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EVALUATION OF A STREAM ECOSYSTEM AS A CLOSING UNIT TO A HIGH SCHOOL BIOLOGY CLASS

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EVALUATION OF A STREAM ECOSYSTEM AS A CLOSING UNIT TO A HIGH SCHOOL BIOLOGY CLASS

By

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ABSTRACT

EVALUATION OF A STREAM ECOSYSTEM AS A CLOSING UNIT TO HIGH SCHOOL BIOLOGY

By

Susan M. Townsend

A unit on ecology was taught at the end of the school year using a stream ecosystem, the Thornapple River. The unit was designed to pull together the major concepts learned during the biology course, and to reinforce two of the main unifying themes of biology, evolution and ecology. In addition, this unit was intended to leave the students with an increased positive attitude towards science.

Pre-tests and post-tests were given to the students during the unit to measure students progress. Students scores showed a significant increase in academic achievement. Pre- and post-attitude tests indicated a positive attitude change as a result of the teaching of the unit.

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CHAPTER 1

INTRODUCTION

With the advancements in research in biology, a high school biology teacher has been put in the position of too much information to present and not enough time. Generally, the sequence of topics taught at the high school level have begun with cell biology and biochemistry. These are followed by cell division and genetics, animal phylogeny, and finally human biology. Plants are seldom discussed to save time. This type of format did not seem to pull together two of the unifying themes that underlie all biology, evolution and ecology. In this instructor's opinion, too much time is being concentrated on content, and not enough on the unifying themes. This view has been shared by others. Sandra R. Kransi states in her Master's thesis:

> Most courses and texts begin with a review of chemistry, a unit of biochemistry, and a longer unit on cells and their processes. Most courses next attempt to cover genetics, reproduction, animals, plants, microorganisms, ecology and evolution in varying sequences. This instructor, teaching exactly that type of course, has long felt the burden of too much content in our biology courses and too little concentration on the really basic themes that underlie all biology.

Kransi later reveals these themes to be evolution and ecology. Evolution provided an explanation of how there are so many varieties of organisms on the Earth present and past. The study of ecology suggests why there are so many different organisms and how the environment affects the organisms in it. It is the opinion of this instructor that these themes combine to make our understanding of life clearer. The authors of the BSCS Green Version appear in agreement with this idea for in the preface they write:

> If as T. H. Dobzhansky said, 'Nothing in biology makes sense , unless in the light of evolution', then, equally very little in evolution makes sense, except in the light of ecology--that is, in terms of the interactions between organisms and their physical, chemical, and biological environment." (Begon, Harper, and Townsend 1986)

The text book used for this biology course was Biology by Kenneth Miller and Joseph Levine. This book provided innovative evolutionary theme interwoven throughout all the chapters. The course for this class is divided into five main units : cell biology and chemistry, cell reproduction and genetics, evolution, plant and animal diversity, and ecology. The two themes are alluded to constantly during the course of the year to help the student better understand life processes as described in each unit. An outline of some of the topics covered follows:

Cell Biology and Chemistry

1. Characteristics of Living Things
2. Chemistry of Living Things
3. Cell Structure, Function and Movements of Materials In and Out
4. Cell Energy: Photosynthesis, Respiration, Fermentation.
5. Nucleic Acids and Protein synthesis

Cell Reproduction and Genetics

1. Cellular reproduction: Mitosis and Meiosis
2. Mendelian Genetics
3. Chromosome Theory
4. Human Heredity
5. Genetic Engineering

Evolution

1. Fossils: Evidence of Change
2. Theory of Evolution
3. Concepts of Adaptation, Natural selection, Population Genetics
4. Classification Systems

Plant and Animal Diversity

1. Simple Life Forms: Monera, Protista and Fungi
2. Plant Kingdom- Evolutionary View
3. Animal Kingdom- Evolutionary View

Ecology

1. Food Chains, Food Webs
2. Energy Flow
3. Biogeochemical cycles
4. Limiting Factors
5. Mankind Impact

Some time was spent in deciding when to teach the ecology unit. Should it be taught at the beginning of the school year as an introduction to biology, or at the end of the school year as a closing unit to bring together all of the ideas taught earlier during the year? The latter was chosen for two reasons. The first reason was to tie the main concepts together and to provide a theme that the students could relate to. The second reason was the makeup of students that were in this class which will be discussed in chapter two. At the end of the year an outdoors ecology unit should leave a much more pleasing memory of science in their minds. The expectation is that ending with this unit would improve their attitudes towards science.

The ecology unit was divided into three sections 1) an introduction to the key terms and concepts, 2) biotic or living factors, and 3) abiotic or non-living factors. All three sections were centered on a local ecosystem very familiar to the students, the Thornapple River. The Thornapple River flows through the two main towns of the Maple Valley school district, Nashville and Vermontville. Focusing on a familiar ecosystem such as a river was intended to instill the relevance of the ecology unit to the student.

