

## **Appendix 8.0**

### **Invasive Species Science Education Program (ISSEP)**



#### **Teaching plant biology and ecology through invasive species focused activities**

**An integrative approach to meeting science benchmarks meaningfully, using  
real world teaching examples from classroom, field and restoration projects**

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June 2003

## **Acknowledgements:**

We would like to thank the following agencies for financial support in the production and implementation of the Invasive Species Science Education Program:

US Fish and Wildlife Service, Oregon Watershed Enhancement Board, USDI Bureau of Land Management, Oregon Department of Agriculture and Metro.

Thanks to Wolftree, Jennifer Carson, Jay Hopp, and Dale Waddell for their physical and intellectual contributions through their advice, review and field implementation of the Invasive Species Science Education Program.

## **Table of Contents**

Program Description: .....	5
Program Goals: .....	5
Evaluation:.....	5
Results:.....	5
MODULE I. Summary .....	8
Module I. Plant Structure and Function .....	10
Introduction.....	10
Roles and Importance of Plants .....	10
What are some other ways plants influence other organisms? .....	11
Defining Species .....	11
Plant Structures and Functions.....	12
Plant Reproduction.....	14
Life Cycles and Growth Stages .....	16
Life Cycles.....	16
Growth Stages .....	16
Reflection Topics for Discussion:.....	17
Species Focus: Noxious Weeds in Your Backyard.....	17
Activity/Project Example: Plant Research and Presentation .....	18
MODULE II. Summary .....	20
Module II. Invasive Plant Ecology.....	22
Introduction.....	22
What is a weed: Human and Ecological Definitions of Weeds .....	22
How Invasive Plants Invade .....	23
Arrival .....	24
Establishment .....	24
Spread.....	24
Impacts of Invasive Plants .....	25
Impacts to Composition, Structure and Function.....	25
Succession.....	25
How Ecosystem Functions Benefit Society.....	26
Disturbance: Invader's Favorite Event.....	27
Natural controls or enemies: A system of checks and balances .....	28
Invader Traits and Adaptations .....	29
Reflection Topics for Discussion:.....	29
Species Focus: Noxious Weeds in Your Backyard.....	30
MODULE III. Summary .....	31
Module III. Monitoring and Measuring Plant Populations.....	33
Introduction.....	33
Monitoring vs. Research .....	33
A Piece of the Pie: Sampling.....	33
Determining What to Sample .....	35
Sampling Methods and Techniques .....	35

Qualitative Methods.....	35
Quantitative Methods .....	35
Photo-monitoring: A Quick Look.....	37
The Photo-point .....	38
Sampling Vegetation .....	39
Basic Field Equipment .....	39
Selecting Random Samples.....	39
Data Management: What to do with the data collected? .....	40
6 Key Sampling Design Questions?.....	40
6 Important Steps of a Good Sampling Program!.....	41
Reflection Topics for Discussion: .....	41
Species Focus: Noxious Weeds in Your Backyard.....	41
Activity/Project Example: Measuring Frequency by Simple Random Sampling.....	42
Activity/Project Example: Measuring Forest Canopy Cover With A Spherical Densiometer and A Visual Estimate Cover Comparison Template .....	43
Activity/Project Example: Measuring Stem Density by Simple Random Sampling.....	45
Activity/Project Example: Measuring Density by Systematic Random Sampling.....	48
Activity/Project Example: Scotch Broom Seed Bank Sampling .....	50
Related Field and Laboratory Activities: .....	52
MODULE IV. Summary.....	53
Module IV. Ecological Restoration .....	55
What is ecological restoration?.....	55
Why conduct restoration?.....	55
How to choose what to restore?.....	55
Invasive Plant Control Methods and Strategies .....	56
Invasive Plant Control Options.....	56
Biological: .....	57
Physical: .....	57
Chemical:.....	57
Cultural: .....	58
Planning Your Project .....	58
The Planning Process .....	58
Measuring Success .....	59
Reflection Topics for Discussion: .....	59
Species Focus: Noxious Weeds in Your Backyard.....	59
Activity/Project Example: Restoration Project Planning.....	60

## **Program Description:**

Because most people learn by doing, the Invasive Species Science Education Program (ISSEP), developed by The Nature Conservancy (TNC), integrates classroom and field ecology lessons with ongoing local restoration projects. Targeting high school students within the entire Portland metropolitan area, TNC seeks to provide a realistic and meaningful learning experience through structured lessons and field monitoring projects focusing on invasive plant ecology and ecological restoration.

ISSEP is designed to be compatible with different teaching and learning styles. ISSEP is hands-on, community-based, and meets most science education content standards for the State of Oregon.

There are four modules to the ISSEP curriculum: Plant Structures and Functions, Invasive Plant Ecology, Measuring and Monitoring Native and Invasive Plant Populations, and Restoration Ecology. Designed in series, each of the modules can work independently.

## **Program Goals:**

Our goal is to increase noxious weed awareness within our community while simultaneously supporting local natural resource management through the contribution of time and energy from students. We seek to reach this goal through the following principle objectives:

- Teach invasive plant ecology and ecological restoration to high school students.
- Address important learning benchmarks through scientific inquiry and the practice of ecological restoration.
- Use real, ongoing natural area management projects at local natural areas and preserves to provide a meaningful and structured learning experience.
- Offer special learning opportunities for exceptionally motivated and talented students.
- Increase field volunteerism for restoration, research, and monitoring projects – Service Learning.

## **Evaluation:**

The success of the ISSEP will be evaluated in cooperation with teachers and students through verbal and written feedback. Since this program is both academic and hands-on, student test scores will reflect their aptitude while field project involvement will reflect their interest and enthusiasm.

## **Results:**

The experiences students will have will contribute to the livability of both human and natural communities. Connections will be made to the natural areas

within their community through active participation with it. As a result, students will develop a sense of stewardship with their environment and sense of progress and accomplishment in their lives. Restoring natural areas creates a positive and more meaningful learning environment where students can develop their maximum potential and prepare themselves for successful transitions from scientifically literate students to active members of their community.



## **MODULE I. Summary**

### **Subject:**

### **Plant Structures and Functions**

### **Overview:**

Ecosystems are composed of a complex variety of interconnected processes and components, both biotic and abiotic. Through this section, students will focus on the various types of plants and their respective structures, habits, and identification.

### **Goals:**

- Students will develop skills in observation, problem solving, and decision making.
- Students will know and understand the diverse native plant community.
- Students will gain an appreciation for and a sense of connection to the plants in their community.

### **Strands:**

Unifying Concepts and Processes; Life Science: Organisms, Heredity, Diversity/Interdependence; Scientific Inquiry

### **Benchmarks:**

- Use basic scientific process skills to observe, measure, use numbers, classify, question, infer, hypothesize and communicate (CCG).
- Identify and describe the relationship between structure and function at various levels of organization in life science (CIM).
- Compare and contrast interactions between structure and functions in biological examples (CAM).
- Describe different kinds of functions necessary for organisms that are adapted to a particular type of ecological niche (BM3).
- Describe and explain the structure and functions of an organism in terms of cells, tissues, and organs (BM3).
- Apply knowledge and concepts from the life sciences to investigations, projects and new learning (CAM).
- Recognize how structural differences among organisms at the cellular, tissue and organ level are related to their habitat and life requirements; give examples of common structures in plants (BM3).
- Distinguish between asexual and sexual reproduction; identify traits, which are inherited through genes and those acquired through interaction with the environment (BM3).

- Apply concepts of inheritance of traits to determine the characteristics of offspring (CIM).
- Formulate and express scientific questions and hypotheses to be investigated (CCG).
- Recognize that over time, natural selection may result in speciation as well as the development of subspecies (CIM).

**Concepts for classroom or field discussions:**

Introduction  
Roles and importance of plants  
Defining species  
Plant structures and functions  
Plant reproduction  
Growth stages and life cycles

**Field or laboratory project examples:**

Basic plant taxonomy  
Common native and non-native plant identification  
Tracking growth cycles/stages of native plants and weeds  
Study/research a plant

- Teach plant to other students
- Developing outreach materials

# Module I. Plant Structure and Function

## Introduction

The plant kingdom is a unique one, filled with a diverse assortment of colors, shapes, sizes, and habits. From microscopic algae to giant redwoods, the plant kingdom has evolved over 3 billion years. Harnessing energy from the sun, these organisms possess the ability to manufacture their own food. These so-called **autotrophs** are the foundation of our food chain.

Plants are some of the easiest organisms to study in detail because they can't run away from you. Plants are found just about everywhere you look; in the cracks of the sidewalk, around your school and home, in parks, and in natural areas. However, identifying plants can be very challenging at first. Most are green, have leaves, a stem, and some of them look very similar to each other. Take a closer look and notice that their shapes actually vary, flower color is different, and their stems have different textures. Some are so small and others very tall, as fat as a baseball bat or as thin as a pin.

## Roles and Importance of Plants

Why should we study plants, are they really so important? Well, of course!

- **Plants are responsible for the clean air we breathe and the clear water we drink.**
- **Plants provide us with building materials, medicines, and food.**
- **Some plants help other plants and animals survive. Other plants inhibit the growth of neighboring plants. And plants like POISON OAK produce chemicals that cause itchy skin rashes!**
- **Our food crops depend on the genes of their wild plant relatives.**

We also study plants because they tell us something about the place where they are growing; that is, they are good biological indicators of site quality. In this way, some plants act like the canary birds that miners used to take with them into the mining tunnels. Since the canary bird is small and sensitive, the slightest amount of poisonous gas would make it sick. When the miners noticed the canary bird getting sick, the miners knew that something bad was in the air and got out before they got sick. In this way, the bird acted like a biological alarm or indicator of air quality.

**Non-native invasive plants** like Himalayan blackberry, English ivy, Scotch broom, reed canary grass and Japanese knotweed, are taking over natural areas, killing trees, causing erosion, and polluting our environment. They are also biological indicators because their presence tells us that the environment we are a part of has been altered or disturbed. **Exotic weeds** are destroying native biological diversity and are second to the destruction of habitat as the leading cause to the decline of biological diversity.

## **What are some other ways plants influence other organisms?**

Shade created by some plants can both help and hinder the growth of nearby plants. Depending on a particular plant species ability to live in low light conditions or shade tolerance, it may get burned with too much sun or starve without enough. The shade produced by black cottonwood and alder help cool streams and rivers that salmon and other cold water loving organisms need to survive. In addition, the fibrous roots of those trees and other vegetation help prevent erosion and sedimentation, maintaining a clear and clean stream. These are just a few examples of interdependence between plants, animals and their environment.

Other affects of plants include:

- Producing allelopathic chemicals or toxins that create unfavorable soil conditions for other plants.
- Taking up growing space, water, and nutrients.
- Creating habitat and food for many plants and animals.
- Providing organic soil matter from dead leaves, stems, and roots.

## **Defining Species**

A plant species is a group of plants with a distinct geographic range and physical characteristics, with interbreeding individuals occupying the same role or niche within that population. When attempting to identify separate species from one another, it is necessary to observe and classify the various structural components unique to that species. The structures outlined on the following page are typical for seed bearing plant species. These plants include the woody types, like conifers, broadleaf trees and shrubs, and the non-woody types, like herbs, grasses and sedges. Most invasive plant species of concern in our region fall within one of these sub-groups.

