty Indian fisheries (the state may only regulate when "reasonable and necessary for conservation"). Further, state conservation regulations were not to discriminate against the Indians and must be the least restrictive means.

1974. In *U.S. vs. Washington* (the famous "Boldt Decision"), Judge Boldt mandated that a "fair share" was 50 percent of the harvestable fish destined for the tribes' usual and accustomed fishing places and reaffirmed tribal management powers. (Belloni then applied the 50/50 principle in Columbia River fisheries).

1975. The U.S. Army Corps of Engineers completed the last of four lower Snake River dams, compounding downstream passage problems and causing further declines in fish runs. The total number of dams on the main stem Columbia and Snake rivers rose to 18.

1977. The federal court, under its jurisdiction in *U.S. vs. Oregon*, approved a five-year plan that set up an in-river harvest sharing formula between non-Indian and Indian fisheries. The plan failed because it did not include specific controls on ocean harvests or specific measures to replace fish runs destroyed by development.

1979. The Supreme Court upheld *U.S. vs. Washington* (Boldt Decision). Columbia River, Puget Sound, and Washington coastal tribes sued the Secretary of Commerce over ocean fishing regulations because a large percentage of treaty fish were being caught in waters managed by the Department of Commerce. Columbia River tribes also sued in 1980, 1981, and 1982 (*Confederated Tribes et. al. vs. Kreps; Yakima et al. vs. Klutznik; Hoh vs. Baldrige; and Yakima et. al. vs. Baldrige*).

1980. Congress passed the Northwest Power Act, which for the first time, mandated that Columbia River power production and fisheries be managed as co-equals. It called for a fish and wildlife program to make up for losses caused by federal water development in the basin.

1980. The Federal District Court issued the *U.S. vs. Washington* (Phase II) decision that affirmed a right to protection of the habitat that supports fish runs subject to treaty catch.

1982. The Northwest Power Planning Council, the body charged with implementing the Power Act, adopted a Fish and Wildlife Program that drew heavily on recommendations made by the tribes. Unfortunately, the program has been amended at least three times since its inception, effectively filtering out or ignoring most of the tribes' original recommendations.

1985. President Reagan and Canadian Prime Minister Mulroney signed, and Congress later ratified, the U.S.-Canada Pacific Salmon Treaty, which reduced Canadian and Alaskan harvest of Columbia River salmon and reserved a seat at the table for Indian tribes along with other government fish managers.

1988. After five years of negotiation, the states of Oregon, Washington, and Idaho, federal fishery agencies, and the tribes agreed to Columbia River Fish Management Plan, a new, detailed harvest and fish production process under the authority of *U.S. vs. Oregon*. Judge Marsh entered the plan as an order of the U.S. District Court.

1991. Sockeye and Spring, Summer, and Fall Chinook from the Snake River, the Columbia's largest tributary, are listed under the Endangered Species Act.

1994. *Idaho Department of Fish and Game (IDFG) vs. National Marine Fisheries Service (NMFS*) brought under the ESA, Judge Marsh ruled that NMFS' biological opinion of "no jeopardy" regarding hydrosystem operations on the Columbia and Snake violated the act. He ordered the fish management parties to determine what hydrosystem changes were needed to restore endangered salmon.

1994. With Spring Chinook runs on the Columbia at record lows, the tribes reopened tribal fishing at Willamette Falls near Oregon City, Oregon. In recent decades this usual and accustomed Indian fishing place had been taken over by a large sport fishery supported by strong runs of hatchery fish.

1994. The tribes develop their own Columbia River salmon plan, *Wy-Kan-Ush-Mi Wa-Kish-Wit*: "Spirit of the Salmon."

Basic Principles of "Spirit of the Salmon" from the Columbia River Inter-Tribal Fish Commission, Portland, OR

Adaptive Management

Past salmon restoration efforts have been based on status quo management rather than adaptive management. Adaptive principles allow resource managers to take immediate on-the-ground actions to reverse salmon decline even in the face of scientific uncertainty. The tribes' "technical recommendations" are designed as testable hypotheses: they define problems, propose remedial actions, set objectives, and describe means to evaluate the actions. Using this adaptive management framework, restoration actions can be modified as indicated by scientific evaluation.

Consistency With Treaties and Federal Obligations

This plan establishes a foundation for the United States and its citizens to honor their treaty and trust responsibilities to the four tribes. If implemented, it would begin to return fish to many of the tribes' usual and accustomed fishing places, as guaranteed in the 1855 treaties, and would begin to meet ceremonial, subsistence and commercial needs of tribal members. If these obligations were met, the non-Indian public would be a beneficiary, enjoying its legal allotment of harvestable fish and sharing a healthier, more natural river system.

Gravel-To-Gravel Management

The plan's technical recommendations are aimed at increasing survival at each stage of the anadromous life cycle-from spawning gravel to spawning gravel; that is, from eggs hatching in streambed gravel to juveniles migrating downstream through dams and reservoirs to saltwater homes where young fish feed and grow in the ocean to adult fish returning to spawn in fresh water gravel to begin the process again. Rather than continuing current hatchery rearing and release methods, the plan outlines new propagation strategies to reestablish wild salmon runs. With so many Columbia Basin stocks at such low numbers, supplementation, which is what the tribes call their propagation proposal, is now an indispensable part of any restoration plan. While accounting for genetic concerns, the tribal plan asserts that any risks associated with supplementation are exceeded by the far greater risk of further extinctions. The plan also calls for taking juvenile salmon out of barges and trucks, returning them to the river, and providing adequate water conditions so that they can complete their downstream migration to the ocean.

Co-Management

The tribes are co-managers of the salmon resource pursuant to their inherent sovereignty and their 1855 treaty rights as interpreted by federal court decisions, including United States vs. Oregon and United States vs. Washington, and as ordered by the federal court in the U.S. vs. Oregon Columbia River Act of 1980 recognizes the tribes' treaty reserved rights and responsibilities and a 1996 federal Memorandum of Agreements calls for coordination of fish and wildlife mitigation with Columbia Basin tribes. By considering tribal culture and history, biological and legal requirements, institutional reforms, economic implications and technical recommendations, the plan helps provide a holistic context for decision-making. Not all societal problems can be properly weighed in terms of costs and economics nor solved by technological fixes. The costs of restoration must be equated with the value of restoration. That value must include the spirit of the salmon, Wy-Kan-Ush-Mi-Kish-Wit.

RESOURCES

"Salmon Species" (includes topics on Salmon Life History & Migrations, Columbia River Salmon Status, Pacific Salmon Managers and Partners for Restoration, Pacific Salmon Treaty, and StreamNet, maps, charts, and species drawings); provided by the Columbia River Inter-Tribal Fish Commission, May, 2000 (phone: 503-238-0667).

"Protected Resources," National Oceanic and Atmospheric Administration, Fisheries (provides drawings and identification of fish species, vital maps); February, 2000.

"Recovery Planning for West Coast Salmon," National Marine Fisheries Service Northwest and Southwest Regions (includes Conservation Crisis, Response to Crisis, Recovery Planning and the ESA, maps and charts).

"MOU Between Federally Recognized Tribes of Washington State and the State of Washington." The Fourth World Documentation Project, Olympia, 1999.

Federal Register Document; Vol. 64, No. 201; October, 1999. Dept. of Commerce and Trade Mission regulations.

"Treaty Indian Fisheries and Salmon Recovery" (videotape 10 min.). Northwest Fisheries Commission, Olympia, WA. (phone: 304-438-1180)

"Empty Promises – Empty Nets," ISBN 1-885790-01-5 (videotape 30 min.) Wild Hare Media, Portland, OR (phone: 800-Wild-Hare)

"Matter of Trust", ISBN 1-885790-02-3 (videotape 30 min.) Wild Hare Media, POB 3854, Portland, OR 97208

Soils

INTRODUCTION

The following activities were derived from an introductory soils course that takes an ecosystems approach to the physical, biological, and chemical properties of soils and how they relate to agriculture, forest, range, recreation, and urban uses. The application of research techniques to help solve management problems is emphasized and the concept of sustainable use is a primary focus. The laboratory and field activities described here can be used to supplement an introductory soils course or as stand-alone laboratories within related courses.

For activities and to augment lecture topics, we generally use soil sites (pits) on campus or in local areas. Soil sites are relatively easy to find—dirt is everywhere! Students learn best "by doing," and through activities and site visits, they learn the importance of soils in both managed and unmanaged ecosystems.

The first eight activities and information sheets introduce students to some general characteristics and terminology used in the study of soils. Once students are competent in identification and vocabulary, they begin to evaluate soils based on Land Capability Class, Storie Index, Timber Site Index, Available Water-Holding Capacity and other indicators. This information can then be used to evaluate specific sites for use as farm fields, septic tank leach fields, campground sites, landfills, and other uses.

