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ENVIRONMENTAL SCIENCE I

NORTHWEST CENTER FOR SUSTAINABLE RESOURCES (NCSR)
CHEMEKETA COMMUNITY COLLEGE, SALEM, OREGON
DUE # 9813445

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Environmental Science I

The Northwest Center for Sustainable Resources is an Advanced Technological Education project funded by the National Science Foundation.

Environmental Science 1 was developed at Chemeketa Community College, Salem, Oregon, and was tested and revised at Everett Community College, Everett, Washington. Materials were prepared by Wynn Cudmore, Ph.D., Principal Investigator for NCSR. Cudmore holds a Ph.D. degree in Ecology/Systematics from Indiana State University and a B.S. degree in Biology from Northeastern University.

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

Course materials will also be posted on our website:

www.ncsr.org

Please feel free to comment or provide input.

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Table of Contents
Environmental Science I

LABS & ACTIVITIES

STUDENT ASSESSMENTS

Environmental Science I
4 Credits—3 hours lecture, 3 hours lab

INTRODUCTION TO ENVIRONMENTAL SCIENCE

Environmental Science was developed at Chemeketa Community College as a sequence of three courses that addresses environmental topics. Each 4-credit course requires a three-hour lab that meets once per week and three hours of lecture. The courses are targeted towards several audiences including:

- students in natural resource areas (e.g. Forestry, Fish and Wildlife, Agriculture)
- transfer students in areas other than biology who need a lab science course or sequence
- biology majors who wish to broaden their background in environmental biology
- anyone interested in learning more about environmental issues

I consider the courses to be "Environmental Science for the Citizen" and emphasize those concepts and issues that in my judgement should be understood by all. The approach is science-based and a distinct effort is made to present opposing viewpoints in contentious environmental issues. The three-term sequence was added as a requirement for students in the *Forest Resources Technology* Program at Chemeketa where it serves primarily to introduce students to basic ecological concepts and environmental issues that relate to natural resource management. The following goals have been established for students in the program:

- ➢ introduce science as a "way of knowing"
- ➢ teach basic ecological concepts
- ➢ become familiar with environmental problems at local, national and global scales
- ➢ use *ecosystem management* as a major theme in natural resource management
- ➢ work cooperatively in small groups
- ➢ communicate effectively in written and oral formats
- ➢ apply appropriate technology to scientific exploration
- ➢ access and use supplemental information relevant to course topics
- ➢ engage in hands-on, field and laboratory experiences that require critical thinking
- ➢ introduce societal aspects of environmental issues
- ➢ apply mathematical concepts to scientific inquiry

This document describes several laboratory activities that have been developed for *Environmental Science* in an attempt to meet these general goals. It is my hope that others who have similar goals for related courses will find them useful.

TEXT

Botkin, D. and E. Keller. 2000. Environmental Science: *Earth as a Living Planet*, 3rd ed. John Wiley and Sons, Inc. New York. 649 pp.

COURSE DESCRIPTION

The primary goal of Environmental Science I is to familiarize students with functioning ecosystems before human intervention. This will be necessary background for introducing "ecosystem management" as an underlying theme in later terms. Although environmental problems may be used as examples, later terms will more closely examine the specifics of most enviromnmental issues. Additionally, students will be given a brief overview of environmental science—historical perspectives, philosophies, and definitions and a thorough understanding of how science operates. Human population growth will be examined in detail as an environmental topic.

COURSE OBJECTIVES:

Upon successful completion of the course, students should be able to:

1. Distinguish between science and other "ways of knowing."
2. Design a scientific experiment that conforms to the scientific method.
3. Critically evaluate articles written on environmental topics.
4. Describe the structure and function of ecosystem components.
5. Analyze population growth and distribution as inherent features of populations.
6. Evaluate the relationship between human population growth and other environmental problems.
7. Debate solutions to human population problems.

STUDENT ASSESSMENT

Grades are based on a point system with an approximate breakdown as follows:

Exam #1	100 points
Exam #2	100 points
Final Exam	100 points
Labs and related activities	150 points
	450 points total

Term letter grade is based on a percentage of total points accumulated according to the following schedule:

90 - 100 %	A
80 - 89 %	B
70 - 79 %	C
60 - 69 %	D
< 60 %	F

READING SCHEDULE (IN BOTKIN AND KELLER)

WEEK	CHAPTER	TOPICS
1	Chap. 1	Basic Issues in Environmental Sciences
2	Chap. 2	Thinking Critically About the Environment
3	Chap. 3	Systems and Change
4	Chap. 4	The Biogeochemical Cycles
5	Chap. 6	Ecosystems and Ecological Communities
6	Chap. 8	Biological Productivity and Energy Flow
	Chap. 7 (in part)	The Geography of Life (pp. 130-138 only)
	Chap. 9 (in part)	The Earth's Biomes (pp. 174-182 only)
7	Chap. 7 (in part)	Biological Diversity and Biogeography (pp. 112-130 only)
8	Chap. 9	Succession and Restoration: How Ecosystems Respond to Disturbance
9	Chap. 5	Human Population as an Environmental Problem
10	Chap. 5	Cont'd - Plus supplemental reading
11	Chap. 5	Cont'd - Plus supplemental reading

TOPICS:

I. Introduction to environmental science

A. Sustainability

B. Ecosystem management

1. Elements and goals
2. Examples of implementation

C. Environmental unity—interconnectedness

II. The nature of science

A. Scientific method

B. Science vs. other disciplines

III. Environmental attitudes and values

IV. History of natural resource use, conservation and environmental protection in the U.S.

A. Major events

B. Impacts on public opinion and public policy

V. Basic ecological concepts

A. Biosphere

1. The "Gaia Hypothesis"
2. Role and nature of solar radiation

B. Ecosystems—components and processes

1. General characteristics of systems (reservoirs, fluxes, etc.)
2. Biotic and abiotic components
3. Biogeochemical cycles (nutrient cycling)
4. Primary productivity and energy flow
5. Interaction between climate and biomes

C. Communities

1. Biological diversity
   a. levels and methods of measurement
   b. role in ecosystems
   c. island biogeography
2. Species interactions
   a. competition
   b. symbiosis—mutualism, commensalism, parasitism
   c. predation

3. Ecological sucession
    a. terrestrial vs. aquatic succession
    b. general trends
    c. role of fire and other disturbances in ecosystems
    d. ecological restoration

D. Populations
  1. Biological properties of populations
  2. Population growth
     a. logistic growth
     b. exponential growth
     c. carrying capacity and limiting factors
  3. Human population growth as an environmental issue
     a. historical perspective
     b. factors affecting fertility rates
     c. demographic transition
     d. proposed and implemented solutions

LABORATORIES:

Edge Effect One—Experimental Design and Hypothesis Testing
Edge Effect Two—Data Collection—Field Study
Edge Effect Three—Analysis and Interpretation
Edge Effect Four—Creating Charts
Edge Effect Five—Applications
Ecosystem Analysis
Primary Production in Constructed Wetlands
Log Decomposition in Forest Ecosystems
Biomes
Symbiosis
Ecological Succession
World Population
Human Population Debate

Environmental Science I— Detailed Schedule

Date	**Topic/Activity**
Week 1	Lecture 1—Course introduction, Syllabus, Text discussion, NCSR, Student Information, Current topics
	Lecture 2—What Is Science?, What is Environmental Science?
	Lecture 3—What Is Science? (continued.), Discussion of Carl Sagan article, *"Why do we need to understand science?"*
	LAB #1 Evaluation of Edge Effect—Hypothesis Testing and Experimental Design
Week 2	Lecture 4—History of Resource Use in World and U.S.
	Lecture 5—History of Resource Use in World and U.S.
	Lecture 6—History of Resource Use in World and U.S.
	LAB #2 Evaluation of Edge Effect—Field Activities
Week 3	Lecture 7—"Evaluating the Media" activity—Amphibian Deformities (adapted from Botkin and & Keller p. 27)
	Lecture 8—Biological Organization/Hierarchy
	Lecture 9—Introduce Biosphere/Biosphere 2 Video
	LAB #3 Evaluation of Edge Effect—Analysis and Applications
Week 4	Lecture 10—Introduce Ecosystems—Nutrient Cycling/ Biogeochemical Cycles
	Lecture 11—Gaia Hypothesis Discussion/Hydrologic Cycle
	Lecture 12—Carbon and Nitrogen Cycles
	LAB #4—Ecosystem Analysis <u>OR</u> Net Productivity Lab (Aquatic Ecology Laboratory)

Week 5

Lecture 13—Nitrogen Cycle Applications/Introduction to Energy Flow

Lecture 14—EXAM #1

Lecture 15—Energy Flow

LAB #5—Log Decomposition Lab

Week 6

Lecture 16—Energy Flow Activity (adapted from Botkin and Keller p. 154, "*Should people eat lower on the food chain?*")

Lecture 17—Biomes/Tropical Rainforests as an example—characteristics and human impacts

Lecture 18—introduce Communities/Biodiversity definitions

LAB #6—Log Decomposition Analysis Lab (Worksheet)

Week 7

Lecture 19—Communities—Measures of Biodiversity
Video - *Infinite Voyage - Life in the balance* (in part—Terry Erwin Tropical rainforest insect studies)

Lecture 20—Communities—Biodiversity (contd.)

Lecture 21—Communities—Biodiversity (contd.)/Keystone species

LAB #7—Biomes Lab/Assign Population Debate activity

Week 8

Lecture 22—Law of Tolerance/Fundamental Niche

Lecture 23—Competition, Predation, Symbiosis

Lecture 24—Introduction to Ecological Succession

LAB #8—Symbiosis Lab

Week 9

Lecture 25—Ecological Succession—Primary vs. Secondary Succession/Examples

Lecture 26—Trends in Ecological Succession/Introduce Ecological Restoration
Videotape—"Helping Homeless Woodpeckers" *Scientific American Frontiers*

	Lecture 27—Ecological Restoration/Prescribed Fire
	LAB #9—Ecological Succession Lab
Week 10	Lecture 28—Introduction to Populations
	Lecture 29—EXAM #2
	Lecture 30—Population Growth (logistic growth, carrying capacity and limiting factors)
	LAB #10—Human Population Lab (PRB World Population Data Sheets)
Week 11	Lecture 31—Populations (factors that affect population growth)
	Lecture 32—Human Populations
	Lecture 33—Human Populations
	LAB #11—Populations Debate
Week 12	FINAL EXAM

Evaluation of the Edge Effect
Experimental Design and Hypothesis Testing

I. INTRODUCTION

The **"edge effect"** refers to those physical and biological changes that occur along the transition between two different ecosystems or habitats. The forest border adjacent to a clearcut, for example, represents a boundary between two very different environments that differ in minimum and maximum temperature, relative humidity, soil moisture, amount of solar radiation that reaches the surface, wind velocity, plant and animal species, among others. Along edges, there may be profound influences of one habitat upon the other often in rather complex ways. Temperatures, for example, might be expected to be higher in forested areas that are along an edge as compared to interior forested areas that are not adjacent to such an edge. Living organisms such as plants and animals may respond to these temperature differences.

There are a number of practical applications of the edge effect, especially in forest and wildlife management. For example, forested areas with a significant percentage of their total area in edge may be functioning differently biologically or physically as compared to interior forests. Effective sizes of old growth islands, for example, may be significantly less than actual acreage due to the edge effect. This reduces the amount of habitat available for wildlife species associated with old growth forests. Harvesting patterns at the landscape level may be modified to take this into account.

For the next three laboratory periods, you will be evaluating the edge effect using a scientific approach. You will proceed in the same manner that a scientist might follow to answer questions. This procedure has been traditionally called the "scientific method," but, as we will see, there are several scientifically-valid ways to approach a problem.

In today's lab, you will pose a question to be answered and design an approach that attempts to answer that question. Next week, your group will implement the procedure you have designed in the field, and the following week you will analyze the results and discuss their application to natural resource management.

OBJECTIVES:

- To familiarize you with the approach taken by scientists to pose and answer questions
- To apply appropriate technology in the field and laboratory
- To gain an understanding of the theoretical and practical aspects of the "edge effect"

II. POSING THE QUESTION

The basic question to be addressed in this exercise is as follows:

To what extent do the physical characteristics of an open area penetrate a forest stand?

More specifically, we will attempt to measure how air temperature, soil temperature, relative humidity, wind velocity and solar radiation change as one proceeds from open to edge to interior (forested) habitats.

III. PROCEDURE

A. Development of Hypotheses

A local field site has been identified that illustrates a significant edge as defined above (e.g., forest/clearcut boundary). Various instruments will be available to measure **microclimate**—small scale changes in physical variables such as temperature and humidity. Next week, each group will establish a transect (a line) that runs perpendicular to an edge and measure these physical variables along the transect. The following devices can be used to measure these variables:

- **digital thermohygrometer**—relative humidity and air temperature
- **light meter**—solar radiation
- **field thermometers**—soil temperature
- **digital anemometer**—wind velocity

Each of these devices is available in lab for your inspection. *If you would like to measure other variables consult with the instructor to see if this is feasible.*

The following physical parameters will be measured by each group to evaluate the edge effect:

1. Air temperature
2. Soil temperature
3. Relative humidity
4. Wind velocity
5. Amount of solar radiation that reaches surface

Working in groups of three or four, develop a set of hypotheses that provide reasonable answers to the questions posed above. These hypotheses should be as specific as possible and be directly related to what you will be measuring. For example:

Air temperature will be highest in the open area and at the edge, decrease rapidly once the forest is entered and then stabilize at this lower level.

After each hypothesis, briefly describe your rationale for your hypothesis (i.e., what information or logic have you used to make this prediction?) Record your hypotheses and rationale for each on the Information Sheet (attached).

B. Experimental Design

✐**Note: As above, please record all of your answers from this section on the attached information sheet**

Once you have developed a set of hypotheses, discuss within your group precisely how you might design an experiment that would either support or refute your hypotheses. Since you will actually perform this experiment next week in the field, be sure to consider the practical nature of the experiment (time constraints, available personnel and equipment, etc.). The details of the procedure will be left up to your group. However, to allow comparison between groups, each group should design a procedure in which measurements are taken at regularly spaced stations along a transect that runs perpendicular to the edge. Draw what your transect will look like here:

Describe your experimental design in a draft form that includes:

1. Identification of independent and dependent variables
2. Sampling protocol (step by step procedure)

✐**Note: A critical part of the sampling protocol is how you will define a particular variable. This is called the "operational definition" of that variable. An operational definition for "air temperature" might look like this:**

"Air temperature will be measured at the center of each station with a thermometer held for 1 minute at 1 meter, 2 meters and 3 meters above the surface. These three numbers will then be averaged."

3. Equipment needed
4. Approximate time required to complete experiment
5. Data sheet design—what information will you collect and how will it be recorded?

If time allows, each group will present their experimental design to the class for discussion and improvement. During these discussions we will attempt to reach a consensus on how each experiment should be conducted and what data will be recorded.

Once your experimental design is determined, each group member should become familiar with the operation of the instruments that you will use and the specifics of the sampling protocol.

Experiment with these instruments in lab today and do not leave without understanding how they operate!

IV. LAB PRODUCT

Your final lab product for this laboratory will be a report. You will find the information your group has put together today to be *invaluable* for the writing of this report. Please see the following "Information Sheet" for a description of what should be handed in today.

Evaluation of the Edge Effect—Information Sheet

Each group should submit the following information as a lab product for today's laboratory. This lab product is worth ten points.

I. HYPOTHESES AND RATIONALE

Hypotheses are "educated guesses" based on prior knowledge that provide a possible answer to a question. We have posed several questions that relate to how physical variables change along a transect perpendicular to an edge (see Section II). Clearly state your hypotheses for each variable and describe the rationale that you have used to make this prediction.

A. Hypothesis 1—Air temperature:

Rationale:

B. Hypothesis 2—Soil temperature:

Rationale:

C. Hypothesis 3—Relative humidity:

Rationale:

D. Hypothesis 4—Wind velocity:

Rationale:

E. Hypothesis 5—Solar radiation:

Rationale:

II. EXPERIMENTAL DESIGN

A. Identification of independent and dependent variables

Independent variable(s):

Dependent variable(s):

B. Equipment needed—List <u>all</u> equipment that will be needed to carry out the sampling procedures you have outlined below.

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

C. Sampling Protocol

Briefly describe or diagram what your sampling design will look like in the field. Include such information as length of transect, number of sampling stations, distance between stations, etc. All measurements should be in metric units.

Operational Definitions—Describe exactly how you will measure each variable in the field.

1. Air temperature:

2. Soil temperature:

3. Relative humidity:

4. Wind velocity:

5. Solar radiation:

D. Estimation of time required to complete data collection in the field.

1. Estimated Time:

2. Briefly describe how you have come about this estimate.

E. Data sheet design

You have now decided what information your group will collect and how it will be measured. Now, design a data sheet that will easily accommodate this information. Submit this data sheet with today's lab product.

“Evaluation of Edge Effect” Lab Write-up Guidelines

The final product of the Edge Effect Lab is a report that summarizes and evaluates the results of this study. The following guidelines should help you in the preparation of the report. The report must be typewritten (4-6 pages of narrative; tables, graphs, references, etc., should be included in the report, but do not include them in the total number of pages). Be sure to spell-check and proofread your report before it is submitted. (See NCSR’s Environmental Ethics course for more on these disciplines)

Format—The report should be in a format that is similar to that seen in scientific journal articles. Use the following headings for each section of your report:

I. INTRODUCTION—(1 OR 2 PARAGRAPHS)

Use this section to briefly set the stage for what the report will cover. Assume that your reader knows nothing about the edge effect or why it might be important. Briefly describe why the study was done, what your major hypotheses were, what applications there might be for the study and what contributions your study makes to the understanding of the edge effect.

II. METHODS AND MATERIALS—(2 OR 3 PARAGRAPHS)

Use this section to describe the experimental design of the study and procedures you have followed to obtain the data you have collected. Include sufficient detail such that another researcher could duplicate your efforts. Be sure to include information such as dates, location, equipment used, etc.

III. RESULTS—(2 OR 3 PARAGRAPHS PLUS GRAPHS, CHARTS, ETC.)

This section should include only data that was collected during this study (i.e., field notes and data taken during field sampling). Where possible, summarize information in tables, charts and graphs that *help to visualize* the data (for example, a graph that illustrates soil temperature vs. distance from edge). You *must* reference these tables, charts and graphs in the body of this section (see example).

EXAMPLE: ***"Soil temperatures were highest at the edge and gradually decreased to a minimum of 18 degrees C in the forest interior (Table 3)."***

In this section you will describe *major trends* in your data. Extract as much information from your tables, charts and graphs as possible but do not try to recount *everything* that appears in them.

IV. CONCLUSIONS AND DISCUSSION (20 POINTS)

In this section you will summarize your conclusions (logically drawn from the RESULTS section) and attempt to place your findings into a broader context. It should be the longest section of your report. What applications might your findings have, for example, to forest management or wildlife management? In this section you should return to your original hypotheses. What findings were unexpected? Which hypotheses were supported by the data? Which hypotheses were not supported by the data? What changes would you make in experimental design if you were to duplicate the study? Use resources provided to you such as the "Evaluation of the Edge Effect—Applications" handout and any supplemental articles.

NOTES FOR INSTRUCTORS

I. THE SCIENTIFIC METHOD (topic is covered in greater detail in lecture)

"How do we know things?"
"How do we try to understand the world around us?"

Science is *one* way of evaluating and seeking explanations for the material world around us. Other methods based on intuition, authority, religion, philosophy, etc., also exist, but these disciplines exist outside the domain of science (see NCSR's *Environmental Etihics* course for more on these disciplines).

Use a specific question to focus the discussion.
(e.g., "Does pesticide X cause mortality in trout?")

A. State problem or question—as narrowed and concise as possible; usually after careful observation of nature or previous works (research articles in scientific journals).

Refine question - perhaps to *"At what concentration does pesticide X cause 50% mortality in mature rainbow trout?"*

B. Propose hypotheses—educated guesses, tentative suppositions or specific testable claims based on previous knowledge (gained from literature, discussions with other scientists in field, your understanding of the problem)

C. Experimentation/Observation—Hypothesis testing may be based on controlled experimentation (i.e., experiments in which only one variable is manipulated at a time) and **data** collection (the **facts** of science). Note that a **control group** receives the same treatment as the **experimental group** *except* the one variable that is being tested (in medical trials a **placebo** is commonly used).

A scientific experiment developed without controls is like saying you won the race when there were no other competitors!

Define types of variables:

independent variable—manipulated variable; scientist deliberately changes; usually graphed on the X-axis
dependent variable—responding variable; scientist assumes that changes in independent variable will result in corresponding changes in dependent variable; these changes will be measured, usually graphed on the Y-axis
controlled variable—those variables that are kept constant for both the control group and the experimental group

The goal is to collect data in an *unbiased* manner—large, repeated, random samples are required for statistical analysis and personal bias should be eliminated from experimental design. Pertinent observations may be substituted for an experimental approach.

D. Analysis—Analysis usually requires use of statistics and computers to summarize data and test for significant differences between experimental and control groups.

E. Draw Conclusions—After analysis, some hypotheses may need to be modified or discarded. Those that are well-supported by available data are offered as possible answers to the original question. Keep in mind that if new information comes to light, these hypotheses may be discarded in favor of new ones. *Science is "falsifiable"* and scientific conclusions should be stated: "Based on the evidence available to me, interpreted to the best of my ability, I believe that ....."

✐**The first three labs are designed to provide students with the opportunity to design their own experiment and implement the "scientific method." A local forest ecosystem is used as a model.**

II. INTRODUCTION TO THE EDGE EFFECT

✐**I use a series of slides to introduce the Edge Effect and to place the laboratory exercise into a broader context. I emphasize the following points:**

Ecological research conducted in the early 1980's examined forest patterns at the landscape level in forests in the Pacific Northwest and tropical rainforests. Concern was raised at this time that the *pattern* of the forested landscape was not adequately protecting the biodiversity of these forests. The decline of northern spotted owl populations, for example, was linked to habitat loss and was later followed by the marbled murrelet, salmon and other species found to be associated with old-growth forests in Oregon, Washington and northern California. At the same time, widely-published satellite imagery documented tropical rainforest deforestation in South America. Since these habitats were known to be "hotbeds of biodiversity" there were concerns that the extinction of species was occurring at an unprecedented rate.

In both of these situations, research has suggested that biodiversity loss is not simply a matter of decreased acreage (and habitat loss) but also the *patterns* of habitat loss including:

> **Fragmentation**—the break up of large forested stands resulting in the isolation of small parcels of interior forest; the developing field of conservation biology began applying island biogeography theory to these habitat islands.
>
> **Formation of extensive edges**—in areas where none existed previously.