**Table 1. Typical Plant Structures and Functions**

<b>Structure</b>	<b>Function</b>
Seeds	Genetic material storage, protects plant embryo, provides energy for germination, transport packages
Fruits	Provides food, moisture, and shelter for developing seeds
Flowers	Reproduction, attraction
Leaves	Food manufacture, transpiration
Stem	Support, moisture and nutrient transport
Roots	Anchor, moisture and nutrient intake and storage

## **Plant Structures and Functions**

**Roots** come in many different shapes and sizes. They function to secure the plant in the soil and to obtain and store moisture and nutrients. Some, known as **taproots**, are very long, growing straight and narrow vertically and help the plant obtain moisture deep in the soil. These carrot-like structures also store a lot of moisture and nutrients. **Fibrous roots** look tangled and matted and are usually found in the first several inches of soil. Grasses typically have fibrous roots.

Microscopic **root hairs** covering the visible root portions increase the root's surface area and function to absorb moisture and nutrients from the soil. The root hairs are connected to vascular tissue inside the root that conducts water and mineral nutrients from the roots to all parts of the plant and sugars manufactured in the leaves to the roots for storage. Some plants possess roots with special structures or nodules containing **Nitrogen-fixing bacteria**. The plant "trades" some of the nutrients stored in its root mass for Nitrogen converted to ammonia by these important bacteria (**symbiosis**). The invasive Scotch broom is one example of such a plant possessing these structures.

**Stems** are the plant's rigid support structures that hold the plant leaves and flowers. Some stems help the plant obtain light by climbing over and on other plants and objects and into the light. Stems also contain bundles of special plumbing-like structures or **vascular tissues**.

Woody plants have advanced in the plant kingdom by developing very strong rigid stems with differentiated vascular cells called xylem and phloem. These structures allowed plants to leave the confines of the ground, to grow tall, thereby increasing these plants ability to obtain light. **Xylem** transports water and nutrients upwards from the roots and **phloem** moves materials like sugars and hormones produced in the leaves and growing tips downwards.

Besides conducting water and nutrients, they help the plant breathe by conducting oxygen through small openings along the stem called **lenticels**. Between the xylem and phloem, a layer of cells called the **cambium**, divide and differentiate into xylem or phloem, which eventually die and harden into wood and bark, respectively.

Not all stems are rigid and upright. **Rhizomes** are unique stems in that they travel underground, and like roots, store nutrients. Rhizomes can regenerate new roots and aboveground stems if they are fragmented. Other types of stems include stolons and runners. **Stolons** are arching stems that take root at their tips. **Runners** are creeping stems that root at swollen nodes along their entire length. Some stems possess modified structures like prickles for defense or fine adhesive roots for clinging to and climbing up vertical surfaces.

**Leaves** come in many shapes and sizes and beside the flower are one of the key distinguishing characteristics identifying one plant from another. They also serve one of the most important roles for most plants. They are the plant's "solar panels". They contain **chlorophyll** that converts sunlight into food energy, through a process called **photosynthesis**. The leaves are also the location of small breathing holes called stomata. **Stomata** are abundant on the leaf's underside and aid in the exchange of gasses. They also help cool the leaf surface by releasing heat trapped in moisture vapor. The surfaces of some species leaves are shiny or waxy to help prevent moisture loss and to repel excess moisture. Some plants possess miniscule leaves that also help the plant conserve moisture. **Veins** are distributed across the leaf in a net-like or a parallel fashion and function like support trusses and extensions of the stem's vascular system. Grasses have only one seed leaf and veins that run parallel to the leaf margins. Broadleaf plants have two seed leaves and a vein pattern that can be either parallel or net-like. They may be composed of simple or compound leaves with alternate, opposite or whorled arrangements along the stem.

**Flowers** can be some of the most uniquely attractive and appreciated components of flowering plants. And it serves them right, since flowers contain the reproductive organs of the species. Some possess beautifully colorful structures or sweet fragrances to attract potential pollinators. Other flowers are less grandiose, relying on the wind to distribute pollen. The flowers of grasses are quite small but very complex in structure. Flowers may occur in clusters or singly on a stem. Some plants bear male and female structures separately on different flowers or on separate plants. The male structures provide pollen grains that contain the male reproductive cells. After contact with the female structures, sperm in the pollen grain fertilizes the egg within the ovary of the flower. The egg then develops into a seed.

**Fruits** are actually the seed-bearing structures of some plants or the swollen ovaries of the flower. The developing seeds are encased in a protective sheath or pulpy flesh till they mature. There are many types of fruits from conifer cones to hawthorn pomes. Some fruits are edible or possess special structures that facilitate their dispersal, thus expanding the plant's range.

**Seeds** usually possess tough seed coats that protect the plant embryo from desiccation or digestion till conditions turn favorable for germination. Some plant species seeds remain viable for many years, storing all the genetic material to promote the species success into the future. These seeds may remain dormant in a "seed bank" in or on the soil for some time before germinating when conditions are favorable for that plant species.

## Plant Reproduction

Non-native invasive plants possess some very successful reproductive strategies. In addition, they possess some interesting adaptations that enable them to spread and establish themselves over a wide range of habitats. Most invasive plants can reproduce by both sexual and asexual means, depending on their current growing condition.

**Sexual reproduction** is a strategy, in flowering plants, which requires that pollination, by wind or another organism, take place in order for viable seed production to occur.

### Disadvantages

- Sexual reproduction is demanding; timing, temperature, light, moisture, and spatial requirements must be meant in order for the seed to germinate and establish itself.
- Sexual reproduction happens only when the plant is mature; English ivy often takes 10 years or more to mature.

### Advantages

- Seed can be dispersed over a wide range especially if equipped with a mechanism that aids transport: wings, sails, floats, burrs (Velcro), exploding seed pods, lightweight, edible.
- Edible fruits attract wildlife to eat them, help breakdown seed coat (scarify) in animal intestinal tract, and provide a package of nutrient rich scat/droppings around the seed. These dispersal agents transport seed far from source, thus helping weed increase its range and establishment.
- Sexual reproduction increases genetic diversity and the ability to adapt to changing conditions.
- Sexual reproduction allows the plant genetic resources to go dormant as seed in the soil (seed bank) and wait till environmental conditions are favorable for the species.

**Asexual reproduction** or vegetative reproduction is a method by which plants propagate themselves from established root systems and/or stem or root fragments. See Table 2 below for specific examples.

<p><b>Asexual or Vegetative Reproduction</b></p> <p><b>Advantages</b></p> <ul style="list-style-type: none"> <li>• Asexual reproduction allows a plant species to reproduce during its current living conditions especially when these living conditions are less than favorable for sexual reproduction.</li> <li>• Asexual reproduction utilizes existing plant biomass for propagation without the investment and expense of directing energy to flower, fruit and seed production.</li> <li>• Some asexual reproductive strategies use disturbances like soil erosion and flooding as a means to promote spread and establishment.</li> </ul> <p><b>Disadvantages</b></p> <ul style="list-style-type: none"> <li>• Vegetative reproduction doesn't increase a plant's local genetic diversity.</li> <li>• Successive plant generations are genetically identical to the parent plant stock and therefore lack the ability to adapt to local changing conditions.</li> </ul>
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**Table 2. Vegetative Reproductive Structures**

<b>Structure</b>	<b>Description</b>	<b>Plant Examples</b>
basal stem	new shoots form near the base of the stem, forming multiple-stemmed shrubs	Scotch broom, Himalayan blackberry
root	new shoots called suckers, formed from adventitious buds on roots	Himalayan blackberry, Japanese knotweed
rhizome	new shoots from underground stems	Japanese knotweed, reed canary grass
stolon	arching branches that take root at the nodes or the tips upon reaching the ground	Himalayan blackberry
runner	creeping stems that root along their entire length at soil surface	English ivy
fragment	stem or root pieces that regenerate new roots, stems and leaves	Japanese knotweed, English ivy, Himalayan blackberry, reed canary grass

## Life Cycles and Growth Stages

Invasive plants have very successful reproductive strategies. Weedy plants that can reproduce both asexually and sexually can be especially difficult to control once established. Since some invasive plants are vulnerable at certain stages of growth, it is important to be able to identify and understand these various stages and life cycles.

### Life Cycles

Plants fall into one of three life cycle categories: annuals, biennials, or perennials. These categories pertain to the number of calendar years the plant lives.

**Annuals** complete their entire life cycle in less than one year. The plant germinates from a seed, grows, flowers, sets seed, and dies over one or two seasons but within a year. For example, some annual grasses germinate from seeds during the fall, grow tall during the spring, flower and set seed early in the summer, and then die. Weedy invasive annuals tend to be copious seed producers.

**Biennials** complete their life cycle within two years. The first year is usually dedicated to vegetative growth, and the second to flower and seed production. After flowering and seed maturity, the plant dies.

**Perennials** live more than two years, and grow from existing roots or stems. Woody plants are typical perennials. Deciduous woody perennials, like Scotch broom, lose their leaves after the growing season, go dormant through the winter, and resume growth the following spring from over-wintering buds. Evergreen woody perennials like English ivy retain healthy leaves and grow throughout the year except during the coldest and driest periods of the year. The above ground vegetation of some non-woody perennials, like Japanese knotweed, die back completely after the growing season. New shoots spring up through the previous season's dead stems from persistent underground roots and stems. Many perennials can reproduce vegetatively as well (See Table 2 above). Perennial invasive weeds are the most difficult plants to get rid of.

### Growth Stages

There are three general stages of growth upon seed germination. These include: seedling, vegetative, and flowering. The amount of time spent in each of these stages varies from species to species

The **seedling** stage immediately follows germination. The seed has swelled with moisture and the seed root or radicle anchors itself into the soil. The seed leaf or leaves (cotyledons) have emerged from the seed and upon emerging from the soil, begin photosynthesis. The tiny seedling grows, takes up nutrients and moisture, and true root hairs form as well as the first true leaves. Root growth is rapid during this stage.

The formation of true leaves begins the **vegetative** stage, during which the plant puts on a lot of stem and leaf growth to keep up with the demand for solar energy. As the daily provision of solar energy wanes (days get shorter after Summer Solstice), vegetative growth slows.

Shorter days cue some mature plants to enter the **flowering** stage. Vegetative growth slows or ceases and most of the energy harnessed and stored within the plant goes to the manufacture of flower parts, fruits and viable seeds. Soon after flowering, plant vigor declines and depending on the species particular life cycle and growth habit, the plant resumes growth, dies or goes dormant.

### **Reflection Topics for Discussion:**

- Describe structural and functional components that facilitate the spread and establishment of an invasive weed.
- Name several plants of medicinal, edible, cultural, and economic value.
- What advantages do plants have that reproduce asexually? Sexually?

### **Species Focus: Noxious Weeds in Your Backyard**

Now take some time to become familiar with the above concepts by examining the following exotic invasive plants. **Example:** Obtain or find any or all of the species listed below and observe their respective structures. Think about the functions they serve for the plant(s). Describe how those structures help the plant survive and possess invasive habits. Describe the current growth stage(s) of the plant and determine its life cycle. How does it reproduce? Why is it so successful?