To introduce the students to the main concepts in this unit, worksheets out of The Biology Coloring Book were used. The book was ordered through the Carolina Biological Supply Catalog. Three different plates all dealing with ecological concepts were distributed to each student. This assignment was done in place of the traditional vocabulary assignment. The color plates are a highly effective learning tool in that students had to read about a concept and on the color plate diagram provide a specific color code for that concept. Students had to pay attention while reading each paragraph to know where to fill in the color plate. When finished, the students had a color-coded sheet for easy reviewing for the unit test.

Biotic factors are the living organisms within an ecosystem. They include the producers, as the autotrophs which have the ability to take energy from the sun and convert it to chemical energy via photosynthesis. Reinforcing the concept of photosynthesis is appropriate at this point in the development of the unit.

Consumers make up the next living part of the ecosystem. Herbivores, predators, parasites and scavengers are found in the middle of the food chain and are all known as consumers. Showing the consumption of other organisms to get nourishment makes it possible to demonstrate energy flow through an ecosystem.

The final group bacteria and fungi make up the decomposers which are at the end of any food chain or web. They decompose dead plants and animals back into the constituent atoms and molecules. Decomposers are the recyclers of nature. The process of respiration (aerobic and anaerobic) by the decomposers was re-introduced to emphasize the releasing of energy from the organic molecules in the dead plant or animal matter.

The decomposers make a natural lead into the last part of the ecology unit, the abiotic factors. Most students ask, "after the decomposers break down this organic matter, what happens to it?" The answer is one of the key concepts of the biogeochemical cycles. Materials are continually being recycled by the environment. Cycles that receive the main focus are the carbon, nitrogen, and water cycles. The overall concept taught to the student is that molecules that make up each one of them are only borrowed. The molecules represent millions of years of recycling and that they too will be recycled.

Another abiotic principle covered in this unit is that of limiting factors. Dissolved oxygen, pH, temperature, nitrates, light, carbon dioxide and some trace minerals were tested for in the Thornapple River and also tested in classroom laboratories. These factors were found which showed that too much of a given factor can be limiting to an organism as well as not enough.

The distribution of energy through an ecosystem was the third abiotic principle in the instructional unit. The concepts of food chains and food webs were related to energy flow. Students see how energy originates from the sun, is captured by the producers which in turn are eaten by the consumers, with energy transferred from one organism to the next. Students also learn that only ten percent of energy is transferred from one trophic level to the next. Energy is used by consumers to find and eat food, therefore not storing it in their body for the next consumer in the food chain. This accounts for the energy loss between trophic levels. Energy does not recycle, it transfers to different forms, usually heat.

Throughout the whole school year students were taught to approach problems using the scientific method. This unit has many labs and activities that emphasize the formation of hypothesis to predict the outcome of the lab or activity. Students were expected to make predictions via hypothesis, gather data, analyze that data, and draw conclusions based on the data but with little guidance from the instructor. Students studied the results of their test on the Thornapple River and from them drew conclusions concerning the health of the river.

Some central questions about the effectiveness of this ecology unit are to be answered in this thesis. 1) Would the students be able to learn the main concepts of this unit? 2) Would this ecology unit at the end of the year be able to tie together and reinforce many of the major concepts taught prior to the unit? 3) Would having a familiar ecosystem to study outdoors make a difference in the students' attitudes towards science in general and the environment specifically?

CHAPTER 2

INSTRUCTION

OVERVIEW

This thesis is based on an ecology unit that was taught during the last four weeks in a high school biology class. Students were a mixture of sophomores, juniors, and seniors. The students came from a rural area in south central Michigan and were mainly middle to lower economic level Caucasians. The school is a consolidated unit classified as class C. In the spring of 1991, the Michigan Core Curriculum for science was implemented by the state of Michigan into the class C schools science program which was part of a mandatory three year general science program for grades seven through nine. Prior to implementing this core curriculum, ninth graders had to be recommended to get into biology. This process made the biology course unavailable to the above average freshmen for the first time. This also meant that only students that were not recommended as freshmen or did not elect to take the course the first time offered made up the entire student body of this course. As a result the number of scheduled sections of biology went from a yearly count of three down to two. The class size ranged from fifty-five at the beginning of the year to thirty-two at the end of the year. During the ecology unit, the third hour section had sixteen students and the fifth hour section had eighteen students. The abilities of the students ranged from above average to learning disabled. Original student interest in biology was not high. Preparing this unit for this clientele was not easy. Many hands-on activities were incorporated into the unit to encourage student interest in the material being taught.