An "edge" is simply any boundary that occurs along two dissimilar habitats (e.g., old growth/ clearcut, meadow/forest, young/mature stand, etc.) The "edge effect" refers to those physical and biological changes that occur along the transition between two different ecosystems or habitats. The forest border adjacent to a clearcut, for example, represents a boundary between two very different environments that differ in minimum and maximum temperature, relative humidity, soil moisture, amount of solar radiation that reaches the surface, wind velocity, plant and animal species, among others. Along edges, there may be profound influences of one habitat upon the other often in rather complex ways. Temperatures, for example, might be expected to be higher in forested areas that are along an edge as compared to interior forested areas that are not adjacent to such an edge.

Forested areas with a significant percentage of their total area in edge may function differently biologically or physically as compared to interior forests. For example:

- Some of the physical attributes of the clearcut will penetrate the mature forest (sunlight, relative humidity, temperature, etc.), thereby reducing the effective size of a mature forest stand
- Edge areas are exposed to higher wind energy—resulting in greater risk of blowdown
- Edge effects favor some plant and wildlife species—e.g., deer and elk may do better in a mosaic landscape
- Dispersal of plant and animal species may be impaired by cutting pattern
- Edges may facilitate the entry of exotic species
- Edges have been linked to the decline of songbirds due to brood parasitism and predation

The effects of harvest patterns on the creation of edge can be illustrated by showing two landscapes—both with same acreage, harvested, but in different patterns. One landscape is harvested in a single large block, the other in a checker board pattern of smaller blocks. Have students calculate the amount of edge in each landscape.

The presence or absence of an edge is highly dependent upon how it is measured (physical variables vs. biological variables). Also, it is important to point out:

- there are different kinds of edges—soft edges, hard edges, etc.
- the species-specific nature of edge habitat
- the dynamic nature of edges
- the effect of orientation on edges

This laboratory is designed to illustrate the complexity of edge effects and to give students an opportunity to apply the "scientific method" (hypothesis testing, experimental design, data collection, analysis, etc.) to a relevant natural resources issue. Students evalute some of the physical and biological changes that occur in edge habitat in an attempt to answer such questions as, "Where is the edge?" or "How far does a clearcut influence the adjacent forest?". This is followed by exploring the implications their findings may have for modern natural resource management. To answer these questions, students establish a transect perpendicular to an edge and establish a number of stations at regular intervals along that transect.

A study site should be selected that illustrates an edge as defined above. Woodlots on campus, city or county parks, natural areas and public or private timber land are good candidates. Students should be introduced to the study site. The primary objective for the first lab is to design a study (hypotheses to test and experimental design) that allows each group to evaluate microclimatic changes that occur at the edge. Next week the study will be implemented and the following week each group will summarize and analyze their data. The final product is a report written by each student that summarizes and interprets the results of the study.

✐**To stimulate discussions related to experimental design, have each group briefly present their:**

- Question under study
- Hypotheses
- Experimental design (including "operational definitions" of each variable)

MATERIALS

Unless indicated otherwise, catalog numbers and prices are from:

Fisher Scientific
485 S. Frontage Rd.
Burr Ridge, IL 60521
TEL: 1-800-955-1177
FAX: 1-800-955-0740
http://www.fisheredu.com

QUANTITY	ITEM
6	Digital thermohygrometers (measures relative humidity and air temperature) Cat. No. CHS54113 Price $44.95
6	Light meters (measures solar radiation) Cat. No. CHS42234 Price $91.85
6	Armored field thermometers (measures soil temperature) or soil thermometer Cat. No. CHS45085G Price $16.80 OR Cat. No. CHS45114 Price $11.85
6	Digital anemometers (measures wind velocity) Cat. No. H-05951-75 Price $165.00 Available from: Cole-Parmer Instrument Company 7425 North Oak Park Avenue Niles, IL 60714 TEL: 1-800-323-4340 FAX: 1-708-647-9660
6	Rolls of flagging (any color)
6	Clipboards
6	Data sheets (students' design)
6	Metric tapes (30 m) Cat. No. CHS40560 Price $49.60
6	Compasses
6	Meter sticks
6	Metric rulers

Additional materials will be required if plant or animal sampling is to be conducted in conjunction with physical variables. For example:

- Insect sweep nets
- Pitfall traps
- Mammal livetraps
- Tape recorders
- Litter samplers
- Field guides

Evaluation of the Edge Effect–Data Collection

This laboratory is a field activity in which students implement the study they have designed in the previous lab. The laboratory is designed to give students the opportunity to apply the *data collection* phase of the "scientific method." Students are expected to be familiar with the experimental design of their study as well as the proper use of the instruments they will be using to measure physical variables. Students establish a transect perpendicular to an edge and mark a number of stations at regular intervals along that transect. Variables are measured according to operational definitions the group has defined. Data are recorded on a data sheet of their own design. The various tasks that need to be completed should be identified by the group and distributed among group members.

A suitable study site should be selected that illustrates a distinct edge between habitats and has sufficient area to accommodate the class. Woodlots on campus, city or county parks, natural areas and public or private timber land are all good candidates. With some modification, the activity can be altered to explore other natural resource issues. The measurement of environmental gradients along transects perpendicular to streams, for example, may be used to examine the effectiveness of riparian buffers in forest management.

MATERIALS
See materials list for Lab One.

Evaluation of the Edge Effect
Analysis & Interpretation

ANALYSIS OF TRANSECT DATA

1. Summarize all of your data in tables or graphs. Calculate means (averages) for each parameter where appropriate and plot these means against distance along the transect. You may find it useful to use data from other groups to supplement your information. Seek out this information from other groups and share your data with them where appropriate.

2. If you are familiar with the use of spreadsheet computer programs such as EXCEL or QUATTRO, I encourage you to use these tools to produce finished tables or graphs. I will introduce you to the basics of graphing data in Excel during lab. If you are not comfortable with these programs, just graph by hand. Graph paper will be provided.

INTERPRETATION AND APPLICATION OF RESULTS

After you have graphed the data or placed the information in a table, discuss within your group overall trends that are seen in the data. Then, answer the following questions in the space provided.

1. What conclusions can be logically drawn from the information you have collected? *(Extract as much information from your graphs as possible)*

2. What hypotheses are supported by the data? Which ones are not supported?

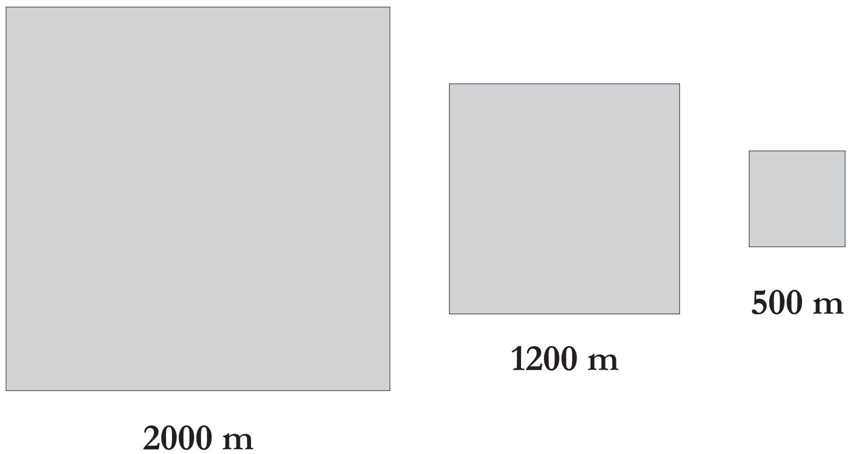
3. If you were to repeat this study, what changes would you make?

4. Based on your measurements, does it appear that the transects were long enough to reach true "interior habitat"? Describe the evidence you have used to reach your answer.

5. Assuming that we have sampled some true "interior habitat," what is the approximate width of the edge in the habitats sampled? Describe how you have arrived at this number.

6. Relationship between stand size and the edge effect:

For each of the forested stands below, assume that each is surrounded by clearcuts, and the "edge effect" penetrates 200 m into the interior forest. For each stand, calculate the total area of edge habitat and the percent of total area in edge (SHOW ALL OF YOUR WORK).

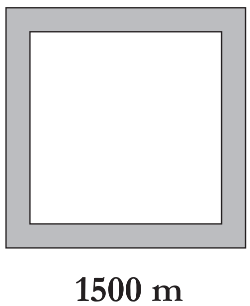


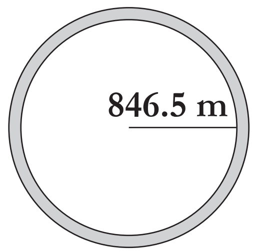
What conclusions can or did you draw from this exercise?

At what stand size does true interior forest habitat disappear entirely?

7. Relationship between stand shape and the edge effect:

Assume that each of the following stand shapes encompass exactly the same area and that the edge effect (area shaded in gray) penetrates 200 m into each. Calculate the total area of edge habitat and the percent of total area for each (SHOW ALL OF YOUR WORK).





What conclusions can or did you draw from this exercise?

8. Review the handout entitled "Evaluation of the Edge Effect—Applications" and the Temple and Flaspohler article entitled *The Edge of the Cut*. Of the several biological impacts of the edge effect described, which of these might be considered "negative"? Which might be considered "positive"?

9. Overall, does the edge effect have a positive or negative influence on forest ecosystem health and sustainability? Explain.

10. The stated goal of a land management agency is to preserve a tract of forest as intact interior forest. The forest is currently surrounded by clearcuts resulting in a reduction in the effective area of the tract as intact interior forest due to the edge effect. Describe specific practices that could be employed to reduce the edge effect in this situation over the long term.

NOTES FOR INSTRUCTORS

The primary goal of the Edge Effect Lab is to design and implement a study that uses the scientific method to answer the question—"To what extent does open area influence forest?". The final product is a 50 point report in the format of a scientific journal article that summarizes and interprets the results.

This lab provides the foundation for the RESULTS and CONCLUSION/DISCUSSION sections of Edge Effect report. Methods for presenting and interpreting data that were collected in field last week are emphasized. The INTRODUCTION and METHODS AND MATERIALS sections have essentially been done in the first two laboratories.

REVIEW GUIDELINES FOR EDGE EFFECT REPORT

- Write to a reader who has no prior knowledge of "edge effects"
- Hypotheses are "supported" or "not supported"; NOT "proven" or "disproven"
- Extract as much information as possible from your graphs (a common weakness)
- When drawing a conclusion, explain to the reader how you know this to be true
- Make use of articles and APPLICATIONS handout to see what is already known about the edge effect—relate your findings to these

IMPORTANT POINTS:

- **DISCUSS THE UTILITY OF GRAPHS AND THE DESIGN OF AN EASILY INTERPRETED GRAPH (TITLES, LABELS, AXES, DEPENDENT/INDEPENDENT VARIABLES, CAPTION). DISCUSS INTERPRETATION OF A SAMPLE GRAPH.**

- **DEMONSTRATE USE OF EXCEL — ENTRY OF DATA, SELECTION OF DATA, GENERATION OF GRAPHS, EDITING OF GRAPHS.**

- **STUDENTS GENERATE GRAPHS FROM THEIR DATA. WHEN COMPLETE, COPY SOME GROUPS' GRAPHS TO TRANSPARENCIES AND HAVE CLASS DISCUSS THEIR INTERPRETATION.**

- **HAVE STUDENTS PROCEED WITH QUESTIONS ON HANDOUT (#1-10). THIS IS TO BE COMPLETED OUTSIDE OF CLASS AND SUBMITTED INDIVIDUALLY.**

- **SHOW VIDEOTAPE, "ON A WING AND A PRAYER"; BEGIN VIDEOTAPE AFTER DISCUSSION OF BIRD KILLS AT LARGE CITY BUILDINGS AND SHOW FOR APPROXIMATELY 25 MINUTES TO END OF TAPE. BEGINNING OF VIDEOTAPE COULD BE USED ALSO BUT CONTAINS SOME PERIPHERAL MATERIAL.**

The decline of **neotropical migrants** *has been documented in many areas of the globe. Hypothesized causes include both the decline of wintering habitat in tropics (tropical deforestation) and the decline of nesting habitat in North America. This videotape describes the research of Scott Robinson that examines the impact of forest fragmentation in the Midwest. His strategy is to measure the nesting success of neotropical migrants in forested habitats.*

MATERIALS

QUANTITY	ITEM
12	Calculators
12	3.5" Floppy Disks (for student files)
12	Blank acetates (for making transparencies of graphs)

VIDEOTAPES

"On a Wing and a Prayer" (in part)—New Explorer Series, Dec. 1995 - #426075 B VHS 27 - 60 min.

Films Incorporated
5547 N. Ravenswood
Chicago, IL 60640-1199
312-878-2600 ext. 43

"Forest Fragmentation: Issue and Implications" (optional) #968V-T - 18 min.

Forestry Media Center
College of Forestry
Peavy Hall 248
Oregon State University
Corvallis, OR 97331-5702

Evaluation of the Edge Effect
Creating Charts in EXCEL

EXCEL is a powerful spreadsheet program that allows you to record data, create tables, charts and graphs and to perform calculations and statistical analyses. Although there are a number of possible uses for *EXCEL* in *Environmental Science*, today we will concentrate on its ability to generate graphs from a data set you have collected. By letting the software take care of the tedious task of creating graphs, it frees us up to concentrate on their interpretation and application of the results. There will be a number of opportunities throughout the year to apply your skills in *EXCEL,* and even if you are computer-phobic, I would encourage you to give it a try. I think you will find it to be a useful tool in this course and probably in others as well. The following instructions are written for *EXCEL 97* but they can be adapted to other versions of the program

Creating graphs in *EXCEL* is easy! It is essentially a three step process:

1. Enter your data on to a spreadsheet.
2. Select the data you wish to graph.
3. Use the *ChartWizard* to walk you through the selection of a graph type and the generation of your graph.

Each of these steps is more fully explained below.

Entering your data

1. If you have not yet done so, open up *EXCEL* from the main menu. The program will open up with a new worksheet where you will enter your data.

2. Starting in the top row (upper left corner), enter a title for your data table (e.g., *Bonesteele Park Edge Effect Study*). You can move around the worksheet using the direction arrows.

3. On the second row enter the headings for the data you have collected (Station #, Air Temperature, Soil Temperature, etc). Data are generally entered in as columns, so below each heading enter all the data you have collected. When you have done this, your spreadsheet should look something like this:

Bonesteele Park Edge Effect Study					
Station #	Air Temp (C)	Soil Temp (C)	Relative Humidity (%)	Wind Speed (mi/hr)	Solar Radiation (f-c)
10	24.3	18.6	86	0.1	78
9	23.8	18.3	79	0.1	123
8	24.1	17.9	84	0.3	87

Selecting your graph

1. Select the data you wish to graph by holding down on the left mouse button and dragging it across the rows and columns. Selected data will be highlighted by filled-in cells.

✐**NOTE: For most graphs it is a good idea to select the column headings as well as the data itself. EXCEL will use this information to label the axes on your graph.**

2. If you wish to select columns of data that are **not adjacent** to one another (e.g. Station #, Air Temperature and Relative Humidity), simply hold down the CTRL key while you are selecting your data.

Selecting and generating your graph

1. After you have selected your data, click on the *ChartWizard* button. The *ChartWizard* dialog box will appear and walk you through 4 steps to complete your graph.

2. The **first** step allows you to select the type of graph (3-D Pie, Bar graph, Line graph, X-Y Scatter, etc.) to present your data. Select the most appropriate graph type for your data. The "Edge Effect" data are probably best presented using either an X-Y Scatter or Line Graph. A specific sub-type of your graph can also be selected. Choose the **Next** button to go to the next step.

✐**NOTE: If at any point during the *ChartWizard* process you wish to go back to a previous step to make a change, choose the** Back **button.**

3. The **second** step displays your data in the graph type that you have selected and allows you to tell EXCEL how your data is organized. EXCEL uses this information to automatically label axes and set up a legend for your graph. Try changing some of these settings to see how they change your graph. When you are satisfied with the results, choose the **Next** button to continue.

4. The **third** step allows you to add a title to your graph and text to your legend and axis labels. Type in this information and when you are satisfied with the results choose the **Next** button to continue.

5. The **fourth** step asks where you would like to place your graph. If you want the graph on its own page, choose **"As a new sheet."** If you want it on the same page as your data table, choose **"As object in."**

To edit your graph

Nearly all features of the chart you have created can be edited. One of the first things you will probably want to do is *re-size* your chart so it is easy to read. Click once on the chart and drag the "handles" (small black squares) on the corners or side of the chart to make the chart any size you like.

In general, if you want to make other changes in your chart, click anywhere on the chart to highlight it. Then double click on the feature you want to change. This will bring up a dialog box that allows you to make changes.

To print your graph

If you want to print only the graph (probably the most common need), select the graph by clicking on it, then choose the **Print** button from the tool bar or **Print** under the **File** menu.

If you want to print both your data table and the graph, simply choose the **Print** button from the tool bar or **Print** under the **File** menu.

✐**NOTE: You can preview what will print by clicking on the** Print Preview **button on the tool bar or selecting** Print Preview **under the** File **menu.**

To add another y-axis

There may be times when you would like to plot two variables on the same graph to compare them. In the "Edge Effect" activity, for example, you may want to look at both solar radiation and air temperature at the same time. This can be difficult when the units used to measure each are so different (foot-candles vs. degrees C). Adding a second y-axis solves the problem. Simply proceed as described above, plotting both variables on an X-Y Scatter or Line Graph. Then, double click on one data series on the graph. A **"Format Data Series"** dialog box will appear. Select **Axis** and then choose **Secondary axis**. The variable you have chosen will be plotted on a second y-axis that appears on the right side of your graph.

STUCK??

EXCEL has an easy to use HELP program. Just click on **Help** from the main menu or the **Arrow/Question Mark** icon on the tool bar.

Consult with the instructor or another student who is familiar with the program.

Evaluation of the Edge Effect–Applications

APPLICATION OF RESULTS

The fragmentation of large forested stands has resulted in the formation of extensive edges in areas where none existed previously. The "edge effect" refers to those physical and biological changes that occur along the transition between two different ecosystems or habitats. The forest border adjacent to a clearcut, for example, represents a boundary between two very different environments that differ in minimum and maximum temperature, relative humidity, soil moisture, amount of solar radiation that reaches the surface, wind velocity, plant and animal species, among others. Along edges, there may be profound influences of one habitat upon the other often in rather complex ways. Temperatures, for example, might be expected to be higher in forested areas that are along an edge as compared to interior forested areas that are not adjacent to such an edge.

There are a number of practical applications of the edge effect, especially in forest and wildlife management. Forested areas with a significant percentage of their total area in edge may be functioning differently biologically or physically as compared to interior forests.

The following is a sampling of some of the current research that has been conducted on the consequences of the edge effect:

1. Relationship between microclimate (air and soil temperature, relative humidity, wind speed, air and soil moisture) and the edge effect.

Since edge habitat is located between interior forest and clearcuts, it might be expected that microclimate measurements at the edge would be intermediate. Chen, et al., 1993 investigated changes in microclimate between three distinct habitats—clearcuts, edge and interior forest. The following results were obtained taking measurements at weather stations installed in the center of clearcuts, at the forest edge and in the interior of the forest patch. Numbers in the table are averages over a recording period of 35 days (June - September).

Note that although lowest average air temperatures were recorded in the forest (as expected), highest average temperatures occurred in edge habitat rather than in clearcuts. This may be due to Note that although lowest average air mixing that occurs in open clearcuts but is inhibited along the edge due to the presence of trees and other structural components. Soil temperatures and relative humidity followed the expected pattern.

	Air Temperature (^oC)	Soil Temperature (^oC)	Relative Humidity (%)
Clearcut	16.33	18.34	70.90
Edge	16.67	17.08	75.99
Forest	15.72	13.93	79.38

Also, forests had a moderating effect on both air and soil temperature. Daily air and soil temperature fluctuations were greater in clearcuts and edges than in interior forest.

Wind velocity decreased from clearcut to edge to interior forest. Wind velocity in the forest was only 15-20% of that in the clearcut, while at the edge wind velocity was 60-70% of that in the clearcut.

Soil moisture was highest in edge habitat (17.3%), intermediate in the forest (13.8%) and lowest in the clearcut (13.8%). This may be due to weaker winds at the edge resulting in a lesser drying effect there. Another possibility may be a greater abundance of surface cover (vegetation and organic litter) and precipitation (condensation) at forest edges than inside the forest and on the clearcut.

References:

Chen, J., Franklin, J.F. and Spies, T.A. 1993. Contrasting microclimates among clearcut, edge and interior of old-growth Douglas fir forests. Agricultural and Forest Meteorology. 63:219-237.

Chen, J., Franklin, J.F. and Spies, T.A. 1990. Microclimate pattern and basic biological responses at the clearcut edges of old growth Douglas-fir stands. The Northwest Environmental Journal. 6:424-425.

2. Relationship between forest fragmentation and wildlife.

Forest edges have become a conspicuous landscape feature in western North America. Wildlife biologists for years have promoted forest edge as beneficial to wildlife (especially for deer and elk). Managers were encouraged to create as much edge as possible because the meeting of two different habitats was thought to create more habitat diversity and forage and therefore enhance wildlife. However, with increasing concern over species that require interior forest habitat, managers must now assess the balance between edge and interior habitat.

A. Bird nesting success

Forest fragmentation and the resulting creation of edge habitat is hypothesized to be a major cause of population decline in birds because fragmentation reduces nesting success. Small nature preserves fail to protect nests from predators, such as cowbirds, which lurk along forest edges. Robinson, et al. (1995) monitored 5000 nests of eight bird species in five Midwestern states for four years. Nests in areas of high fragmentation suffered higher rates of destruction and cowbird invasion. Cowbirds lay their eggs in other birds' nests. The surrogate mothers raise the young cowbirds and may neglect their own offspring. Young cowbirds are often bigger than the resident nestlings and either outcompete them for food or may actually push them from the nest. Also, nest predators such as raccoons and snakes are more abundant and successful in edge habitats.

Researchers note that study results suggest that a good regional conservation strategy for migrant songbirds is to identify, maintain, and restore large tracts. Researchers report they see consistent, catastrophic loss of forest migrants in smaller forests but not in woodlands larger than 100 hectares.

References:

Adler, T. 1995. Think big to save birds on edge. Sci. News. 147

Robinson, S.K., F.R. Thompson III, T. M. Donovan, D.R. Whitehead and J. Faaborg. 1995. Regional forest fragmentation and nesting success of migratory birds. Science 267:1987-1990.

B. Tropical frog diversity

The conversion of continuous forest into a patchwork of forest fragments surrounded by pasture, farmland and second growth is a common landscape pattern in tropical rainforests. Ecologists have warned that such patterns reduce populations by habitat loss and the creation of inhospitable edge habitat. A 10-year experiment in the Brazilian Amazon, however, has demonstrated that frog diversity actually <u>increases</u> after patches are isolated. This was surprising considering that frogs have long been thought to be an ecologically sensitive group. The authors suggest caution in interpretation of their findings. The increase in frog diversity may be a short-term increase caused by migration from cleared areas.

Reference:

Culotta, E. 1995. Forest fragments favor frogs. Science 269: 1045-1046.