- Himalayan blackberry
- English ivy
- Scotch broom
- Japanese knotweed
- Reed canary grass

## **Activity/Project Example: Plant Research and Presentation**

### **Introduction:**

Using both native and invasive plants as investigative subjects, students play the roles of both researcher and teacher. Presentations can be held in the classroom or in the field. Set aside some time for questions at the end of each presentation. Regardless of format used to present the plants, each presentation should include the following in a typed report:

- Plant names (common and scientific/Latin)
- Physical description or structural characteristics, from the roots to the leaves, including fruits and seeds. Include any unique features that distinguish it from similar plants.
- List and describe any related or similar species both native and non-native.
- Origin of plant. Describe its native habitat, roles, and habits. If it is non-native, include how and when the plant was introduced, and habits in its new environment.
- Natural controls or limiting factors, for example, diseases, insects or other herbivores, and environmental factors such as light or moisture.
- Reproductive biology. Describe the plant's reproductive strategy.
- Population control. If the species is native, describe some ways in which humans can enhance its survivability. If invasive, describe methods to control it.

### **Goals:**

- Students will examine plants with greater acuity and gain more knowledge and appreciation for them from their personal investigations.
- Students will develop and enhance research and presentation skills through scientific inquiry in a structured format.

### **Materials Required:**

Depending on the format used by the students and the location: paper, computer, overhead, slide, film, or performance.

### **Time Allotted:**

5 minutes

### **Procedures:**

1. Compose a list of native and invasive plants common in the area. These should be plants that inhabit or invade natural areas adjacent to the school or student's community. Assign each group or individual a species.
2. Students should be allowed 1-2 weeks to research and prepare their reports and presentations.

3. Group meetings should be encouraged. Students should check in with each other at least twice during the time allotted.
4. Groups should clearly define and understand individual roles within the group to avoid redundancy and increase efficiency.
5. Students should be encouraged to use a variety of resources besides the internet for information. Investigate local sources such as libraries, universities, natural resource agencies, conservation organizations, and native plant societies.
6. Journals can be used to document their research progress.
7. During the presentations, groups can facilitate each other's presentation by actively listening and providing their full attention and participation to the group presenting; students should be taking notes. If time allows, encourage constructive questions and comments from the class.
8. Educators can provide a quiz at the end of the class or week that summarizes the presentations in order to gauge student aptitude of what was discussed.

**Related Activities:**

- Encourage outreach. Students can take their presentations outside of the classroom and effectively communicate invasive species issues from within their school and outside in their communities. Local community events and gatherings, libraries and other schools offer opportunities to reach out to a broader audience.
- Mentor younger student groups outdoors at a natural area or in their schoolyard. Older students can lead them on a guided interpretive hike.

## **MODULE II. Summary**

### **Subject:**

### **Invasive Plant Ecology**

### **Overview:**

Ecosystems are composed of a complex variety of interconnected processes and components, both biotic and abiotic. In this section, students will study those forces and the ecological communities they influence using non-native invasive plants as a central theme. In addition, students will focus on the various roles that ecosystem components play for humans.

### **Goals:**

- Students will develop a deeper understanding and appreciation of diversity, interdependence and community in an ecological context.
- Students will broaden their spatial awareness to include themselves as an integral component of an ecosystem's structure and processes.

### **Strands:**

Unifying Concepts and Processes; Life Science: Heredity, Diversity and Interdependence; Earth Science: The Dynamic Earth; History and Nature of Science; Scientific Enquiry

### **Benchmarks:**

- Identify and describe the factors that influence or change the balance of populations in their environment (BM3).
- Describe and analyze the effect of species, including humans, on an ecosystem (CIM).
- Explain the water cycle and its relationship to weather and climatic patterns (BM3).
- Identify a system's inputs and outputs. Explain the effects of changing the system's components (BM3).
- Define a system by specifying boundaries and subsystems, indicating its relation to other systems, and identifying its inputs and outputs (CIM).
- Identify and describe the relationship between structure and function at various levels of organization in life, physical, or Earth/space science (BM3).
- Compare and contrast interactions between structures and functions in physical and biological examples (CIM).
- Identify and explain patterns of change as cycles and trends (BM3).
- Describe the relationship between constancy and change within systems (CIM).

- Understand that science is a human endeavor practiced by individuals from many different cultures (CCG).
- Understand that scientific knowledge is subject to change based on new findings and results of scientific observation and experimentation (CCG).
- Describe how the Earth's surface changes over time (BM3).
- Describe and explain the theory of natural selection as a mechanism for change over time (BM3).
- Formulate and express scientific questions and hypotheses to be investigated (CCG).
- Use basic scientific skills to observe, measure, use numbers, classify, question, infer, hypothesize, and communicate (CCG).

**Concepts for classroom or field discussions:**

Introduction

What is a weed: Human and ecological definitions

How invasive plants invade: The invasion cycle

Impacts of invasive plants

Impacts to ecosystem composition, structure, function

Succession

How ecosystem functions benefit society

Disturbance: Invader's favorite event

Specialists vs. opportunistic generalists: Niche

Natural controls: A system of checks and balances and interactions

Invader traits and adaptations

Species ecology focus: Noxious weeds in your community

**Field or laboratory project examples:**

Observing plant distribution and ecosystem composition, structure, function

- Identifying plant communities
- Defining and mapping plant communities
- Survey for weed occurrence, cover, and density
- Monitoring changes over time: succession and disturbance

## Module II. Invasive Plant Ecology

### Introduction

Habitat loss is the greatest threat to biological diversity. What is the second greatest threat? Second to habitat loss, invasive, non-native plants and other invasive species are the leading cause contributing to the decline of quality natural habitat and biological diversity. This is a special concern for The Nature Conservancy since we own and manage many spectacular natural areas. Invasive species steal habitat and important resources from plants and animals. In addition, these organisms change important ecological processes that all species, including humans, depend on for their survival.

In order for us to understand the roles of invasive plants in their new environment, it is important to understand their ecology. **Ecology** is the branch of science that studies the interrelationship of organisms and their environments. Therefore, **invasive weed ecology is the study of the interaction of invasive plants with their environment.**

### What is a weed: Human and Ecological Definitions of Weeds

Humans have struggled with weeds for many generations. They seem to follow us wherever we go. Dandelions, for example, are infamous for invading “pristine” turf, lawns, and gardens.

***Typically, weeds are defined as undesirable plants growing where they are not wanted (by humans), with harmful or aggressive habits.***

This is a human-valued definition because the plants aren’t necessarily harmful in all cases or in every location. Some individuals may be attracted to another’s undesirable plants.

In addition, some highly adaptive and opportunistic native plants like horsetails, bracken fern, red alder, and poison oak have been considered “weedy”. However, “weedy” native plants don’t cause serious harm to their environment.

***Native plants, of course, are plants occurring naturally in an ecosystem, having evolved and adapted to conditions within its natural range without human intervention.*** All native plants are important components within their natural ranges.

Ecologists and land managers use many terms to describe and classify weeds. To think about weeds objectively, that is, without bias, it would be helpful to reflect on the following definitions. These terms are sometimes used interchangeably and sometimes in error. So to avoid confusion:

***Exotic plants are non-indigenous or non-native plants that have been introduced to a new location outside of their normal growing range.*** These plants were introduced intentionally or unintentionally. Remember that not every exotic plant is invasive. Many garden flowers, shrubs and trees are exotic species that won't thrive outside of your backyard. Of those plants that do thrive, most will not displace native species in the wild.

***Invasive plants are a subset of exotic plants that negatively impact the biological diversity, functions, and productivity of ecosystems.*** Invasive plants eliminate, reduce, or displace native plants by competing for nutrients, moisture, habitat, and sunlight. Invasive plants also negatively affect human systems like gardens, farms, ranches, and tree nurseries.

***Noxious weeds are invasive plants of serious concern that legally designated by the Oregon State and U.S. Departments of Agriculture.*** Noxious weeds are recognized as serious pests that can cause economic losses and ecological damage to the environment. Agencies and resource managers manage some noxious weeds for their destruction and/or control. The highest legal designation is ***Quarantined weeds***. By law, the sale of these plants is prohibited and their distribution strictly regulated. These plants are treated like toxic waste in some countries because of the damage to the environment caused by them.

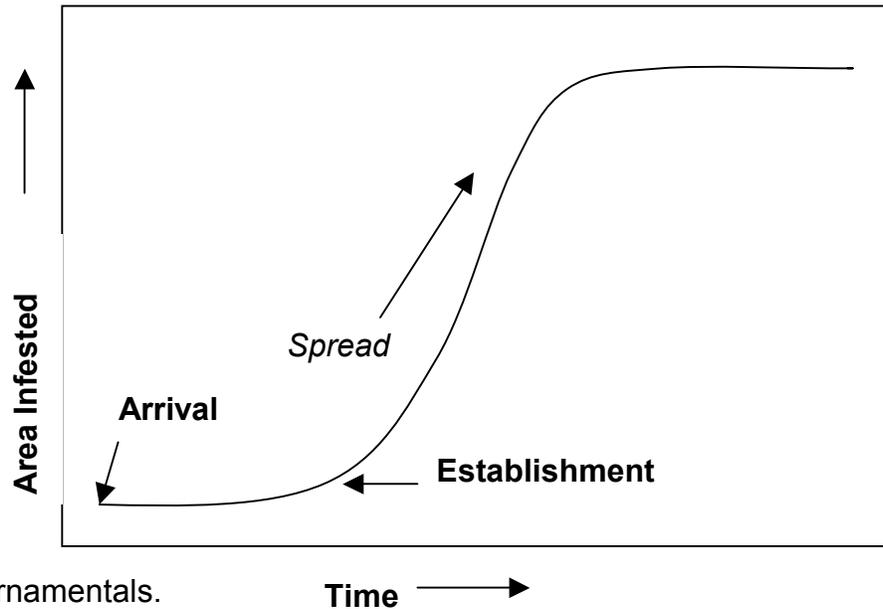
## **How Invasive Plants Invade**

The invasion cycle has three general components: Arrival, Establishment, and Spread. Most of the invasive plants in your community were intentionally introduced to North America within the last 100 years. The growth curve illustrated below demonstrates the general population trend of invasive plants if left undisturbed.

## Invasive Population Growth

### Arrival

Invasive plants may be intentionally or unintentionally introduced to a new range. Invasive plants may arrive as a stow-away seeds or stem and root fragments in cargo, in contaminated soil, transported by boat, automobile, animal or clothing. Some were purchased from nurseries and planted in gardens as ornamentals.



### Establishment

The establishment of invasive plants usually depends on some agent(s) of disturbance or where native plants are weakened and stressed. Most weeds usually do not compete well in healthy, intact ecosystems. However, there are exceptions. The ever-increasing urban forests (due to urban sprawl), construction sites, roads and trails are often the first places to be invaded. These fragmented and disturbed areas are like “open wounds” that are vulnerable to “infection”, in this case by invasive plants. Once established, they reproduce and become increasingly more widespread with time.

### Spread

Invasive plants spread when seeds or fragments of live roots and stems are moved from one area to another. Natural disturbances like floods transport these seeds or plant fragments downstream where they may root and start a new infestation. Some plants like Scotch broom have special structures such as exploding seedpods that help disperse seeds away from the mother plant. Some weed seeds have special structures that help them disperse by wind, water or by clinging to animals or clothing. Others have fruits that contain seeds and may be eaten by animals and spread in the animal’s scat. People also contribute to the spread of invasive plants as equipment or soil contaminated with weed fragments or seeds are accidentally transported to new sites. The spread of invasive plants has increased over the last 100 years as transportation technology has progressed. More roads, more traffic, and more commerce are contributing to the expanding range of invasive plants.