Additionally, students participate in a three-day field trip to areas in our region of northern California, where they conduct transect studies and produce a final project.

Instructors will find the following resources useful and widely available:

- Natural Resources Conservation Service (NRCS) [formerly, the Soil Conservation Service (SCS)]
- State departments of forestry or natural resources
- State extension service (located at state universities)
- Soils labs in NCSR course, *Environmental Science II*
- Plaster, E.J. 1997. Soil Science and Management, 3rd Edition. Delmar Publishers, Albany, New York. ISBN 0-8273-7293-0

Soil Classification

Soils, like plants and animals, are named within a hierarchical system where large groups are divided into more specific groups using the U.S. System of Soil Classification, or Comprehensive System. Similar to a botanist naming a common clover Trifolium repens, a soil scientist identifies the “Miami silt loam”. Moving up the hierarchy, the clover is a member of the Leguminosae family of plants, and the phylum Pterophyta; similarly, the Miami silt loam is found in the soil family Fine Loamy, Mixed, Mesic, in the order Alfisol. Soil identification is based on characteristics such as differences in parent material, climate, geography, horizon development, and other factors.

There are six categories within the U.S. Soils Classification System: 1. order (broadest); 2. suborder; 3. great group; 4. subgroup; 5. family; and 6. series (most specific). There are 10 soil orders. A brief description follows:

1. **Alfisols** Pedalfer (tall grass, savanna, oak); found in humid and subhumid climates.

2. **Aridisols** “Dry soils” (grasses, desert shrubs and vegetation); found in low rainfall areas.

   - Almost any parent material; extremely variable
   - Little leaching
   - Concentration of calcium carbonate, gypsum or soluble salts

3. **Entisols** “Recent soils” (vegetation not diagnostic); found in wind and water-influenced areas—e.g., flood plains, mountainous areas, beach sands.

   - Rainfall high and low
   - Unique among soil orders; no distinct horizons

4. **Histosols** “Tissue soils” (marsh grasses and sedges); found in boggy areas.

   - Precipitation and humidity high
   - Based upon physical properties
   - Highly organic

5. **Inceptisols** "Beginning," inception (mostly under trees); found in humid climates from the Arctic to the Tropics.

- Uniformity in texture through horizons
- Texture finer than loamy sand
- Slight evidence of weathering

6. **Mollisols** "Soft soils," grassy areas; found in subhumid to semiarid regions from mountainous to tropical.

- High in organics, water in surface horizon
- Deep surface organic layer

7. **Oxisols** "Oxide soils"; found in tropical climates (hot and humid regions).

- Weathered minerals absent
- No translocation of clay
- High permeability, little erodability

8. **Spodosols** "Wood ash soils"; forested vegetation at temperate latitudes; found in humid climates with cool temperatures.

- Translocated humus, aluminum or iron
- Silicate clay in B horizon
- Sandy B horizon; cemented
- Virgin soils—albic horizon A2

9. **Ultisols** Last, "ultimate soils"; savanna vegetation to forest; found in subtropical regions.

- Low base saturation (35% or less)
- Highly weathered clay horizon; clay accumulation

10. **Vertisol** "Turn soils"; tall grasses and scattered trees and shrubs; found in subhu mid to semiarid climates.

- Parent material—limestones, marls, basic rocks
- Montmorillonite-clay
- When dry, large cracks
- Inverted, turned soil

Soil Profile

Weathering of rock and layering or horizon development gradually gives rise to soils. Each soil is characterized by a given sequence of horizons. A vertical exposure of the horizon sequence is termed a **soil profile**. Attention now will be given to the major horizons making up soil profiles and the terminology used to describe them.

The Master Horizons and Layers

For convenience in study and description, five master soil horizons are recognized. These are designated using the capital letters O, A, E, B, and C. Subordinate layers or distinctions within these master horizons are designated by lowercase letters. A common sequence is provided below:

oi	Organic, slightly decomposed
oe	Organic, moderately decomposed
oa	Organic, highly decomposed

A	Mineral, mixed with humus, dark colored

E	Horizon of maximum exultation of silicate clays, Fe, Al oxides, etc.

AB	or EB transition to B, more like A or E than B

BA	or BE transition to A or E, more like B than A or E

B	Most clearly expressed portion of B horizon

BC	Transition to C, more like B than C

C	Zone of least weathering, accumulation of Ca and Mg
R	Carbonates, cementation, sometimes high bulk density

This sequence illustrates a hypothetical mineral soil profile showing the major horizons that may be present in a well-drained soil in the temperate humid region. Any particular profile may exhibit only some of these horizons and relative depths vary. In addition, however, a soil profile may exhibit more detailed sub-horizons than indicated here. The **solum** includes the A, E, B horizons plus some cemented layers of the C horizon.

SOIL HORIZONS TERMINOLOGY

Surface Horizons (Epipedons)

Anthropic ("man"): High in phosphates due to cultivation over a long period of time.

Histic ("tissue"): Peaty or mucky, usually less than a foot thick and normally water saturated.

Mollic ("soft"): High in organic content; A Horizon of at least 7 inches.

Ochric ("pale"): Light colored, low in organic content; A Horizon is thinner than a mollic soil.

Plaggen ("sod"): Accumulations of organic matter due to farming.

Umbric ("shade"): Same as mollic, except water saturated.

Subsurface Horizons (Endopedons)

Albic ("white"): Clay and iron oxides are leached out, leaving sand and salt.

Argillic ("white clay"): the B Horizon is enriched with clay; clay skins remain on the peds or surface.

Cambic ("to exchange"): Slightly weathered horizons (between A & C); no clay skins.

Natric ("natrium/sodium"): Same as argillic with columnar or prismatic structure and over 15% exchangeable sodium.

Oxic ("oxide"): Concentrated oxides of iron or aluminum; no clay skins. Formed at low eleva tions on old land surfaces (humid tropics).

Spodic ("wood ash"): B Horizon with accumulation of humus; no clay accumulation—rarely clay skins.

Soil Consistence

Consistence refers to the attributes of cohesion and adhesion, or the resistance of soil to rupture or deformation. Although structure and consistence are interrelated, **structure** refers to the shape, size, and distinctness of natural aggregates (**peds**), whereas consistence refers to the force required to rupture soil material or to properties of a deformed soil mass. Like texture, consistence may be described under wet, moist, or dry conditions.

I. Determination of Consistence when Soil is Wet

Consistence when soil is wet is determined at a moisture content slightly above the field capacity. When wet, the soil material is characterized by stickiness and plasticity. Each of these characteristics is described below:

A. Stickiness

Stickiness is the quality of adhesion to other objects. For field evaluation of stickiness, soil material is pressed between the thumb and forefinger, and its adherence is noted. Descriptions follow:

1. Non-sticky: After releasing pressure, practically no soil material adheres to thumb or finger.

2. Slightly sticky: After applying pressure, the soil material adheres to both thumb and finger but comes off rather cleanly. The soil is not appreciably stretched when the digits are separated.

3. Sticky: After applying pressure, the soil material adheres to both thumb and finger; it tends to stretch somewhat and pull apart rather than pulling free from either digit.

4. Very sticky: After applying pressure, the soil material adheres strongly to both the thumb and forefinger, it becomes decidedly stretched when digits are separated.

B. **Plasticity**

Plasticity is the ability to change shape continuously under the influence of an applied stress, and to retain the impressed shape on removal of the stress. For field determination of plasticity, roll the soil material between the thumb and forefinger and observe whether or not a thin rod of soil (a "wire") can be formed. Descriptive ranges of moisture content or a "plasticity continuum" may occur: plastic when slightly moist or wet; plastic when moderately moist or wet; plastic only when wet; or plastic within a wide, medium or narrow range of moisture content.

Descriptions of plasticity follow:

1. Non-plastic: Wire cannot be formed.

2. Slightly plastic: Molded wire can be formed, but soil mass easily falls apart.

3. Plastic: Wire can be formed, but moderate pressure can make it fall apart.

4. Very plastic: Wire can be formed, but much pressure is required to make the soil mass fall apart.

II. **Determination of Consistence when Soil is Moist**

Consistence when soil is moist is determined at a moisture content approximately midway between air dry and field capacity. At this moisture content, most soils exhibit a form of consistence characterized by:

- A tendency to break into smaller masses rather than into powder
- Some deformation prior to rupture
- Absence of brittleness
- Ability of the material after disturbance to cohere again when pressed together

Resistance of soil to rupture or deformation decreases with moisture content, and accuracy of field descriptions of this consistence measure is limited by the accuracy of estimating moisture content. To evaluate this quality of consistence, select a soil sample and attempt to crush a slightly moist mass in your hand. The following categories are used:

1. Loose: Non-coherent.

2. Very friable: Soil material crushes under very gently pressure; coheres when presset-together.

3. Friable: Soil mass crushes under strong pressure; barely crushable between thumb and forefinger; coheres when pressed together.