C. Pacific Northwest Interior Forest Species

Creation of edge reduces effective area of habitat for interior forest species (e.g., spotted owl, Oregon slender salamander, red tree vole, tailed frog, marten, etc.). Preferred foods of northern spotted owls (flying squirrels, red tree voles, etc.) are more abundant and more available to owls in interior forests than along edges. Spotted owls suffer greater predation by great horned owls at forest edges than in forest interiors. Therefore, as more edge is produced, predation pressure on spotted owl populations increases.

Barred owls are aggressive competitors with spotted owls and seem to be better adapted to fragmented landscape and edge habitats.

Reference:

Swindle, K. 1995. Oregon Sate University, Corvallis, Oregon.—personal communication

3. Relationship between management of old-growth forests and the edge effect.

Old-growth forests exist as habitat islands surrounded by stands of varying ages. To achieve the same effective island size, a stand of old growth that is surrounded by clearcuts should be ten times as large as an old growth habitat island surrounded by a buffer zone of mature timber. The penetration of wind and sunlight into the forested stand has a profound influence on the physical and biological nature of the stand. The "three-tree height" rule has become widely accepted; i.e., climatic effects of a surrounding clearcut will penetrate three dominant tree heights into an old growth stand. A surrounding buffer zone of young or especially mature timber greatly reduces the penetration of light and wind into the old-growth stand.

Wind damage such as blowdown of dominant trees is more common in edge habitat than in interior forest. Trees at edges are more likely to be toppled by winds along roads and clearcuts since they are not protected by adjacent trees. In the Bull Run watershed of the Mt. Hood National Forest, 48% and 81% of two major blowdown events were adjacent to clearcuts and roads.

References:

Harris, L.D. 1984. The fragmented forest. Univ. of Chicago Press, Chicago, Illinois. 211 pp.

Norse, E. 1990. Ancient forests of the Pacific Northwest. Island Press, Washington, D.C., 327 pp.

4. Relationship between growth of dominant trees and the edge effect.

The influence of the edge effect on dominant trees in a stand has been evaluated by several researchers. Vegetation sampling of edges and interior forests has provided us with useful comparisons between these two different habitats.

What is the depth of the edge effect?

It depends on how the edge effect is measured and the forest type:

Douglas-fir forests (based on vegetation changes): 0-137 m
Douglas-fir forests (based on wildlife changes): 300-600 m
Hardwood forests of eastern U.S.: 10-20 m
Tropical rainforests in Panama: 15-25 m

What are the effects of edge habitat on dominant trees?

- reduced stocking density (as measured by canopy cover and # stems per hectare)
- increased growth rates of dominant trees (Douglas-fir and western hemlock)
- elevated rates of tree mortality (as measured by standing dead trees [snags] and fallen trees (logs)
- increased regeneration of conifer species (as measured by number of seedlings along edge)

References:

Chen, J., Franklin, J.F. and Spies, T.A. 1993. An empirical model for predicting diurnal air-temperature gradients from edge into old-growth Douglas-fir forests. Ecological Modeling 67:179-198.

Franklin, J.F. and R.T, Forman. 1987. Creating landscape patterns by forest cutting: Ecological consequences and principles. Landscape Ecology 1(1): 5-18

Chen, J., Franklin, J.F. and Spies, T.A. 1992. Vegetation responses to edge environments in old-growth Douglas-fir forests. Ecological Applications. 2 (4) 387-396.

Some Additional References on Edge Effect and Habitat Fragmentation

1. Cunningham, W.P. and B.W. Saigo. 1999. Environmental Science: A Global Concern. Wm. C. Brown/McGraw-Hill Publishers, Boston, MA. pp. 85-86.

Edge effects and applications to endangered species management are briefly introduced in a chapter on "Biological Communities and Species Interaction."

2. Kruess, A. and T. Tscharntke. 1994. Habitat fragmentation, species loss and biological control. Science 264:1581-1584

An experimental study on the effects of habitat fragmentation on insect populations. Authors test the hypothesis that extinctions in small isolated habitat patches do not affect all insect species equally.

3. Noble, I.R. and R. Dirzo. 1997. Forests as human-dominated ecosystems. Science 277:522-525.

An article from a special issue from Science *that addresses human-dominated ecosystems. Consideration of harvest patterns is discussed in the quest for a "sustainable forestry."*

4. Several authors. 1998. Fragments of the Forest. *Natural History* 107(6):34-51

A "Special Report" prepared for Natural History by a number of leading conservation biologists including William F. Laurance, Jay R. Malcolm, Richard Bierregaard and Thomas Lovejoy. The focus is on tropical forests and some results from the Biological Dynamics of Forest Fragments Project (formerly the Minimum Critical Size of Ecosystem Study) initiated by Lovejoy and others in Brazil in 1979 are discussed. The effects of forest fragmentation on insects, birds, amphibians and small mammals are described in a non-technical manner.

5. Forest Ecosystem Management Team (FEMAT). 1993. Forest ecosystem management: An ecological, economic, and social assessment. U.S. Departments of Agriculture, Commerce and the Interior and Environmental Protection Agency, Washington, D.C.

In a discussion of "Riparian Ecosystem Components" on pages V-25 to V-29, the authors address the significance of edge effects along streams. There is a detailed discussion of riparian processes as a function of distance from stream channels. A graph illustrates how various microclimatic factors (soil moisture, relative humidity, solar radiation, wind speed, air and soil temperature) change with distance from the edge of a riparian forest. This information is particularly of interest to those who deal with the establishment of riparian buffers in forest management plans.

6. Temple, S.A. and D.J. Flaspohler. 1998. The edge of the cut. Journal of Forestry Aug 98:22-26.

A brief review article that summarizes current and historical thinking on the implication of forest edges for wildlife populations. I assign this article as required reading for my Environmental Science students prior to the first Edge Effect Lab.

7. Chen, J., et al. 1999. Microclimate in forest ecosystem and landscape ecology. BioScience 49(4):288-297.

A recent review of microclimate research in forest ecosystems that includes gradients in microclimates along edges. Theoretical and management considerations are discussed. The same microclimate parameters measured in the Edge Effect Lab (air temperature, soil temperature and relative humidity) are graphed along a transect from a clearcut into a forest stand. These data are useful for comparison to student-collected data.

Ecosystem Analysis

I. INTRODUCTION

An **ecosystem** is defined as an ecological (biotic) community and its abiotic environment. Although ecosystems vary greatly in size and attributes, there are certain minimum requirements. There must be an autotrophic (usually photosynthetic) organism to convert sunlight into a more useable form (energy stored in carbohydrates). There must be an energy source (usually sunlight) and a sink (usually stored as carbohydrates in plant and animal tissues). There must be a decomposer to break down complex materials in the system so they can be used by autotrophs. All of the chemical elements required by the autotroph and the decomposer must also be present. Although not essential in a simple ecosystem, most also have one or more levels of consumers that ingest (directly or indirectly) carbohydrates stored in plants.

This laboratory is designed to familiarize you with the structure and function of ecosystems. We will limit our initial study to a small ecosystem with definite borders in the *Aquatic Ecology Laboratory*—constructed wetlands that were designed by students to study the treatment of agriculture wastewater.

II. CONSTRUCTED WETLAND DESCRIPTION

Six identical model wetlands were constructed in Chemeketa's *Aquatic Ecology Laboratory* by the *Environmental Science* class (for more information, refer to NCSR's Aquatic Ecology Laboratory). The initial conditions in each tank were as follows:

Substrate

Two layers of substrate were placed in each tank:
- coarse sand/gravel (3/4" minus) mix - 6"
- organic soil - 11"

Since the tank height is 24', this left approximately 7" of head space at the top of the tank to allow for fluctuating water levels. The top layer of organic soil was slightly excavated. A 4" deep depression was created in the center of the tank, approximately 2' in diameter. This was done to create two different water depths and/or saturation levels of soil to accommodate the different tolerance of flooding and submersion of plant species.

PLANTS

Four species of wetland plants were selected for planting:

- Yellow iris (*Iris pseudacorus*) - a single plant was placed in the center of each wetland
- Broadleaf cattail (*Typha latifolia*) - 12 plants were placed in a roughly circular pattern around the iris at approximately 4" spacing
- Smooth rush (*Juncus effusus*) - 30 rushes were placed on the "shelf" at 4" spacing
- Slough sedge (*Carex obnupta*) - 30 sedges were placed on the "shelf" at 4" spacing

WATER

Rainwater that collected in other tanks was used to saturate the soils in the wetlands. Water levels have been held relatively constant by either adding or draining water depending on inputs from rainfall and outputs from evaporation.

The constructed wetlands have been allowed to mature for approximately 20 months since planting.

A. PROCEDURE

Enter your tank number here: __________

Answer each of the following questions concerning your model ecosystem as completely as possible in the space provided.

III. ECOSYSTEM COMPOSITION

A. ABIOTIC COMPONENTS

List the abiotic components of your ecosystem in the space below:

B. Biotic Components

1. Identify as many plant species as you are able using available guides. The instructor will also be available to assist in identification.

The following plants have been identified recently in these constructed wetlands:

Yellow iris	*Iris pseudacorus*
Broadleaf cattail	*Typha latifolia*
Smooth rush	*Juncus effusus*
Slough sedge	*Carex obnupta*
Bolander's rush	*Juncus bolanderi*
European bittersweet	*Solanum dulcamara*
Waterpepper	*Polygonum hydropiperoides*
Ovate spike rush	*Eleocharis ovata*
Large barnyard grass	*Echinochloa crus-galli*
Curly dock	*Rumex crispus*
Common velvet grass	*Holcus lanatus*
Soft-stem bulrush	*Scirpus tabernaemontani*

2. Confirm identification of your plant species with instructor before proceeding.

3. Estimate the number of individual stems of each plant species either by direct count (for those with 50 or fewer individuals) or by sampling (for those with more than 50 individuals). Record your results in the table below:

Plant Species	No. Stems

4. Describe the sampling method you have used to estimate those plant species with more than 50 individuals.

5. Are there any species present in the ecosystem now that were absent when the wetland was constructed? Which ones?

6. What are some possible sources of these plants you have listed in #5?

7. Which of the species originally planted in your wetland have increased in number? Which ones have decreased?

8. What do the changes you have described in questions #5, 6 and 7 suggest to you?

9. The term "ecological succession" is used to describe changes in ecosystems that occur over time. Describe how each of the following ecosystem characteristics has changed since planting:

Total biomass -

Species diversity -

Species composition -

10. Based on the changes that have occurred in this ecosystem over the past 20 months, how do you think each of the following will change over the next 20 months? Describe your rationale for each (i.e., why do you think this change will occur?).

Total biomass -

Species diversity -

Species composition-

11. Carefully examine and sample the water and vegetation within your ecosystem for animal species. Collect as many animal species (mostly insects and aquatic invertebrates) as you are able without seriously disturbing the ecosystem. Collection equipment will be available. Use available references and dissecting microscopes to identify these animals.

12. For each animal species you have observed or collected, record your best estimate of numbers of individuals in the table below. Also, indicate whether each is a primary consumer (herbivore) or secondary consumer (predator).

VEGETATION			WATER		
Species	Estimated Number	Consumer Level	Species	Estimated Number	Consumer Level

II. ECOSYSTEM PROCESSES - ENERGY FLOW AND NUTRIENT CYCLING

1. Which organisms in the ecosystem are photosynthetic?

2. Construct a biomass pyramid that illustrates your estimate of the relative amounts (weights) of producers, primary consumers and secondary consumers in your wetland.

3. List all the possible fates of a single green leaf in your ecosystem.

4. Describe how plant and animal biomass accumulate in this ecosystem. Include the following terms in your description - *carbon dioxide*, *photosynthesis*, *carbohydrate*, *respiration*, *ingestion*

5. Which organisms in the ecosystem are decomposers? What evidence do you see of their existence? Describe their role in nutrient cycling in this ecosystem.

6. The ecosystems you have been working with are only models of actual ecosystems. In what ways are these constructed wetlands different from a fully functional wetland ecosystem? In what ways are they the same?

NOTES FOR INSTRUCTORS

This laboratory is designed to introduce students to the structure and function of ecosystems. It establishes the foundation for more sophisticated and quantitative laboratories to follow. Topics such as energy flow, nutrient cycling and ecological succession have been (or will be) discussed in lecture and it is assumed that students have at least some background in these areas. These topics are covered in detail in Chapters 4, 6, 8 and 9 in Botkin and Keller 2000.

The lab is written specifically for small wetland ecosystems that have been constructed in the *Aquatic Ecology Laboratory* at Chemeketa Community College. However, the laboratory could be easily adapted to any ecosystem where real or artificially created boundaries are established (e.g., tidepool, marked area in forest or field, small pond).

Ecosystem definition: ecological (biotic) community and its abiotic environment.

REVIEW MINIMUM CRITERIA:

1. There must be an energy source (usually sunlight)

2. Autotrophic organisms (photosynthetic or chemosynthetic) convert sunlight into a more useable form (energy stored in carbohydrates).

3. Decomposers to break down complex materials in the system so they can be used by autotrophs.

4. Chemical elements are required by the autotroph and the decomposer (e.g., nitrogen, carbon, calcium, potassium, etc.).

Although not essential in a simple ecosystem, most also have one or more levels of consumers that ingest (directly or indirectly) carbohydrates stored in plants.

DESCRIBE SEVERAL EXAMPLES OF ECOSYSTEMS THAT VARY IN SIZE, COMPLEXITY AND COMPOSITION.

"Sustained life on earth is a characteristic of ecosystems—not of individual organisms or populations," Botkin and Keller (2000) p. 45. Have students describe why this is so.

MATERIALS

QUANTITY	ITEM
3	Plankton nets (for collection of aquatic invertebrates)
3	Ring stands and rings (to support plankton nets)
12	Dissecting microscopes
12	Fine forceps
12	Eye droppers and bulbs
6	Finger bowls/Large crystallization dishes
24	Small. coaster type watch glasses
6	1000 ml beakers (for collection of water sample from wetlands)
12	Golden Guide - "Pond Life" books
6	Insect sweep nets
3	Insect identification guides
3	Wetland plant identification guides
24	Specimen jars with lids (for insects)
12	Clipboards
6	Meter sticks

Primary Production in Constructed Wetlands

I. INTRODUCTION

A. What is Primary Production?

Primary production is defined as the accumulation of organic matter in an ecosystem that results from photosynthesis. Autotrophic organisms such as green plants, algae and some bacteria can make their own organic matter (carbohydrates) from a source of energy (sunlight) and inorganic compounds (carbon dioxide and water). You may recall that photosynthesis can be summarized by the following chemical reaction:

$$6\,CO_2 + 6\,H_2O \rightarrow C_6H_{12}O_6 + 6\,O_2$$

The structure and function of nearly all ecosystems is dependent upon the ability of photosynthetic organisms to convert sunlight into carbohydrates. These carbohydrates then serve as a source of energy for heterotrophic organisms such as insects, small mammals, fungi and some bacteria. The production of organic material and its use can be described as a three-step process:

1. A photosynthetic organism produces organic matter through photosynthesis—**Gross Primary Production (GP).**
2. The organism uses some of this matter to fuel its own processes (growth, reproduction, synthesis of other compounds, etc.)—**Respiration (R).**
3. Whatever is not burned as fuel can be stored and accumulated for future use (either by the photosynthetic organism itself or by consumers in the community)—**Net Primary Production (NP).**

The mathematical relationship between these three can be described as:

$$NP = GP - R$$

The situation is analogous to your paycheck. **Net Primary Production** is your take-home pay after taxes (**Respiration**) have been taken out of your gross pay (**Gross Primary Production)**.

For a more detailed discussion of primary production see pp. 145-147 in Botkin and Keller (2000).

B. How can Net Primary Production be Measured?

Net primary production is generally reported as the amount of biomass that accumulates in a given area over a specific time frame. Thus, units such as "$g/m^2/day$" or "tons/hectare/year" are commonly used. There are a number of ways this determination can be made depending on *why* the measurement is being made, the type of ecosystem, desired accuracy, and other factors. Estimates of primary production are commonly made as part of ecosystem studies where biomass pyramids are constructed to represent energy flow through the system. Also, primary production is often estimated in agricultural systems where maximizing yields (and thus profits) is a common goal.

We will use a "clip method" to estimate net primary productivity in constructed wetlands in Chemeketa's *Aquatic Ecology Laboratory*. The method is based on weighing the plant material that has accumulated during a growing season. We will clip a sample of the vegetation from a known area and then weigh this material. Since we know the exact date at which these wetlands were planted and can measure the total area of each wetland, an estimate of net primary production for the system is possible.

Background

In today's laboratory we will be measuring net primary production in six constructed wetlands that were established in Chemeketa's Aquatic Ecology Laboratory. The wetlands were planted in 300-gallon tanks with identical substrate, topography and water volume. The top layer of organic soil was slightly excavated. A four-inch deep depression was created in the center of the tank (approximately two feet in diameter). This was done to create two different water depths and/or saturation levels of soil to accommodate the different tolerance of flooding and submersion of plant species. Four species of obligate wetland plants were planted—smooth rush, slough sedge, cattail and yellow iris. The iris and cattails were placed in the slightly depressed area in the center of the tank. Rushes and sedges were placed on a shelf at a slightly higher elevation. Since construction, water levels have been held relatively constant by either adding or draining water depending on inputs from rainfall and outputs from evaporation.

Once the plants became established, these constructed wetlands were used to test their effectiveness in the treatment of agricultural wastewater. Over the three-month period (April to June), wastewater of two different concentrations was added to the tanks. Tanks A1, A3 and A5 received a total of 40 gallons of wastewater treated with a *moderate* amount of commercial fertilizer. Tanks A2, A4, and A6 received 40 gallons of wastewater treated with a *high* amount of the same fertilizer.

We will test the hypothesis that the application of higher concentrations of fertilizer had a positive effect on net primary production in these wetlands. Since tanks A2, A4, and A6 received greater amounts of fertilizer, it might be predicted that net primary production in these tanks would be higher. Let's see how we can test this hypothesis.

II. PROCEDURE

1. Examine the plants in your wetland and be sure you are able to identify the following:

   Smooth Rush
   Slough Sedge
   Cattails
   Grasses

   Samples will be available for comparison.

2. Calculate the surface area of your wetland and record it on your data sheet.

✐**Note: Assume that the tank approximates a circle, and therefore, its area can be calculated from the formula: A= 3.14 (r^2)**

3. Select a representative area in the rush/sedge zone of your wetland and carefully place the 0.1 m^2 quadrat on the surface to establish the boundaries of your sample.

4. Using scissors, carefully clip all vegetation (dead or alive) within your sample area *exactly* at ground level.

5. Separate the clippings into the following categories using paper bags to store the samples:

   Smooth Rush
   Slough Sedge
   Cattails
   Grasses
   All other vegetation

6. Using digital balances, weigh each category and record to the nearest 0.1 g. These are **wet weights** for your samples. Record your measurements on the data sheet.

7. Label your samples with your name and lab section and place them in the drying oven. Allow samples to dry for one week.

8. Re-weigh your samples after one week to determine dry weights.

9. Calculate the **net primary production** (dry weight/m^2/day) and **total above-ground biomass** (g) for each plant category. Enter your estimates on the attached data sheet.

10. As estimates of net primary production become available for other tanks from other groups, record this information on your data sheet.

III. ANALYSIS

Answer each of the following questions in the space provided.

1. The experimental period for this study was April to October. How would your estimate of net productivity differ if the experimental period was May through July? November through January?

2. Place all class data into either a table or summarize in graphical form. Is our original hypothesis supported or refuted by the data? Explain fully.

3. Which plant species accounts for the majority of primary production in your wetland?

4. How much biomass was accumulated in your entire wetland during the experimental period? Show how you determined this.

5. We measured **net production** in today's experiment; that is, the **accumulated biomass** over time. In addition to this material, however, these plants produced much more biomass that was *not* measured (i.e. **gross production**). Describe some of the possible fates of this "missing biomass."

6. Did you encounter any heterotrophic organisms in your sampling or observations? If so, what were they? Discuss their influence (direct or indirect) on **primary productivity**.

7. Why is **"dry weight"** rather than **"wet weight"** used as a standard measure of **net productivity**?

8. On the next page are some estimates of growing season above ground net primary production for several grassland ecosystems:

Ecosystem Type	Above-Ground Net Primary Production ($g/m^2/day$)
Tallgrass Prairie, Oklahoma (grazed)	2.25
Tallgrass Prairie, Oklahoma (ungrazed)	1.48
Mixed-grass Prairie, Kansas (grazed)	1.64
Mixed-grass Prairie, Kansas (ungrazed)	1,06
Shortgrass Prairie, Texas (grazed)	2.66
Shortgrass Prairie, Texas (ungrazed)	0.77

At least for the ecosystems listed here, it appears that grazing has a positive impact on net primary production. Why do you think this is the case?

How do your net primary production estimates compare to those given above? What do you think accounts for differences?

Do you think, in general, that wetlands are more or less productive than prairies? Explain.

9. List five environmental factors that may influence the primary production of a wetland ecosystem. Include only “natural” factors, not human-caused influences such as mowing or the application of commercial fertilizer.

a.

b.

c.

d.

e.

10. Explain why our net primary production estimates are an under-estimate of total net primary production.

Above-Ground Net Primary Production for Constructed Wetlands in Chemeketa's Aquatic Ecology Laboratory

SPECIES: **Smooth Rush**						
Tank #	Sample Wet Weight (g)	Sample Dry Weight (g)	Growth Period (days)	Net Primary Production ($g/m^2/day$)	Area of Tank (m^2)	Total Above-ground Biomass (g)

SPECIES: **Slough Sedge**						
Tank #	Sample Wet Weight (g)	Sample Dry Weight (g)	Growth Period (days)	Net Primary Production ($g/m^2/day$)	Area of Tank (m^2)	Total Above-ground Biomass (g)

SPECIES: **Grasses**						
Tank #	Sample Wet Weight (g)	Sample Dry Weight (g)	Growth Period (days)	Net Primary Production ($g/m^2/day$)	Area of Tank (m^2)	Total Above-ground Biomass (g)

SPECIES: **Miscellaneous Wetland Plants**						
Tank #	Sample Wet Weight (g)	Sample Dry Weight (g)	Growth Period (days)	Net Primary Production ($g/m^2/day$)	Area of Tank (m^2)	Total Above-ground Biomass (g)

SPECIES: **Cattails**						
Tank #	Sample Wet Weight (g)	Sample Dry Weight (g)	Growth Period (days)	Net Primary Production ($g/m^2/day$)	Area of Tank (m^2)	Total Above-ground Biomass (g)

SPECIES: **All Plants Species Combined**						
Tank #	Sample Wet Weight (g)	Sample Dry Weight (g)	Growth Period (days)	Net Primary Production ($g/m^2/day$)	Area of Tank (m^2)	Total Above-ground Biomass (g)

References:
Botkin, D. and E. Keller. 2000. Environmental Science: Earth as a Living Planet. 3rd ed. John Wiley and Sons, Inc. New York. 649 pp.