## Impacts of Invasive Plants

Invasive plants can be very destructive if ignored. The two main impacts invasive plants have on our natural areas are native species exclusion and disruption to ecological functions.

More specifically, these impacts affect native plant communities by:

- **Crowding, shading, and starving native plants of light, nutrients, moisture and growing space.**
- **Altering the plant community composition and structure, and as a result, impacting the ecological functions that native plants and animals, and human communities need to survive. See: How Ecosystem Functions Benefit Society**
- **Supporting other non-native species including plants, animals, and pathogens.**
- **Altering the soil chemistry and pH by releasing chemicals that make it difficult for native plants to grow and reproduce.**
- **Causing erosion due to inadequate root structures from the lack of native plant diversity.**

## Impacts to Composition, Structure and Function

Ecosystems are composed of interacting living or **biotic** and non-living or **abiotic** components. The biotic or living parts are collectively referred to as a **community**. Ecologists organize ecosystems by their composition, structure, and functions. The **composition** represents the plant and animal species, the **structure** is the spatial arrangement of those species by their various ages, sizes, shapes and living requirements, and the **functions** are ecosystem processes like nutrient and water cycles unique to that ecosystem. **Invasive plants can drastically alter the composition, structure and function of an ecosystem even over a short period of time.**

## Succession

**Succession** can be thought of as a progressive natural change in the structure and composition of vegetation within an ecosystem over time. **Invasive plants can alter the natural succession patterns of ecosystems.** One hypothetical scenario to illustrate this is a stand of willows growing along low-elevation riverbanks and floodplains.

Over time, alder and cottonwood trees eventually may establish themselves and dominate these same floodplains. These short-lived trees, which contribute large amounts of organic matter to soil formation, may be replaced by or joined with Douglas-fir and cedar and a diverse assortment of undergrowth. This mixture of riparian vegetation provides many functions like effective erosion control to habitat, providing clean air and water, regulating water levels and nutrient cycles.

But when invasive plants like Himalayan blackberry or Japanese knotweed invade a riparian ecosystem, they form huge dense thickets that steal light, water and nutrients from native plants. Eventually, the invaders spread and take up more space. The structure changes from a mixture of different native plants to a thicket of just Himalayan blackberry or Japanese knotweed.

As a result, the ecosystem ceases to provide the same functions as it did before the invasion, like habitat and food for native biological diversity to regulating stream temperatures and preventing bank erosion. **Healthy ecosystems serve many more functions than disrupted or destroyed ones.**

## **How Ecosystem Functions Benefit Society**

To summarize, ecosystem functions that we benefit from include:

- **Providing clean air and water**
- **Nutrient cycling**
- **Biomass storage/decomposition**
- **Mineral weathering and soil formation**
- **Regulating and moderating temperature, water levels, and disturbance extremes like floods and fires**
- **Providing habitat and resources for things we all depend on (wood, food, medicine)**

## Disturbance: Invader's Favorite Event

In nature, disturbances are natural or unnatural events that change an ecosystem's composition, structure and function. The impacts of a disturbance depend on the type, frequency, and intensity of the event. An example to illustrate this is a natural wildfire (type) burning down thousands of acres (intensity) of pristine forest every year (frequency). Some disturbances are natural, some are human influenced, others are a combination of them both.

Disturbances have many origins. Multiple disturbance events are often interconnected. One disturbance may provoke another directly or indirectly. Some examples of disturbance include:

- **Fire or fire suppression**
- **Catastrophic – Massive flood, volcano, earthquake, landslide**
- **Human directed – Development, logging, agriculture, recreation**
- **Insects/disease**
- **Invasive species introduction\***
- **Seasonal flooding**
- **Water/wind**

Major disturbances disrupt ecological functions or processes. These disruptions may put pressure on native plant and animal communities, thus increasing their vulnerability to stress and disease. Riparian communities, for example, are well adapted to seasonal flooding and moisture extremes. In addition, Eastern Oregon forest communities have evolved to tolerate annual fires. However, humans have modified many of these ecosystems. Years of fire suppression and fuel accumulation create extreme fire conditions that may stress native plant communities and favor invasions of weeds. Some invasive weeds even intensify natural wildfires.

Different organisms have varying degrees of tolerance to stress. Think of your own bodies, for example. If you are stressed out all the time, your body becomes prone to illness, and then you get sick. Your immune system can't ward off pathogens if it's constantly stressed. Like disease causing germs invading stressed out bodies, invasive plants take advantage of invading disturbed areas since these sites are easy to colonize and become established. The disturbance may have created bare soil conditions or killed competing overhead and ground vegetation. **Most invasive plants are opportunistic and well adapted to exploiting disturbed environments.** They are not specialists, but rather generalists, that is, they don't have specific living requirements that must be met in order to thrive in a new environment. In other words, invasive plants aren't too picky.

Disturbed areas like old pastures, abandoned lots, and urban landscapes tend to be ecosystems with **low native species richness**, that is, these areas are not biologically diverse. These ecosystems may have “open niches” which can accommodate new exotic species. If a plant community is not biologically diverse, invasive species become well established in those “vacant” environments.

Plant communities have various species each with their own **niche** or role. Each species niche defines their competitive abilities, inter-species relationships, living requirements, life cycles and reproductive strategies. In addition, a species niche defines the natural control mechanisms that limit their presence.

### **Natural controls or enemies: A system of checks and balances**

Organisms are influenced by both biotic and abiotic components within an ecosystem. From the willows to the worms, all species are connected to and affected by the flow of energy in ecosystems. **Abiotic** components like moisture, sunlight, and soil minerals are limiting factors that affect plant growth. Local microclimate changes in temperature, moisture, and air movement may drastically impact the health of a plant community.

In addition to these physical components, plants interact with many biotic components in their environment. The most common species-to-species interactions fall into three categories: competition, mutualism, and predation.

- ***Predation* on plants is also known as herbivory or disease, in which one organism damages or consumes another.**
- ***Mutualism* is when two different species provide some benefit to each other that enhances each other's survival.**
- ***Competition* is the relationship between different individuals or species sharing the same resources. The outcome of this relationship is affected by each individual's tolerance to change to their best possible growing condition.**

Disease, herbivory, and competition may reduce or enhance a species success in a community. By eliminating the competitively weak individuals of a species, traits that will advance that species are favored. In addition, natural controls are nature's system of checks and balances, facilitating a biologically diverse ecosystem. Without natural controls or enemies, most species would become overcrowded and die due to lack of resources or disease.

Since most invasive plants arrived from another part of the world, these plants lack the natural control mechanisms that keep their populations in check. Without any natural enemies like diseases or herbivores, or limiting factors like freezing temperatures, some invasive plants can spread throughout and dominate their new environment forming homogenous areas of vegetation or ecologically simple environments.

## **Invader Traits and Adaptations**

What makes one invasive plant more invasive than another? The most invasive species are well adapted to living in disturbed environments especially those as a result of human modifications to the environment. The following are specific traits or adaptations that many invasive plants possess. These traits help them become successful competitors in a new location:

- As generalists, they can occupy a broader range of habitat and growing conditions than specialized species.
- Abundant small seed producers.
- Possessing both sexual and asexual reproductive strategies (options for changing growing conditions).
- Extended flowering and fruiting stages during the growing season.
- Lack of special seed germination requirements.
- Self-fertility allows isolated individuals to reproduce successfully.
- Fruits and seeds are edible and consumed by animals, especially birds, which aid in their dispersal over wider ranges.
- Having unique seed structures or dispersal mechanisms like exploding seed pods to aid seed transportation.

## **Reflection Topics for Discussion:**

- Why are invasive plants invasive?
- Are all weeds or exotic plants noxious or invasive? Why/not?
- Describe 3 contributing factors that facilitate the spread and establishment of invasive plants.
- Describe several variables that account for the species and ecological diversity at any given site. Why does one site have a greater variety of plants than another?

## **Species Focus: Noxious Weeds in Your Backyard**

Where and how have you seen these plants growing? Observe these plants in the field and describe some of the traits that make them successful invaders. How do these species impact ecosystems? Consider impacts to the ecosystem's components, structures, and functions as well as impacts to succession. How does the species spread? Describe what and how disturbances enhance each species survival.

- Himalayan blackberry
- English ivy
- Japanese knotweed
- Scotch broom
- Reed canary grass

## **MODULE III. Summary**

### **Subject:**

### **Measuring and Monitoring Plant Populations**

### **Overview:**

Objective scientific data forms the basis of management and restoration strategies for natural resource managers. Through this section, students will focus on developing analytical skills by sampling or measuring various components of their ecosystem. Students will also explore the possible factors that allow for the variability and similarity between collected data.

### **Goals:**

- Students will enhance their analytical skills and their awareness of the variables affecting their environment.
- Students will be able to utilize the knowledge they've obtained from the previous sections to develop a deeper understanding of the complex interactions within their community.
- Students gain valuable decision making skills that can be used in personal life experiences.

### **Strands:**

Scientific Inquiry; History and Nature of Science; Unifying Concepts and Processes

### **Benchmarks:**

- Use basic scientific process skills to observe, measure, use numbers, classify, question, infer, hypothesize, and communicate (CCG).
- Use scientific processes to observe, infer, compare, order, classify, and recognize relationships (PASS Criteria).
- Use integrated scientific process skills to predict, design experiments, control variables, interpret data, define operations, and formulate models (CCG).
- Understand that scientific knowledge is subject to change based on new findings and results of scientific observation and experimentation (CCG).
- Understand that scientific knowledge distinguishes itself through the use of empirical standards, logical arguments, and skepticism (CCG).
- Ask questions and form hypotheses that are based on observations and scientific concepts and that can be explored [and/or] tested through scientific investigations related to a domain of science (BM3, CIM, CAM).
- Determine areas of inquiry, frame scientific problems, and pose research questions and hypotheses involving scientific relationships (PASS Criteria).

- Design a scientific investigation to answer questions or test hypothesis and that provides data to address a question or hypothesis specific to a domain of science (BM3, CIM, CAM).
- Design scientific investigations that use precise and appropriate methodology to address questions, examine scientific relationships and test hypotheses (PASS Criteria).
- Conduct procedures to collect, organize, and display scientific data (CCG).
- Analyze scientific information to develop and present conclusions (CCG).
- Communicate scientific information, problems, processes, results, conclusions, and arguments, using and integrating writing, speaking, mathematics, and media (PASS Criteria).

**Concepts for classroom or field discussions:**

Monitoring and research  
 Sampling: A piece of the pie  
 Determining what to sample  
 Types of data collected: qualitative vs. quantitative  
 Cover, density, and frequency  
 Key sampling design questions  
 Steps to a good sampling/monitoring program  
 Data management  
 Photo-monitoring

**Field or laboratory project examples:**

Designing or maintaining a monitoring project: Sampling methods

- Collecting data
- Analyzing data
- Maintaining data

Monitoring weed spread and changes to ecosystem over time

- Tracking regeneration and rebound of native/non-native plants following restoration
- Seed bank monitoring
- Estimating cover and density
- Calculating rate of growth and percent change
- Photo-monitoring

Presenting data in a structured format

# Module III. Monitoring and Measuring Plant Populations

## Introduction

Plants make excellent study subjects since they can't run away or hide when you approach. This makes identification and measurement a lot easier. Plants are also good biological indicators, organisms whose presence, absence or abundance help determine the health status of an ecosystem. The decline of a rare plant population or the increase of an invasive species may indicate a change to the historic environmental condition.