Two different sites on the Thornapple River, within walking distance from the school, were used in this study. The river at the first site is a wide open area crossed by a bridge. Here, the river is shallow and moves slowly so the students could wade in safely. The second site is in a wooded forest where the river is narrow and moves faster. Students and instructor could easily go to either section of the river and perform experiments within the 55 minute class period. Student's interest at the end of the year was maintained by doing field work at the river ecosystem and by doing lots of hands-on laboratory activities.

The four week period was divided into three parts, consisting of an introduction to ecology, its biotic factors, and its abiotic factors. Field work, laboratory exercises, reading assignments, audiovisuals, lectures, and testing were used in the instructual process. Interrelationships of evolution and ecology were emphasized and constituted the two unifying themes.

OUTLINE OF ECOLOGY UNIT

I. Preliminaries

A. Pre-Test (See Appendix C)
B. Attitude Survey (See Appendix D)

II. Introduction to Ecology

A. Reading Assignment: Ch. 47 pp 1006-1009. Biology: Miller-Levine
B. Lecture: Ecosystems, Biotic Factors, Abiotic Factors, Food Chains, Food Webs, and Energy Pyramids.
C. Handouts: Biology Coloring Book (See Appendix A)
D. Simulation: Living Food Web

III. Biotic Factors

A. Handout: Biotic and Abiotic Factors Data Sheet (See Appendix A)
B. Class discussion on area biotic factors
C. Field Work: Thornapple River-Bridge organism collection
D. Field Work: Thornapple River-Forest organism collection
E. Lab: Identification of Microorganisms
F. Lab: Analysis of Feeding Groups of Stream Macroinvertebrates (See Appendix B)
G. Film: Ecology of Ponds
H. Film: Ecosystem: Struggle for Survival
I. Simulation: Predator-Prey Game (See Appendix E)
J. Lab: Schooling Behavior (See Appendix B)

IV. Abiotic Factors

A. Lab/Demonstration: Limiting Factors for Algae (See Appendix B)
B. Reading Assignment: Ch. 47 pp 1021-1027. Biology: Miller-Levine
C. Lecture: Specific Biotic Factors, Nutrient Cycles,
D. Film: Communities of Living Things--Abiotic Cycles
E. Lab: Effect of Temperature on Dissolved Oxygen Concentration (See Appendix B)
F. Field Work: Thornapple River-Bridge Abiotic Data
G. Field Work: Thornapple River-Forest Abiotic Data
H. Class discussion on normal ranges of abiotic factors
I. Reading Assignment: Ch. 49 pp 1052-1062. Biology: Miller-Levine
J. Group Work: Analyzing the Thornapple River- Is It Polluted?

V. Post-Test (See Appendix C)

DESCRIPTION OF LABORATORY EXERCISES

All but one of the laboratory exercises in this unit were based on the scientific method of figuring out an approach to a problem and forming a hypothesis. One exercise involved the identification of organisms. Laboratory exercises based on the scientific method all followed the same format. Problems were enunciated and discussed in the introductory phase to give the students background information. Students were then asked to state three hypothesis dealing with the problem and select their favorite one. Students were expected to record observations and present appropriate data in tables, grafts or charts. At the end of each laboratory exercise, each student was to draw his/her own conclusion based on the data gathered in the exercise and its relationship to the hypothesis chosen.

Student laboratory reports were written for each lab using the format of introduction, hypothesis, procedure, data, analysis and conclusion. Prior to this unit the students were already familiar with laboratory reports in this fashion. This format had been the standard for many of the labs given throughout the year. Laboratory reports were graded by the instructor and returned to the student. Many students saved their reports and used them as a guide for writing future reports. Quality of laboratory reports improved through the school year.

The following is a description of each of the laboratory exercises used in this unit:

1. IDENTIFICATION OF MICROORGANISMS

This laboratory exercise lets the students see that the river is teeming with life, especially at the microscopic level. Students were able to share a highly active slide of pond water containing microorganisms with the class by using the a microscope camera hooked up to a TV. This procedure made it possible for students to see one another's slides at the same time and to identify more organisms than was possible through direct microscopic examination. Students were able view living organisms and compare them to the prepared slides and drawings supplied by the instructor. Common names of the organisms were used whenever possible. Identification keys came from the classroom library and the instructor's field notebook from a freshwater invertebrate course taken at the Kellogg Biological Station. Stress was placed on their role in a food web rather than their exact identification. At the end of this exercise, students were asked to identify the location of the organisms in a food chain and a food web.