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MATERIALS

QUANTITY	ITEM
6	metric tapes
12	scissors
6	large plastic basins
18	sorting trays
3	digital balances
3	drying ovens
60	.1 m^2 wire quadrats
100	small (approx. 1" X 2") tags w/ ties

Log Decomposition in Forest Ecosystems

Which is more alive—a standing live tree or a decaying log on the forest floor?

The answer seems so obvious that at first glance one would think it must be a trick question. Clearly a living organism must be more alive than a dead one! Upon closer examination, however, we find that by any measure, a decayed log is far more alive than a living tree! In cross-section the majority of a living tree is made up of dead cells that make up xylem tissue. Living tissue is restricted to a few tissues such as the leaves and a thin cambium layer that lies inside the bark. A decayed log on the other hand contains a myriad of living organisms. Termites, ants, beetles, mites, bacteria, nematodes, protozoans, fungi and small vertebrate animals such as voles and salamanders may all call the "formerly living tree" home.

As we attempt to manage our forests under the guiding philosophy of "ecosystem management," an understanding of short-term and, in particular, long-term ecological processes becomes essential. The processes that maintain and enhance soil fertility, for example, are long-term processes and are an important consideration as we manage on broader scales of both time and space. We have recently gained a greater understanding of the role of decomposing materials, particularly in forests. Today's laboratory is designed to explore the nature of log decomposition as one component of nutrient cycling in forest ecosystems.

I. BACKGROUND

A. How has the role of woody debris been viewed in the past?

In the past, woody debris (logs, branches, bark, standing dead trees, etc.) was viewed either as a wasted resource or an impediment to the management of forest resources. In streams, logs formed natural dams that impeded water travel by humans and anadromous fish. On the forest floor, woody debris was thought to contribute to disease and fuels that feed forest fires. Standing dead trees (snags) were seen as victims of disease or chance events like lightning strikes or wind storms—trees that "died before they could be harvested." Snags with dead limbs—"widow-makers"—were hazards to logging crews. Forests with an abundance of woody debris were considered "over-mature," suggesting that harvesting had been delayed too long. The removal of woody debris was seen as a priority in the proper management of forests and streams running through these forests. Until recently, the U.S. Forest Service spent hundreds of dollars per acre to remove logs from stands prior to replanting.

B. What do we know now about the role of woody debris in ecosystems?

Rotting logs and snags are a dominant feature in old-growth forests of the Pacific Northwest. A 500-year stand may hold over 80 tons of logs per acre in various stages of decay. Recent research has dramatically changed our view of the role of dead trees in forested ecosystems. They form an important part of what is known as the "biological legacy" of the forested stand. As we will see in later labs, this legacy speeds up the recovery of a forest after a disturbance such as a fire or a harvest.

Woody debris is now known to serve the following ecological functions in forest ecosystems:

- Rotting logs serve as substrates for wood-rotting fungi. These fungi are an important source of food for many wildlife species and they play an important role in nutrient cycling in forest soils.
- Rotting logs are an important substrate for tree seedlings and shrubs. By establishing on logs, these seedlings have a ready source of nutrients and water and gain a competitive advantage over plants on the forest floor in the competition for available sunlight. For this reason, these logs are sometimes referred to as "nurse logs."
- Woody debris holds soil in place and reduces erosion on slopes.
- Large logs retain moisture throughout the year and are important sources of moisture during drought conditions.
- Woody debris is an important habitat component for a number of wildlife species. Populations of some species of salamanders and small forest mammals, in particular, have been shown to be associated with the abundance of large woody debris on the forest floor.
- Decaying logs are important reservoirs of plant nutrients that are slowly released into the soil which contribute to soil-forming processes.
- The formation of pits and mounds due to wind throw of trees causes soil disturbance and an increase in plant and animal diversity in forests.
- In streams, large logs are important habitat components for aquatic organisms including anadromous fish (salmon and steelhead). They divert energy during high flows, reduce streambank erosion, create pools and serve to retain nutrients in streams.
- Standing dead trees (snags) are an important habitat component for cavity-nesting birds, wood-boring insects and some forest mammals.

As a result of these new findings, there have been some changes in policies that include leaving woody debris (both logs and snags) in managed timber stands as well as in streams. Stream restoration efforts today even include the *addition* of woody debris to streams.

"No one had considered that, ecologically, the logs might be doing a great deal. In retrospect, it's almost unbelievable that we could have been that stupid."

- Jerry Franklin, University of Washington College of Forest Resources

II. LAB OVERVIEW: LONG-TERM STUDY OF WOODY DEBRIS DECOMPOSITION

In today's lab, we will contribute to a long-term study of woody debris decomposition that began in October 1997. Unlike most laboratories in *Environmental Science* where the results are known in a very short period of time (usually by the end of the lab period), the final results of this study may not be known for 10 or 20 years! We will examine logs that have been decomposing for one year and establish initial conditions; then new logs that will be added to the study. We will also develop hypotheses that will be tested by future classes.

The lab I've developed is a scaled-down version (using smaller logs) of a long-term study of decaying logs being conducted at the H.J. Andrews Experimental Forest, a Long-Term Ecological Research (LTER) site funded by National Science Foundation, located in the Blue River District of the Willamette National Forest (this study is described briefly in this lab). For information on the larger, 200-year study, see the references listed, including Harmon's *"Long-term experiments at the H.J. Andrews Experimental Forest"*; and check these websites:

- **www.fsl.orst.edu/lter**
- **www.lternet.edu/**

Decomposition rates might be expected to be influenced by a number of physical and biological characteristics of logs. Smaller logs, for example, since they have proportionally greater surface areas and smaller volumes, would be expected to decompose more rapidly than large logs. Species with high densities (mass per unit volume) would be expected to decay more slowly than those with low densities. Some species may be more resistant to decay due to chemical characteristics of the wood. Bark may be an effective barrier to entry by some insects and decomposing bacteria and fungi. Bark thickness and percent of a log covered by bark may, therefore, be important as well.

The measurements you are taking today were selected to be representative of the initial conditions of the logs. Once these measurements are taken, the logs will be placed in a forested study area where decomposition will proceed. Each year some logs will be retrieved from the study area and the measurements will be repeated and compared to the initial conditions. This will continue until the logs are completely decomposed. It is expected that as decomposition proceeds, values such as "mass" and "density" of the logs will decline while "moisture content" will increase.

The importance of obtaining accurate information concerning the initial conditions of these logs cannot be over-stated! The study is based on making comparisons with these initial conditions. *Precise and accurate measurements are a must.* Be sure that you are using measuring instruments properly. Especially when starting out, I would suggest that you have another group member check your measurements for agreement.

III. PROCEDURE

A. Collection of log pieces

Log pieces of four tree species were collected during the summers of 1997 and 1998 from a location three miles northwest of Dallas, Oregon. In 1997, approximately 25 pieces were collected from trees of each species. In 1998, eight pieces were collected from each species to replace those that have been pulled to examine in today's lab and to add more logs to the study.

In an effort to make all pieces as uniform as possible:

- Pieces were taken only from bole (trunk) sections of live trees.
- Only pieces with a minimal number of lateral branches were selected.
- Pieces were selected to be approximately the same diameter—a target diameter of 8 cm was selected with log diameters of ± 25% (6 to 10 cm) allowed.
- All pieces were cut to approximately 37 cm in length.

B. Initial Measurements on New Logs

Your lab group will be responsible for the measurement of three or four new log pieces in lab today. Carefully measure or calculate the following parameters of your log pieces. Record measurements on your *Log Decomposition Data Sheet*. You will need one sheet per log; all measurements are metric.

Variable	Device/ Method
Diameter	Digital Calipers—measure diameter at both ends to nearest 0.1 mm. Record average of 2 measurements
Length	Tape—measure to nearest 0.5 mm
Volume	**V = A** x **L**; where, A = area of base and L = total length Record volume to nearest 0.1 cm^3 ✐**Note: Area of circle = 3.14 $(radius)^2$**

✐**Note: In addition to "Total Volume", you will also estimate "Heartwood Volume", "Sapwood Volume" and "Bark Volume". To do this:**

1. Measure the diameter of <u>heartwood</u> (if any) and divide by 2 to calculate radius.
2. Calculate the area of a circle using this radius.
3. Plug this new area into the formula above to obtain **heartwood volume** (record to nearest 0.1 cm^3).

4. Measure diameter of sapwood and divide by 2 to calculate radius.
5. Calculate the area of a circle using this radius.
6. Plug this new area into the formula above to obtain volume of heart wood plus sapwood.
7. Subtract heartwood volume from this figure to obtain **sapwood volume** (record to nearest 0.1 cm^3).
8. To obtain **bark volume**, subtract heartwood and sapwood volume from total volume (record to nearest 0.1 cm^3).

Total Surface area	$\mathbf{TSA = (L \times P_B) + A_{B1} + A_{B2}}$; where TSA = total surface area, L = length, P_B = average perimeter of base, A_{B1} = area of one end, A_{B2} = area of opposite end. Record TSA to nearest 0.1 cm^2
Bark Surface Area	$\mathbf{BSA = TSA - (A_{B1} + A_{B2} + BR)}$; where BSA = bark surface area, TSA = total surface area, A_{B1} = area of one end, A_{B2} = area of opposite end, BR = area in which bark is removed (if any). Record to nearest 0.1 cm^2.
Bark Thickness	Average of four measurements taken with a metric ruler and re corded to nearest 0.5 mm.
*Density (g/cm^3)	Dry weight of each piece measured in its entirety to nearest 0.1 g after oven drying at 55° C for 7 days divided by its volume.
*Moisture content (%)	**[(Wet weight - Dry weight)/Wet weight]** x **100** Record to nearest 0.1%.
†Presence of fungal hyphae	Enter "YES" or "NO." If "YES," is it "brown rot" or "white rot?"
†Evidence of boring (insects)	Enter "YES" or "NO." If "YES," describe evidence (collect specimens, draw galleries, etc.).

***** **Determination of initial moisture content and density of these logs will require a sampling technique described in "C" below.**

† **Fungal hyphae and insects are not expected to be present in new logs at this time. They <u>may</u> be present in logs that have been decomposing for one year.**

C. Determination of Initial Moisture Content and Density

At first glance, the determination of initial moisture content and densities of logs may appear to be a rather straight-forward affair. Unfortunately, we cannot determine dry weights of new logs directly without interfering with the decomposition process. Oven-drying logs prior to placing them on the forest floor would clearly create an artificial situation. We must therefore resort to a less direct method of determination.

1. Moisture Content

During the preparation process, a 3 cm section (sample) was cut from each log. Wet weights were taken on each and these are recorded in the table on page 75. The samples were then placed in a drying oven at 55^0 C for 7 days. These dried samples are now available for you to weigh (to the nearest 0.1 g). Percent moisture for the sample can then be determined by the formula:

$$\% \text{ Moisture} = [(\text{Wet weight} - \text{Dry weight})/\text{Wet weight}] \times 100$$

We can then assume that this percent moisture is representative of the entire log. Record your results for each sample on the data sheet below. Record to the nearest 0.1%.

2. Log Density

The initial density for each log can now be determined. First, determine the wet weight of a log using the digital balance. Then, using the percent moisture estimate above, determine the dry weight of the entire log as follows:

$$\text{Dry Weight} = \text{Wet Weight} - (\text{Wet weight} \times \% \text{ Moisture}/100)$$

Again, we are assuming that the 3 cm sample is representative of the log as a whole.

Since the volume of the log has already been determined, the density can easily be determined by the formula:

$$D = W_D/V$$

Where, D = density (in g/cm^3), W_D = dry weight of the log (determined above) and V = volume of the log (determined above). Record densities on the Log Decomposition Data Sheet (to the nearest 0.1 gram per cubic centimeter).

D. Labeling Log Pieces

After initial measurements are taken on the new logs and recorded carefully on the data sheets, permanently label each piece in the following manner:

- Indicate the species and sample number on aluminum tags using the following code:

SPECIES:
Douglas-fir (*Pseudotsuga menziesii*)—DOFI
Black locust (*Robinia pseudoacacia*)—BLLO
Lodgepole pine (*Pinus contorta*)—LOPI
Bigleaf maple (*Acer macrophyllum*)—BLMA

SAMPLE NUMBERS:
"30" through "37"

Example:
DOFI-32 Indicates "Douglas-fir sample number 32"

- Attach the aluminum tag securely to the midpoint of the log with a plastic cable tie

- Seal the ends of each piece with paraffin or "Gacoflex." Completely cover the ends (about 1cm. depth in paraffin wax.) Carefully dip each end of the log into the solution (approx. 1 cm) and place on racks to dry.

E. Measurements on Decomposed Logs

In addition to measuring new logs, your lab group will be responsible for the measurement of one or two logs that have been decomposing for a year. These logs will be discarded after today's lab so they can be handled quite differently from the new logs you have just measured. Wet weights were obtained from these logs when they were removed from the study site last week. They were then placed in a drying oven at 55^0 C for seven days.

Using the master data sheet entitled "Initial Measurements for 1997 Log Decomposition Study." enter the initial (1997) measurements for your log on a *Log Decomposition Data Sheet*. Then, carefully measure or calculate the following parameters of your log pieces. Record these measurements below the 1997 measurements on the *Log Decomposition Data Sheet*. You will need one sheet per log (all measurements are metric).

Density (g/cm^3)	Dry weight of each piece measured in its entirety to nearest 0.1 g after oven drying at 55° C for 7 days divided by its volume ✐ **NOTE: Do not measure diameter, length or volume for these logs. Just use last year's volume to calculate density.**
Moisture content (%)	**[(Wet weight - Dry weight)/Wet weight] ´ 100** Record to nearest 0.1%.
Presence of fungal hyphae	Enter "YES" or "NO." If "YES," is it "brown rot" or "white rot?"
Evidence of boring by insects	Enter "YES" or "NO." If "YES," describe evidence (collect specimens, draw galleries, etc.).

F. Development of Hypotheses

A great number of questions concerning the decomposition of woody debris can be answered using the approach we have selected. For example, each of the following questions could be explored:

How does the presence of bark influence the decomposition process?

How does the local environment (forest vs. open area) influence the decomposition process?

What insect and fungal species contribute to the decomposition process of these species and what are their roles?

We will, however, narrow our interest to the following:

1. Of the tree species under study, which species will decompose most rapidly? Least rapidly? In what order will these species decompose?

2. Is decomposition of these species a constant, linear process or a non-linear process? In other words, if a log is completely decomposed in ten years, does it lose 10% per year (linear) or is there some other pattern?

3. How does position in the substrate (on substrate surface vs. buried in substrate) influence the decomposition process?

For each of these questions, develop a hypothesis that provides a plausible answer. Your hypotheses should be based on what is currently known about woody debris decomposition. Initial measurements will provide some information on physical characteristics of the different species. Also, comparisons between initial values and values after one year of decomposition should be useful. References will be on reserve for your use. You may also conduct your own research (e.g., try an Internet search on "log decomposition") to find additional information that relates to these questions and helps you develop your hypotheses. After you have stated your hypotheses, briefly describe your supporting information and cite your sources.

G. Placement of Logs

Original logs were placed on 1 November 1997 in a 25-year old Douglas-fir plantation located 3 miles NW of Dallas, Oregon. Elevation is 830 feet above sea level. The terrain is nearly flat. The canopy is closed and vegetation is dominated by Douglas-fir averaging 30 cm DBH. Vertical stratification is negligible. The forest floor is covered by a litter layer of 2-4 cm (needles, cones twigs and small branches) and mosses.

Logs were arranged in groups of eight logs each—two logs of each species (lodgepole pine, black locust, Douglas-fir and bigleaf maple). All logs were placed in a horizontal position. Odd-numbered logs were buried in the topsoil (A horizon) to a depth equal to the diameter of the log. The duff (litter) layer was then replaced over the log. Even-numbered logs were laid directly on the duff. Log groups were separated from each other by one meter spacing.

All logs prepared for this study today and in the future will be placed at this site.

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Log Decomposition

Species____________________ Sample Code_______________ Treatment________________

Observers____ Date__________________

Ave. Dia. (mm)	Length (mm)	Volume				TSA (cm^2)	BSA (cm^2)	Density (g/cm^3)	Wet Weight (g)	Dry Weight (g)	Moisture (%)	Bark Thickness (mm)	Insects/ Hyphae
		% HW	% SW	% BK	TOT (cm^3)								

Key: HW = heartwood, **SW** = sapwood, **BK** = bark, **TSA** + total surface area, **BSA** = bark surface area

Initial Dry Weight Determinations

SPECIES: Douglas-Fir | **SPECIES: Black locust**

Log #	Sample Wet Weight	Sample Dry Weight	% Moisture	Log #	Sample Wet Weight	Sample Dry Weight	% Moisture
30	99.4			30	76.2		
31	99.8			31	105.3		
32	99.1			32	98.7		
33	150.7			33	157.1		
34	63.5			34	164.6		
35	67.2			35	135.6		
36	82.0			36	151.5		
37	67.1			37	155.4		
38				38	163.9		
39				39	100.4		
40				40			
41				41			
42				42			

Initial Dry Weight Determinations

SPECIES:	Bigleaf maple			SPECIES:	Lodgepole pine		
Log #	Sample Wet Weight	Sample Dry Weight	% Moisture	Log #	Sample Wet Weight	Sample Dry Weight	% Moisture
30	99.4			30	76.2		
31	99.8			31	105.3		
32	99.1			32	98.7		
33	150.7			33	157.1		
34	63.5			34	164.6		
35	67.2			35	135.6		
36	82.0			36	151.5		
37	67.1			37	155.4		
38				38	163.9		
39				39	100.4		
40				40			
41				41			
42				42			

DEVELOPMENT OF HYPOTHESES

Question #1 **Of the species under study, which of these species will decompose most rapidly? Least rapidly? In what order will these species decompose?**

Hypothesis #1 **The order of decomposition from most rapid to least rapid based on loss of dry weight is predicted to be:**

Rationale:

Application: Woody debris is an important component of forest and stream ecosystems. With this recognition, there is great interest in maintaining appropriate levels of woody debris in these systems over broad scales of time and space. It is therefore important to be able to estimate decay rates to determine the longevity of logs left or placed in managed ecosystems. Riparian vegetation, for example, may be managed to ensure long-term input into streams. Riparian areas dominated by relatively short-lived and quickly decaying contributors such as red alder or bigleaf maple may not contribute large woody debris to streams as effectively as conifers over long periods of time. Restoration efforts often involve interplanting conifer species for this reason. Also, in recognition of the value of conifer logs in streams, Oregon's forest practive laws (and perhaps others) offers incentives to forest owners who leave or place conifer logs in fish-bearing streams.

Question #2 **Is decomposition of these species a linear process or a non-linear process? In other words, if a log is completely decomposed in ten years, does it lose 10% per year (linear relationship)—or is there some other pattern?**

Hypothesis #2

Rationale:

Application: Decomposition rates influence the rate of release of nutrients into forest ecosystems, the availability of habitat characteristics in the forest, etc. Some salamanders, for example, appear to select logs on the basis of their stage of decay.

Question #3 **How does position in the substrate (on substrate surface vs. buried in substrate) influence the decomposition process?**

Hypothesis #3

Rationale:

Application: The management of slash, woody debris that is left behind as a result of harvest or thinning operations, is an important consideration in forest management. Slash is often piled by heavy machinery and either burned or allowed to decay. Woody debris in natural forests may become partially buried in soil upon impact. Woody debris may also be buried as a result of natural disturbances such as landslides and volcanic eruptions (e.g., Mt. St. Helens).

How do logs decompose?

"Wood decomposition represents a long-term stabilizing force within the forest ecosystem."

Ausmus, B.S. 1977. Ecol. Bulletin 25:180-192

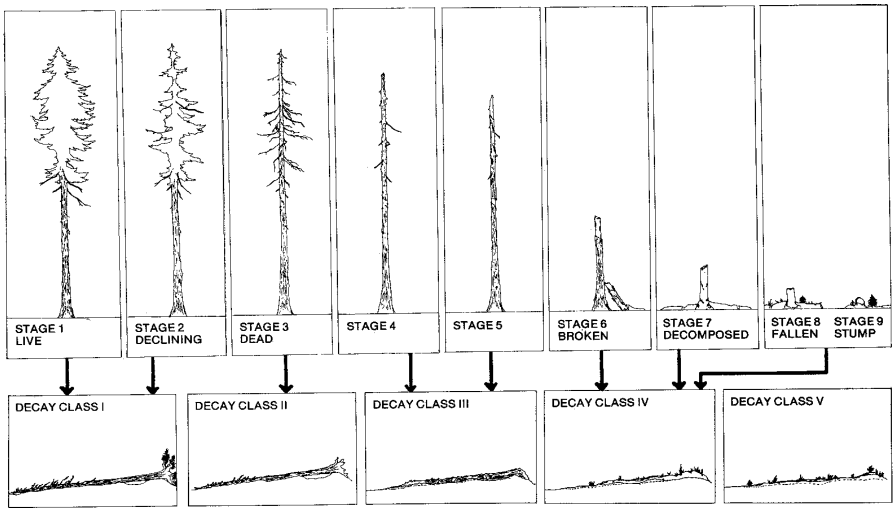
Decomposition is a complex chemical process that results in the breakdown of complex organic compounds in dead organisms into simpler compounds. This breakdown is caused by enzymes produced by bacteria and fungi—the ***decomposers***. In plant materials such as logs, the majority of mass is made up of complex carbohydrates such as cellulose and lignin. When these are completely broken down, the end products are carbon dioxide and water. Upon breakdown, these end products become available for entering the carbon cycle and hydrologic cycle. Other breakdown products such as ammonium, nitrates, phosphates, potassium and calcium are released into the soil where they become important soil nutrients that contribute to plant growth.

A number of studies conducted over the past two decades have advanced our knowledge of the decomposition of woody debris in forest ecosystems. In one approach, known quantities of organic matter are placed on the forest floor and monitored over time. Decomposed materials are re-weighed and re-measured at periodic intervals (typically one year) to document the decomposition process. Logs are also sampled for evidence of fungi and insects as well as levels of important soil nutrients such as nitrates and phosphates.

One particularly ambitious study examines the process of decomposition of large logs in Douglas-fir forests. In 1985, Mark Harmon and researchers at Oregon State University placed 530 large logs (50 cm diameter, 5.5 meters long) of four tree species on the forest floor of H.J. Andrews Experimental Forest in Blue River, Oregon. These logs are being analyzed to study the rate and nature of log decomposition—a process that takes centuries in some species. The duration of the study is expected to be 200 years! Preliminary results from this study as well as others have helped to create the following picture of woody debris decomposition in Douglas-fir forests:

- Dead, fallen trees decay continuously through recognizable stages of decomposition. For Douglas-fir, among the best studied species, five decay classes are generally recognized (see figure on next page).

A five-class system of decay based on fallen Douglas-fir trees.