Since plants and animals are interconnected, that is, plants provide habitat and food for animals, and some animals help plants by pollinating their flowers and dispersing their seeds, the lack of one particular animal or plant species can disrupt an entire ecological web. So ecologists often study plant populations to help us understand what is going on at a particular place in time.

## Monitoring vs. Research

When we look at something, count or measure it, and then do it again later, we are using a method of observation that scientists commonly use. **Monitoring** is the collection and analysis of repeated observations or measurements over time. The information obtained may be used to evaluate changes in ecosystem condition or progress towards meeting a management objective or goal. Monitoring simply observes trends or changes of something over time. **Research**, on the other hand, is a study designed to determine the cause(s) of some observed phenomena or attempts to explain or answer a trend or question, respectively. Monitoring information is sometimes used in research to answer questions or to explain events observed in nature if supported with evidence or experimental results.

## A Piece of the Pie: Sampling

Most plant populations are distributed over very large areas. In addition, the terrain may create conditions that make it difficult to measure the entire population. So instead of trying to count or study every single plant in a ten acre meadow, for example, scientists make observations and draw conclusions based on a sample or a portion of that population.

**Sampling** is the process of selecting and measuring a part of something with the intent of showing the status of the whole. Sampling plant populations, therefore, is a useful way to evaluate or estimate a plant species condition based on data collected from a portion of the whole plant population.

**Population** also refers to a complete set of individual objects or sampling units about which you want to make conclusions or learn something.

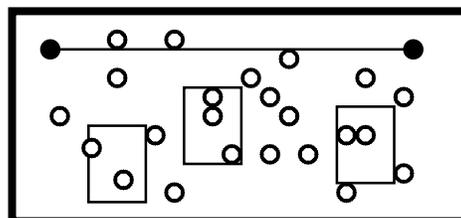
**Sampling units** are the actual items being measured. They may be individual plants, components of plants like stems, or they may be the plants contained in quadrat study plots, at random points in an area, or along transects.

**Quadrats** are square or rectangular plots positioned randomly within the population of interest. The quadrat contains the information that will be recorded, for example, number of flowering stems.



**Transects** are lines, usually measuring tapes randomly positioned through the population of interest. The information recorded may be taken at random points or quadrats positioned along the transect line. ●—————●

Transects and quadrats are randomly placed in the area containing the sampled population, called a **macroplot**. The macroplot is a larger area encompassing a defined area within the entire population of interest. The macroplot is usually a rectangular area containing the complete number of possible sampling units, either quadrats, points, or transects. The information or data collected refers only to the plants within the macroplot. This information is only an estimate of the whole population. The small circular objects in the figure represent individual plants scattered throughout the macroplot.



Monitoring doesn't always involve a sampling technique. Sometimes you can count or measure all of the individuals within a population of interest. But when the plant population is too large and you want to learn something about the entire population, sampling is required.

## Determining What to Sample

Management objectives or restoration goals should be used to determine the purpose of monitoring, and what and how to measure or monitor. For example, in order to determine a restoration project's success in reducing the number of Japanese knotweed plants in the Sandy River Watershed, one might consider monitoring the number of new stems that sprout the following growing season. By comparing the number of stems previous to the restoration activity to the number of stems following, the project's success may be determined by the percent change as well as the actual decline in number. Determining what to sample is an important step in the development of a monitoring project. This will help determine the type of sampling unit and the sampling method or technique used.

## Sampling Methods and Techniques

### Qualitative Methods

**Qualitative** sampling methods use visual means to estimate quantity and quality. Examples of qualitative methods include photographic monitoring, monitoring the presence or absence of a species, estimating population size and condition, assessing habitat condition, and mapping population boundaries. Qualitative sampling methods are quick and usually inexpensive. However, observations and estimates vary significantly among different observers, since the estimates are relative to the observer's skill and personal judgment. The variability can be minimized if standards are developed, for examples, using standardized data sheets to collect data, utilizing visual aids for eyeball estimates, and quantifying conditions in measurable classes or categories. It is important to develop standards for consistency among observers, that is, to get everyone on "the same page."

### Quantitative Methods

**Quantitative** sampling methods measure or count some attribute or characteristic unique to the target species being monitored. Examples of quantitative methods include census counts, cover, density and frequency. Some techniques are time consuming and/or expensive to conduct but these methods are generally more accurate than qualitative methods.

**Census counts** count every individual in a population. If populations are small and confined, this method is practical. However, a counting unit has to be defined since there is much variability among individuals within a population based on size, age, and sex. In addition, some clumping plant forms make it difficult to differentiate

between individuals and clones. Several observers should conduct the census in order to improve accuracy.

**Cover** is the vertical projection of vegetation from the ground as viewed from above. It is the percentage of area occupied by the target being sampled. Three methods to measure cover are commonly used: visual estimates in plots, line intercepts, and point intercepts.

**Estimating cover visually in plots** is simply the percentage of area within the quadrat plot, as viewed from above, occupied by the target species. This method is often used for dense grasses because of the difficulty measuring or counting individual grass plants. One disadvantage of this method is that estimates can vary between observers so a standard and pre-sampling training must be developed to reduce observer bias.

**Line intercepts** are typically used to measure shrub or tree canopy cover by measuring the canopy's spread along a transect line. The observer looks up and notes the point where the canopy begins and the point at which it ends along the transect or measuring tape and records this distance. All of the canopy distances are added up, divided by the total transect length, and then multiplied by 100 to get the percent cover for that species. The line intercept method is a useful way to measure cover of plants with dense canopies.

**Point intercepts** measure the number of times the observer intercepts a species at a point within the macroplot, usually with a metal pin or rod. Divide the number of points intercepted by the total number of points sampled within the macroplot. The quotient is the percent cover. Points can be measured along a transect line, randomly within the macroplot, or with a special sampling frame. Cover measurements are also a preferred method for measuring total biomass. One disadvantage, however, is that cover estimates can change dramatically over the course of a plant's growing season. So, be sure to sample at the same time of the year.

**Density** is the number of counting units per unit area, for example, the number of plants per square meter. Measuring density is most effective when counting units are individual stems of plants or the plants themselves. The sampling unit is usually a quadrat plot. The size and shape of the quadrat plot will depend on the distribution and form of the target plant species. Since most plants typically clump together in nature, a plot that accommodates this patchy distribution should be used. Rectangular plot shapes are most efficient since they can "catch" scattered and clumping individuals simultaneously. See example.

**Frequency** is usually measured using quadrat plots, and can be defined as the percentage of sampling plots within a sampled area occupied by the target species. For example, visualize laying a gigantic piece of graph paper over a forested area.

The area within the borders of the graph paper is our macroplot. Each square of the graph paper represents a quadrat plot within the macroplot that could be sampled. Fifty of these quadrat plots are randomly picked and sampled. We want to know the percentage of this macroplot occupied by a particular invasive species, for example, Scotch broom. So we must determine if Scotch broom is present in the square sampled or not. We then divide the number of samples that have Scotch broom by the total number of squares that could be sampled within the macroplot. Multiply this new value by 100 to get the frequency percentage. Frequency measurements are good for monitoring or sampling invasive species populations. However, frequency measurements are sensitive to plot sizes. For example, the larger the sampling plot the greater the chances that the species will occur in the plot and the less sensitive the sampling will be in detecting frequency changes over time.

## **Photo-monitoring: A Quick Look**

Photographic monitoring is one of the simplest and cheapest methods of recording conditions and changes within a landscape or population. It is a lot less time consuming than data collection and offers more in terms of its visualization value. Almost everyone can appreciate and interpret a sequence of photographs but not all can understand a statistical analysis of a data set. However, photos can be misleading and don't provide much "hard" data. A photograph may be worth "a thousand words," but can miss details that quantitative methods can measure.

Taking photographs requires some basic equipment:

- 35mm camera with several lenses, wide and short angle
- tripod
- compass
- film suitable for the current site conditions and presentation format (unless digital)
- a 8" x 11" photo ID label with date/time and location ID number. This can be a small dry erase board or simply a sheet of paper with the required information written clearly enough to be seen in the photograph.
- a photo-point datasheet for each photo (see example below)
- brightly colored stakes or flagging

For low-budget projects, pocket or "disposable" cameras are just as useful if a photo-point datasheet is completed with accurate and detailed information. In addition, photo-monitoring can be a good way to supplement the hard data obtained from a quantitative sampling method. That way, one has both visual and mathematical information to communicate the results of a project to a diverse audience.

## The Photo-point

Completely fill out a photo record and ID label at the site, making sure to document the location from a known permanent feature. Be sure to write clearly and legibly. Draw a map with directions to photo-point. The following example illustrates some information that should be included on the record.

### Photo-point Record sheet

Date (dd/mm/yy) \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_  
Time \_\_\_\_\_  
Photo-point ID number \_\_\_\_\_  
Photographer initials \_\_\_\_\_  
Canopy shade?(Y/N) \_\_\_\_\_  
Direction photo taken (degrees) \_\_\_\_\_°  
Slope (degrees) \_\_\_\_\_°  
Weather (dense cloud – partial cloud – full sun) \_\_\_\_\_  
Tripod? (Y/N) \_\_\_\_ If yes, approx. camera height from ground \_\_\_\_\_  
Lens size \_\_\_\_\_  
Map and directions to photo-point from a fixed permanent landmark:

### 8"x11" Photo-point ID Label

Date/time:

ID:



### Photo-point Procedures

1. The ID label should be placed somewhere in the field of the camera viewfinder. It needs to be clearly legible in the photograph.
2. Take the photograph and place a brightly colored stake at the position from which the photograph was taken. Mark the location of the stake on the map and note the compass direction that the photograph was taken.
3. To take follow-up photos, follow the same steps as above, and be sure to take the photos from the stake at the same bearing, and close to the same time of year as the last. Refer to the photo-point record for this information.

## **Sampling Vegetation**

### **Basic Field Equipment**

To sample vegetation, the tools used to conduct the data collection will be determined by what type of information is being collected and how it will be collected. Measuring tapes 50 to 100 meters long (150-300 feet) for transect lines, compasses to site the lines, maps or aerial photos for noting locations of macroplots, and field notebooks and/or datasheets are some very basic equipment that is required. Some advanced equipment like GPS (global positioning systems) and handheld computers aren't necessary but are being used by today's resource scientists to help in the speed of data collection, recovery and transfer.

In addition to the basic equipment described above, a sampling device designed and constructed to fit specific needs help with the speed and ease of data collection. The device may be as simple as a meter stick, a square or rectangular wooden frame or a stiff-wire hoop of a standard size and shape. The size and shape is determined by the sampling method used and the target species of interest.

### **Selecting Random Samples**

It is important that the sampling units are picked at random and scattered relatively evenly throughout the population without introducing any personal bias. The sampling units must have the same chance of being selected in order to accurately represent the entire population of interest. Furthermore, plants in nature tend to be distributed in dense clusters of individuals as well as sparsely scattered individuals within the same population. Sampling units that are evenly spread out at random throughout the population will be representative of this irregular distribution.