4. Firm: Soil mass crushes under moderate pressure between thumb and forefinger; resistance is distinctly noticeable.

5. Very firm: Soil mass crushes under strong pressure; barely crushable between thumb and forefinger.

6. Extremely firm: Soil mass crushes only under very strong pressure; cannot be crushed between thumb and forefinger, and must be broken apart bit by bit.

NOTE: The term “compact“ should be used only to denote a combination of firm consistence and close packing or arrangement of particles. A soil can vary from “very” to “extremely” compact.

III. Determination of Consistence when Soil is Dry

The consistence of soil material when dry is characterized by rigidity, brittleness, maximum resistance to pressure, more or less tendency to crush to a powder or to fragments with rather sharp edges, and inability of crushed material to cohere again when pressed together. To evaluate, select an air-dry mass and break it in the hand. The following categories are used:

1. Loose: Non-coherent.

2. Soft: Soil mass is very weakly coherent and fragile; breaks into a powder of individual grains under very slight pressure.

3. Slightly hard: Weakly resistant to pressure; can be broken in the hands without difficulty, but is barely breakable between thumb and forefinger.

4. Hard: Moderately resistant to pressure; can be broken in the hands without difficulty, but is barely breakable between thumb and forefinger.

5. Very hard: Very resistant to pressure; can be broken in the hands only with difficulty; not breakable between thumb and forefinger.

6. Extremely hard: Extremely resistant to pressure; cannot be broken in the hand.

IV. Determination of Consistence when Soil is Cemented

Cementation of soil material refers to a brittle, hard consistence caused by some cementing substance other than clay materials, such as calcium carbonate, silica, or oxides or salts of iron and aluminum. Typically, cementation is altered little if at all by moistening. Hardness and brittleness persist in the wet condition. Semi-reversible cements, which generally resist moistening but soften under prolonged wetting, occur in some soils, and give rise to soil layers, resulting in cementation that is pronounced when dry but very weak when wet.

NOTE: Some layers cemented with calcium carbonate soften somewhat with wetting.

Unless the contrary is stated, descriptions of cementation imply that the condition is altered little, if at all, by wetting. If the cementation is greatly altered by moistening, it should be so stated. Cementation may be either continuous or discontinuous within a given horizon. The following categories are used:

1. Weakly cemented: Cemented mass is brittle and hard; can be broken in the hands.

2. Strongly cemented: Cemented mass is brittle and hard; cannot be broken in the hand but is easily broken with a hammer.

3. Indurated: Very strongly cemented; brittle, does not soften under prolonged wetting, and is so extremely hard that, for breakage, a sharp blow with a hammer is required.

Soil Structure

Soil structure is the combination or arrangement of primary soil particles into secondary particles, units, or **peds**. They may be arranged in a distinctive pattern, and can be classified on the basis of size and shape.

1. **Plate-like (platy)**. Soil aggregates are arranged in relatively thin horizontal plates, leaflets or lenses. If the units are quite thin, the term **laminar** is used. Although most noticeable in the surface layers of virgin soils, platy structure may characterize the subsoil horizons as well. And though most structural features are usually a product of soil-forming forces, the Platy is often inherited from the parent materials, especially when the latter have been laid down by water or ice.

2. **Prism-like (columnar, prismatic**). Characterized by vertically oriented aggregates or pillars. These elongated columns vary in length with different soils and may reach a diameter of 6 inches or more. They commonly occur in the subsoil horizons of arid and semiarid region soils, and when well developed, they form a very striking feature of the profile. When the tops are rounded, the term **columnar** is used—this may occur when the profile is changing and certain horizons are degrading. When the tops of the prisms are still plain, level, and clean cut, the structural pattern is designated **prismatic**. Both the prismatic and columnar types of aggregation are divided into classes, depending on the horizontal diameter of prisms.

3. **Block-like (blocky, subangular blocky**). Original aggregates have been reduced in size; fragments range from a fraction of an inch to 3 or 4 inches in thickness. In general, the design is so individualistic that identification is easy. When the edges of the cubes are sharp and the rectangular faces distinct, the type is designated **blocky**. When subrounding has occurred, the aggregates are spoken of as **subangular blocky**. These types usually are confined to the subsoil, and their stage of development and other characteristics are related to soil drainage, aeration, and root penetration.

4. **Spheroidal (granular, crumb)**. All rounded aggregates may be placed in this category, although the term more properly refers to those not over 1/2 inch in diameter. These rounded complexes usually lie loosely and are readily shaken apart. When wet, the intervening spaces generally are not closed readily by swelling—as may be the case with a blocky structural condition. Ordinarily the aggregates are spoken of as granules and

the pattern as **granular**. However, when the granules are especially porous, the term **crumb** is applied. Granular and, less frequently, crumb structures, are characteristic of many surface soils, especially those high in organic matter. Granular and crumb structures are the only types of aggregation that are commonly influenced by practical methods of soil management.

NOTE: Two or more of the structural conditions listed usually occur in the same soil solum; i.e., in humid regions, a granular aggregation in the surface horizon with a blocky, subangular blocky or platy type of some kind in the subsoil is usual, although granular sub-horizons are not uncommon.

Soil Salinity

Especially in arid areas where land is used to grow crops, **salinity**, or salt content, can be a key factor in how and what crops will grow. Dry regions like the Imperial Valley in California contain a mixture of salts. A white crust on the surface is an indication of salinity; this white deposit is usually a mixture of sodium, calcium, and magnesium salts. Most moist, dark, oily spots indicate an excess of calcium chloride. All of these salts have one property in common—they dissolve freely in water. Other salts like lime and gypsum are only slightly soluble, and do not increase soil salinity appreciably.

Sources of salts in soils may include irrigation water, high ground-water tables or original deposits left behind during soil formation. For example, irrigation water from the All American Canal System in northern California contains about 2,000 pounds of salt per acre foot of water. If the water does not penetrate the soil deeply, most of the salt brought in by this water will remain close to the soil surface. If all the salt brought in by the canal water remained in the top foot, a good soil could become salty in one crop season.

Ground waters generally contain more salt than do irrigation waters. When the ground-water level is close to the surface, a good deal of the salty ground water moves upward as a result of evaporation and plant use. This increases the salt content of the surface soil, where a majority of plant roots are found, and may decrease crop growth.

Salinity may affect plant growth either by decreasing the availability of water to plants or by having direct toxic effects. The degree of these effects is dependent upon both the moisture content of the soil and the amount of soluble salt present. A given amount of salt is more injurious in a sandy soil than in a clay soil because sandy soil holds less water, resulting in a saltier condition.

Measuring Salinity

To test saltiness, a soil solution can be prepared by mixing soil in enough water to prepare a saturated soil paste and filtering off the solution. This method takes into account the texture and the water-holding properties of the soil. The saltiness of the filtered solution is most easily measured by its ability to carry an electrical current. This ability is called (**electrical conductivity**) and is usually expressed in millimhos per centimeter at 25 degrees Celsius; for brevity, the term “millimhos” is used.

The salt content of a soil sample can also be measured using a soil test. Often a grower learns that his/her field is too salty only after a crop failure. It is cheaper to get this information before planting by making a few simple soil tests. Samples can be analyzed by most commercial soil laboratories. A list of these commercial laboratories can be secured from your local farm advisor. Salinity varies with depth and from place to place in a field. At each location, samples should be taken from several depths, such as from 0-8 inches and 8-24 inches. In sampling any field and in selecting locations, previous crop history and visible soil differences should be taken into account.

Preventing salt build-up

Salt build-up in agricultural soils can be prevented by using proper irrigation and management practices and by providing good drainage.

Good land leveling and irrigation methods help prevent salt accumulation. High spots in a field generally do not receive enough water. This favors the build-up of salts and may result in poor crop production. Therefore, high spots should be leveled and salt should be removed by uniform heavy irrigation; adequate drainage is necessary for the removal of salt. If natural drainage is not adequate, tile or open drains should be installed.

Shallow water tables bring about salt build-up because ground water moves up and evaporates, depositing salt near the surface. The water table should be at least 4½ to 5 feet below the surface during most of the crop growing season. Frequent water table measurements in an open hole (observation well) in several locations in a field will indicate whether drainage is adequate. On fields that are furrow irrigated, salts are generally leached from under the furrows and build up in the ridges. However, an established crop is generally not affected by the build-up of salt in the ridges, since most of the active roots are in the less salty soil under the furrow. On the other hand, adequate flood irrigation in basins or checks do not result in zones of salt accumulation. Light flood irrigation may also produce a salinity problem.

Available Water-Holding Capacity

Available water-holding capacity (AWC) denotes water held in soil that is readily available to plant roots. It is considered to be the difference between field capacity and permanent wilting point.

Available moisture is influenced by texture and other soil properties and qualities, such as structure, organic matter, salts, bulk density, pore space, and related soil features.