- Four major tissues may be identified in a cross-section of a Douglas-fir log, each decomposing at a different rate:

Outer bark may be thick, accounting for 5-20% of cross-sectional area; resistant to decay

Inner bark thin, < 5% of cross-sectional area; active growing portion of the tree; serves to transport food; high in most nutrients; decays rapidly

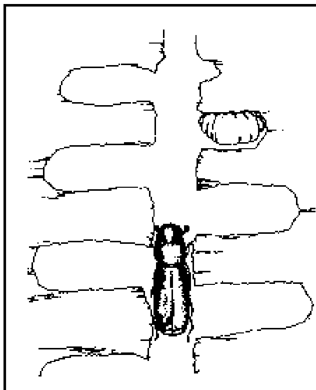
Sapwood 5-20% of cross-sectional area; transports and stores water and dissolved salts; generally lighter in color than other tissues; high water content

Heartwood 60-80% of cross-sectional area; supports tree; darker in color than sapwood; low water content

Decay Class I

At this stage, the log is highest in readily available nutrients. Tree bark, however, is an effective barrier between the inner world of the log and the outer world of the surrounding forest. A number of organisms are specially adapted to access these resources. Bark beetles chew their way through the bark of Class I logs until they reach the inner bark and cambium layers. An egg gallery along the axis of the tree is then constructed, and eggs are laid in small grooves along this gallery. The larvae hatch and feed on the inner bark. Their expanding galleries increase the surface area that can be acted upon bacteria and fungi. Also, their refuse (borings) and wastes (frass) provide substrates for mites, bacteria and fungi. As a result, decomposition of the log is accelerated.

One particular group of bark beetles—the ambrosia beetles—do not derive food from wood although they do excavate galleries. These beetles have specialized structures that carry fungal spores into logs as the galleries are constructed. The fungi grow inside the log and are



Bark beetle in egg gallery

harvested by the beetle larvae and adults—a primitive form of agriculture! Spores of a wide variety of decomposing fungi as well as mites, nematodes (round worms), protozoans and other species are also transported by beetles in a similar manner and become established in the log. Spores of mycorrhizal fungi may also be transported. These fungi form symbiotic associations with many tree and shrub species in the forest and greatly increase rates of growth in these species.

Carpenter ants may also penetrate Class I logs. Galleries are constructed that run longitudinally through the wood. These are enlarged as the colony grows. The wood is not eaten and the borings are cast outside the log through openings excavated by the ants.

Decay Class II

As a result of the activities of the insects mentioned above, portions of the log have become riddled with galleries and the moisture content of the wood has increased but the wood is still relatively sound. Wood boring beetles, which up to this point have been eating the bark, penetrate deep into the sapwood. By late class II, the log is colonized by the Pacific dampwood termite. Termites use the wood as a food source and are able to extract nutrients from the cellulose in the wood as a result of the actions of symbiotic protozoans that reside in their digestive tracts. Methane, a powerful greenhouse gas, is produced as a result of this chemical break-down of cellulose. Termites create extensive galleries in the wood that are used by many other insect species and provide natural channels that are followed later by plant roots.


Flatheaded wood borer

Decay Class III

During this stage most of the bark has sloughed off and roots have invaded the sapwood. Small conifer seedlings become established on the log and the diversity of plants increases. Insect galleries are found throughout the sapwood. Further colonization by insects increases the internal surface area of the log.

Decay Class IV

By this stage the outer bark and sapwood has decomposed and the heartwood of the log is in the process of decomposing. Since heartwood decays at a slower rate than other tissues, this stage often lasts a very long time (several decades). Lichens, mosses, liverworts and larger hemlock seedlings have become established on the surface. The roots of seedlings may penetrate deep into the heartwood of the log. Mycorrhizal fungi have formed associations with the roots of these species and begin to produce fruiting bodies called truffles. For many vertebrate species such as salamanders, shrews and voles, this stage provides the most optimum habitat.

Decay Class V

As the log enters the final stages of decomposition it may no longer be recognizable as a log to the casual observer. It loses structure, adopts a low profile and becomes covered with forest floor materials. Moisture content remains high and these logs serve as important sources of moisture during summer drought conditions. The depletion of nutrients and physical deterioration that has occurred in previous stages make this stage less hospitable to most animal species. As a result species diversity is lower than previous stages. Roots penetrate the entire log and may actually be holding the log together. At this stage the distinction between the log and the surrounding soil blurs.

Adapted from:

Maser, C. and Trappe, J., eds. 1984. The seen and unseen world of the fallen tree. Gen. Tech Rep. PNW-164. Portland, OR: USDA Forest Service, Pacific Northwest Forest and Range Experiment Station. 56 pp.

Initial Measurements for 1997 Log Decomposition Study

The following pages contain student-collected data which describe the initial condition of each of the logs used for the study. Measurements and calculations for each parameter are described in the procedure for the lab. All measurements were taken in October 1997.

Sample Code. Each log was assigned a unique code designation. Comprised of four letters, a code designates the tree species, and a number represents the log's number. Species codes were as follows:

DOFI—Douglas-fir
BLMA—Bigleaf Maple
BLLO—Black Locust
LOPI—Lodgepole Pine

Ave. Dia. The average of diameters taken at three locations along the log (each end and middle of log) with digital calipers to nearest 0.1 mm. In logs that were not round in cross-section, multiple measurements were taken at each location and these were averaged.

Length Log Length measured with a metric tape to the nearest 0.5 mm.

Volume Total Volume of log in cm^3. Calculation assumes each log approximates a cylinder with a radius equal to 1/2 the average diameter and a height equal to the log length.

Volumes of three tissue types (heartwood, sapwood and bark) were estimated and reported as % of total volume.

TSA Total Surface Area of log in cm^2. Calculated using diameter and length above.

BSA Bark Surface Area in cm^2. Area of log covered with bark. If bark is intact on entire log, then BSA = TSA minus area of ends. If some bark is removed on a log, that area is measured with a metric tape and subtracted as well.

Density Density of log in g/cm^3 and equal to dry weight of log divided by total volume.

Wet Weight Wet weight of log measured directly on electronic balance to nearest 0.1 g.

Dry Weight Dry weight of log to nearest 0.1 g estimated by sampling procedure described in lab protocol.

% Moisture Initial percent moisture in log estimated by sampling procedure described in lab protocol.

Bark Thickness Average of four measurements taken with digital calipers and recorded to nearest 0.1 mm.

Data Summary - Initial Measurements
Log Decomposition Study

	Douglas-fir	Bigleaf Maple	Black Locust	Lodgepole Pine
N	29	28	28	25
Ave. Diameter (mm)	75.4	76.4	73.9	77.6
Ave. Length (mm)	368.9	369.5	368	369.2
Volume (cm^3)	1671.6	1717.4	1622.3	1783
Total Surface Area (cm^2)	972.3	978.9	942.1	996.2
Bark Surface Area (cm^2)	872.8	885.9	854	899.6
Density (g/cm^3)	0.42	0.5	0.61	0.41
Net Weight (g)	1139.5	1152.1	1369.6	1446.7
Dry Weight (g)	659.7	955.9	993.3	717.6
%Moisture	38.5	25.4	26.9	49.4
%Heartwood	0.1	0.2	13.9	0.3
%Sapwood	93.6	90.5	68.3	94.5
%Bark	6.3	9.3	17.8	5.2
Bark Thickness (mm)	1.2	1.8	3.8	1

Log Decomposition in Forest Ecosystems — Worksheet

The following worksheet was developed to guide students through the logic of developing and supporting hypotheses for the three principal questions addressed by the log decomposition study. Handouts that summarize the measurements taken on new and decomposed logs will need to be prepared and provided to students for reference. This worksheet was developed for Year 3 of the study and will need to be modified to accommodate laboratories that occur at earlier and later stages. Students were asked to conduct some research on log decomposition that would help answer the three principal questions and to use this information in the completion of the worksheet.

Question #1 Of the species under study, which of these species will decompose most rapidly? least rapidly? In what order will these species decompose?

Hypothesis #1 The order of decomposition from most rapid to least rapid is predicted to be:

TABLE 1. PREDICTED ORDER OF DECOMPOSITION

	Species
1 -Most rapid	
2	
3	
4 -Least rapid	

Rationale:

This is the information I have used to arrive at this hypothesis:

A. Initial Measurements of Logs

Initial measurements of the physical characteristics of logs may provide some <u>indirect</u> information related to how rapidly a log will decompose.

In general:

As **bark thickness** increases, decomposition rates ________________ (increase/decrease) because

____

As **density** increases, decomposition rates _________________ (increase/decrease) because

____

As **% heartwood** increases, decomposition rates ________________ (increase/decrease) because

____

As **% moisture** increases, decomposition rates _________________ (increase/decrease) because

____

Use the information from the New Logs measured in the lab and the summarized measurements from new logs measured previously to fill in the table below. Use a rank of "1" to indicate the most rapid decomposition and a rank of "4" to indicate the slowest rate. Ranks of "2" and "3" are used to indicate intermediate rates.

TABLE 2. INITIAL CONDITIONS OF LOGS

	Bark Thickness		Density		% Heartwood		% Moisture		Sum of Ranks
	Value	Rank	Value	Rank	Value	Rank	Value	Rank	
Douglas-fir									
Bigleaf Maple									
Black Locust									
Lodgepole Pine									

Examine the rank totals for each species. Remember, the <u>lowest</u> numbers indicate the <u>most</u> <u>rapid</u> rate of decomposition. Based only on the analysis above, I conclude that the order of decomposition will be:

1. ____________________ which has a rank sum of __________.
2. ____________________ which has a rank sum of __________.
3. ____________________ which has a rank sum of __________.
4. ____________________ which has a rank sum of __________.

B. MEASUREMENTS ON DECOMPOSING LOGS

Logs that have been decomposing for one year or two give us <u>direct</u> evidence to examine. It would seem that as logs decompose they would lose **density** and **dry weight** as carbohydrates are broken down into ___________________ and __________________. Some of this lost material would be replaced by water, so it seems that **% moisture** of the logs should ________________ (increase/ decrease) as decomposition proceeds.

Complete the following table using the summarized information on your handout.

TABLE 3. COMPARISON OF INITIAL CONDITIONS AND CONDITIONS AFTER ONE YEAR OF DECOMPOSITION

LOG #	Density (g/cc)			Dry Weight (g)			% Moisture		
	Initial	1-Yr.	Density Lost	Initial	1-Yr.	% Dry Weight Lost *	Initial	1-Yr.	% Increase **
DOFI-1									
DOFI-2									
BLMA-1									
BLMA-2									
BLLO-1									
BLLO-2									
LOPI-1									
LOPI-2									
DOFI-30									
DOFI-31									
BLMA-30									
BLMA-31									
BLLO-30									
BLLO-31									
LOPI-30									
LOPI-31									

* "Percent Dry Weight" lost can be calculated by the following formula:

$$\% \text{ Dry Wt. Lost} = \frac{(\text{Initial Dry Weight} - (\text{1-Year Dry Weight}))}{\text{Initial Dry Weight}} \times 100$$

** Note: If log lost moisture, enter "% Increase" as a negative number.

Now, do the same for those logs that have been decomposing for <u>two</u> years. Complete Table 4.

TABLE 4. COMPARISON OF INITIAL CONDITIONS AND CONDITIONS AFTER TWO YEARS OF DECOMPOSITION

LOG #	Density (g/cc)			Dry Weight (g)			% Moisture		
	Initial	2-Yr.	Density Lost	Initial	2-Yr.	% Dry Weight Lost*	Initial	2-Yr.	% Increase **
DOFI-3									
DOFI-4									
BLMA-3									
BLMA-4									
BLLO-3									
BLLO-4									
LOPI-3									
LOPI-4									

Use the information from Tables 3 and 4 to complete Tables 5 and 6 below. To determine the "average values" simply add the values from each log of that species (e.g., all DOFI logs) together and divide by the number of logs. Assign ranks as you have before. Remember that the lowest ranks indicate the most rapid rates of decomposition.

TABLE 5. DENSITY, DRY WEIGHT AND MOISTURE CHANGES AFTER ONE YEAR OF DECOMPOSITION

Log Species	Density (g/cc)		Dry Weight (g)		% Moisture		Rank Sum
	Ave. Lost	Rank	Ave % Lost	Rank	Ave. % Gained	Rank	
DOFI							
BLMA							
BLLO							
LOPI							

TABLE 6. DENSITY, DRY WEIGHT AND MOISTURE CHANGES AFTER TWO YEARS OF DECOMPOSITION

Log Species	Density (g/cc)		Dry Weight (g)		% Moisture		Rank Sum
	Ave. Lost	Rank	Ave % Lost	Rank	Ave. % Gained	Rank	
DOFI							
BLMA							
BLLO							
LOPI							

Based only on the analysis above, I conclude that the order of decomposition will be:

1. ____________________ which has a rank sum of __________.

2. ____________________ which has a rank sum of __________.

3. ____________________ which has a rank sum of __________.

4. ____________________ which has a rank sum of __________.

C. Other Information

Based on my research on log decomposition I have conducted outside of class, I have learned the following information that may be relevant to this hypothesis:

____

____

____

My source for this information was:

____

____

D. Putting It all Together

If all of your information points to the same order of decomposition, putting all of your information together is easy. However, it is more likely that you will have some conflicting or inconclusive information. It will therefore be necessary to examine the objectively collected information and make some "command decisions" as to which of the criteria are more important in determining the order of decomposition. This process is called *prioritizing*. Explain in the space below what decisions you had to make about priority in reaching the hypothesis stated in Table 1.

____

____

____

____

____

____

____

Question #2 Is decomposition of these species a linear process or a non-linear process? In other words, if a log is completely decomposed in 10 years, does it lose 10% per year (linear) or is there some other pattern?

Hypothesis #2

____

____

____

____

Rationale

This is the information I have used to arrive at this hypothesis:

Since at this point we only have two years of decomposition data, we have very little direct evidence from our study that can shed light on this hypothesis. In later years we will have more information to call upon. For now, we must rely on previous studies that have been conducted and some "good, old-fashioned common sense."

Based on my research on log decomposition I have conducted outside of class, I have learned the following information that may be relevant to this hypothesis:

____

____

____

My source for this information was:

____

____

Describe in the space below the logic you have used to arrive at your hypothesis:

____

____

____

____

____

____

____

Question #3 How does position in the substrate (on substrate surface vs. buried in substrate) influence the decomposition process?

Hypothesis #3

____

____

____

____

Rationale

A. MEASUREMENTS ON DECOMPOSING LOGS

Initial measurements on new logs do not help us much with this hypothesis. However, the logs that have been decomposing for one year and two years provide us with some direct evidence. Remember, half of the logs were buried (odd-numbered logs) and half were placed at the surface (even-numbered logs). Analysis of these logs will provide some information that can be used to determine how position in the substrate influences the decomposition process.

Refer back to Tables 3 and 4 which summarize relevant information on logs that have decayed for one year and two. Use information from these tables to complete Tables 6 and 7 below. These tables group logs by their position in the substrate rather than by species. Remember, odd-numbered logs were buried, even-numbered logs were placed at the surface.

TABLE 7. DENSITY, DRY WEIGHT AND % MOISTURE CHANGES IN BELOW-GROUND AND ABOVE-GROUND LOGS AFTER ONE YEAR OF DECOMPOSITION

Position in Substrate	Density (g/cc)		Dry Weight (g)		% Moisture	
	Ave. Lost	Rank	Ave % Lost	Rank	Ave. % Gained	Rank
Below Ground						
Above Ground						

TABLE 8. DENSITY, DRY WEIGHT AND % MOISTURE CHANGES IN BELOW-GROUND AND ABOVE-GROUND LOGS AFTER TWO YEARS OF DECOMPOSITION

Position in Substrate	Density (g/cc)		Dry Weight (g)		% Moisture	
	Ave. Lost	Rank	Ave % Lost	Rank	Ave. % Gained	Rank
Below Ground						
Above Ground						

Using the information in the tables above, I conclude that logs placed ________________ (above/below) ground will decompose at a more rapid rate. I base this conclusion on the observation that ________________ (above/below) ground logs lost more density and more dry weight than ________________ (above/below) ground logs. Also, ________________ (above/below) ground logs gained more moisture than ________________ (above/below) ground logs.

B. OTHER INFORMATION

Based on my research on log decomposition I have conducted outside of class, I have learned the following information that may be relevant to this hypothesis:

____

____

____

My source for this information was:

____

____

C. Putting It all Together

Use the information above as well as any other thoughts you may have to discuss the different rates of decomposition in above ground and below ground logs. Use the space below to comment on how each of the following will be affected by "position in the substrate" and how they might affect decomposition rates.

Exposure to "the elements" (sunlight, wind, rain):

____

____

Moisture content:

____

____

Exposure to flying insects:

____

____

Exposure to below-ground insects:

____

____

Exposure to air:

____

____

Exposure to decomposing fungi and bacteria:

____

____

NOTES FOR INSTRUCTORS

The study of nutrient cycling (biogeochemical cycles) was begun in lecture. Decomposition (the chemical breakdown of complex organic compounds into simpler compounds) is a critical process in the recycling of essential elements (CO_2, nitrates, phosphates, calcium, etc.). Despite the central role that nutrient cycling plays in longevity of ecosystems, we have incomplete knowledge of how these cycles work. Today's lab is designed to expand our understanding of nutrient cycling in forests. It is unique for the following reasons:

- it is on the frontier of science
- results will not be known for 10 or 20 years
- results will contribute to our knowledge and may be published

I have developed a series of slides to introduce the log decomposition lab to students. Main points are as follows:

- General methodology for the lab is to place small logs of known decomposition into a forest and monitor these logs over time.
- There has been a tremendous amount of interest in recent years in the role of woody debris in forest ecosystems. Logs and snags are a dominant feature of Pacific Northwest forests— especially old forests and forests that have regenerated after natural disturbance such as fire or blowdown.
- Until recently we have had a poor understanding of the role of woody debris in forests—historically it has been seen as something that needed to be removed from forests before replanting could begin. Excessive amounts of woody debris in forests as a sign of disease and over-maturity. There has been a metamorphosis in thinking of woody debris as a nuisance and hazard to a critical ecosystem component that plays a significant role in wildlife habitat, nutrient cycling, maintaining water quality, etc.

Discussion points:

- ➢ Logs and snags as reservoirs of nutrients and water—importance in forest regeneration
- ➢ Logs as nurse logs for regeneration of forest after disturbance—sources of new trees
- ➢ Logs as habitat for mycorrhizal fungi that are required for tree growth
- ➢ Logs and snags as habitat for wildlife—cavity-nesting birds, salamanders, voles

- This laboratory introduces students to some of this current thinking while engaging them in a lab exercise that emphasizes long-term processes. Unlike most labs, the results of this one may not be known for 20 years!!
- Students will develop hypotheses that are possible answers to three questions and will provide their rationale for these predictions. Sources of information will include initial data on physical characteristics of logs and information from the literature.

Discuss measurement of initial values on new logs and, if available, lots that have been decomposing.

Students will be measuring and recording volume, surface area, dry and wet weights of logs. Entire study is based on comparison with these measurements.

Discuss "Accuracy" and "Precision."

Accuracy—how close is measured value to actual value?
Precision—how fine is the measurement (to what decimal place)?

Is it possible to have an inaccurate measurement that is very precise?
Is it possible to have a imprecise measurement that is accurate?
What establishes the limits?

The goal is to make measurements that are both accurate and precise within the limits of human ability and quality of instruments.

All data are entered on spreadsheets to be summarized and presented for easy visualization. If desired, a spreadsheet can be pre-prepared that performs calculations for volume, surface area and density.

Logs are placed on forest floor at a pre-selected study site and samples will be retrieved at set intervals (once per year) for analysis. Although data will come in at regular intervals, the study will not be complete until decomposition is complete (10 - 20 years).

Discuss how to handle irregularities in the logs.

Logs and samples are assumed to be perfect cylinders. When it is obvious that this is not the case, accommodate by taking several measurements and averaging these values. This is especially important in linear measurements.

Required measurements and calculations are described on handout (an understanding of simple high school geometry is assumed)

Describe the difficulties of initial dry weight and density.

Since drying entire logs prior to lab would disrupt decomposition process, log dry weights are determined indirectly. Samples (3 cm "cookies") were cut from each log and it is assumed these samples are representative of the entire log. Each "cookie" is given the same number as log they came from. Wet weights were taken shortly after the "cookies" were cut and then they were dried at 55°C for one week. Students measure dry weights and determine percent moisture.

Demonstrate labelling of logs and use of *EXCEL* spreadsheet.

Analysis of decomposed logs.

In addition to new logs, each lab group is responsible for the measurement of one or two logs that have been decomposing for a year (or longer, depending on availability). These logs will be discarded after measurement so they can be handled quite differently from the new logs just measured. Wet weights should be obtained from these logs when they are removed from the study site. Students should conduct observations and take measurements on these logs after they have dried at 55^0 C for at least 7 days. Initial measurements on these logs should be made available to students for comparison.

ASSESSMENT

Students are expected to submit properly completed data sheets for "new logs," "cookies," and "decomposed logs". If a spreadsheet is used to calculate some parameters, a floppy disk with their data entered is also submitted. The "DEVELOPMENT OF HYPOTHESES" handout is also submitted.

A follow up Analysis Lab may be required for students to complete the Log Decomposition Worksheet. Prior to this activity, all data taken the previous week from all lab groups must be summarized and made available to each lab group.

MATERIALS

QUANTITY	ITEM
1	Demo of log in early stages of decomposition - bark beetle galleries
1	Log cross sections that show heartwood, sapwood, bark, etc.
6	Floppy disks w/EXCEL spreadsheet
24	Logs of 4 species (40 cm length, 6-10 cm diameter)
24	3 cm sample cross sections cut from each log above
1	Drying oven (55° C)
24	Aluminum tags (for labelling logs)
24	Cable ties to attach tags to logs
12	Digital or vernier calipers
12	Metric measuring tape (to nearest 0.5 mm)
12	Metric Rulers
12	Meter sticks
3	Digital or triple beam balances (to nearest 0.1 g)
12	Calculators
4 boxes	Paraffin wax (for dipping log ends)
3	Electric hot plates
3	Small pots for melting paraffin wax

Important Note To Instructors

The log decomposition lab activity is challenging and time-consuming for both instructor and students. Prior to the laboratory, logs must be collected and cut by the instructor and students must be prepared for the activity. A field site must be identified where logs can be placed (either buried below ground or laid above ground) and monitored over a long period of time; some rather specialized equipment is required.

One might consider using a locally-owned woodlot, school property, or other accessible, protected lands for field sites for this activity. It is key that these sites be undisturbed (especially from trampling by students and others, etc.).

However, for those who are willing to attempt the activity, there are wide-ranging benefits, including:

- Students will be engaged in a long term study that is relevant to a number of topics in Environmental Science such as nutrient cycling and global warming.

- The activity is an authentic application of the "scientific method" and has strong connections to on-going research on forest ecosystems by major universities.