There are several methods that can be used to select random samples. Random number generators on some calculators, random number tables, wristwatch method, and dice are some examples used to select coordinates for the placement of sampling units within the macroplot. Whatever the method, the observers conducting the sampling must determine the range of numbers that can be used for the coordinates. These ranges are based on the dimensions of the macroplot and the size and shape of the sampling unit.

## Data Management: What to do with the data collected?

Once monitoring data is recorded, it is stored somewhere that will prevent it from becoming lost or damaged. If the data becomes lost, it will be necessary to start over and re-sample the plot. Successive data collections may be meaningless without the original baseline data to compare it to. Depending on the collection method used, the original data is almost always backed up with a second copy stored on a CD, on a computer hard-drive, or a paper hardcopy in a physical file. It should be somewhere conspicuous and practical to make it accessible to others in the future. Also, the data should be stored in a format that makes the information it contains useful to others.

## 6 Key Sampling Design Questions?

When designing a sampling or monitoring project, there are several questions to keep in mind that will help in developing the project. Generally, there is no right or wrong answer since every response will depend upon the goals of the project.

1. **What is the population of interest?** Or, what are you trying to measure? Management or restoration goals will help answer this question which is the foundation for any sampling and monitoring goals.
2. **What is an appropriate sampling unit?** Depends on what is sampled, why and how it is being sampled. Also, the amount of time, expertise and availability of resources will determine what is appropriate.
3. **What is an appropriate sampling unit size and shape?** The distribution pattern and size of the target population determine the size and shape of the sampling units. Sometimes one must experiment with several different size and shape combinations in order to come up with the optimal sampling unit.
4. **How should the sampling units be positioned in the population?** Sampling units must be positioned without bias, that is, randomly, and evenly interspersed over the target population in the macroplot.
5. **Should the sampling units be permanent or temporary?** Permanent sampling units should be used whenever there will be a correlation between two sampling units taken from different time periods. Temporary sampling units can be used but more of them must be sampled to accurately detect the same level of change.
6. **How many sampling units should be sampled?** There is no “real” answer to this one. Depends on many factors: target population, time, resource availability, and statistical goals. However, at least five units should be sampled for statistical analyses.

## 6 Important Steps of a Good Sampling Program!

1. **Specify information that must be collected.**
2. **Determine the approach or techniques to collect information.**
3. **Do a practice run and adjust procedures if necessary.**
4. **Do sampling project and collect data.**
5. **Analyze information collected and interpret your results.**
6. **Process information for use in a presentation, experiment or research.**

Pilot studies are often done before a full-scale project is initiated to “weed-out” any glitches in the sampling procedures and to determine the best plot size for a monitoring project. It is best to avoid sampling errors from the beginning since a lot of work may go into a monitoring project from sampling design to data analysis.

### **Reflection Topics for Discussion:**

- Discuss factors that affect the quality and/or accuracy of collected data and possible ways to avoid errors.
- Based on previous observations and/or data collected, describe several factors that account for the variability in your data-set.

### **Species Focus: Noxious Weeds in Your Backyard**

As a group, discuss how you might sample the species listed below. Think about their growth habits and forms and their growing locations. Consider the various possible factors, conditions, and situations that might affect your measurements.

- Himalayan blackberry
- English ivy
- Scotch broom
- Japanese knotweed
- Reed canary grass

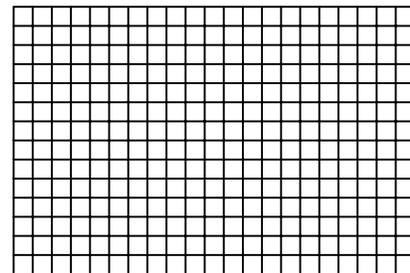
## Activity/Project Example: Measuring Frequency by Simple Random Sampling

### Introduction:

Frequency is defined as the percentage of possible sampling units within a sampled area occupied by the target species. In this example, the frequency of a target species within a 20 x 5 meter macroplot is being measured. You can visualize frequency by imagining the sampling area overlaid with a sheet of graph paper with each square of the grid the same size as the sampling unit (see grid example below). A 1 x 1 meter sampling plot frame acts as the sampling unit in this case. Since it would take too long to sample every square within the grid, we will only sample 20 of those squares. After randomly selecting and sampling 20 plots, divide the number of samples that have the target species present in them by the total number of sampling plots sampled (20). The percentage of sampled plots occupied by the target species is the frequency. The number of stems per plot doesn't matter, only whether it is present in the plot. Frequency measures are sensitive to the size and shape of the sampling unit. Explain why is this so? For comparative studies, should sampling units be permanently located or can they be relocated using a different set of 20 randomly selected plots? What effect does this have?

### Equipment:

1 x 1 meter sampling frame   
1 - 50 meter measuring tape/group  
Data sheet/pencil  
Table of 2500 Random Digits  
Compass



### Time Allowance:

2 hours

### # Students:

2-3/sampling group/macroplot

### Goals:

- Sample 20 quadrat plots.
- Calculate the % frequency of the target species.
- Calculate a mean % frequency between the groups.
- Understand what and how sampling variables influence measurements.

**Procedures:**

1. First, use the 50 meter measuring tape to establish 20 x 15 meter border around the area to be sampled. This newly defined area is the macroplot and should be representative of the target species distribution. Secure the tape at the corners with sticks staked into the ground.
2. Use the Table of 2500 Random Digits to obtain 20 pairs of coordinates for the random placement of the sampling plots. Use the length and width dimensions of the macroplot as the X and Y axis, respectively. In this exercise, the range of possible X coordinates is 0-19; Y coordinates is 0-14. Create a data sheet with four columns. At the top of the data sheet, label the respective columns: Sample, X, Y, Present.
3. After locating the first plot, thoroughly check for the presence of the target species. If the species is present, put a check (✓) in the column under Present (or 0 if it's not). Record the Sample number in the appropriate column; 1 for the first sample, 2 for the second, and so on.
4. Locate the remaining plots and record your observations.
5. If time permits, obtain a different set of 20 coordinates and re-sample the macroplot.
6. To calculate % frequency, add up all the (✓) Present and divide the sum by the number of plots sampled (20). Then multiply by 100.

**Activity/Project Example: Measuring Forest Canopy Cover With A Spherical Densiometer and A Visual Estimate Cover Comparison Template****Introduction:**

Spherical densiometers are used to measure forest canopy cover. The spherical densiometer is a simple tool possessing a concave mirror with a grid of 24 squares etched into it. A visual estimate comparison template is a card showing different percentages of cover as percent black within ovals. The card is used as a reference guide to help the observer estimate canopy cover visually. Canopy cover is the percentage of overhead area or sky occupied or blocked by vegetation and branches from trees and shrubs. Canopy cover is an important variable that influences the amount of light hitting the ground and can also be used as an indicator of forest health.

**Equipment:**

1 – spherical densiometer

1 – cover comparison estimate card (source: [www2.champaign.isa-arbor.com/tree-ord/ordprt3c.htm](http://www2.champaign.isa-arbor.com/tree-ord/ordprt3c.htm))

Tripod (optional but very helpful)

Paper/pencil

Compass

**Time Allowance:**

1-2 hours

**#Students:**

2-3/group

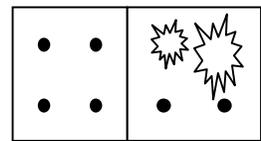
**Goals:**

- Calculate and estimate percent canopy cover in various forest types.
- Understand what variables affect canopy cover.
- Understand what components canopy cover affects.
- Explain the differences between accuracy and precision.
- Understand how objective and subjective observations affect sampling and monitoring.

**Procedures:**

1. Measure canopy cover at a representative location of the forest type being sampled. Position the tripod so that it is stable and level. Place the densiometer on the tripod at elbow height of the observer (you). You will have to adjust the tripod to the correct height. Now look down into the mirror. You should stand so that the reflection of your head is just outside of the grid area. Stand in the same place throughout the entire count.

2. To use it, first, imagine 4 equally spaced dots in each square of the grid. See example on right. Now count the total number of imaginary dots covered by vegetation and branches (2) OR not covered by vegetation and branches (6).



3. Hint: If canopy cover is high, it is faster to count the number of dots NOT covered and subtract that total from 96. When canopy cover is low it is easier to count the number of dots covered and record that number on the datasheet. Regardless of what you decide to count, always record the number of dots covered by vegetation and branches.

4. Do not count tree trunks that you may see in the mirror. Move tripod away from the tree if necessary and take four readings per location facing East, South, West, and North. Record each of the readings on a sheet of paper under the respective cardinal direction.
5. Dot numbers should be converted to percent (%) canopy cover. Divide the number of dots covered by 96 and then multiply the quotient by 100.
6. Calculate the % canopy cover average of the four directions (E, S, W, N) measured.
7. Hold the ocular standard template card overhead and determine the percent canopy cover. Compare the visual estimate to the spherical densiometer reading. What variables influence the estimates and differences between them? Record your observations and final estimates.

## **Activity/Project Example: Measuring Stem Density by Simple Random Sampling**

### **Introduction:**

Density measures the number of counting units per unit area, for example, the number of plants per square meter. For this exercise, the goal is to estimate the target species population in the meadow by sampling 200, randomly located, 1 m<sup>2</sup> quadrat plots. The macroplot, defined by the perimeter of the meadow, is divided into 4 sectors. Each group is assigned one of these sectors. Using the Table of Random Digits, each group obtains 50 unique pairs of coordinates for the location and placement of the plots. You may want to experiment with the quadrat plot size since changing the dimensions of the sampling unit will achieve varying results. If time permits, repeat this exercise using long rectangular quadrat plots instead. What changes and why? Which size is better suited for the target plant species and why?

### **Equipment:**

2 – 100 meter measuring tapes  
1 - 50 meter measuring tape per group  
Paper/pencil  
Table of Random Digits  
1 m<sup>2</sup> sampling frame or 1 m measuring stick per sampling group  
Compass

### **Time Allowance:**

2-3 hrs

**# Students:**

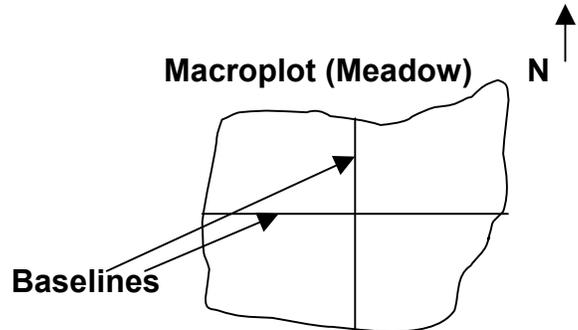
2-3/sampling group

**Goals:**

- Sample 200 quadrat plots.
- Calculate the mean density of the macroplot.
- Calculate the total population estimate of the macroplot.
- Understand what and how sampling variables influence calculations.

**Procedures:**

1. As a whole group, the first step is to establish 2 intersecting baseline transect lines with the 100 meter measuring tapes. One tape should run approximately West-East and the other tape, North-South. The measuring tapes should intersect at the 50 meter marks on both tapes. This divides the macroplot (Meadow) into 4 equal quarter sections, NE, SE, SW, and NW. Each section is 50 meters x 50 meters. The baseline transects will serve as the x-axis (West-East) and the y-axis (North-South) for the entire macroplot. The increments on the tapes will also make it easier to locate the coordinates.