This chart provides basic water values based on texture in soils located in northern California:

Texture	Water (inches per ft. of soil)
very coarse	0.4 - 0.075
coarse	0.075 - 1.0
moderately coarse	1.0 - 1.5
medium and fine	1.5 - 2.0
moderately fine	2.0 - 2.3

NOTE: These values are considered the most accurate for use in California based on research findings and literature. For stony, cobbly, or gravelly soils, the listed values should be reduced by the percent of coarse fragments present in the soil mass.

Land Capability Classification

When a Natural Resource Conservation Service (NRCS) soil scientist examines land, s/he not only records findings about the soil, slope, erosion, and other land factors as described in preceding pages, but classifies the land according to its ability to produce crops under specified uses and treatments with due regard to the inherent limitations and hazards of the land.

The **Land Capability Classification** provides a description, represented by a symbol (e.g., IIIs4), to designate a particular kind of land, which is known as a **Land Capability Unit**. The first part of the symbol is always a Roman numeral and indicates the **class**. The Land Capability classes from I to VIII express an increasing degree of hazard or limitation. The second part of the symbol is always a lower-case letter and indicates the **subclass**, which expresses the kind of major limitation or hazard. The third part of the symbol is always an Arabic numeral and indicates the **unit** or secondary limitation or hazard.

Land Capability Classes

Suitable for Cultivation

I. Very good land that can be cultivated safely with ordinary farming methods

II. Good land that can be cultivated with easily applied, protective measures

II. Moderately good land that can be used regularly for most crops in a good rotation but requires intensive treatment

IV. Fairly good land that has limited crop adaptations and is best maintained in perennial vegetation, but can be cultivated in a limited way if handled with great care

Not Suitable for Cultivation

V. Land very well suited for grazing or forestry, or both, with few hazards in use

VI. Land well suited for grazing or forestry, or both

VII. Land fairly well suited for grazing or forestry, or both

VIII. Land that is suited only for wildlife, recreation, or watershed purposes

Land Capability Subclasses (the major problem)

e erosion
w wetness
s soil limitation
c climatic limitation

Land Capability Units (the secondary problem)

0 coarse underlying material

1 erosion hazard

2 drainage or overflow

3 slowly permeable subsoils

4 coarse textures

5 fine textures

6 salinity or alkali

7 stony or rocky

8 cemented layers or bedrock

9 low fertility or rock elements

Source: Natural Resources Conservation Service

The Storie Index

This method of soil rating, known as the **Storie Index**, is based on soil characteristics that govern the land's potential utilization and productive capacity. It is independent of other physical or economic factors that might determine the desirability of growing certain plants in a given area.

Four factors (described below) are evaluated and assigned a value from 0 to 100. Highest values indicate the most favorable conditions for agricultural production and the lowest values indicate the least favorable conditions. The percentage values or ratings for the four factors are then multiplied and the result is the **Storie Index Rating** of the soil.

Factor A Characteristics of the soil profile
Soils that are deep and readily pervious to roots and water are rated at 100 percent. Profiles with dense clay subsoils are rated lower. Primary or residual soils (listed in profile groups VII, VIII, and IX) are rated in accordance with the depth to bedrock.

Factor B Soil texture of surface soils
Medium-textured soils, such as the loams and slit loams, are rated highest; extremes in texture, such as sands and clays, are rated lower.

Factor C Slope of the land
Nearly level or gently sloping land is rated at 100 per cent. As the slope increases, the rating for this factor decreases. (The percent slope is expressed as the number of feet rise or fall for 100 feet horizontal distance.)

Factor X Conditions exclusive of profile, soil texture, and slope
Examples may include drainage, alkali or salt content, general nutrient level, acidity, erosion, and microrelief (surface regularity). If two or more conditions exist that are listed under Factor X, the ratings for each are treated independently; that is, they are multiplied in order to obtain the Factor X rating.

Using Field Data Sheets

INTRODUCTION

This exercise provides students the opportunity to collect soils data from a local environment and use these data to evaluate management practices on the site.

PROCEDURE

1. Visit a local site and assess the soil using soil test kits, county soil surveys and other techniques previously described.

2. Record all data on the attached data sheet

3. In groups of two, answer the following questions:

- Describe the present soil use on the site.

- Based on your analysis, is the current use also the most appropriate use for soils on this site?

- How could the soil on this site be managed in a more sustainable manner?

- What would be the long-term benefits to the ecosystem if soils were managed in a more sustainable manner?

LAB PRODUCTS

Completed data sheets and answers to questions.

SOILS FIELD DATA SHEET

Soils Series Type Phase ________________________________ Site# _______________
Location ____
Geographic Landscape Position ____________________ Type of Relief ______________
Parent Material ____
Elevation __________________ % Slope ________________ Aspect _______________
Climate: Mean Annual Precip _______________ Mean Annual Temp _______________
Natural Vegetation____

Horizons and Depth	Texture	Color	Structure Grade/ Type	pH	Consistence Dry/Moist/ Wet/Plastic	Miscellaneous	AWC (Available Water-Holding Capacity)

Depth to Groundwater _________________Drainage __________ Permeability _______
Stony or Rocky _____________________Salts or Alkali _________________________
Depth to Limiting Layer _______________________ AWC Profile Group _____________
Amount and Type or Erosion _______________________ Erosion Hazard ____________
Major Problems in Use ____
Land Capability Classification _________________ Major Factor for Placement ________
Storie Index : Agriculture _______________________________Grade _______________
Forestry ________________________________Storie Index _______________________
Present Use ____
Suitability of Use: ____
Irrigated Field Crops ______ Irrigated Pasture ________ Native or Seeded Range _______

Cropland Management (Practices, Fertility Tillage, Erosion) _______________________

Rangeland Management (Seeding, Grazing, Brush Control, Erosion) __________________

Timber Management (Growth, Seeding, Brush Control, Erosion) _____________________

Orchard or Vineyard ____________________ Non-Irrigated Pasture __________________

MATERIALS

Topographic maps of study sites
Soil test kits
Soil sampling equipment (trowels, soil bags, etc.)
County soil surveys

Using The Soil Survey

INTRODUCTION

In an effort to provide useful information on soils to farmers, foresters, developers and others, the Natural Resources Conservation Service has produced a Soil Survey for every county in the United States. In this lab exercise you will learn how to access soils information in a Soil Survey and use this information to identify appropriate uses of the land based on soil characteristics.

OBJECTIVES

Upon successful completion of this activity, students should be able to:

- use a County Soil Survey
- interpret data and use information to solve problems related to soil, the environment, and sustainable human use
- to collect statistical information on local soils

PROCEDURE

1. Secure a local County Soil Survey and become familiar with the organization of this document by examining the following:

   - Table of contents
   - Soil descriptions
   - Tables of soil characteristics
   - Aerial photographs

2. Identify three sites in the soil survey that differ in their elevation:

   - Mountains (higher elevation)
   - Foothills (mid-elevation)
   - Terraces/valley bottoms (low elevation)

3. Use the County Soil Survey to complete Table A (“General Site Characteristics”) and Table B (“Soil Characteristics”).

TABLE A General Site Characteristics

Site #	Legal Description	Climate			Slope
		Annual Precip.	Ave. Temp.	Frost-free days	
1.					
2.					
3.					

TABLE B Soil Characteristics

Site #	Series	Type	Phase	Soil Land Capability Classification	% in County	Limiting features
1.						
2.						
3.						

LAB PRODUCT

Prepare and submit a summary soil survey report on each of your study sites. Include completed Tables A and B and recommendations for land use and planning on each of these sites in your report.

MATERIALS

Local County Soil Surveys (one per group)
Topographic maps of study area

NOTES TO INSTRUCTORS

Tables A and B may be expanded to include additional information from the County Soil Survey. Most Soil Surveys will include a wide variety of soil data including engineering properties, physical and chemical properties, water features, estimates of agricultural production, etc. Instructors may want to select those features most relevant to course objectives.

Students should be required to base their recommendations for land use on site and soil characteristics.

Determination of Soil Texture

INTRODUCTION

Soil texture is a fundamental characteristic of soils as it strongly influences engineering and agricultural uses. In this lab students will estimate soil texture using two different methods - the "feel method" and the "hydrometer method". Textural classes are determined using the Soils Textural Triangle and students are asked to consider how soil texture influences potential land use.

Soil texture is a physical property of soil determined by the relative proportion of mineral particles of various sizes in a given soil. Soils are generally made up of larger mineral fragments embedded in or coated with microscopic or submicroscopic particles called colloids, and other fine materials. In some cases, larger mineral particles predominate and gravelly or sandy soils result, whereas in others, mineral colloids are more prevalent, leading to clayey soil characteristics. Soil texture is very important in determining plant growth because it affects nutrient, water, and air supply to the roots of plants. Texture categories are determined by the relative amounts of silt, clay and sand as seen in Figure 2 below.