- Students apply appropriate technology to a real problem and are required to use communi cation and mathematical skills that they have learned in other courses.

Thus, the log decomposition lab is a truly integrated activity. For those instructors who wish to engage their students in a hands-on, scientific approach to an interesting topic, I would encourage you to give this activity a try.

Biomes

INTRODUCTION

Many places on Earth share similar climatic conditions and similar communities have developed in response to these conditions. The tropical rainforests of Brazil, for example, share many physical and biological characteristics with the rainforests of southeast Asia as do the coniferous forests of Canada and northern Asia. Large regional types of ecosystems such as tropical rainforests, deserts and grasslands are called **biomes**. They are determined largely by climate, especially temperature and rainfall, although other features such as soil type and topographic features may also influence the type of biome that develops in a region. Although biomes may be geographically separated from each other, they commonly support a similar mixture of animal and plant species. Since environmental pressures are similar at both locations, species that make up the community have become **adapted** to a similar set of environmental conditions.

In today's laboratory you will evaluate the influence of temperature and rainfall patterns on the development of biomes. You will first predict which biome should develop given a set of temperature and rainfall data for a particular site. You will then verify your prediction by locating the site on a world biomes map.

PROCEDURE

1. Each group will be assigned two locations identified only by number. For each location you will be provided with a data set that includes monthly average temperatures (in degrees Celsius) and monthly average rainfall (precipitation in centimeters).

2. For each of your two assigned stations, calculate the **annual average temperature** and **total precipitation**. You may enter the data on a spreadsheet.

3. For each of your two assigned stations, plot the monthly averages of temperature and precipitation on the same graph (either using spreadsheet or graph by hand - graph paper will be provided). ***Submit these graphs with your lab product today.***

4. Using figure 7.15 on p. 134 of Botkin and Keller, predict which biome each of your stations lies within. Record your predictions on the chart below.

5. As annual values for average annual temperature and total precipitation become available for other sites (calculated by other groups), predict and record the biomes for each of the other sites.

6. When your predictions are complete and recorded on the chart, verify your predictions by checking the locations on a biomes map. These will be available in lab.

7. Record the verified biomes on the chart also.

STA	Average Temp (C)	Annual Precip (cm)	Predicted Biome	Actual Biome
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

ANALYSIS AND CONCLUSIONS

Answer the following questions in the space provided and submit as a group. You may find pages 131-136 and 174-182 in Botkin and Keller useful as references. Other texts and maps will also be available in lab for your use.

1. How well were you able to predict the biome for each of the 12 stations? Which of the stations were properly classified?

2. For each station that was *not* properly classified, what factors might explain the error?

3. Which biomes show similar average temperatures? If temperatures are similar, what accounts for the differences in vegetation in these biomes?

4. Which biomes show similar average annual precipitation? If precipitation values were similar, what accounts for the differences in vegetation in these biomes?

5. Examine your two graphs that illustrate month by month changes in temperature and rainfall. Clearly describe the patterns for each of your stations. What differences and similarities exist in these two patterns?

Consider the following in organizing your answer:

- Temperature and precipitation patterns may be **synchronous** (temperature is high when precipitation is high and vice versa), **asynchronous** (temperature is high when precipitation is low and vice versa) or there may appear to be no particular relationship between the two.

- Temperature and/or precipitation may be distinctly **seasonal**—with distinct dry seasons, wet seasons, cold seasons, or hot seasons *or* either may be quite consistent throughout the year.

6. Describe why <u>monthly</u> <u>patterns</u> of temperature or precipitation (as opposed to average annual values) might be important in determining the vegetation that occurs in a region. (i.e., what "challenges" are presented to plants as a result of different distribution patterns of temperature and rainfall throughout the year?)

✐***NOTE: Questions #7,8 and 9 may require some research on your part. I would suggest consulting any General Biology or Botany text.***

7. Plant adaptations are physical and physiological characteristics that allow a plant to grow and reproduce in a certain area. The thick, fire-resistant bark of ponderosa pine, for example, is thought to be an adaptation that allows that species to survive in an area with frequent fires. What type of plant adaptations do you think would be most successful at station #2? Describe why.

8. What type of plant adaptations do you think would be most successful at station #6? Describe why.

9. What type of plant adaptations do you think would be most successful at station #10? Describe why. Name some plants that exhibit these adaptations.

Temperature and Precipitation data for 12 sites

STA	VAR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Temp	0.3	0.6	2.4	6.8	17.2	19.9	22.7	22.8	14.9	11.8	7.9	0.5
	Precip	8.5	11.8	11.7	5.8	4.7	11.6	11.1	19.2	12.9	8.8	4.5	7.4
2	Temp	26.8	25.4	24.6	19.4	13.3	11.8	11.6	11.4	13.9	19.3	23.3	25.8
	Precip	0.5	3.3	4	0.8	2.8	1.4	0.3	3.1	1.4	0	2.3	2.3
3	Temp	5.4	5.4	13.6	18.6	19.4	25.2	26.5	26.3	21.6	17	9.7	4.3
	Precip	2	0.5	6.3	14.5	10.8	5.8	3.1	3.6	8	7.4	1	2.6
4	Temp	8.4	11.3	12.7	12.3	16.4	19.5	22.4	23.5	22.4	17.3	13.3	11.8
	Precip	3.2	2.3	5.4	8.7	2.3	4.7	2.1	0.6	3.8	8.4	0	2
5	Temp	24.4	29	32.5	30	28.2	26.3	24.9	24.9	25.3	26	24.5	23.8
	Precip	0	0	0	4.1	13.6	11.1	23.6	45	18.5	2.6	0	0
6	Temp	25.9	26.6	27.1	27.1	27.5	27.2	26.9	27.4	26.8	26.8	25.9	25.7
	Precip	29	9.3	18.8	14.6	17.5	19.7	16.7	13	18.5	14.3	35.7	67
7	Temp	-31.9	-33	-32.7	-20.5	-12.6	-0.7	1	-0.4	-1.3	-9.8	-19.1	-30
	Precip	0.8	2	0.6	1.7	1.2	2	2.6	0.7	1.7	1.8	1.8	0.4
8	Temp	-24.8	-18.7	-21.4	-6.8	4.2	8.1	12.5	11	4.1	-2.1	-11.7	-19.9
	Precip	4	3.7	4.8	1.9	7	16.4	17.2	21.6	11.4	8	4.7	3.2
9	Temp	26.2	26.6	26.4	26.6	27.2	25.1	24.8	24.4	25.8	26	26	26.4
	Precip	0.8	27.5	15	14.2	29	8.7	30.8	15.3	4.2	6.5	1.1	6.5
10	Temp	2.8	4.2	6	9.4	13.1	15.4	18.1	18	15.8	11.4	6.4	4.3
	Precip	42.29	31.27	26.44	15.42	8.46	6.20	3.25	3.51	9.50	24.71	37.41	46.18
11	Temp	-1.2	1.4	6.5	13.2	18.3	23.9	27.0	26.1	21.3	15.2	6.7	0.8
	Precip	2.79	2.54	5.38	9.07	11.07	11.53	8.18	11.71	8.66	6.55	4.04	3.00
12	Temp	-12.7	-10.7	-2.9	6.2	12.7	17.9	22.3	20.7	14.7	7.6	-2.0	-9.2
	Precip	0.91	1.09	1.93	3.53	4.93	8.46	5.92	3.81	3.63	2.54	1.35	1.02

BIOMES LAB - STATION LOCATIONS

Station #	Location	Latitude/Longitude
1	Pittsburgh, PA, U.S.A.	latitude 40° 30' N, longitude 80° 13' W
2	Kalgoorlie, Australia	latitude 30° 46' S, longitude 121° 27' E
3	Oklahoma City, OK, U.S.A.	latitude 35° 24' N, longitude 97° 36' W
4	Barcelona, Spain	latitude 41° 24' N, longitude 2° 9' E
5	Moundou, Chad	latitude 8° 37' N, longitude 16° 4' E
6	Singapore	latitude 1° 22' N, longitude 103° 55' E
7	Cape Cheljuskin, Russia	latitude 77° 43' N, longitude 104° 17' E
8	Nitchequon, Canada	latitude 53° 12' N, longitude 70° 54' W
9	Aracaju, Brazil	latitude 13° 12' S, longitude 37° 3' W
10	Cushman Dam, Washington, USA	latitude 47° N, longitude 124° W
11	Topeka, KS, USA	latitude 39° N, longitude 96° W
12	Bismarck, ND, USA	latitude 46° 46' N, longitude 100° 45' W

BIOMES LAB - KEY

✐**NOTE:** **Names of biomes may differ from those listed here due to differences in biome nomenclature among sources.**

Site	Location	Biome	Temp(°C)	Precip.(cm)	Pattern
1	Pittsburgh	Temp. For.	10.6	118	Synchronous, Seasonal
2	Australia	Desert	18.9	22.2	Precip - low and even Temp - seasonal
3	Oklahoma	Grassland	16.1	65.6	Asynchronous (esp Su) Precip - highest Sp & F Temp - seasonal
4	Spain	Chaparral/ Shrubland	15.9	43.5	Asynchronous (esp Su) Precip - highest Sp & F Temp - seasonal
5	Chad	Savanna	26.7	118	Temp - high and even Precip - strongly seasonal (wet in Summer)
6	Singapore	TRF	26.7	274	Temp - high and even Precip - highest in Wtr.
7	USSR	Tundra	-15.9	17.3	Temp - low and seasonal Precip - low and even
8	Canada	Taiga	-5.5	103.9	Synchronous Temp - low and seasonal Precip - moderate and seasonal
9	Brazil	Monsoon (Tropical)	26.0	159.6	Temp - high and even Precip - high, except Sep - Jan

Site	Location	Biome	Temp(°C)	Precip.(cm)	Pattern
10	Washington	Temp. RF (Taiga)	10.4	254.6	Asynchronous Temp - seasonal (highest in Summer) Precip - seasonal (highest in Winter.)
11	Kansas	Grassland (Seasonal Forest)	13.3	84.5	Synchronous Temp - seasonal Precip - seasonal (highest in Summer)
12	N. Dakota	Grassland	5.4	39.1	Synchronous Temp - seasonal Precip - seasonal but low (high in Summer)

NOTES FOR INSTRUCTORS

Biomes are major regional ecosystems identified by a distinct vegetation pattern. They are determined primarily by climate — particularly temperature and rainfall. A variety of vegetation patterns form because different organisms are adapted to different sets of environmental conditions. Discuss plant adaptations to desert habitats, for example.

A variety of biomes maps from several sources can be shown to illustrate differences in biome nomenclature among different authors.

The relationship between temperature, rainfall and biomes should be discussed with an ordination graph similar to figure 7.15 on p. 134 of Botkin and Keller. In addition to total precipitation and average temperature, the month by month pattern of these variables is very important in determining which plants and animals can survive and reproduce there. Some sites may have same average value but a very different monthly pattern.

> ***Each group of students is given a floppy disk with the temperature and precitiptation data for all 12 sites. These data are opened into an EXCEL spreadsheet and used to generate graphs of monthly avrages of temperature and precipitation for their two sites. Students then proceed with lab as indicated on handouts.***

MATERIALS

World Atlas (for students to locate study sites) - for example:

1. Oxford Atlas of the World. 1992. Oxford Univ. Press, Inc. NY, NY 285 pp.
2. Hammond, C.D. and K. Hammond. 1998. Hammond Atlas of the World, 2nd ed. Hammond, Inc. Maplewood, NJ 312 pp.

World Map - wall size

Biomes maps (or transparencies) - available in most general biology, environmental science, ecology and botany texts as well as world atlases cited above

General biology/Botany texts as resources on plant adaptations

Bailey, R.G. 1998. Ecoregions Map of North America. USDA Forest Service Misc. Publ. No. 1548. Washington, D.C. 10 pp.

Available from:

Ecosystem Management Analysis Center
USDA Forest Service
3825 East Mulberry St.
Fort Collins, CO 80524

6 Floppy disks with rainfall and temperature data entered on EXCEL spreadsheet (optional).

Symbiosis

The populations of all living species occurring in a given area define the **community**. Animals, plants, fungi, protists and bacteria are all included in this assemblage. In addition to sharing a common piece of turf, the members of a community are also tied together by often complex interrelationships. Symbiosis is an example of one of these relationships.

The term **symbiosis** is used to describe an ecological relationship between organisms of two different species that live in very close association with one another. The smaller participant in the relationship is called the **symbiont**, and the larger participant, the **host**. Different types of symbiotic relationships are described based on which member benefits or is harmed by the relationship. In **mutualism**, *both* members gain some benefit from the relationship. In **parasitism**, only one member (the parasite) benefits (usually the smaller) at the host's expense. If there is no clear harm *or* benefit to the host, the relationship is **commensalism**.

In today's laboratory we will examine a number of examples of **symbiotic relationships**.

PROCEDURE

Examine the various examples of symbiosis available in the laboratory as described below.

1. *Paramecium bursaria*—Make a wet mount from the *Paramecium* culture and view at 100X and 450X. Note the symbiotic green algae (*Zoochlorella*) inside the membrane of *Paramecium*.

2. *Lichens*—make wet mounts of various lichens after grinding up lichen tissues with a mortar and pestle. View slide at 100X and 450X and note the filamentous brown and colorless tissue (the fungus) and the symbiotic single-celled algae.

3. *Termites*—remove termite gut as demonstrated and place contents on a microscope slide containing several drops of 0.6% saline. Pick the tissue apart with probes and prepare a wet mount. View at 100X and 450X and observe symbiotic protozoans (*Trichonympha*) and, perhaps, bacteria.

4. *Azolla* (a floating fern)—make wet mounts of *Azolla* after grinding up tissues with mortar and pestle. View at 100X and 450X. The larger, light green cells are those of *Azolla*. The darker blue-green chains of cells are *Anabaena*, a symbiotic, nitrogen-fixing blue-green algae.

5. *Scale insect on pine needle*—while viewing under a dissecting microscope, gently lift the small, white, teardrop-shaped scale and observe the tiny symbiotic scale insect underneath.

6. *Oak galls*—cut open the central "core" of a gall carefully with a razor blade or scalpel and observe the larva under a dissecting microscope. Adult wasps that have emerged from galls may also be available for observation. They are very small and do not sting.

7. *Mossy rose galls*—cut open gall with scissors or scalpel. Observe larva under dissecting microscope.

8. *Hydra*—see demonstration under dissecting microscope on rear lab table. Note symbiotic green algae (*Zoochlorella*) within the tissues of *Hydra*.

✐**Please note:**

Specimens #1, 2, 3, and 4 require the preparation of a microscope slide and observation using a compound microscope. Specimens #5, 6, 7 and 8 may be viewed directly using a dissecting microscope and do not require the preparation of a slide.

Enter information for each symbiotic relationship on the charts on the following pages. Be sure to fully describe the nature of the benefit or harm brought to each member of the relationship under "Description of Symbiotic Relationship."

Make brief sketches of the host and symbiont for each relationship on the following pages.

No.	Host Name	Symbiont Name	Type of Symbiosis	Description of Symbiotic Relationship
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				

DRAWINGS

1.

2.

3.

4.

5.

6.

7.

8.

NOTES FOR INSTRUCTORS

Symbiosis is a type of interaction between members of a community (i.e., all species occurring in a given area) in which one organism lives in or on another. The term literally means "living together." The association is always beneficial to at least one member of the relationship. The **symbiont** is the partner that lives on or in the other organism — the **host**.

The classification of different types of symbiosis is based on which member of the relationship benefits and which is harmed:

Mutualism—reciprocal benefit (both symbiont and host benefit)

Examples:

- Cleaning wrasses allowed to enter mouth of much larger grouper to eat ectoparasites on gills of grouper
- Oxpeckers in Africa eat ticks off the backs of large grazing animals
- Mycorrhizae—"fungus roots" associated with many species of trees—describe relationship
- Vitamin B-synthesizing bacteria in digestive tract of humans
- *Trichonympha*—flagellated protozoans in termite digestive tract—termite gains nutrients as a result of action of cellulase produced by protozoans; protozoan gains nutrients, protection and habitat
- Lichens—component parts = algae and fungus. What is gained by each?

Commensalism—one benefits, the other neither benefits nor is harmed

Examples:

- *Escherichia coli* in digestive tract of humans
- Remora on shark

Parasitism—one benefits (parasite), the other is harmed (host) as a result of the relationship

Considered by some to be a special case of predation in which the predator is much smaller than the prey and consumes only small portions of the prey. Classified according to where they occur on the host:

Ectoparasites—live outside host on skin, hair or imbedded in glands where they feed on blood, skin, body fluids

Examples:

- mites (scabies, *Demodex* follicular mites, chiggers)
- ticks
- fleas
- lice (head, body, pubic)
- leeches
- copepods (on fish)

Endoparasites—live inside body often in digestive or respiratory tract or in blood where they feed on body fluids (especially blood) of the host

Examples:

- nematodes (round worms, pin worms)
- cestodes (tapeworms)
- trematodes (flukes)

Parasitoids—insect endoparasites that always kill and devour host:

- eggs laid on or near host (usually another insect)
- eggs hatch and larvae burrow into host
- larvae consume host from the inside and then emerge

Very important as natural control of insect pests. Most parasitoids are wasp species.

Strategies of Parasites

Strategies of most predators is to kill prey and eat immediately. Parasites, on the other hand, generally do not harm the health of the host. Most highly adapted parasites cause host little or no harm — an evolutionary strategy to avoid "habitat destruction." If the host is harmed or killed, this often suggests a recently-evolved relationship (e.g., malaria pathogen of humans and mosquitos).

Evolution of Parasites

We know that parasites evolved from free-living forms. So, what was the niche of the first organisms that were to become mammalian parasites? Ectoparasites were probably nest associates that were initially attracted to the warmth of the nest and gradually spent more and more time on the host. Endoparasites were probably dung feeders that were re-ingested by the host and gradually lost appendages (except mouth parts) and sensory organs. Endoparasites are essentially a "gonad with a mouth"!

MATERIALS

Amount	Materials and Equipment
25	Microscope slides
25	Coverslips
12	Eye droppers
12	Probes
12	Fine forceps
12	Scalpels or razor blades
12	Dissecting pans
6	*Nalgene* 5-gal aquaria (cover with cellophane for storage of specimens)
6	Mortar and pestle
6	0.6% insect saline (in dropper bottles)
2	1000 ml beakers (for used slides and coverslips)
12	50 ml beakers
12	Dissecting microscopes
12	Compound microscopes
1 culture	*Hydra* w/symbiotic *Zoochlorella*
1 culture	*Azolla* (floating fern)
1 culture	*Paramecium bursaria* w/symbiotic *Zoochlorella*
25	Oak galls*
25	Mossy rose galls*
25	Assorted lichens*
25	Live termites*
25	Pine needles with scale insect*

* Local examples that illustrate symbiotic relationships may be substituted

Ecological Succession

The eruption of Mt. St. Helens in 1980 provided scientists with a natural laboratory for the study of **ecological succession**. Preliminary results from these studies are contradicting some long-held beliefs concerning the recovery of ecosystems after catastrophic events.

Respond to the following questions after viewing segments of the videotapes — “Return to Mt. St. Helens” and “St. Helens: Out of the Ash.” Use discussions in lecture to supplement the information provided in the videotapes.

1. Prior to the eruption, Spirit Lake was a typical **oligotrophic** high Cascades lake. Describe the chronology of physical and biological events that have occurred in the lake from eruption to the present time. Specific events are described in the videos for most years but, there are voids. For those years, use your understanding of ecological succession to fill in the gaps.

1980-1981

1982-1983

1984-1985

1986-1987

1988-1989

1990-1991

1992-1993

1994-1995

2. How would you expect ecological succession in Spirit Lake to differ from that occurring in other high Cascade lakes? Describe why.

3. For each of the following groups of organisms, describe some of the major findings resulting from the past twenty years of research at Mt. St. Helens.

Fish

Tailed frog

Insects

Higher plants

Elk

Archebacteria

4. Perhaps the most important discovery on Mt. St. Helens has been the importance of "biological legacies" in determining the rate and direction of ecological succession.

a. What is meant by the term "biological legacy"?

b. The roles of pocket gophers, Douglas-fir and red alder as part of the "biological legacy" are described in detail in the videotapes. Describe how each of these species has influenced ecological succession at Mt. St. Helens.

Pocket gophers

Douglas-fir

Red alder

5. Since a new substrate was laid down on Mt. St. Helens after the eruption, the recovery of this area is described as **primary succession**. Using information from the videotape and discussions in class, indicate during which stage you would expect various plant and animal species to *first* appear:

Ecological Stage	Plants	Animals
Pioneer		
Early-Sere		
Mid-Sere		
Subclimax		
Climax		

6. Assuming that Mt. St. Helens does not have another major eruption, what would you expect the "blast zone" to look like in the year 2500? Be specific.

NOTES FOR INSTRUCTORS

Introduce the concept of **ecological succession** with a series of slides using local examples. I have a series of slides that illustrate ecological succession as it occurs at approximately 1000' elevation in the Oregon Cascade Mountains. As an alternative, these slides can be shown in lecture.

Why is an understanding of ecological succession important in management of natural resources?

Humans routinely disturb natural systems (agricultural practices, forest management, urban expansion, etc.). Patterns of natural recovery from disturbances can be used as models for methods that we use for natural resource management. For example, we may use disturbance by fires as a model for forest harvest patterns. Our knowledge of successional patterns is necessary if we wish to manage for late successional species (e.g., Western Redcedar or Western Hemlock).

This lab examines the recovery of a forest and lake ecosystem after a catastrophic disturbance — the eruption of Mt. St. Helens in May of 1980. **Primary succession** occurred in the blast zone where existing vegetation was obliterated and new substrate was laid down (volcanic ash). **Secondary succession** occurred on the margins where trees are damaged or burned but soils are relatively intact.

> ***Students discuss responses to questions within their lab groups after viewing video tape segments and submit one set of answers per group.***

VIDEO - *"Return to Mt. St. Helens"* (program first aired 8 January 1991)

Show entire videotape (approx. 1 hour) ***or*** omit geology portion at beginning of tape and start at Spirit Lake satellite view. The first half of the program is mostly background information on the geological nature of the eruption. I do not hold students responsible for geological aspects of the eruption. The second half of video details the biological recovery after the eruption and provides an opportunity for more detailed study of ecological succession. I emphasize the importance of understanding ecological succession and the concept of "biological legacy" in natural resource management.

The term **biological legacy** is used to describe those components of the original ecosystem that remain after a disturbance and contribute to the recovery of that ecosystem. Large Douglas-fir trees, for example, after the Mt. St. Helens eruption contributed nutrients if completely incinerated but also snags and logs in both terrestrial and aquatic habitats. Less impacted areas also left broken-top trees and patches of trees that were largely unaffected. These components play a critical role in the recovery of the ecosystem. They provide nutrient sources, refuges for small animals, seed sources for plants, microhabitats for mycorrhizal fungi, 3-dimensional structural components, etc. Without these components, recovery would be much slower.