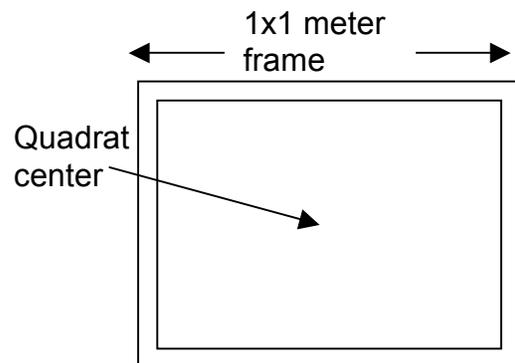
2. Assign each group a quarter section. Each group will have a unique set of possible X and Y coordinates depending on the quarter section assigned to the group and the orientation of the measuring tapes. Since the tapes intersect at the 50 meter mark, there will be 2 coordinate intervals, 0-49 and 51-100, for both the X and Y axis. For example, a group assigned to the NW quarter may have numbers 0-49 for possible X coordinates and 51-100 for possible Y coordinates; a group assigned to the SE quarter would have numbers 51-100 for possible X coordinates and 0-49 for possible Y coordinates in this case.

3. Use the Table of 2500 Random Digits to obtain the coordinates of your sampling quadrat locations. Review the instructions on how to pick coordinates without bias. Obtain 50 X coordinates and record them in a column on the sheet of paper. This is your data sheet. Label this column X. Then obtain 50 Y coordinates and record them in the column next to the X coordinates. Label this column Y. You should now have 50 unique pairs of coordinates to locate your sample quadrats. If any of the sets are identical, choose another pair. Next to the Y coordinate column, make another column and label it: # Plants

The heading of your data sheet should look like this: SAMPLE, X, Y, # PLANTS

4. Now you are ready to sample. Be sure that everyone can identify the target plant species.

5. Locate your first quadrat position with the first set of coordinates. Use the 50 m tape to help in the placement of the quadrat's center. Place the sampling frame over the center or use the measuring stick to trace a 1 x 1 meter square.



6. Count only the living plants that fall within the boundary of the frame.

7. Record the number of plants in the space provided on your datasheet.

8. Locate the next quadrat and follow steps 5-7 described above.

9. After all the plots have been sampled, calculate the mean (average) density of the target species in the macroplot. The answer should be converted to the number of plants per square meter.

10. Use this figure to estimate the target species population of the macroplot. To do this, first calculate the total number of possible quadrat locations in the macroplot by dividing the total macroplot area by the area of one quadrat. Then multiply this product by the mean density to obtain the population total estimate. Why is this only an estimate? Which sampling variable(s) effects this estimate and why? How can we make our estimates more accurate or closer to the true population mean and total?

## Activity/Project Example: Measuring Density by Systematic Random Sampling

### Introduction:

Density measures the number of counting units per unit area, for example the number of stems per square meter. For this exercise, the goal is to estimate the target species population in the meadow by sampling the target species density in 200 rectangular quadrat plots. The macroplot, defined by the perimeter of the meadow, contains the target species population. We are sampling systematically since we will set a distance interval between each of the side transects and between each of the plots. The first transect and plot, however, will be located using different random start points for each.

### Equipment:

1 – 50 meter measuring tape  
1 – 100 meter measuring tape  
Paper/pencil  
1 – 0.5 meter measuring stick  
Compass

### Time allowance:

2-3 Hours

### # Students:

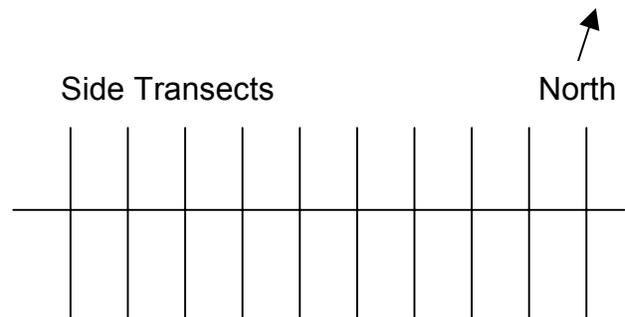
2-3/sampling group

### Goals:

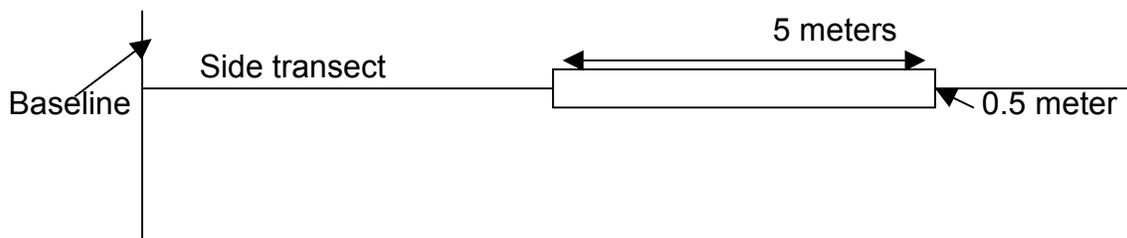
- Sample 200 quadrat plots.
- Calculate the mean density of the macroplot.
- Calculate the total population estimate of the macroplot.
- Understand what and how sampling variables influence calculations.

### Procedures:

1. The first step is to establish a baseline transect with the 100 m measuring tape. This tape should stretch across the middle of the target species population (macroplot). The baseline transect will serve as the backbone for the side transects that will be placed perpendicular to it.



2. Next, measure the baseline's distance and divide it by 10 to obtain an interval. This number will be the interval or distance between each of the side transects.
3. Now, we want to pick a random whole number between 0 and the interval number. This number will be our random start point and distance from 0 on the baseline measuring tape. The random start point is where the first side transect will be located. Place a 50 meter tape perpendicular to the baseline transect starting from this point and ending at the macroplot boundary.
4. Place the remaining side transects equidistant from each other, using the interval as the distance between them.
5. The goal is to count the target species in 5 meter x 0.5 meter rectangular plots. Each rectangular plot will lie directly over the side transect. See illustration below.



6. Now, pick a random number between 0 and 5.
7. This will be the random start point and distance from 0 on the side transects. This start point is where the quadrat plot will start. Use a 5 meter interval between each plot, that is, each plot will have a 5 meter gap between them.
8. Now prepare a datasheet using a piece of paper. The heading on the paper (datasheet) provided should look like this:  
**TRANSECT#, PLOT#, #PLANTS**
9. Now, you are ready to count plants. Using a 0.5 meter long measuring stick for the small side of the plot, place the device at the start point. Hold the sampling device directly over the side transect tape at the start point of your plot, carefully and systematically count the number of plants within a 5 meter length, sweeping slowly over the tape. Use the measurements of the tape to determine a 5 meter length.
10. After sampling the first plot, record the transect and plot numbers and number of plants under the respective columns on the datasheet.
11. Continue down the side transect another 5 meters without counting any plants. Repeat steps 9 –11 until you reach the end of the side transect.

12. Move onto the next transect when complete.
13. After you finish sampling, calculate the mean (average) density of the target species in the macroplot. The answer should be the number of plants per square meter.
14. Use this figure to estimate the target species population in the macroplot. To do this, first calculate the total number of possible quadrat plots in the macroplot by dividing the total macroplot area by the area of one quadrat. Then multiply this product by the mean density to obtain the population total estimate. Why is this only an estimate? Which sampling variable(s) effects this estimate and why? How can we make our estimates more accurate or closer to the true population mean and total?

### **Activity/Project Example: Scotch Broom Seed Bank Sampling**

#### **Introduction:**

Mature Scotch broom plants generally produce 5-8 seeds per pod. A two-year old plant can produce up to 60 pods per plant. About 50% of the seeds produced in those pods will germinate. Germination is promoted on disturbed, exposed mineral soil and by scarring the seed's hard shell. If this activity is performed during the flowering or seeding season, ask some of the students to count the number of flowers or seeds on some of the plants. How many Scotch broom plants are flowering? Scotch broom seeds may remain viable for up to 30 years. How is this advantageous? Describe several factors that may affect germination and describe how?

#### **Equipment:**

- Compass
- Soil core sampler (short PVC tube or similar device to push into ground)
- Sorting tray or plastic sheet
- Paper/pencil
- 50m tape
- Soil sieve or forceps
- Laminated card or vials containing examples of various weed seed specimens (standards)

#### **Time Allowance:**

2 hours

**# Students:**

2-3/sampling group

**Goals:**

- Calculate the mean density of Scotch broom seeds.
- Understand the scale and impact of invasive weed reproduction in natural areas.
- Develop a faculty for consistency and attention to detail and its application to sampling methods.
- Predict population dynamics and reproductive trends of Scotch broom.

**Procedures:**

1. Each group obtains one core sampling device, one sorting tray or plastic sheet and forceps.
2. Set up the transect using a compass bearing from a random point and a 50m tape. One student will site a line with the compass while holding the tape, directing the other with the tape's end. Once transect is established, slowly pull tape taut, then take two strides to the left and anchor each end to the ground.
3. On the sheet of paper, record direction and degrees from the known point, length of transect, number of core samples, and draw an accurate sketch of the area with the correct orientation of the transect to the landscape. The sketch should include any conspicuous feature in the terrain, for examples, trees, shrubs, boulders, swales, and trails.
4. Students should stagger themselves along the transect in 1 meter intervals. Students can carefully kneel down and bore their sampler into the ground flush with the surface. Place one hand over the bottom opening of the sampler, being extremely careful not to lose any of the contents from the top or bottom.
5. Empty the contents into the sorting tray or plastic sheet and sort through contents, removing and collecting seeds from soil matrix with forceps.
6. Seeds can then be categorized by shape, size, etc. and counted.
7. Students may use the standard to identify the desired seeds.
8. Once the target species has been identified, the data collector will then tally all the collections for a total count for that transect.
9. Repeat this procedure from step 3 and from another random point.

10. Now, students will need to convert the data to useful information. Students should be able to answer the following and record this information on their data sheet:

- Mean #seeds/sampler/transect
- Mean #seeds/volume of soil
- Mean #seeds/area of soil
- If a quarter of the total number of seeds that were found today were to germinate the following spring, how many seeds would these new plants produce if they produced 6 seeds/pod when they mature two years? Note: Typically, only about 50% of the seeds produced by Scotch broom will germinate.

### **Related Field and Laboratory Activities:**

- If time permits, students should note the pH of the soil from a sample of the core samples and then record the pH and its respective sampler number.
- How can soil pH affect the germination and growth of the seeds?
- What variables influence pH of the soil in the sample area?
- Students may take some of the seeds and respective soil from the samples and attempt to germinate and rear the seedlings in various controlled environments. Students may want to control some variables such as temperature (seedlings can be placed in a refrigerator), light (various light sources and intensities can be used; sunlight, fluorescent, incandescent) and exposure time, and moisture.
- In addition, some of the seeds can be germinated in other types of medium, for examples, paper towel, sand, clay, floodplain silt, mulch, peat, or a combination of them all. Over time, students will want to record data such as germination, growth rates and leaf to stem ratio. Data should be carefully recorded and the results and conclusions discussed in the form of a presentation at the end of the cycle (semester or year). Students may also want to monitor the growing medium's pH.
- Does germination affect the medium's pH? How?
- Does the soil pH change throughout growth? How may this affect other plants growing in the same vicinity outdoors?
- How does the seed's structure influence its dispersal, survival and germination?