2. ANALYSIS OF FEEDING GROUPS OF STREAM MACROINVERTEBRATES

Students in this exercise were asked to study the food base of a river by examining leaf litter found along the banks and bottom. This procedure allowed the students to see ecosystems within ecosystems. Leaf litter was collected in the morning of the day in which it was to be examined and kept in the refrigerator between class periods. We are grateful to Dr. Mike Klug of the Kellogg Biological Station for the identification key. According to the authors of this key, Cummins and Wilzbach, 80-90% of the organisms in the leaf litter can be classified by feeding habitats. Again the lesson plan emphasized the role each organism plays in the food chain, not their scientific name. Grouping of organisms was based on their feeding habits as shredders, scrapers, collectors and predators. The student handout for this exercise is in Appendix B.

When the students first started to do this lab, many were hesitant to touch the "slimy" leaf litter. After a while though, the students began to enjoy searching for the "critters", especially the fast moving predators with the long jaws. Many students were surprised to see the amount of life within what appears to be dead organic matter. Overall, this exercise seemed to be the most enjoyable for the students.

3. SCHOOLING BEHAVIOR

Biology students that fish were familiar with some of the fish found in the river. The others had never or barely encountered fish. The purpose of this laboratory was to teach students about schooling behavior in fish. The evolutionary theme shows the student that animal behavior is a trait that is selected for survival. Tropical fish of the same genus were used instead of stream fish because they survive better in an aquarium. One species was marked and the other species was unmarked. Ten gallon tanks filled three quarters full were divided into regions based on the different sections in the lab. Each species of fish was placed in a beaker closed off by cheese cloth and placed into the different regions. One fish was set free and students recorded how long the free fish stayed in each region. This laboratory exercise can be found in Appendix B.

4. LIMITING FACTORS FOR ALGAE

The main objective of this exercise was to give the students an example of factors limiting growth of algae. Fish tank algae were scraped from an aquarium in measured amounts to make a standard population. The Spectrometer 20 set at a wavelength of 430 was used to measure algal growth. Absorbency was plotted against the concentration of nitrogen. Students discovered that the growth rate was best not at the highest concentration as many of them predicted, but at the middle concentration. From this exercise, students were able to conclude that too much of a factor can adversely affect growth as not enough. Details of this laboratory exercise are in Appendix B.

5. EFFECT OF TEMPERATURE ON DISSOLVED OXYGEN CONCENTRATION

In this exercise, students learned how to test for dissolved oxygen using a portable test kit suitable for application in the field. Students were surprised to learn that the amount of oxygen dissolved in water increases with decreasing temperature. Their assumption prior to the exercise was that warmer water would have more living things in it. Knowing that organisms need oxygen for respiration to release energy, they quickly tied together the ideas of oxygen being a limiting factor and that colder water, having more oxygen, would have more capacity for living things. Using an aquarium aerator to put oxygen in the water helped reinforce the concept of dissolved oxygen. This exercise is included in Appendix B.

DESCRIPTION OF FIELD TECHNIQUES

A lot of hands-on labs were done prior to the field trips to both river sites. Ground rules were established and students understood that this part of the unit was going to be fun but measurements and tests had to be made in a limited amount of time.

Each class was divided into six pre-assigned groups consisting of three to four students each. Groups were numbered 1-6 and each group was given two measurements or tests to complete. Prior to each field trip instructions concerning procedures were given to the students. The class along, under the supervision of the teacher, would walk to the river. Each group was given two abiotic and biotic data sheets, one for each of the two river sites. All the students names in the group were placed on the final sheet to be turned in by the group. The following is a summary on each of the procedures the students ran:

1. DISSOLVED OXYGEN

Because of the expense of this test, only one analysis was completed each hour at each site. Because students had already practiced the laboratory exercise, accuracy was not a major concern. Instructions were photocopied in case of destruction during the field work. Students seemed to be more at ease doing this test than any of the other probably because of the practice in the lab the day before. Dissolved oxygen was measured at different levels in the water of both locations for comparison. All used chemicals were placed in a waste bucket so that none of the chemicals would be put into the river. The results of the DO were between ten parts and eleven parts per million at both sites.

2. TEMPERATURE

The temperature of the air was measured at ground level and recorded. Water temperature was taken at all sites were dissolved oxygen tests were completed. The water were measured in degrees Celcius. Standard laboratory thermometers were used.

3. NITRATE

Portable test kits suitable for field study were used to measure the nitrate concentration in low range. Farmland surrounds the river, but the nitrates from the fertilizer did not seem to affect the result which ranged between 0.01-0.04 ppm.

4. pH

Earlier in the year students learned the importance of pH and buffers within a living system. Acid rain was discussed in lecture earlier in the week. Full range pH paper was used to measure the pH. Students results were between 7-8 pH.