Other components of biological legacy at Mt. St. Helens that persisted after the eruption include pocket gophers, red alder and trout. The role of these species in the recovery is described in the videotape. Other species certainly play similar roles and will continue to be discovered.

As a result of studies at Mt. St. Helens and elsewhere in the Pacific Northwest, the concept of biological legacy is being incorporated into modern natural resource management. Logs, for example, are now being left on site after a timber harvest and added to streams during stream restoration projects. These logs provide habitat, alter stream flows and slowly release nutrients into the system. Live trees are frequently left untouched in harvested areas to provide refuge for forest species and to serve as reservoirs of biological diversity. Forest practices such as "green tree retention" and "group selection" where small groups of live trees are left on site are the result of an understanding of the biological legacy concept. These practices are an attempt to imitate the biological legacy that is left behind after a natural disturbance and are becoming commonplace in forest operations in the Pacific Northwest. Current laws have institutionalized their practice.

VIDEO - *"Mt. St. Helens - Out of the Ash"* - in part - (aired PBS May 1995)
Show approximately last 15 minute segment to end of program. This is an update of the biological recovery at Mt. St. Helens including vegetation, rivers, fish at Spirit Lake, etc. At the end of the segment the role of Mt. St. Helens National Monument as an education and research site are discussed.

VIDEOTAPES

"Return to Mt. St. Helens" NOVA (Public Broadcasting) Produced by WGBH-TV Boston, MA (first aired 8 January 1991)

"St. Helens - Out of the Ash" Produced by KSPS-TV (Public Broadcasting) Spokane, WA (first aired May 1995)

OTHER RESOURCES

Larson, D. 1993. The recovery of Spirit Lake. American Scientist 81:166-177

World Population

Overpopulation of the Earth by humans has long been recognized as a major environmental problem. It has been suggested, in fact, that all other environmental problems—pollution, loss of biodiversity, ozone depletion, global warming, etc.—are nothing more than symptoms of having too many humans using too many resources. Some countries have taken rather dramatic steps in an effort to curb population growth. China, for example, in 1979 adopted a "one child per couple" policy with strong financial and social incentives for the use of birth control, especially voluntary sterilization.

The scientific study of human populations is called **demography**. In today's laboratory, you will be using data compiled by the Population Reference Bureau (PRB)—a private, nonprofit scientific and educational organization that gathers, interprets and disseminates information about the human population. PRB seeks to increase awareness and understanding of population trends and their implications by presenting information that is reliable, unbiased and up-to-date. Although you will be working extensively with numbers in today's lab, *do not attempt to memorize the information*. Rather, what's important is your group's *interpretation of major trends and understanding of important concepts*.

Objectives—After today's lab, you should be able to:

- Describe current trends in the world's population growth using proper terminology
- Describe differences in population size, growth rates and other population parameters among nations and regions of the world
- Discuss some of the underlying reasons for these differences—biological, religious, socio-economic, and political

Predictions

Before examining the PRB World Population Data Sheet, answer the following questions concerning human populations.

	Predicted	Actual
1. What is the current world population?	________________	________________

2. How do you think each of the following world regions compare in population size? Rank the regions by putting a "1" after the largest, a "2" after the next largest, etc.

	Predicted	Actual
North America	________________	________________
Latin America	________________	________________
Asia	________________	________________
Europe	________________	________________
Africa	________________	________________

3. What is the population of the United States?

________________ ________________

4. If the effects of immigration are ignored, *what is the United States population growth rate?* (e.g., growing rapidly, growing slowly, declining rapidly, declining slowly, or stable population) See Natural Increase (annual %) on chart.

________________ ________________

5. What is the *world population growth rate?* (growing rapidly, growing slowly, declining rapidly, declining slowly, or stable population)

__________________ __________________

6. Which do you think are the three most populous countries in the world?

1.__________________ __________________

2.__________________ __________________

3.__________________ __________________

7. How long do you think people live on average?

In the world __________________ __________________

In the U.S. __________________ __________________

8. What do you think are the three wealthiest nations in the world?

1.__________________ __________________

2.__________________ __________________

3.__________________ __________________

After making your predictions, verify your answers by checking the World Population Data Sheet and recording the *actual values* in the space above.

Fertility and Growth

Review the definitions of the terms that are commonly used to describe various population parameters. These are listed on the reverse side of the World Population Data Sheet.

1. Using "birth rate per 1000" as a measure, which three countries have the highest rate of natality?

   1. ________________ 2. ________________ 3. ________________

Which three have the lowest?

   1. ________________ 2. ________________ 3. ________________

2. Which major geographic region (Africa, North America, etc.) has the highest birth rate? (include China with Asia).

   ____

Which has the lowest? ________________

3. The Rate of Natural Increase (column #4) is used as a measure of the annual rate of population growth without regard for immigration or emigration. What two values would need to be taken into account to calculate the Rate of Natural Increase for a region?

   1. ________________

   2. ________________

4. Examine the first four columns for several countries or regions. What is the mathematical relationship between the Rate of Natural Increase (RNI), Birth Rate (BR) and Death Rate (DR)?

   ____

5. Using the current world population and the *Rate of Natural Increase*, calculate the predicted world population at the end of 2000.

____

6. Using *Rate of Natural Increase* as a measure, are there any countries that appear to be *losing population?* (Remember that this figure ignores immigration and emigration). If so, in what region of the world are most of these countries located?

____

7. **Replacement rate** is defined as the number of children a woman should have to replace herself and her mate (assuming only one mate!). Although it would appear that the universal replacement rate would be "2.0," in reality the replacement rate varies from one country to another and is always somewhat greater than "2.0." Explain why this is the case.

____

____

____

8. The **Total Fertility Rate (TFR)** is defined as the average number of children a woman will have assuming that the current age-specific birth rates will remain constant throughout her child-bearing years (ages 15-49). What is the TFR for women in the United States?

____

How does this number compare with the replacement rate?

____

What does this tell you about the source of population growth in the United States?

____

9. PRB uses the United Nations distinction between less developed and more developed nations. **More developed nations** = all of Europe and North America plus Australia, Japan, and New Zealand; **Less developed nations** = all others. At least 90% of future population growth is expected to occur in less developed nations.

Examine each of the following population parameters for the 6 major regions of the world and describe why this is so:

% of population <15 yrs.—

% of population >65 yrs.—

Rate of Natural Increase—

Total Fertility Rate—

% Married Women using modern contraception—

10. Does there appear to be a political awareness in less developed nations of population problems? One way to assess this is to examine the *"Government View of Current Birth Rate,"* which is the official stated position of country governments on the level of the national birth rate (too high, too low, or satisfactory). Assign a value of "3" to "too high," "2" to "satisfactory" and "1" to "too low" for each country. Then calculate an "average government view" for more developed and less developed nations.

More Developed Nations ____________________

Less Developed Nations ____________________

What conclusions can you draw from these numbers?

____

____

____

11. Predicted contributions to world population by each country can be calculated by using the "Current Population" level and the "Natural Increase %." Which nation will contribute more to the world population in 1999—China or India?

Contribution by China ______________

Contribution by India ______________

What do you think accounts for this difference?

____

____

____

China instituted its population control policy in 1979 . Total fertility rates in China have changed as follows:

Year	TFR
1970	5.93
1979	2.66
1984	1.94
1995	1.90
1998	1.80

In your mind, how effective has the population control program been?

____

____

____

What are the positive and negative aspects of such a policy?

____

____

____

12. Based on the numbers you have seen so far, it may appear that population growth is primarily a problem of *less developed nations*. Population size by itself, however, only tells part of the story. When considering the impact of human population growth on global resources and global environmental quality, relative rates of resource use must be taken into account. Consider the following:

Region	1999 Energy Consumption (in petajoules*)	1999 Population	Per Capita Energy Consumption
North America	85,055		
Latin America	16,430		
Western Europe	53,062		
Africa	8,102		
Former Soviet Union	59,213		
China	28,082		

* 41.87 petajoules are equivalent to the energy in one million metric tons of oil

A. Complete the chart above for "1999 Population" and "Per Capita Energy Consumption."

B. What does the comparison above imply about the relative impact on global resources of each North American versus each additional citizen of Latin America, Africa, or China?

____

____

13. What is your definition of a "developed country"? Use some of the criteria on the World Population Data Sheet (infant mortality, average life expectancy, per capita GNP, etc.) in your definition.

____

____

____

Based on your definition, which three countries would you guess to be the "most developed"?

Rank them in order:

1. ________________

2. ________________

3. ________________

Now check the criteria you have used to define "developed" on the World Population Data Sheet and list the three most developed countries based on these criteria:

1. ________________

2. ________________

3. ________________

How do you account for any differences between these two lists?

____

____

NOTES FOR INSTRUCTORS

In this lab students evaluate data collected by the Population Reference Bureau (PRB) — a non-profit, non-advocacy organization that provides objective information on U.S. and international population trends and their implications. PRB publications can be ordered from:

Population Reference Bureau
1875 Connecticut Ave., NW, Suite 520
Washington, D.C. 20009-5728
Tel.: 202-483-1100
E-mail: popref@prb.org
Web site: www.prb.org

PRB produces a number of publications including the annual *World Population Data Sheet* upon which this lab is based. Their web site has full text and excerpt versions of many PRB publications, as well as links to many other Web sites on population.

The U.S. Census Bureau Web site (http://www.census.gov) also has information that is relevant to this lab. Students will find their "World Vital Events Per Unit Time" and "Dynamic POPClocks" of particular interest.

STUDENTS SHOULD REVIEW DEFINITIONS ON BACK OF PRB WORLD POPULATION DATA SHEET BEFORE PROCEEDING WITH LABORATORY.

MATERIALS

QUANTITY	ITEM
12	PRB World population data sheet
12	Calculators

Human Population Issues
Debate

In our final lab, we will stage a debate on issues that relate to human population growth. You will be assigned to one of two sides of the issue:

1. ZPG (Zero Population Growth)/NPG (Negative Population Growth)

Your position will be that humans have already (or will soon) exceed the carrying capacity of the Earth and that many of the environmental problems we now face are caused by overpopulation. Steps should be taken to reduce population growth.

2. PPG (Positive Population Growth)—Pro- Growth

Your position will be that humans are a valuable resource on Earth. The carrying capacity of the Earth can be increased by technological advances and human populations will level off at a sustainable level sometime in the future.

Your responsibilities are as follows:

1. Background Research—Each student will be responsible for seeking information from five sources that in some way supports their side of the issue. A narrative summary of each source should be prepared. The length of your summary should be determined by the amount of detail presented in the article and the amount of information that would be useful in support of your side of the argument. Most sources should be summarized in a single page or less.

Be sure to include a complete citation for each reference (Author, Date, Title, Volume, Pages). Summaries must be typewritten and in a form that will be easily accessible by other members of the group.

Submit your summaries and one copy of each article you have used to the instructor. If you are using a book as a reference rather than a journal article, simply copy the title page of the book. These summaries will be made available to other members of the group during the week prior to the debate to assist in their preparation.

2. Debate—Each student is expected to participate in the debate by presenting supporting arguments for their side of the issue. This will be done in response to questions posed by the moderator (see attachment) and by the opposition. Also, a short (2-3 minute) "Summary of Position" statement should be given by one member of each group to begin the debate.

Each side will have the opportunity to pose questions to the opposition. These should be prepared prior to the debate and used to illustrate the weaknesses of their position.

Debate Format

1. One presenter on each side will give a short (2-3 minute) summary of position statement to begin debate.

2. Moderator will pose questions which will be answered by each side.

3. After moderator's questions, questions may be asked by each side to be answered by the opposition.

HUMAN POPULATION DEBATE - QUESTIONS

The following questions will be presented by the moderator to the two opposing sides of the population debate. Please use the reference material you have gathered to respond to them in a manner that best supports your position. The bulk of the debate should be *your responses to questions that are based on the research you have conducted*. This is different from simply repeating the thoughts of others. To keep responses in the debate as spontaneous as possible, *do not read statements from these other authorities*.

Questions to PPG'ers:

1. What are the two strongest arguments in support of your contention that population growth is a "good thing," resulting in an overall increase in the quality of life on Earth?

2. According to a 1994 *Times-Mirror* Poll, most Americans believe that human population growth has a detrimental effect on the environment. How do you respond to these concerns?

3. If, as Julian Simon contends, people really are "the ultimate resource" then, how do you explain the fact that the countries that dominate militarily and economically *are not* the most populous?

4. What are the consequences for life on Earth if you are wrong?

5. What is the carrying capacity of the Earth? Assuming that the world population stabilizes at some point, at what **percent of carrying capacity** should this level occur? Be prepared to defend your decision.

Questions to ZPG'ers:

1. What are the two strongest arguments in support of your contention that population growth is a "bad thing," resulting in an overall decrease in the quality of life on Earth?

2. A number of authors and scientists (Paul Ehrlich, Thomas Malthus, etc.) have predicted that the human population would outrun its ability to produce food. Such an imbalance would obviously have dire consequences. This fear, however, has been largely unrealized on a global scale. Are these scientists just "crying wolf"?

3. Opponents to population control contend that efforts to decrease the **fertility rate** will infringe upon the rights of individuals to exercise personal freedom (choice of religion, family values, etc.). How do you respond to these concerns?

4. What are the consequences for life on Earth if you are wrong?

5. What is the carrying capacity of the Earth? Assuming that the world population stabilizes at some point, at what **percent of carrying capacity** should this level occur? Be prepared to defend your decision.

Resources for Population Debate

The resources below should be useful in the formulation of main arguments on each side of the human population issue. Articles and books are organized by viewpoint - those that would appear to support "positive population growth" and those that would appear to support "zero population growth." Sources that provide arguments for both sides appear in both lists. A list of authors and journals is also provided for each side.

POSITIVE POPULATION GROWTH

1. Bailey, R. 1993. Ecoscam: The false prophets of ecological apocalypse. St. Martin's Press. New York, N.Y.

2. London, H.I. 1984. Why are they lying to our children? Stein and Day Publ.. New York, N.Y.

3. Meyers, N. and J. Simon. 1994. Scarcity or abundance? W.W. Norton Publ. New York, NY 254 pp.

4. Weber, J.A. 1977. Grow or die. Arlington House Publ. New York

5. Rubenstein, E. 1990. The more, the merrier. National Review

6. Kahn, H., W. Brown and L. Martel. 1976. The next 200 years: a scenario for America and the world. Wm. Morrow Publ. New York.

7. Moffet, G. 1994. The population question revisited. Wilson Quarterly 28:54-79.

8. Moore, S. 1998. Julian Simon, RIP. National Review 50:22.

9. Simon, J. 1996. The state of humanity: steadily improving. Current Feb 1996 (380):8.

10. Cassen, R. et al. 1994. Population and development: old debates, new conclusions. Transaction Publ. New Brunswick. 282 pp.

11. Simon, J. 1995. Population growth is our greatest triumph. Popular University. 4 pp.

12. Horiuchi, S. 1992. Stagnation in the decline of the world population growth rate during the 1980's. Science 257:761-765

13. Simon, J. 1981. The Ultimate resource. Princeton University Press, Princeton, New Jersey.

14. Landsburg, S. 1995. The more, the merrier. Forbes 155:166.

15. Simon, J. and H. Kahn. 1984. The resourceful earth

16. Wattenberg, B. 1987. The birth dearth. BJW, Inc. Pharos Books 182 pp.

17. Cohen, J. 1996. Ten myths of population. Discover 17:42-44.

18. Lambert, T. 1995. What they missed in Cairo. USA Today Jan 1995:33-36.

19. Abernathy, V. 1994. Optimism and overpopulation. Atlantic Monthly Dec. 194:84-91

20. Simon, J. 1996. The ultimate resource 2. Princeton University press, Princeton, New Jersey.

21. Stafford, T. 1994. Are people the problem? Christianity Today October 1994:45-60.

22. Simon, J., and R. Bailey. 1997. The global environment: megaproblem or not? The Futurist March-April 1997 31 (2):17-23.

23. Hyde, H.A. 1997. Slow death in the Great Plains. The Atlantic Monthly June 1997:42-45.

24. Feeney, G. 1994. Fertility decline in East Asia. Science 266:1518-1522.

25. Berreby, D. 1990. The numbers game. Discover April 1990:42-49.

26. Piel, G. 1995. Worldwide development or population explosion: our choice. Challenge July/Aug 1995:13.

27. Olshansky, S.J., B.A. Carnes and C.K. Cassel. 1993. The aging of the human species. Sci. Am. April 1993:46-52.

28. Robey, B., S.O. Rutstein and L. Morris. 1993. The fertility decline in developing countries. Sci. Am. Dec. 1993:60-67.

29. Bongaarts, J. 1998. Demographic consequences of declining fertility. Science 282:419-420.

Authors who have written articles or books that support population growth:

Rubenstein, Ed.
Simon, Julian
Brookfield, Harold
Osterfield, David
Bailey, Ronald
Wattenberg, Benjamin
Forbes, Malcolm
Kahn, Herman

Journals that are likely to include articles that support population growth:

U.S. World Report
Forbes Magazine
Fortune
Money
The Spectator
The Economist
National Review
The Cato Journal
Christianity Today

ZERO POPULATION GROWTH

1. Grant, L. 1992. Elephants and Volkswagens. W.H. Freeman and Co., New York, NY.

2. Daily, G.C. and P. Ehrlich. 1992. Population, sustainability and the Earth's carrying capacity. BioScience 42:761.

3. Mazur, L.A. 1994. Beyond the numbers. Island Press. Covelo, CA 444 pp.

4. Meyers, N. and J. Simon. 1994. Scarcity or abundance? W.W. Norton Publ. New York, NY 254 pp.

5. Cohen, J. 1996. Ten myths of population. Discover 17:42-44.

6. Ehrlich, P. and A. Ehrlich. 1997. The population explosion: Why we should care and what we should do about it. Environmental Law 27 (4):1187-1208

7. McNicoll, G. 1998. Malthus for the twenty-first century. Population and Development Review 24(2):309.

8. Fornos, W. 1998. No vacancy. The Humanist 58(4):15.

9. Cohen, J. 1992. How many people can the world hold? Discover 13 (11):114.

10. Cohen, J. 1995. Population growth and the Earth's carrying capacity. Science 269:341-345.

11. Postel, S. 1994. Carrying capacity: Earth's bottom line. Challenge March/April 1994:4-12

12. Ehrlich,P. and A. Ehrlich. 1990 the population explosion. Simon and Schuster. NewYork

13. Lader, L. Breeding ourselves to death. Ballantine Books, New York.

14. Prosterman, R. L. , T. Hanstad and L. Ping. 1996. Can China feed itself? Scientific American Nov. 1996:90-96.

15. MacKenzie, D. 1994. Will tomorrow's children starve? New Scientist Sept. 1994:24-29.

16. Bongaarts, J. 1994. Can the growing human population feed itself? Scientific American March 1994:36-42.

17. Bongaarts, J. 1994. Population policy options in the developing world. Science 263:771-776.

18. Motavalli, J. 1996. Contents under pressure. E Magazine 7(6):28-37

19. Bender, W.H. 1997. How much food will we need in the 21st century? Environment March 1997:7-28.

20. Ehrlich, P. and A. Ehrlich. 1997. Ehrlich's fables. Technology Review Jan 1997:38-47.

21. Meyers, N. and J. Simon. 1994. Scarcity or abundance? W.W. Norton Publ. New York, NY 254 pp.

22. Ehrlich, P., A. Ehrlich and G.C. Daily. 1995. The stork and the plow: The equity answer to the human dilemma. G.P. Putnam's Sons, New York

23. Kates, R.W. 1994. Sustaining life on earth. Scientific American Oct. 1994:114-121.

24. Sadik, N. 1991. World populations continue to rise. The Futurist March-April 1991:9-13.

25. Murdock, S.H. 1995. An America challenged - Population change and the future of the U.S. Westview Press, Boulder, CO

26. Erickson, J. The Human Volcano: population growth as geological force

27. Keyfitz, N. 1989. The growing human population. Sci. Am. Sept. 1989:119-126

28. Raloff, J. 1996. The human numbers crunch. Sci. News 149:396-397.

29. Smith, C. 1995. Assessing the limits to growth. BioScience 45(7):478-483.

30. Linden, E. 1992. Too many people. Time Fall 1992:64-65.

31. Budiansky, S., et al. 1994. Population wars. U.S. News and World Report Sept 12 1994:54-65.

32. Hinrichsen, D. 1994. Putting the bite on population growth. International Wildlife Sept./ Oct. 1994:36-45

33. Berreby, D. 1990. The numbers game. Discover April 1990:42-49.

34. Roush, W. 1994. Population: The view from Cairo. Science 265:1164-1167.

35. Bongaarts, J. 1998. Demographic consequences of declining fertility. Science 282:419-420.

36. Meadows, D. H. 1998. We still haven't proved Malthus wrong. Common Ground Nov. 1998:4.

37. Brown, L.R., G. Gardner and B. Halweil. 1999. Beyond Malthus: Nineteen dimensions of the population challenge. WorldWatch Institute, Washington, D.C.

Authors who have written articles or books that support ZPG:

Brown, Lester
Ehrlich, Paul
Daily, Gretchen
Daly, Herman
Durning, Alan Thein
Vitousek, Peter
Cohen, Joel
Sadik, Nafis
Rees, William
Malthus, Thomas
Meadows, Donella
Meadows, Dennis
Postel, Sandra
Bongaarts, John
Tobias, Michael

Organizations that support ZPG:

WorldWatch
ZPG
NPG
World Resources Institute
Population Reference Bureau
United Nations Population Fund

Journals that are likely to include articles that support ZPG:

Environment
BioScience
Scientific American
Science
Audubon
E Magazine
Science News
Mother Earth News
Discover

STUDY GUIDES

The study guides on the following pages are designed to assist students in structuring their studying for each exam. Each includes a brief description of text and lab materials covered on the exam, a detailed listing of topics covered and a list of new terminology. Study guides are handed out to students approximately one week before each exam.