OBJECTIVES

Upon successful completion of this activity students should be able to:

- determine the texture of soil using the "feel method"
- use the textural triangle to determine textural classes of soil
- determine the percentage of sand, silt, and clay in a soil sample using the "hydrometer method"
- compare the accuracy of two different methods for the determination of soil texture

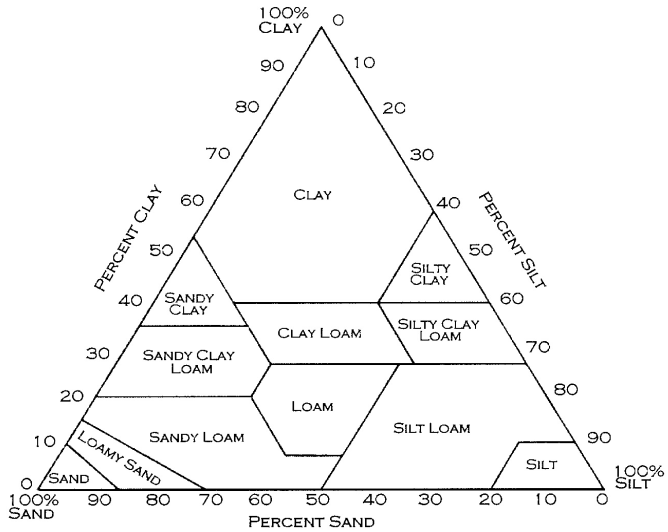


Figure 2. The Soil Triangle - relative proportions of clay, sift and sand determine texture categories (Source: Natural Resources Conservation Service)

DETERMINING SOIL TEXTURE USING THE FEEL METHOD

NOTE: Also see NCSR's *Environmental Science II*, Soil Texture, pp. 29-30.

In a field setting or sometimes in a laboratory when a quick determination is required, the "feel method" may be used to determine soil texture. A soil sample is mixed with a small amount of water and manipulated in the hand. In general, grittiness (detected both by feel and sound) denotes a sandy soil. Clay or loam is indicated if the soil can be rolled into a moist soil ball and it stains your fingers. Clay is sticky; silt is smooth and velvety. Clay soil will "ribbon," that is, by pressing and working a moist sample, it can rolled and pushed into a ribbon; a silt loam will form a firm ball.

Specific soil texture categories as determined by the "feel method" are described below.

Sand or Loamy Sand

Dry Loose, single grained, gritty; no clods (or they are very weak).

Moist Gritty; forms easily crumbled ball; does not ribbon.

Wet Lacks stickiness, but may show faint clay stainings (especially loamy sand). Individual grains can be both seen and felt under all moisture conditions.

Sandy Loam

Dry Clods break easily.

Moist Moderately gritty to gritty; forms a ball that withstands only careful handling; ribbons very poorly.

Wet Definitely stains fingers; may have faint smoothness or stickiness, but grittiness dominates. Individual grains can be seen and felt under nearly all moisture conditions.

Loam

NOTE: This is the most difficult texture to identify since characteristics of sand, silt, and clay are all present but none predominates.

Dry Clods are slightly difficult to break; somewhat gritty.

Moist Forms firm ball; ribbons poorly; may show poor fingerprint.

Wet Gritty, smooth, and sticky-all at the same time; stains fingers.

Silt or Silt Loam

Dry Clods are moderately difficult to break and they can rupture suddenly, turning them into a floury powder that clings to fingers; shows fingerprint.

Moist Has smooth, slick, velvety, or buttery feel; forms firm ball; may ribbon slightly before breaking, shows good fingerprint.

Wet Smooth with some stickiness from clay; stains fingers; the grittiness of sand is present, but other separates are more dominant

NOTE: There are few true silt soils, most in this category would be silt loams.

Sandy Clay Loam

Dry Clods break with difficulty.

Moist Forms firm ball, becoming moderately hard on drying; ribbons fairly well, but ribbons barely support their own weight; shows fair to good fingerprint.

Wet Moderately sticky, with stickiness dominating over grittiness and smoothness; stains fingers.

Silty Clay Loam

NOTE: Resembles silt loam, but with greater stickiness from clay.

Dry Clods break with difficulty.

Moist Shows a good fingerprint; forms a firm ball, and dries moderately hard; ribbons 1/2” (fairly thin).

Wet Stains fingers; has a slick-smooth feel with little grittiness of sand.

Sandy Clay

Dry Often cloddy; clods are broken only with extreme pressure.

Moist Forms a very firm ball and dries quite hard; shows fingerprint; squeezes to thin, long, somewhat gritty ribbon.

Wet Stains fingers; clouds water; usually quite sticky and plastic; some grittiness present.

Silty Clay

Dry	[See sandy clay].
Moist	Forms a very firm ball and becomes quite hard on drying; shows fingerprint; squeezes out into a thin, smooth ribbon.
Wet	Stains fingers and clouds water; stickiness dominates over smoothness; grittiness is virtually absent.

Clay

NOTE: Think of molding clay here (smooth and sticky).

Dry	Clods predominate.
Moist	Forms very firm ball, very hard on drying; ribbons very easily; shows fingerprint.
Wet	Stains fingers, sticky, no grittiness.

DETERMINING SOIL TEXTURE USINGTHE HYDROMETER METHOD

1. Weigh 50 grams of air dry, screened soil and place it in a metal dispersion cup. Half fill the cup with water and add 10 ml of sodium phosphate solution. Soak for 10 minutes. To disperse the soil and to avoid subsequent flocculation, a dispersing agent is used. Using sodium hexametaphosphate $(NaPO_3)_6$, the sodium replaces exchangeable calcium. Precipitation of the calcium results as the phosphate prevents its re-absorption and flocculating action. The net negative charge on clay particles increases due to absorption of the large sodium ions, which cause the particles to repel each other and disperse.

2. While your sample is soaking, determine the texture of the same air dry, screened material using the "feel method" described above. Record the texture on the data sheet.

3. Place the cup on the stirrer and stir until soil aggregates are broken down. Most soils in their natural condition tend to be aggregated. These aggregates are broken down by chemical (sodium hexametaphosphate) and physical (stirrer) dispersion techniques to enable the sand, silt, and clay particles to become separated and free in the suspension. This takes 3 to 5 minutes for coarse textured soils and 12 to 15 minutes for very fine textured soils.

4. Transfer the mixture to a Bouyoucos glass cylinder and fill it to the lower mark with water while the hydrometer is in suspension. Use a squirt bottle to wash all soil particles into the Bouyoucos cylinder.

5. Remove the hydrometer and shake the suspension vigorously. Place the cylinder on your desk and record the time. Carefully insert the hydrometer and read the hydrometer at the end of 40 seconds. Record the reading on the data sheet.

6. Remove the hydrometer from the suspension and insert the thermometer.

7. For each degree above 68° F, add 0.2 to the reading to get the corrected hydrometer reading. For each degree less than 68° F, subtract 0.2 from the hydrometer reading. Record the corrected hydrometer reading.

8. Calculate the percent sand in the sample. The hydrometer is calibrated so that the corrected reading gives the grams of soil material in suspension. The sand settles to the bottom of the cylinder within 40 seconds; therefore, the 40-second hydrometer reading actually gives the amount of silt and clay in suspension. The weight of sand in the sample is obtained by subtracting the corrected hydrometer reading from the total weight of the sample. The percentage of sand is calculated by dividing the weight of sand by the weight of the sample and multiplying by 100.

9. Take a second hydrometer reading at the end of two hours. Insert the hydrometer just before the two-hour reading is made. Make corrections for temperature and record the second hydrometer reading and the corrected reading on the data sheet.

10. Calculate the percent of clay in the sample. At the end of two hours, most of the silt in addition to the sand has settled out of suspension. The corrected hydrometer reading at the end of two hours represents the grams of clay in the sample.

11. Calculate the percent of silt in the sample. Find the percent silt by subtracting the sum of the percentage of sand and clay from 100.

12. Determine the class name or textures of the soil using the Soils Textural Triangle (see page 85).

LAB PRODUCT

Record all of your results in the tables and worksheet below.

Answer the following questions:

1. How did your classification using the feel test method compare with the hydrometer method?

2. What might account for any observed differences between the two methods?

3. What are the strengths and weaknesses of the two methods you have used to estimate soil texture?

4. Under what conditions might one be favored over the other?

5. Based on your estimates of soil texture, what evaluation can be made about this soil? Consider the physical qualities of the soil such as its ability to retain moisture and nutrients and its tilth (its ability to be "worked").