5. FLOW RATE

Students measured a thirty-foot section of the river near the bridge, placing yardstick markers at each end. An orange was allowed to float between the two markers. Students timed the orange with stopwatches and recorded the stream flow rate at both sites. At the bridge site the water was shallow enough for wading. At the forest site, students released the orange off an old but safe train trestle because the water was too deep. Starting from the trestle and going downstream, the students marked off the thirty feet along the bank of the river. Students safely caught the orange with a long handled net. Speed of the river was calculated in feet per second. When the students returned to the classroom, an assignment was given to convert the speed of the river to miles per hour. This calculation allowed the students to see how fast the river was traveling in a unit that is very familiar to them. Students would calculate their walking speed and compare it to the speed of the river. This lab was fun for the students. They enjoyed going outdoors and, those that wanted to, could go into the river to get their water samples for both the abiotic and biotic parts of the unit.

DESCRIPTION OF SIMULATIONS

Some concepts can be better taught in the classroom than in the field by doing simulations. Two simulations were done in class to strengthen a few main concepts. The simulations are as follows:

1. PREDATOR/PREY SIMULATION

The owl and the mouse predator-prey concept is easy to simulate. In this simulation, the population of owls were compared to the population of mice in an imaginary ecosystem called "Hoot Woods". Laboratory tables became the woods and two different colored construction papers represented the mice and the owls. Owls were dropped from a certain height and allowed to fall at random on the table full of mice. If the owl landed on any mouse square, the mouse was "eaten". The mice that weren't eaten were allowed to reproduce at a specific rate by adding mouse squares to the table. Only the owls that ate three or more mice could reproduce. The students recorded the results of each generation and made a line graph between the two populations. This activity allowed the students to see that it is very hard for a predator to eat all the prey in the area. It also reinforced the interdependence of the predator and prey populations. The one problem with the lab is the amount of time spent making and counting the squares. Two suggestions for next year would be to have a student assistant make the squares ahead of time or to replace the squares with paper punch holes instead. Overall, students enjoyed the activity and the concepts were made clear to the students.

2. LIVING FOOD WEB

This is a simple, but effective way of illustrating the difference between food webs and food chains. Cards were prepared ahead of time with the names of several area producers, primary consumers, secondary consumers, tertiary consumers, and decomposers. Students drew two cards, one for each hand. The teacher then had the students display their cards to the rest of the class so that each student's organisms would be known to the whole class. The first job of the class was to make food chains one at a time using a ball of string. The string always started on a producer and ended on a secondary or tertiary consumer. Organisms could be used only once at the beginning until all the food chains were identified. Then the fun began by creating the food web. The organisms now represented a population of the species instead of an individual within that population and therefore could be used more than once. By the end of this activity, the class was one big living food web. The students could clearly see that the producers were at the beginning of many food chains because of how many strings were being held by a person with a producer. This was a good activity because it let the students actively participate in their learning.

DESCRIPTION OF FILMS

There were several reasons for using films in this unit. Films let the students see how other ecosystems are similar the river that they are studying in class. With only 55 minutes per class period, time needed to visit other ecosystems than the nearby river was not available. These films effectively bring the other ecosystems into the classroom within the time allotted.

These films also applied many of the terms taught that week to the students and let them see how these terms relate to the ecosystem.

All films came from the Regional Education Media Center 13, or REMC 13. Films had to be planned in advance by at least a three week time period. The best way to ensure the films were available for the time need in the unit, orders were placed at the beginning of September. This gave ample time for the films to be reserved for the final four weeks of school when the unit was taught.

1. ECOLOGY OF PONDS 7 min. Recommended for grades 6-12.

This film provides a good introduction to the interactions of life and nonlife in a pond. It shows how nature balances itself between the biotic and the abiotic factors. This film is very effective in showing the nutrient cycles, food chains, and predator-prey interactions.

2. ECOSYSTEM: STRUGGLE FOR SURVIVAL 22 min. Recommended for grades 6-12.

This ecosystem movie makes a point that seems to be overlooked by the students , that humans are a big part of almost any ecosystem and that they have a huge impact on the balance within the system. The main focus of this film is a India's Gir Forest where mankind, domestic animals, and an endangered species of predator, the Asiatic lion all interact. Again the interaction of the living and the nonliving are reinforced along with some of the terminology used in this unit.

3. COMMUNITIES OF LIVING THINGS--Abiotic Cycles 15 min.
Recommended for grades 6-12.

This film discusses the biogeochemical cycles in an ecosystem. Earlier in the year students were told that they were only borrowing the chemicals that make them up. There was a quote in this film that completely reinforced that concept well; "living things only borrow the chemicals of which they are made". A few students commented that they had heard that statement before.