Study Guide/Exam #1

COVERAGE:

Botkin and Keller—Chapters 1, 2, 3, and 4
Labs—Evaluation of the Edge Effect Labs I, II, and III; Net Productivity Lab;
Log Decomposition Lab
Supplemental Reading—Carl Sagan article, Edge Effect article

Be familiar with the following:

I. THE NATURE OF SCIENCE

- What is "science" and how does it differ from other disciplines?
- What is the scientific method?
- Be able to recognize the various components of a controlled scientific experiment
- What is the difference between pseudoscience and true science? Know examples
- Scientific Method Labs (Bonesteel Park Edge Effect Studies) as an illustration of how to apply the scientific method to a particular question (hypothesis and methods development, data collection, analysis, interpretation, etc.)
- Applications of edge effect (see lab handouts)

II. HISTORY OF CONSERVATION AND RESOURCE USE

- major events in human history that relate to resource use
- major events in U.S. (legislation, publications, environmental disasters, etc.) that have influenced public opinion and policy towards environmental issues

✐ **Note: See Lecture Outline. Do not memorize dates; rather, be aware of approximately when major events occurred, the sequence in which they occurred and their importance.**

III. BIOSPHERE AND ECOSYSTEMS

A. Biological organization from "individual" to "biosphere" levels
B. The Gaia Hypothesis
C. Biosphere as a system with inputs and outputs/ importance of solar radiation
D. Ecosystem components and processes

- biotic and abiotic
- nutrient cycling and energy flow

E. Biogeochemical cycles

- general characteristics of systems (reservoirs, fluxes, etc.)
- specific biogeochemical cycles

  1. Hydrologic (Water) cycle
  2. Carbon cycle
  3. Nitrogen cycle
  4. Other cycles discussed in text

✐ **Note: For each of the biogeochemical cycles, be familiar with:**

a. the nature of reservoirs
b. chemical symbols used to represent the various components of biogeochemical cycles
c. mechanisms of flux between reservoirs
d. human impacts and applications

- log decomposition as an element of nutrient cycling (see lab handouts)
  1. decay classes for decomposing logs
  2. how and why is log decomposition studied?
  3. nature of log decomposition
  4. roles of logs in forest ecosystems

- net productivity as a characteristic of ecosystems

Terminology:

environmental science	environmental unity	materialism
causality	testability	repeatability
falsifiability	scientific method	hypothesis
data	control group	experimental group
independent variable	dependent variable	analysis
theory	pseudoscience	fringe science
hunting-gathering	agricultural revolution	industrial revolution
worldview	multiple use	sustained yield
sustainability	wildlife refuge	forest reserve
national park	wilderness area	DDT
ecosystem management	sustainable development	population
community	ecosystem	biosphere
electromagnetic spectrum	short wavelength	long wavelength
photosynthesis	biotic	abiotic
reservoir	flux	residence time
aquifer	relative humidity	carrying capacity
watershed	rainshadow effect	respiration
net productivity	gross productivity	biomass
decomposition	greenhouse effect	bacteria
fungi	nitrogen fixation	nitrification
denitrification	ammonification	crop rotation
Gaia	fragmentation	rainforest
edge effect	heartwood	sapwood
inner bark	outer bark	bark beetle
ambrosia beetle	decay class	snag

Study Guide/Exam #2

COVERAGE:
Chapters 6 (in part), 8, 7 and 9
The Earth's Biomes—pp. B1-B7
Biomes Lab
Symbiosis Lab
Mt. St. Helens Lab
Fire videotape

Be familiar with the following:

1. Patterns of energy flow through ecosystems, trophic levels and food webs.
2. The "ten percent efficiency rule" and implications for human populations and diets
3. The relationship between gross productivity, net productivity and respiration
3. Biodiversity—definition and levels of measurement
4. Types of species based on habitat or distribution—know examples
5. Various types of symbiotic relationships—know examples from lab
6. What are the possible outcomes of interspecific and intraspecific competition? How do species avoid competition?
7. What is Gause's Law of Competitive Exclusion?
8. Predator—prey relationships—Snowshoe hare-lynx cycles
9. What are the various stages of terrestrial and aquatic succession and what are the driving forces behind these community changes?
10. What are the differences between oligotrophic and eutrophic lakes?
11. Trends in ecological succession (diversity, physical factors, stability, etc.).
12. What is cultural eutrophication? What are its causes and why is it often detrimental to the life in a lake?
13. The recovery of forest and stream communities after the eruption of Mt. St. Helens as a study in ecological succession.
14. The role of fire in ecosystems
15. What are the various ways that the members of a community can be interconnected?
16. The interaction between temperature and precipitation in the determination of biomes (see lab)
17. Tropical rainforests as an example of a biome

TERMINOLOGY:

community	producer	primary consumer
secondary consumer	tertiary consumer	decomposers
autotrophic	heterotrophic	chemoautotroph
coprophagy	food web	biomass pyramid
net productivity	gross productivity	respiration
photosynthesis	biome	soil horizons
genetic diversity	species richness	species evenness
species dominance	keystone species	exotic species
endemic species	cosmopolitan species	ubiquitous species
speciation	extinction	ecosystem diversity
zone of physiological stress	law of tolerance	realized niche
fundamental niche	interspecific competition	intraspecific competition
specialist	generalist	symbiosis
commensalism	mutualism	parasitism
predation	host	symbiont
primary succession	secondary succession	climax community
oligotrophic	eutrophic	cultural eutrophication
pioneer species	biological legacy	riparian

Study Guide/Final Exam

COVERAGE:

Botkin and Keller Chapter 5
Supplemental Reading —2 Human Population articles
Population Lab—Population Reference Bureau Statistics
Population Debate

Be familiar with the following:

1. The three phases of the logistic growth curve
2. The mathematical nature of exponential growth
3. What happens when a population exceeds its carrying capacity? Why?
4. What are limiting factors and how do they contribute to environmental resistance?
5. What is the difference between density— independent and density—dependent limiting factors?
6. What types of factors would need to be taken into account to predict future population growth for a species?
7. How does the age distribution in less developed countries differ from that in more developed countries? Why is this important?
8. What is the difference between Type I, Type II and Type III survivorship curves?
9. What factors have influenced human population growth throughout history?
10. What biological changes occurred as humans converted from hunting-gathering societies to agricultural societies?
11. How have U.S. fertility rates changed over the past 50 years?
12. What factors may influence fertility rates in a country?
13. What is the "demographic transition" and what significance does it have for future human population growth?
14. What is meant by the phrase "the graying of America"?
15. How do carrying capacity and optimum sustainable population differ?
16. What are the limiting factors on human populations today? 300 years ago?
17. What are some of the consequences of overpopulation?
18. What kinds of solutions have been implemented or proposed to deal with global overpopulation?

19. What recommendations have come from the various United Nations Intergovernmental Conferences on Population?
20. Major population trends from "Population Lab"—PRB Population Data Sheets
21. Major issues discussed during population debate (see handouts). Be able to characterize the positions of Paul Ehrlich and Julian Simon.

TERMINOLOGY:

population	sigmoid	logistic
exponential	carrying capacity	overshoot
inbreeding	infectious disease	limiting factor
environmental resistance	natality	mortality
immigration	emigration	sex ratio
cohort	baby boom	biotic potential
survivorship curve	demography	rate of natural increase
replacement rate	total fertility rate	infant mortality rate
demographic transition	contraception	abortion
life expectancy	maximum life span	ZPG
doubling time		

Sample Exam:
The following exams are representative of those given in Environmental Science I.

Sample Exam #1

Multiple Choice (2 points each)—Select the most appropriate answer and enter the letter on the answer sheet.

1. Which of the following statements best describes a "scientific theory"?

   A. a prediction made by scientists
   B. a highly tentative hypothesis
   C. an opinion accepted by most scientists
   D. a collection of hypotheses best supported by available data
   E. an educated guess based on the scientific method

2. Crop rotations such as alternating crops of soybean and corn serve to improve soils by:

   A. increasing aeration of soils
   B. adding carbon to soils
   C. adding nitrogen to soils
   D. increasing soil moisture

3. During which of the following stages of human history was population growth at its <u>lowest</u> level?

   A. modern industrial
   B. early industrial
   C. hunting-gathering
   D. agricultural
   E. pre-industrial

4. The conversion of human populations to an agricultural society resulted in all of the following except:

   A. population increases
   B. stable food supply
   C. increased urbanization
   D. increased conflict due to competition for land
   E. conversion from "male-dominated" to "female-dominated" societies

5. Which of the following land designations is best described as being "dedicated to preserving scenery, wildlife, and natural areas in a manner that leaves them unaffected by human activity"?

A. National Forests
B. Wilderness Areas
C. National Parks
D. National Wildlife Refuges

6. Which of the following federal agencies is primarily responsible for preventing the extinction of native plants and animals?

A. U.S. Forest Service
B. Bureau of Land Management
C. National Park Service
D. U.S. Fish and Wildlife Service
E. Environmental Protection Agency

7. During what decade was the majority of environmental legislation passed in the United States?

A. 1940's
B. 1960's
C. 1970's
D. 1980's
E. 1990's

8. The "Sagebrush Rebellion" and the "Wise-Use Movement" were both grassroots organizations that were formed:

A. to organize "Earth Day" activities
B. to repeal environmental protection legislation
C. to promote protection of wilderness areas
D. to focus environmental protection efforts on grazing lands and timber
E. none of the above

9. The publication of *Silent Spring* by Rachel Carson in 1962 had a dramatic impact on public opinion concerning environmental protection. What was this book about?

A. extinction of high-profile species
B. environmental damage caused by pesticides such as DDT
C. the need for additions to the National Park system
D. environmental problems associated with nuclear waste
E. environmental damage caused by oil spills

10. What process is represented by the following chemical reaction?

$$C_6H_{12}O_6 + O_2 \text{------>} CO_2 + H_2O + \text{energy}$$

A. photosynthesis
B. cellular respiration
C. denitrification
D. ammonification
E. nitrogen fixation

11. Coal, limestone and oil deposits represent:

A. long term reservoirs in the nitrogen cycle
B. short term reservoirs in the hydrologic cycle
C. long term reservoirs in the carbon cycle
D. various fluxes in the carbon cycle
E. none of the above

12. Based on your understanding of the "rainshadow effect" where would you expect the greatest annual rainfall to occur?

A. east side of Rocky Mountains
B. west side of Cascades
C. east side of Cascades
D. Willamette Valley
E. east side of Coast Range

13. Nitrogen fixation is normally accomplished by:

A. bacteria in animals intestines
B. photosynthetic plants
C. animals
D. bacteria associated with legumes
E. decomposition of organic material

14. Which of the following processes involve(s) the consumption of oxygen?

A. photosynthesis
B. decomposition
C. respiration
D. all of the above
E. B and C only

15. Most plants use nitrogen in the form of ________ in the soil:

A. nitrites
B. nitrates
C. nitrogen gas
D. ammonia

16. According to your Environmental Science text, what one single issue underlies all environmental problems?

A. air pollution
B. human population growth
C. water supply
D. biological diversity
E. global climate change

17. Simply stated, the principle of "environmental unity" suggests that:

A. humans have only one environment.
B. resources are finite.
C. time is money.
D. the environment is a closed system.
E. everything affects everything else.

18. Taking an approach similar to ours at Bonesteele Park, a forester determines that the edge effect penetrates 80 meters into an old growth stand surrounded completely by clearcuts. Given this information, how much "interior forest" (i.e. forest that is not impacted by the edge effect) would remain in a stand that is 200 meters by 200 meters?

A. 120 m^2
B. 640 m^2
C. 40,000 m^2
D. 4000 m^2
E. 1600 m^2

19. A chemical spill has occurred on the banks of a lake in an area where the underlying aquifer is widely used as a drinking water supply. The pollutants threaten to flow into both the surface water and the groundwater. The residence time of water in the lake is short, and the residence time in the groundwater is long. Which of the following statements is correct?

A. pollutants will quickly invade the lake and will linger there the longest.
B. pollutants will quickly invade the groundwater and will linger there the longest.
C. pollutants will quickly invade the groundwater, but will linger longest in the lake.
D. pollutants will quickly invade the lake, but will linger longest in the groundwater.
E. there is no cause for alarm.

20. Astrology, channeling and ESP are all examples of:

A. tested hypotheses
B. pseudoscience
C. core science
D. proven theories
E. scientific experiments

ESSAY QUESTIONS—Choose **any four** (and only four) of the following questions (#21-26). Place your answers on the blank sheet—**not** on the exam. To receive maximum credit, answers must be complete, accurate and well-organized. **(15 points each)**:

21. A scientist wishes to test the effects of different amounts of water and fertilizer on yields of corn. In a series of field tests, she varies the supply of water and the amount of fertilizer applied to a given strain of corn and measures the weight of the crop that results. She predicts that moderate amounts of water and fertilizer will produce the greatest yields.

For this experiment, identify each of the following:

hypothesis
independent variable(s)
dependent variable(s)

22. Describe the relationship between the following four terms:

Edge effect
Forest fragmentation
Brood (nest) parasitism
Neotropical migrants

23. You are designing a scientific study to measure the edge effect along a clearcut—old growth boundary. Among the physical variables you will be measuring are relative humidity, wind speed and soil temperature. Describe operational definitions for two of these variables.

24. Describe the relationship between the following five terms:

Net primary production
Waldo Lake clarity
Clip method
Respiration
Gross primary production

25. "Biosphere 2" is a large enclosed ecosystem research facility located in Oracle, Arizona. In 1991, soon after the "biospherians" entered the facility for the first time, three problems surfaced—an insufficient food supply, a decline of oxygen and a build up of carbon dioxide. Using your understanding of the carbon cycle, explain why these problems arose.

26. Describe the human impacts on the nitrogen cycle. Applying the concept of "environmental unity" and your knowledge of the nitrogen cycle, what consequences do you think these impacts will have on the biosphere?

EXTRA CREDIT—Answer the following question for extra credit **(5 points maximum)**. Place your answer on the blank sheet—**not** on the exam.

27. Explain the basic principles of the Gaia hypothesis. In your view, which aspects of the hypothesis are "accepted science", "frontier science" or "pseudoscience"?

Sample Exam II

Multiple Choice (2 points each): Select the most appropriate answer and place the letter on the answer sheet.

1. Which of the following is most characteristic of a mutualistic symbiotic relationship?

   A. One symbiont derives benefit.
   B. Both symbionts are harmed.
   C. Both symbionts derive some benefits.
   D. One symbiont benefits, the other is unaffected.

2. In general, which of the following characteristics or physical factors decreases as succession proceeds?

   A. soil depth
   B. humidity
   C. animal diversity
   D. complexity
   E. soil temperature

3. Trichonympha (a protozoan) in the intestine of a termite:

   A. produces enzymes essential for Vitamin D production in the termite.
   B. aids in the digestion of cellulose.
   C. protects the termite against parasitic bacteria.
   D. causes a parasitic disease in termites.

4. The terminal, stable species combination present at the end of any successional series is known as the ________ community?

   A. climax
   B. old growth
   C. pioneer
   D. seral
   E. subclimax

5. Which of the following species appeared soon after the eruption of Mt. St. Helens in 1980 and are, therefore, pioneer species?

   A. lupines
   B. fireweed
   C. pocket gopher
   D. all of the above
   E. A and B only

6. Since energy flow begins with energy from the sun and ends with energy being given off to the atmosphere, it is a complete cycle.

A. true B. false

7. Why do rabbits sometimes eat their own feces?

A. to avoid predators
B. to obtain minerals in short supply
C. to conserve energy
D. to gross out other rabbits

8. At what trophic level are bacteria and fungi included?

A. primary consumer
B. producer
C. decomposer
D. secondary consumer

9. Jerry Franklin's concept of a "New Forestry", as presented in the Mt. St. Helen's videotape, is based on:

A. the preservation of old growth forests.
B. the incorporation of "biological legacy" into managed landscapes.
C. clearcutting followed by an aggressive replanting campaign.
D. selective cutting of only the largest trees in a stand.
E. none of the above.

10. Approximately 90% of the energy that is consumed at one trophic level does not get converted into energy at the next trophic level. Each of the following contribute to this "waste", except:

A. heat losses.
B. inefficiency of digestive systems.
C. inefficiency of carbohydrate metabolism.
D. ingestion of indigestible foods.
E. loss of biomass due to decomposition.

11. The first insects to appear within the blast zone after the eruption of Mt. St. Helens were herbivorous primary consumers.

A. true B. false

12. According to the "10% efficiency rule", there should be less biomass present in an ecosystem at higher trophic levels as compared to lower trophic levels. As a result, the largest animals on Earth tend to be:

A. producers.
B. decomposers.
C. primary consumers.
D. secondary consumers.
E. tertiary consumers.

13. Algae in a marine ecosystem are consumed by zooplankton which are fed upon by fish. While fishing off a jetty at Newport you catch a fish and eat it on the spot. In your excitement you lose your footing and fall into the water where you are promptly eaten by a shark. At what trophic level should we place you as we explain your misfortune to the reporters?

A. producer
B. secondary consumer
C. tertiary consumer
D. primary consumer
E. decomposer

14. Which stage of terrestrial succession is characterized by an abundance of shade intolerant trees?

A. early sere
B. climax
C. subclimax
D. pioneer

15. Lichens are good pioneer species because:

A. many are nitrogen fixers.
B. they can extract nutrients directly from the air.
C. they are shade tolerant.
D. A and B are correct.
E. all of the above.

16. After which of the following events would primary succession ordinarily occur?

A. forest fire
B. clearcutting
C. flood
D. volcanic eruption
E. abandonment of cultivated land

17. Inverted biomass or energy pyramids represent ________ ecosystems.

A. unstable
B. tropical
C. expanding
D. well-established

18. To obtain the maximum amount of food in an ecosystem, a top predator such as humans should eat primarily:

A. producers
B. decomposers
C. primary consumers
D. secondary consumers

19. Species with large amounts of genetic variation are more likely to become extinct than species with smaller amounts of genetic variation.

A. True
B. False

20. Consider the two following animal communities:

Community A—10 flying squirrels, 12 pileated woodpeckers, 14 red tree voles, 7 spotted owls
Community B—50 flying squirrels, 2 pileated woodpeckers, 1 red tree vole, 1 spotted owl

Which of the following statements best describes the species diversity in these two communities?

A. A and B have approximately the same amount of biodiversity at the species level
B. Although A and B have the same species evenness, species dominance differs
C. Although A and B have the same species richness, species evenness differs
D. A and B have about the same species richness and evenness, but differ in species dominance

21. What does a tailed frog use its tail for?

A. assists in propelling the animal through water
B. to attract females
C. to anchor the animal to rocks
D. assists in internal fertilization
E. to warn other frogs of impending danger

22. Which of the following factors would tend to increase the biodiversity of a community?

A. physically diverse habitat
B. environmental stress
C. catastrophic disturbances
D. geographic isolation
E. introduction of an exotic species

23. The presence of sea otters along the Pacific Coast reduces the population of sea urchins in this area. This results in the development of kelp beds which harbor a large amount of biodiversity. For this reason, sea otters are considered to be a (an) ________ species.

A. exotic
B. ubiquitous
C. keystone
D. specialist
E. endemic

24. The realized niche of any species is always smaller than its fundamental niche.

A. True
B. False

25. Warblers of various species are found in the same general area but feed in different parts of trees. This example is best described as:

A. intraspecific competition
B. geographic isolation
C. commensalism
D. ecological succession
E. competitive exclusion

26. The most recent research on the relationship between lynx and snowshoe hare populations suggests that:

A. Lynx will generally hunt snowshoe hare until they disappear
B. Lynx populations generally decline before snowshoe hare populations
C. At high population levels snowshoe hare feed on less nutritious plants
D. Data from Hudson Bay Co. on population sizes of lynx were not reliable
E. Lynx and snowshoe hare populations generally peak at the same time

27. The fundamental niches of two species overlap and that overlap represents a resource that is in short supply. Given this situation, which of the following is certain to occur?

A. ecological succession
B. coexistence
C. symbiosis
D. interspecific competition
E. adaptive radiation

28. Lichens, oak galls and mistletoe may all be found on Gary Oak growing here in the Willamette Valley. Which of these organisms are considered to be parasitic on the oak host?

A. All of them
B. None of them
C. lichens only
D. lichens and mistletoe
E. oak gall and mistletoe

29. The floating fern, *Azolla*, contains within its tissues a blue-green algae called *Anabaena*. What benefit is gained by the *Azolla* as a result of this situation?

A. a source of carbohydrates
B. exposure to sunlight
C. the ability to float
D. protection from herbivores
E. a source of nitrates

30. The situation described in the previous question is an example of:

A. commensalism
B. mutualism
C. interspecific competition
D. competitive exclusion
E. parasitism

31. The mathematical relationship between gross productivity (GP), respiration (R) and net productivity (NP) is expressed as:

A. NP = GP - R
B. R = GP + NP
C. NP = GP + R
D. GP + NP + R = 1

32. Biomass in a community will accumulate when gross productivity exceeds respiration.

A. True
B. False

33. Tropical rainforests such as those in Brazil and temperate rainforests such as those on the Olympic Peninsula of Washington differ in each of the following <u>except</u>:

A. average annual temperature
B. degree of vertical stratification
C. amount of biodiversity
D. average annual precipitation
E. monthly precipitation patterns

34. Which of the following biomes has frequent fires and has largely been converted to agricultural uses in North America?

A. taiga
B. desert
C. tundra
D. chaparral
E. grassland

35. Which biome has the greatest diversity of plants and animals?

A. Taiga
B. Tropical rain forest
C. Deciduous forest
D. Grasslands
E. Savanna

36. According to your text, the case history of the demise of the American chestnut is an example of:

A. habitat destruction
B. the introduction of an exotic species
C. the environmental effects of climate change
D. pollution of the environment
E. all of the above

37. As a result of photosynthesis, a total of 5000 pounds of carbohydrate is produced by an acre of corn. Of this total, 1500 pounds are used up in respiration by the corn plants themselves. The remaining 3500 pounds would be a measure of:

A. net production
B. trophic efficiency
C. take-home pay
D. gross production
E. primary consumption

38. Redwoods eventually regenerate after disturbances such as fire and floods. In a forest without these disturbances, other species outcompete redwoods. Redwood National Park in northern California is dominated by these large and very long-lived trees. Which of the following descriptions best defines redwoods?

A. pioneer species
B. climax species
C. subclimax species
D. none of the above

39. Since the fires of 1988 in Yellowstone National Park, the park has often been cited as an example of the connection between forest fire and ecological succession. From 1872 when the park was established until 1963, what was the policy regarding wildfires?

A. to suppress all fires
B. to allow all fires started naturally to burn naturally
C. annual controlled burns
D. seasonal control—suppress fires only during the tourist season
E. to allow fires in areas with species that require fire to reproduce

40. The underlying cause (driving force) of ecological succession is best described as:

A. survival of the fittest
B. changes in the physical environment caused by the organisms themselves
C. an illustration of the competitive exclusion principle
D. the ability of an organism to adapt to changing conditions
E. the introduction of exotic and native species to a new area

Essay Questions - Choose two (and only two) of questions 41-43 (10 points each)

41. Restoration ecology is a new field of study that attempts to use our knowledge of natural systems to restore them after a disturbance. Describe one example of how restoration ecology has been put into practice. Clearly indicate in your description those ecological principles that have been used in the restoration.

42. Based on the "Yellowstone Fires" article, the "Firestorm" videotape and readings in your text, describe the ecological role of fire in ecosystems such as the lodgepole forests of Yellowstone National Park or the Ponderosa pine forests of eastern Oregon. Then, describe a wildfire policy that would make better use of this knowledge.

43. The most simple measure of biodiversity is the number of species that occur in an area. This may not be the most meaningful measure of biodiversity, however. Explain why not all species are of equal importance with regards to biodiversity.

✐ **Note: Your responses to the questions on the videotape "Firestorm" shown in class will be applied as extra credit on this exam. Please hand in these answers with your exam. (5 points possible)**