## **MODULE IV. Summary**

### **Subject:**

### **Restoration Ecology**

### **Overview:**

Ecological restoration is a hands-on and experimental science that addresses the needs of a particular site; it is a human constructed healing process to repair environmental impacts caused by, for example, the introduction of noxious weeds. Through this section, students are introduced to several existing projects as model case studies and provided with practical tools so as to develop and/or adopt their own future restoration project(s).

### **Goals:**

- Students will expand their development, implementation and evaluation skills in a project and goal-oriented setting.
- Students will possess the scientific foundation necessary to investigate and develop creative solutions to real world issues in their community.
- Students will develop a sense of stewardship with their environment and a sense of progress and accomplishment in their lives.

### **Strands:**

Life Science: Diversity/Interdependence; History and Nature of Science; Scientific Inquiry; Science in Personal and Social Perspectives

### **Benchmarks:**

- Describe and analyze the effect of species, including humans, on an ecosystem (CIM).
- Understand that scientific knowledge is subject to change based on new findings and results of scientific observation and experimentation (CCG).
- Determine areas of inquiry, frame scientific problems, and pose research questions and hypotheses involving scientific relationships (PASS Criteria).
- Design scientific investigations to address and explain questions and hypotheses (CCG).
- Describe the role of science and technology in local, national, and global issues (CCG).
- Describe how daily choices of individuals, taken together, affect global resource cycles, ecosystems, and natural resource supplies (CCG).

**Concepts for classroom or field discussions:**

What is restoration ecology?  
Why conduct restoration?  
How to choose what to restore  
What to aim for – finding models  
Invasive plant control methods and strategies  
Planning the project  
Measuring success

**Field or laboratory project examples:**

Participate in an ongoing restoration project (The Nature Conservancy, Metro, Friends of Trees, BLM, etc.)  
Applying and studying invasive species control in the field  
Developing a restoration project plan including a monitoring component  
Follow up monitoring

- Data collection and analysis
- Photographic monitoring

## **Module IV. Ecological Restoration**

### **What is ecological restoration?**

Ecological restoration is exactly what it sounds like. It is a human facilitated process that renews, repairs, or enhances an ecosystem's components, structures, or functions. Ecological restoration is usually a goal driven process. Restoration projects may help preserve or increase the abundance of native biological diversity, stabilize eroding stream banks or slopes, or control invasive plant populations. Planting trees, removing invasive plants, prescribing controlled fires, and installing gravel beds in streams for salmon are some examples of restoration projects.

### **Why conduct restoration?**

What is the number one cause contributing to the decline of biological diversity? Habitat loss and disturbance due to human development and activities is causing the extinction of many plants and animals. Without a home or a place to grow, organisms just can't survive. Also, ecosystem processes that provide clean air and water are in jeopardy of being destroyed. Salmon require clean, cold, clear streams and rivers that are moderated by healthy trees growing on the riverbanks. Japanese knotweed and other non-native, invasive plants threaten to change the riparian forest structure and therefore endanger salmon habitat as well. So, we do restoration to help eliminate sources of stress that negatively affect ecosystems or to repair those that have been damaged. Remember, invasive species are the second greatest threat to our native biological diversity.

### **How to choose what to restore?**

Natural resource managers should set priorities and have clear specific goals in mind when deciding on what to restore. The end result should be greater than the costs to achieve it and one that provides the most benefits. For example, The Nature Conservancy uses conservation targets like ecological systems, natural plant communities, and animal species to develop specific goals and to decide on the best approach to reach them. They look for variables or things that threaten those targets and then find ways to eliminate or moderate their impacts. Land managers may tackle the source of the larger problem rather than relieve the symptoms. In the end, choosing what to restore ultimately depends on your goals and the resources at hand to achieve them.

## Invasive Plant Control Methods and Strategies

The approach you take to control or get rid of invasive plants requires some research. There are many techniques available but the one you decide to use will depend on the species you are trying to control and the extent of the infestation. Before choosing any method, consider the following:

- **Know your ecosystem and your target species thoroughly.**
- Understand how the method you choose will affect plants, animals and ecosystem. Consider environmental impacts like erosion, trampling native vegetation, contamination, and soil compaction.
- Consider the costs, equipment, and personnel skills to implement the method chosen.
- When and how you apply your method is just as important as what method you use.
- Practice your method before tackling the plant invaders at full force.
- When removing invasive plants manually, dispose of them properly. If they will be left on-site, ensure that they won't take root and re-sprout.
- Consider replanting the site with vigorous native plants adapted to that site soon after removing the invasive plants.

## Invasive Plant Control Options

Land and resource managers have developed 5 main approaches to manage invasive plants. As stated previously, the approach used should take into consideration. The option chosen may be used exclusively, but more likely than not, achieving control of the weeds will require an **integrated pest management** strategy that utilizes several options simultaneously or sequentially.

**Whatever the method(s), the best method(s):**

- Gets rid of the invasive plants.
- Fits your budget.
- Have the fewest side effects on native plants and animals.
- And most importantly, accomplishes your goals!

**Prevention:**

Preventing the arrival, establishment and spread of weeds into a new area is the first line of defense. Once established, weed control becomes more difficult and costly.

- Recognize and destroy new weeds before they reproduce and spread.
- Clean equipment, vehicles and clothing to prevent spread to other areas.
- Avoid planting questionable non-native plant species around your home.
- Educate your community.

**Biological:**

Using other organisms like insects, goats or fungal and bacterial diseases to control invasive plants has had mixed results. Another form of biological control is planting native plants to out-compete neighboring weeds.

- On a good note, biological control agents can be inexpensive, self-sustaining and environmentally safe.
- Some disadvantages include the slow rate at which satisfactory control occurs and the expensive and time consuming task of testing biological control agents, like insects, before they are released into the wild.

**Physical:**

Hand pulling, cutting, digging, tilling, burning, flooding and the use of mechanical equipment are some examples of physical control methods that are often employed. These methods have a mix of benefits and costs and their effectiveness depends on timing and frequency.

- Some invasive perennial weeds re-sprout vigorously from roots when their stems are removed or damaged. Digging and tillage disturbs the soil, leaving it vulnerable to new weed infestations.
- Methods like cutting and hand pulling target the invasive plants, therefore minimizing damage to nearby native plants.

**Chemical:**

The use of chemical herbicides to selectively kill invasive plants has its opponents and supporters. Herbicides work by disrupting plant growth or physical processes, eventually killing or injuring the plant.

- Herbicides can be expensive, toxic, and require special formulations.
- Although some herbicides are selective, that is, they target only grasses or only broadleaf plants, the application of herbicides may unintentionally kill or injure nearby plants or other organisms.
- Some vigorous invasive plants can be controlled effectively and efficiently with herbicides, especially when they're abundant and widespread.

## **Cultural:**

Examples of cultural methods to control weeds include planting only native vegetation around homes and gardens or refusing to fertilize and irrigate lawns. Any changes in personal habit that promotes the control and reduces the spread of invasive plant species are considered cultural methods.

## **Planning Your Project**

The first thing to remember when planning a project is that successful restoration is a goal driven process. When you have a carefully defined and measurable goal in mind the rest of the process will flow more smoothly. The following points will help you understand the plan:

- Understand your ecosystem and the ecology of the plants you want to remove (IDENTIFY AND MAP, RECORD INFESTATIONS)
- Clearly define your goals before you choose your METHODS and STRATEGY
- Be adaptable and ready to make changes.

**Remember: Let your goals and resources dictate your decisions.**

## **The Planning Process**

The following steps will help you successfully achieve your restoration goals. If you are working on a restoration project now, at which stage is the project in terms of the steps listed below?

1. Establish clear goals for the restoration site.
2. Determine which invasive plant species at your site prevent or could prevent the accomplishment of your goals.
3. Find out which methods are available to control the invasive plants.
4. Design a restoration plan and conduct a restoration project to achieve your goals.
5. Observe and evaluate the impacts of your project towards achieving your goals (SAMPLING, MONITORING, and DATA ANALYSIS).
6. Re-evaluate, modify your restoration plan if necessary and start the cycle again.

**Important note: Most weeds are very persistent, re-sprout vigorously when cut or from stem or roots fragments left in or on soil, and produce a lot of seed that can survive in the soil for many years. Getting rid of invasive plants can be a long-term process. Keep this in mind when planning your restoration project.**

## **Measuring Success**

Your restoration project may take place in a day or may take several years. Regardless of the timeframe, you will need to develop a means to monitor the results of your project to your goal. Oftentimes, this means coming back to the site later in the season or every year thereafter. How will you accomplish this? It may simply be a visit to the site and a visual estimate, taking some photographs from a photo-point, or as tedious as re-sampling the vegetation. Regardless of the method, this is an important component of your restoration project. A restoration program is not complete without a way to measure its success.

Since your restoration project brings about changes to a landscape, monitoring those changes over time is necessary to evaluate the impacts of your activities. Observations may tell you to change the methods or timing of successive restoration events. Photo-monitoring is one of the easiest methods to measure change over time.

First, it is important to take a photo from an established point somewhere at your restoration site before any work starts. About halfway through your project, take another photograph from the same point. This is a good way to document the progress of your project. And finally, after you have finished, take a final shot from the same point. Now, you have at least before and after photographs of your restoration site.

### **Reflection Topics for Discussion:**

- Can a restoration project revert a site to its historic condition? Explain?
- Discuss possible variables and/or challenges affecting a restoration project's progress.
- Given the infinite number of benefits provided by our Planet, describe how the Earth has benefited from your recent experiences with restoration.

### **Species Focus: Noxious Weeds in Your Backyard**

Discuss the various control methods to control these species. Consider the species reproductive strategies and growth habits. Describe several factors that might affect the efficacy of the control strategy used.

- Himalayan blackberry
- English ivy
- Scotch broom
- Japanese knotweed
- Reed canary grass

## **Activity/Project Example: Restoration Project Planning**

### **Introduction:**

The planning phase is one of the most important components of any project. Use the following format as a guide in the planning process of a restoration project. Each step should be well thought-out with the previous and next steps taken into consideration. For simulation, students can be given various written scenarios describing a set of conditions, identifying a problem or real-life situation. After each student or group develops their plan, have them share their plans in small groups or as a class for discussion.

### **Goals:**

- Students will enhance their creative process through the development of realistic solutions.
- Students will learn to identify key variables which affect the outcomes of common goals experienced in life.
- Students will adopt a goal-oriented decision making process that can be used in everyday life situations.

### **#Students:**

Individually or small groups per plan

### **Time Allowance:**

1 hour

### **Procedures:**

1. Establish clear goals. What do you want to accomplish at your restoration site?
2. Identify and describe all obstacles that may prevent you from attaining your goals.
3. Describe what and how methods will be used to attain your goals.
4. Develop a project timeline to help you plan ahead and organize your restoration project. Include: Date – Task Description
5. List all required equipment, personnel, quantities and costs to achieve your goals.
6. Evaluate the effects of your restoration project. How will you measure the success of your project? Did you accomplish your goals?
7. Monitor the progress of your restoration site in the future. Develop a monitoring plan to observe changes over time.