CHAPTER 3

EVALUATION

The evaluation of this unit was accomplished in three parts. The first part of the evaluation was designed to find out if this unit had any affect on the students' academic achievement. The second part of the evaluation determined whether or not an ecology unit taught out doors would influence the students' attitude about science in general. ecology, and a local river. The third part was an exit interview done with randomly chosen students to see what kind of impact the unit had after school was out.

PRE-TESTS AND POST TESTS

The pre-test was given one day prior to the unit and contained twenty-five multiple choice questions pertaining to the unit. The post-test contained all the questions from the pretest, but was expanded to include more of the concepts taught during the unit and was given at the end. A copy of the pre-test and post-test can be found in Appendix C. The results from both tests are found in Table 1.

Table 1. RESULTS OF PRE-TESTS AND POST-TESTS

		Pre-test		Post-test	
Class	Highest Possible Score	Mean	S.D.	Mean	S.D.
3rd Hr	100	67	14.82	84	8.36
5th Hr	100	70	17.86	85	7.40
Total	100	68.5	16.35*	84.4	7.93*

T-test on combined mean. n=32. d.f.=15
*. Significant at the 0.001 level

ATTITUDE SURVEYS

The attitude survey was derived in part from one written by Becky Stout (1986) in her Master's Thesis for Michigan State University. The attitude survey was modified as a part of research at the Kellogg Biological Station by Sandi Kransi, Jerry Kovach. Joe Kuester, and this instructor. All four instructors were a part of the Environmental and Behavioral Ecology Workshop for High School Biology Teachers which was sponsored by the National Science Foundation and Michigan State University. The survey was designed to measure student attitudes toward science and environmental issues.

Attitudes are not easy to change, and measuring them is even harder. The survey format was a single topic followed by a series of opposing ideas. For example the first topic was science.

Students were to choose between the two opposing ideas of whether they think science is fun or boring. The numbers one through five were placed between the two words so that the students could rank their opinion with each pair of words. In all the word pairs, one was positive and the other negative. The teachers working on this survey made sure that the positive and negative words were put randomly on either side of the numbers. This helped insure that the students chose by their opinion and not by just going down the survey and putting in answers. In scoring, the answers were corrected so that the score of one was the most negative and the score of five was the most positive.

The survey needs revision for next year. Students had problems understanding certain words like "inhabited". Throughout the time that the students were taking the opinion survey, they seemed to want guidance from the instructor about their opinion. Giving the survey to a class of non-science students may make it possible to uncover words that thay do not understand and reduce the tendency of the teacher to influence the student's answer. This way students won't feel pressured to answer what they think the teacher wants. English classes would be good for this as these classes are a required course each year.

Three areas in this survey relate to this unit. Questions one through twenty-eight centered on the student's opinion about science in general. Questions twenty-nine through sixty dealt with the student's opinion on environmental issues. Questions sixty-one through sixty-five dealt with the local rivers. Appendix D contains the opinion survey. The results of the three areas of opinions tested can be found in Table 2.

Table 2. RESULTS OF ATTITUDE SURVEY*

Section of Survey	Pre-Survey		Post-Survey	
	Mean	S.D.	Mean	S.D.
All Science (1-28)	3.69	1.00a	3.71	0.75a
Environment (29-60)	3.78	0.46a	3.80	0.33a
Local Rivers (61-65)	3.23	0.67b	3.52	0.34b

*. A score of 1 is a low opinion, 5 is a high opinion.
a. Significant at the 0.1 level.
b. Significant at the 0.05 level.

EXIT INTERVIEWS

Interviews with the students were completed over the telephone two weeks after school was out for the summer. The time lag between the completion of school in the spring and the exit interviews was planned so that the ecology unit not so fresh in their minds. This was intended to make the interview a little less influenced by the ecology unit. Seven questions were asked of twelve students chosen by the grade received in the ecology unit. Gender was half male and half female. Of these twelve students, there were three that received an A, three received a B, three received a C, and three received a D. No students failed the marking period in which this unit was taught.

At the beginning of the interview, students were reminded of the topics covered during the school year. The seven questions were asked and the comments made by each student were recorded as the interview progressed. The seven questions are as follows:

1. Of the four units covered in class, which unit did you enjoy the most?
2. Which of the four units did you enjoy the least?
3. Of the four units covered in class, which one did you learn the most new material from?
4. Which of the four units did you already know a lot about?
5. In this unit, we did a lot of outdoors, hands-on field work. In some of the other units, we followed the book chapter by chapter. Which way was easier for you to learn, by the book or by fieldwork?
6. We did our ecology unit in the spring as a closure to the school year. Another way of teaching the ecology unit would be to use it as an introduction to the biology course. Which time would be better to teach this unit, in the spring or in the fall?

7. Did this unit help to give reason for teaching difficult topics such as respiration and photosynthesis (i.e. the biogeochemical cycles), and evolution (predator-prey interactions)?