MATERIALS

Electronic or triple beam balance
Soil screens
Dispersion cup
Sodium hexametaphosphate $(NaPO_3)_6$ solution
Magnetic stirrer
Bouyoucos glass cylinder and hydrometer
Squirt bottle
Thermometer

I. Hydrometer Data Sheet

	40 Seconds	2 Hours
Hydrometer Reading		
Temperature of Suspension		
Corrected Hydrometer Reading		
Grams of Sand		
Grams of Clay		
Texture of sample as determined by feel		

II. Worksheet Determining Textural Class

1. Weight of sample ___________ g
2. 40 second hydrometer reading ___________ g
3. Temperature reading ___________ °F
4. Corrected hydrometer reading (grams silt plus clay) ___________ g
5. Weight sand (#1 minus #4) ___________ g
6. Percent sand (also enter % in table below) ___________ %
7. Two hour hydrometer reading ___________ g
8. Temperature reading ___________ °F
9. Corrected hydrometer reading ___________ g
10. Percent clay (also enter % in table below) ___________ %
11. Grams silt (#4 minus #9) ___________ g
12. Percent silt (also enter % in table below) ___________ %

Sample	Estimated texture	% Sand	% Silt	% Clay	Actual

Final Project and Field Tour

INTRODUCTION

This capstone project consists of a three-day field tour of multiple sites representing a variety of soil types. Working in small groups, students use skills and knowledge gained from previous classroom and laboratory activities to evaluate these soils. Students make detailed measurements of soil characteristics and also collect information from government agencies. These results are then summarized in a detailed soils report submitted by each group.

PROCEDURE

1. During the three-day field tour, work in groups of four to collect data on soils at each sampling site. Responsibilities for each group are described in detail below.

2. You should also use federal, state and local government agencies as sources of information for your report. Some possibilities include the Natural Resources Conservation Service, State Department of Forestry, State Department of Agriculture and County Extension offices.

3. At the conclusion of the field tour, your group will prepare a written report as a capstone project for this course. The report must be typewritten and include the following sections:

- Title page
- Table of contents
- Maps of study sites
- Legal description of property
- Climate characteristics (from County Soils Survey)
- Complete soils description (from County Soils Survey)
- Completed data sheets for each of the sample sites
- Evaluations of potential uses (e.g., septic system drain field, path and trails, building sites, agricultural use) including what impacts these would have on the soil and ecology of the site

LAB PRODUCT

Group reports with data reported as specified.

MATERIALS

Soil sampling equipment (shovels, augers, trowels)
Soils test kits
Data sheets
County Soil Surveys

SOILS FIELD TRIP

GROUP ASSIGNMENTS

Groups will work as teams at each site to complete their job. Groups will rotate at each new site so that they will not do the same job twice. Group A will do Job 1 at the first site and Job 2 at the second site and continue to rotate until all sites are completed. Group B will start with Job 2, then Job 3 and so on. All groups will rotate in the same fashion. Do not switch groups—work only with persons in your group. Information not assigned to a group becomes the responsibility of each individual.

Group	Job #	Site Description
A	1	SITE PREPARATION: Includes all digging, auger work, and cleanup.
B	2	PROFILE DEVELOPMENT: Includes locating horizons and changes, and identifying them with pins.
C	3	SOIL SERIES: Type Phase, Site #, Location
D	4	GEOGRAPHIC LANDSCAPE POSITION: Type of relief, parent material
E	5	ELEVATION: % Slope, Aspect
F	6	CLIMATE: (MAP) (MAT) (FFD) Natural Vegetation
G	7	TEXTURE
H	8	COLOR
I	9	STRUCTURE, pH
J	10	CONSISTENCE
K	11	DEPTH TO GROUNDWATER, DRAINAGE, PERMEABILITY
L	12	STONY OR ROCKY, SALTS/ALKALI, DEPTH TO LIMITING LAYER

NOTE: Students will be individually responsible for completing items on the data sheet. This includes all the items listed below, plus any additional that are assigned:

Erosion Hazard; Amount and type of erosion; AWC (Available Water Capacity); Problems in Use; Land Capability Classification; Storie Index; Present Use and Suitability of Use; Management.

American-Indian Perspectives — Soils

Produced by tribal partners of NCSR

OBJECTIVES

To provide socio-cultural-religious views of soil resources by the Hopi Indians. Topics include soil quality and health as it relates to Hopi Indian subsistence and environmental sustainability.

To stimulate discussion and critical thinking, and to enhance students' understanding of soil issues and tribes.

INTRODUCTION

The Hopi reservation is located in the Four Corners Area of northeastern Arizona. Called "Pueblo Indians" by Spaniards and later by Western Society, due to the way they built their houses ("pueblo" in Spanish means village), the Hopi reservation covers over 1 million acres, and consists of three major mesas rising up to 7,200 feet. Annual temperatures range from 0° F to 100° F, and average precipitation is approximately 12 inches per year.

Some anthropologists believe the Hopi are descendants of the Anasazi, and others say they stem from the Mayans. They are a very complex religious and spiritual culture. According to legend, the Hopi were guided to where they now live by the Great Creator, who they call Ma'saw. They have ancient respect and reverence for the land, the environment, and all of Nature, and this is perpetuated by religious teachings, practices, ritual, and ceremony, and it is still reflected in the symbolism of their art, mythology, and agricultural lifestyle.

Agriculture has always been an essential element and religious foundation of Hopi culture. Archaeological records indicate that agriculture for the Hopi dates back as far as 1500 BC   Historically, their main subsistence food was corn; blue corn was used predominantly, along with 26 other varieties. Squash, melons, beans, and fruit added variety and were supplemented by limited hunting and wild plant gathering. The Hopi believed that the main staple food, blue corn, was given to them by the Great Creator—hence it was considered sacred and used in all their sacred dances, ceremonies, rituals, and prayer offerings. How they managed to grow this corn and subsist for thousands of years in this harsh and arid environment is still somewhat a mystery in modern society.

The Hopi believed in an esoteric knowledge to live in a peaceful way and in harmony and balance with the land. Perhaps this knowledge was best demonstrated in their agricultural techniques and practices. The Hopi's primary method of agriculture was called "dry farming" and would now be considered "reduced tillage." Farming was done in floodplains using terraces, which prevented water erosion, conserved water and took advantage of flood-enriched soils. They rotated crops, growing legumes such as squash and pumpkin in between corn crops, and combined prayer and spiritual ceremony, such as the Corn Ceremony, to ward off pests and insects, such as beetles and corn root worms. The Hopis appealed to the Great Creator and the spirits in the clouds, lightning and thunder, and mountains to bring them rain.

<u>Traditional Hopi Agriculture</u>

- The Hopi based their agricultural practices on a spiritual approach using "natural laws," including the law of reciprocity— one cannot take something without giving it back as payment in return; this promotes cyclic balance. Similarly, the law of conservation which states that one should be conservative in one's gathering and harvesting, keeping in mind the needs of other "relations" in the environment and ecosystem, and during hard times such as drought and bad weather, take even less.

- Based on an understanding of natural processes, the Hopi developed an agricultural system that was synchronized with the seasons, the weather, and was adaptable to changing natural cycles. Using dry farming and reduced tillage techniques, they constructed terraces and drew upon natural springs, snow and rain flow routes, and redirected flows by using rock structures and small scale irrigation methods. Corn species they planted were diversified and compatible with the environment.

<u>Contemporary Issues</u>

- Conflicts in values and politics developed over land use and lifestyle between the "traditional" and the "progressive" Hopi, and dealings with the tribe over U.S. governmental matters, natural resources, and legal issues, have combined to cause concerns in their community.

- Population growth in surrounding communities has resulted in serious environmental problems, such as mining and related water erosion, and toxic residues upon the land, air, water, and soil. The Hopi's basic survival needs have been threatened.

➢ Despite protests by traditional Hopi and religious leaders, some Hopi farmers plant, grow, cultivate, and harvest the corn with both traditional hand-made tools and modern equipment. Gravity-fed terrace irrigation continues to be used in corn plots.

In conclusion, the "traditional" Hopi way of life is seriously being threatened as a result of growth in population, availability of land and resources, and employment to sustain the tribal population. Western knowledge, technology and economic policies are combining to pose serious threats to soil health on Hopi reservation lands.

Age-old conflicts between historical and spiritual beliefs and economic values are causing social, political, and legal problems as the Hopi move into the 21st Century. How these issues will be resolved is yet to be determined.

ACTIVITIES

1. Visit the following Hopi preservation website via the Internet to conduct research on Hopi farming and subsistence lifestyles: www.nau.edu/~hcpo p/culture/agric.htm

2. Write a short paper that describes Hopi farming methods and how these techniques required an understanding of local environments.