The results of the exit interviews are in Tables 3, 4, and 5.

Table 3. RESULTS OF EXIT INTERVIEWS
QUESTIONS 1-4 ALL STUDENTS

Questions	Percent Answering Per Unit			
	Cells	Genetics	Evolution	Ecology
1 Enjoyed Most	0.0	0.0	50.0	50.0
2 Enjoyed Least	66.7	25.0	8.3	0.0
3 Learned Most	16.7	8.3	66.6	8.3
4 Learned Least	25.0	41.7	25.0	8.3

Table 4. RESULTS OF EXIT INTERVIEWS
QUESTIONS 1-4 BY GRADE CATEGORY

Questions	Percent Answering Ecology			
	A	B	C	D
1 Enjoyed Most	33.3	0.0	100.0	66.6
2 Enjoyed Least	0.0	0.0	0.0	0.0
3 Learned Most	0.0	33.3	0.0	0.0
4 Learned Least	0.0	0.0	0.0	33.3

Table 5. RESULTS OF EXIT INTERVIEWS
QUESTIONS 5-7

Grade Category	Percent Answering Each Question 5 Chapter	5 Field	6 Fall	6 Spring	7 Yes	7 No
A	0.0	100.0	33.3	66.7	100.0	0.0
B	0.0	100.0	33.3	66.7	66.7	33.3
C	0.0	100.0	0.0	100.0	100.0	0.0
D	0.0	100.0	0.0	100.0	66.7	33.3
ALL STUDENTS	0.0	100.0	16.7	83.4	83.4	16.7

When students were asked to choose the topic they enjoyed most, many of them chose quickly. The results of the exit interviews show that the students enjoyed two main topics, evolution and ecology. Some comments made by students who favored the ecology unit were:

"I liked being outside."

"I could learn more by doing."

"It was interesting to see all the living things in the river."

"I liked how everybody worked together to get things done."

One of the students who said she learned the most from the ecology unit stated, "We got to look at what we were studying instead of working out of a book."

In terms of what time of the year to teach the unit, some students said:

"It should be taught at the end of the year, the weather is nice so you should get to go outside."

"It should be taught at the beginning of the year to get the students' interest."

"It should be taught at the end of the year because its warmer and the animals are out."

"We should do more mellow stuff like ecology at the end of the year when our brains are tired."

"It is too cool in the fall to go into the river."

As for the preference by the students between a textbook unit or a fieldwork unit these comments were made:

"The field work was real science, it was easier to relate to."

"The field work was a lot more fun."

"I could learn more by being out there doing the field work."

TEACHER OBSERVATIONS

Students were told about this unit at the beginning of the school year. Rarely did a week go by that one of the students didn't ask if the class could move on to the ecology unit so they could go outside. The students couldn't wait to get to the river.

When the unit finally arrived, the students were very cooperative and exited. It was refreshing to see the enthusiasm in the months of May and June. Samples were brought back from the river to be observed. Exceptional slides of active microorganisms were placed on the microscope camera for the whole class to observe. It was gratifying how this simple honor of having a good slide to put on the microscope camera stimulated the students to find the best slides. As one of the students said in the comment section of the chapter, the whole class worked as a team. Students knew they had a job to complete in a limited amount of time, so the got right to work when they got to each site. This was a fun and relaxing experience for both the students and the instructor.

CHAPTER 4

CONCLUSION

In the first chapter of this thesis, three questions were asked dealing with how effective this ecology unit would be on students' academic achievement and attitude. Chapter three discusses the tests, interviews and surveys used to evaluate this unit. This chapter will discuss what the results mean in relation to the questions.

QUESTION ONE: WOULD THE STUDENTS BE ABLE TO LEARN THE MAIN CONCEPTS OF THIS UNIT?

The results of the pre-test and post-test were compared using the Student T Test and results showed the test results were highly significant. Students did learn the ecological concepts. One reason for this learning may have been the familiarity of the topic covered in the unit. Through most of the students middle school years, ecological concepts were taught to the students. Many of the students had also taken a semester high school environmental class for non-science majors. This might also account for the high means of the pretests of 67% and 70%.

The use of many different teaching methods may have also contributed to the success of the students learning the ecological concepts in this unit. Along with the traditional lectures and laboratory activities, films, simulations and hands-on field work were used to teach the major concepts of ecology. Lecture and films work well for the auditory and visual learners. On the other hand, simulations, laboratories and field work helps the students that learn by active participation.

Another reason for the academic success of the unit was the unifying concept of ecology pulling together ideas that were taught throughout the year. This unit gave relevance to the student. It clearly answered the time old question, "Why do we have to do this?"

The final reason for the academic success of this ecology unit is very simple. It was fun. When something is fun to do, it is easier to remember it. These students and instructor had fun doing this unit.