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Suggested Films

My Hands are an Expression of My Soul. Various films shown on The Discovery Channel and PBS. WNET, P.O. Box 2284, S. Burlington, VT 05407; Phone: 800-336-1917

The Anasazi: Builders of America's First Cities. Shenandoah Films, 538 G St., Arcata, CA Phone: 707-822-1030

More Than Bows and Arrows. 1994.
Phone: 206-523-3456

Line Transect Methods for Estimating Population Density of Birds

INTRODUCTION

A population is a group of individuals of a single species that inhabits a specific area. A population might occupy an area defined by natural boundaries such as an island, mountain range, drainage basin, or lake; or a population might be defined by biologists as the individuals of a species found within an artificially defined area such as a national park, county, or study plot. The abundance of a species in a specific area can be thought of as the number of individuals in the population. Often, particularly in artificially defined areas, the abundance of a species is expressed in terms of population density, which is the number of individuals of the species per unit area. The units of area vary according to the size of the study organism. For birds, population density is often expressed in units of individuals per hectare. A hectare is 10,000 square meters.

The population density of a species in an area is rarely constant over time. Instead, fluctuations in the factors that regulate the population usually lead to temporal variation in population density. The factors that regulate populations fall under two categories: (1) density dependent factors and (2) density independent factors. The effects of density dependent factors increase as population densities of the species increase. Density dependent population regulation is usually a product of intraspecific competition for breeding territories, nesting sites, food, and other factors that exist in limited quantities. Predation may also act in a density dependent manner, if predators focus their foraging efforts on individuals of more common species. Density independent factors include extreme weather, natural disturbances, habitat alterations, and other causes of mortality that are not influenced by the population densities of the species that they impact.

Estimates of abundance or population densities of bird species are integral components of studies designed to monitor the status of populations of rare or endangered species, assess the impacts of proposed developments, manage game bird populations, combat introduced species such as the European starling, monitor the effects of habitat alterations, and examine the dynamics and regulation of bird populations. Consequently, wildlife biologists and field ornithologists frequently conduct counts or surveys that involve estimating abundance or population densities of birds. The methods used to estimate population densities or abundance of birds fall into two categories: (1) complete counts, or true censuses, and (2) sample surveys. A true census involves determining the number of individuals of a species within a given area by counting every individual within the area. All other methods are considered survey, rather than census methods, because the total number of individuals within the survey area is estimated based on a sub-sample of the population.

To take a census of the population of a species within a given area, three conditions must be met: (1) the entire area must be searched, (2) all individuals in the study area must be detected and counted, and (3) the population must be closed during the census. All of these conditions are usually difficult to meet in natural situations. However, true censuses are possible in well defined areas in which birds are clearly visible and fairly stationary. Abundance of birds that congregate in nesting colonies, roost in conspicuous locations, or nest on cliff faces can sometimes be determined by conducting a true census. Under most circumstances, censuses of birds are not humanly possible. This is because birds are highly mobile in both the vertical and horizontal plane, and are often concealed by dense foliage. Even in open habitats, birds might wander in or out of the census area during the count, thereby violating the third condition necessary for an accurate census. Consequently, survey methods, which do not require that every individual within an area be counted, are used in most situations when it is necessary to obtain estimates of abundance or population densities of bird species.

SURVEY METHODS

1. Relative abundance estimates

One of the simplest ways to estimate the relative abundance of birds at a site is to visit the site repeatedly over a period of several days or weeks and keep a checklist of the species of birds detected (observed and/or heard) during each visit. With each visit, the date and the length of time spent searching for birds should be noted. The number of visits a particular species is detected can be divided by the total number of visits to obtain an index of the abundance of the species. All of the species can then be ranked from highest (the species detected during the most visits) to lowest (the species detected during the fewest visits).

2. Line transects

Surveys based on line transects are among the most efficient techniques for obtaining estimates of population densities of birds species. A line transect survey involves having an observer walk along a straight line of known length within the survey area and count all of the individuals of the target species that can be seen or heard from the transect line. When a bird belonging to the target species is detected, the perpendicular distance from the transect line to location where the animal was initially detected is recorded. The perpendicular distance from the transect line can be estimated by using a range finder to determine the distance between the observer and the bird, and using a compass to determine the sighting angle between the transect line and the bird (Figure 1).

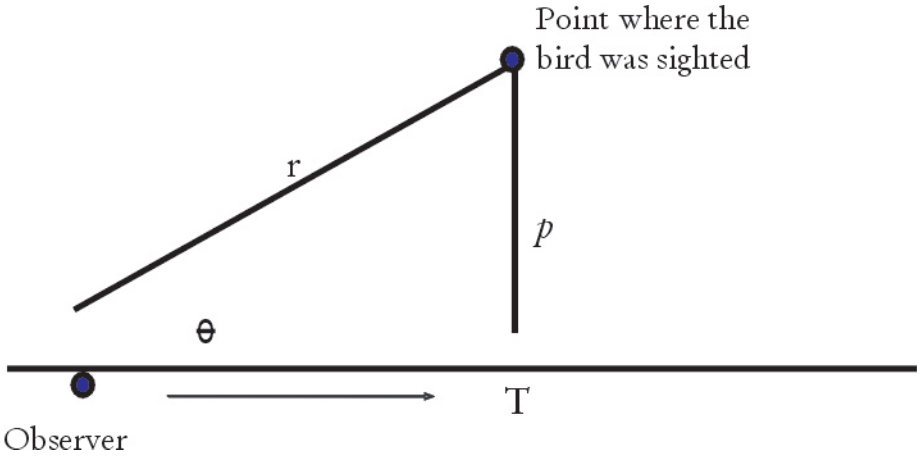

Figure 1. Measurements needed for estimating the perpendicular distance (p) from the point where a bird was initially sighted to the transect line. T is the point on the transect line that is perpendicular to bird. The radial distance (r) is the linear distance between the observer and bird when the bird was initially sighted.

Once the radial distance and sighting angle are determined, the perpendicular distance of the animal from the transect line can be calculated using simple trigonometry.

$p = r(\sin\theta)$

One of the assumptions of the line transect method is that all birds that are located directly on the transect line will be detected. The probability of detection decreases as p increases. Consequently, the probability of detection, as a function of perpendicular distance from the transect line, must be taken into account when estimating population densities using a line transect survey. Many mathematical models have been developed for this purpose (see Buckland et al., 1993). The computer programs LINETRAN (Gates, 1980) and DISTANCE (Laake et al. 1991; Buckland et al. 1993) incorporate several of these models into routines for estimating population density based on perpendicular distances or radial distances and sighting angles.

Under ideal conditions, it is sometimes possible to detect all individuals within a certain distance of the transect line. When this is the case, a set transect width (w) in which there is 100% detectability can be chosen before the survey is conducted, and all of the animals that are more distant from the transect line than w can be ignored. The population density of the species in the survey area can then be estimated using the following equation.

$$D = \frac{n}{2wL}$$

where D is the estimated population density, n is the number of individuals counted within the survey area, w is the distance from the transect line to the outer boundary, and L is the length of the transect. This type of bounded line transect is called a strip transect. The strip transect method is analogous to a complete count, or census, in that w is a distance from the transect line in which we assume that all animals present are detected.

In practice, it is rarely possible to safely assume that all individuals of the target species have been detected within a certain distance from the transect line. Consequently, D is usually estimated from sightings of birds along an unbounded line transect, and an adjustment is made to account for the decreasing probability of detecting an animal as the perpendicular distance of the animal from the transect line increases. Typically, the distance data are entered into one of the computer programs mentioned above, an appropriate mathematical model is selected, and the computer magically reveals the estimated population density.

An alternative is to graphically determine a distance from the transect line in which there is a very good chance of detecting any individuals of the target species that are present. One such method, developed by Ramsey and Scott (1981), consists of plotting the cumulative number of individuals sighted from the transect line (plotted on the y-axis) against distance from the transect line (plotted on the x-axis) to determine the effective width of the transect. The effective width of the transect (w_e) is the perpendicular distance from the transect line beyond which the probability of sighting a bird is significantly lower than the probability of sighting a bird that is directly on the transect line. Remember that for a given distance (p) the cumulative number of individuals sighted at that distance or closer is what is plotted on the graph. For example, if there were 5 birds sighted at $p = 0$ m, 6 sighted at $p = 5$ m, and 4 sighted at p = 10 m, the cumulative number of animals sighted would be 5 at p = 0 m, 11 at p = 5 m, and 15 at $p = 10$ m. After the cumulative number of individuals sighted is plotted against distance, a line is drawn along the steepest part of the slope. Another line is then drawn which extends from n, on the y-axis, and runs perpendicular to the x-axis. The effective width of the transect is the point where this line intersects the line that was drawn along the steepest part of slope (Figure 2). The effective area surveyed (EAS) can then be determined by the equation $EAS = L2w_e$. The estimated population density can then be calculated using the equation

$$D = n/EAS$$

where D = the population density of the target species and n = the number of individuals sighted from the transect line.

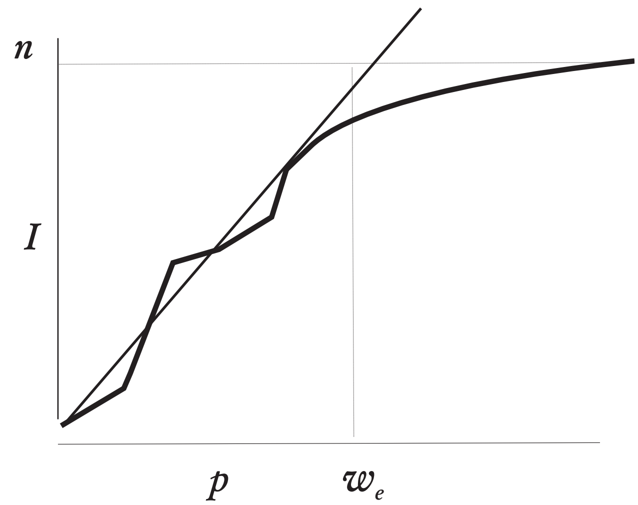

Figure 2. An illustration of the Ramsey and Scott method for graphically estimating the effective width of a transect (w_e) based on perpendicular distances (p) of individuals sighted from the transect line. The cumulative number of individuals sighted (I) is plotted against p, then a straight line is drawn parallel to the steepest part of the slope. Another line is drawn that intersects n (the total number of individuals observed from the transect line) on the Y-axis, and runs parallel to the X-axis. The point where these two lines intersect is used to pinpoint w_e. A vertical line drawn from this point to the X-axis will intersect the X-axis at w_e.

Among many species of birds, particularly passerines, breeding males are much more likely to be detected than females or juveniles. This is because territorial males are often detected by their song before they are observed, and they often bear conspicuous, brightly colored plumage. In addition, they are often easier to identify to species than are females and juveniles. Consequently, in many surveys of passerines, only data on breeding males are collected.

3. Point surveys
   Point surveys are functionally similar to line transect surveys, except that the observer remains at a set point rather than walking a transect line. The effective area surveyed is calculated using the formula for calculating the area of a circle.

$$EAS = \pi r_e^2$$

The effective radius of the survey area (r_e) is synonymous to w_e in a transect survey. Usually, point surveys are conducted over a set period of time. The duration of the survey should not vary from one survey point to another.

4. Indirect abundance indices
   An indirect abundance index is a count statistic of some type of *sign* of a species that is correlated with the population density of the species. Indirect indices are most useful for birds that are very difficult to observe. Nests or other types of signs can be counted within a survey area, and the abundance of the species within the area can be estimated based on a previously established relationship between the abundance of the signs and the abundance of the species.

PROCEDURE

Work in pairs for this assignment. Your first task will be to delineate two 200 m long transects. One of the transects should be located in woodland or forested habitat (Survey Site 1) and the other should be located in (or adjacent to) wetland habitat in which the largest trees or shrubs are small to intermediate sized willows or alders (Survey Site 2).

1. Lay out each transect in a straight line that follows a predetermined compass bearing. Use flagging ribbon to mark the transects at intervals of 25 m.

2. When you are ready to search one of the transects, you should slowly and quietly walk down the transect line with a compass, range finder, and notebook. When you detect a bird, record the species and the perpendicular distance from the transect line to the site where the bird was located when it was initially sighted.

3. Use the range finder to measure the perpendicular distance from the transect line to the location where the bird was first detected; or use the range finder to measure the radial distance from you to the bird when you first see the bird. If you choose the latter option, you will also need to use your compass to determine the sighting angle. Later you will need to convert the radial distances to perpendicular distances by multiplying the radial distance by the sine of the sighting angle.

4. Record all data in Table 1.

CALCULATIONS

Density estimates

1. Select the three most common species on each of the transects and use the Ramsey and Scott method to estimate the population densities of each of these species at each survey site. You will need to plot the cumulative number of individuals sighted against distance to estimate w_e. Calculate a separate w_e for each species and at each transect. Use your estimates of we to calculate the *EAS* for each species at each site. Divide the number of individuals sighted by the *EAS* to estimate the population density. Attach your graphs and show your calculations.

2. Truncate the width of the transect to exclude all observations of individuals farther than 20 m from the transect line. Now you can assume that the transect was a strip transect with a fixed width of 20 meters on each side of the transect line. Calculate the population density for every species detected at each survey site.

MATERIALS

Binoculars
Range finder
Field notebook or appropriate data sheets
Compass
100 m tape measure
Flagging ribbon

QUESTIONS

1. Compare the estimated densities on the truncated strip transect to the density estimates that you obtained using the Ramsey and Scott method on the unbounded line transect. Which method appeared to work better? Why?

2. Compare the population densities of the common species of birds at the wetland site to the population densities of birds at the forested site. Which site appears to support greater number of birds? Which appears to support greater numbers of species? How might you explain these trends?

3. Has does the effective width of the transect (w_e) appear to be influenced by the target species and by the differences in the habitat at your two survey sites?

Table 1(a). Data sheet for recording transect data from Survey Site 1.

Transect Location ________________________________ Transect Length ____________
Date _________________ Beginning Time ____________ Ending time _____________
Habitat description ____
Temperature ________ Weather Conditions _____________________________________
Observer(s) ____

Sighting #	Species	Radial distance	Compass angle	Perpendicular distance	Comments

Table 1(b). Data sheet for recording transect data from Survey Site 2.

Transect Location ______________________________ Transect Length ___________
Date ________________ Beginning Time ___________ Ending time ____________
Habitat description ____
Temperature ________ Weather Conditions __________________________________
Observer(s) ____

Sighting #	Species	Radial distance	Compass angle	Perpendicular distance	Comments

NOTES FOR INSTRUCTORS

Excellent bird identification guides are widely available in different formats. Some examples include:

- Bull, J. and J. Farrand, Jr. 1977. The Audubon Society field guide to North American birds. Alfred A. Knopf, New York 778 pp.
- Peterson, R.T. A field guide to western birds. Houghton Mifflin Co., Boston 309 pp.
- National Audubon Society interactive CD-ROM. Guide to North American birds.
- AXIA interactive CD-ROM. Know your waterfowl and birds of prey. Calgary, Alberta.
- Audubon Society's Video Guide to the Birds of North America Volumes I – IV. 1985. Godfrew-Stadin Productions. Distributed by MasterVision, New York
- Robbins, C.S., B. Brunn and H.S. Zim. 1983. Birds of North America - a guide to field identification. Golden Press, New York. 360 pp.

Students need to have considerable time learning bird songs as this identification takes time to master, and practice is the only way to achieve this. Students should be encouraged to spend as much time as necessary learning bird songs both in the laboratory and in the field.

Identification of all birds at a particular study site can be a daunting task for the novice. To simplify this activity students may be assigned a few, easily-identified species (e.g., sapsucker, chickadee, nuthatch) and learn these well. This will allow the student more time to recognize a limited number of birds by sound and sight.

Another adaptation of this laboratory would be to include a hypothesis. A simple hypothesis could be for example: One finds yellow-bellied sapsuckers more commonly in Northern hardwoods than in red pine forest. Students would apply what they have done in the laboratory to evaluate the hypothesis.

For instructors who wish to expand their coverage of ornithology, additional field and laboratory activities may be found in Pettingill (1985). Some examples and corresponding page numbers in the Pettingill manual:

- External Anatomy (pp. 8-24)
- Feathers, Feather Tracts and Plumages (pp. 29-52 & 162-173)
- Pigeon Dissection- Anatomy and Physiology (pp. 53-110)
- External Characteristics and Identification of Orders and Families of North American Birds (pp. 125-161)
- Field Identification and Observational Techniques (pp. 198-211)
- Behavior -An Exercise in Taking Field Notes on Observations of Birds at a Feeding Station (pp. 212-231)
- Distributions and Habitat Associations (pp. 174-197)

Also, the Time-Life video series hosted by David Attenborough entitled *Life of Birds* is an excellent resource for most aspects of avian biology, evolution and ecology.

RESOURCES

Buckland, S.T., K.P. Burnham, D.R. Anderson, and J.L. Laake. 1993. Density Estimation Using Distance Sampling. Chapman Hall, London, England.

Gates, C.E. 1981. LINETRAN, a general computer program for analyzing line transect data. Journal of Wildlife Management 44:658-661.

Laake, J.L., S.T. Buckland, D.R. Anderson, and K.P. Burnham. 1991. DISTANCE User's Guide. Colorado State University, Fort Collins, Colorado.

Pettingill, O. S., Jr. 1985. Ornithology in Laboratory and Field, 5th Edition. Academic Press, San Diego, California

Ralph, C.J., et al., 1993. Handbook of Field Monitoring Methods. USDA Forest Service Pacific Northwest Research Station. PSW-GTR-144. 41 pp.

Ramsey, F.L., and J.M. Scott. 1981. Analysis Of Bird Survey Data Using A Modification Of Emlen's Method. Studies in Avian Biology 6:483-487.