QUESTION TWO: WOULD THIS ECOLOGY UNIT AT THE END OF THE YEAR BE ABLE TO TIE TOGETHER AND REINFORCE MANY OF THE MAJOR CONCEPTS TAUGHT PRIOR TO THE UNIT?

Topics relating to this ecology unit that were previously covered in class were reinforced throughout the unit. This reinforcement happened during any of the methods of teaching mentioned in the last section. For example, when the predator-prey simulation was being taught, the concept of natural selection was brought back in to the discussion to reinforce the other unifying theme, evolution. Also during the topic of biogeochemical cycles, the two main processes of elemental recycling, photosynthesis and respiration, were joined together to show their importance and inter-relatedness. Discussion of the biogeochemical cycles also brought up the ideas of the chemistry of life, and how the molecules that once belonged to dinosaurs are now part of each students body. Looking at the unicellular protozoans refreshed the students memory on cell structure and function. These were just a few of the many ideas reinforced by this unit. All labs, simulations,and the post-test had questions that made the student accountable for previous material reinforced in this unit.

Ten out of the twelve students interviewed felt that this unit did complete the year by tying together the main ideas taught during the course (question 7, exit interview). The two that did not feel this way were hesitant with their answer, the hesitation was recorded as a no. With eighty-three percent of the students feeling that this unit reinforced the major concepts taught during the school year, this instructor believes that this unit effectively addresses the second central question of this unit.

QUESTION THREE: WOULD HAVING A FAMILIAR ECOSYSTEM TO STUDY OUTDOORS MAKE A DIFFERENCE IN THE STUDENTS ATTITUDES TOWARDS SCIENCE IN GENERAL AND THE ENVIRONMENT SPECIFICALLY?

The third question was answered by giving students a pre- and post-attitude survey during this unit. Three areas of attitude were measured by this survey; 1) the students attitude towards science in general, 2) the students attitude towards the environment, and 3) the students attitude towards the local river.

It is not easy to measure students' attitudes and even harder to change them. This opinion survey was designed to be included in any environmental unit preferably in a ninth grade or higher level. The students' attitude improvement towards both the environment and science in general was significant at the 0.1 level. Part of the general science questions had to do with the scientific method. Students seemed to see the reasoning behind the scientific method after using laboratory activities that incorporated the scientific approach. Another part of the opinion survey addressed clear cutting the rain forests and wiping out the wetlands. These topics inspired a class discussion not originally planned for this unit. It was the teachers belief that a related topic with such high student interest should be discussed, even if it delayed already planned assignments. This discussion of environmental issues could explain for the increased level of concern that showed on the post-survey. However, the primary reason for improved attitude may be the students enjoyment of the outdoors fieldwork and hands-on laboratories within this unit. It appears the more a student enjoys doing science, the better his/her attitude will be about science.

The only area of the survey that was written specifically for this unit was questions 61-65 which dealt with the local rivers. When the students got to these questions on the first opinion survey, the immediate verbal response heard was, "The Thornapple River is dirty, it must be polluted." It was gratifying to see the students reactions as they compared their results from the water tests in the river with what was the normal range for the tested substances. The results showed that the chemistry of the river fell within normal ranges. The animal life handout on pollution indicator organisms also proved that the river was clean enough to contain organisms that would not exist in even slightly contaminated water. The results of the post-opinion survey indicate that the field test results must have made an impact. The students opinion of the river had improved at a significance level of 0.05.

Another form of testing attitude was the exit interviews. Opinions were asked of a random group of twelve students which represented approximately forty percent of the biology classes. Students were asked which topic they enjoyed most and least. They were also asked which topic they learned the most new material from and the least material from. There was a tie between ecology and evolution for the topics enjoyed most. The cell and genetics unit were chosen as least enjoyed. Since many hours were spent preparing both the ecology and evolution units, it was very encouraging to see that the students chose the two unifying themes as the most enjoyed. Evolution was also chosen by 66.7% of students as the unit they learned the most new material from. Evolution may have been so popular because to this teachers knowledge, it has not been taught prior to this year. Genetics was chosen by 41.7% as the topic students learned the least in. This could be due to the fact that genetics is covered in both seventh grade and ninth grade science.

As for the time of year in which students felt this unit should be taught, 83% chose the end of the school year. There are a few probable reasons to explain this. First they were taught the unit in the spring and are not familiar with an alternative format. Another reason may be that the students liked going outside in the warm spring weather. The final reason, as some of the students commented, is that this unit pulls together the main concepts taught throughout the year. The last point was the primary reason for this thesis.

The students enjoyed this unit so much, that 100% chose the field study unit as opposed to the chapter-by-chapter unit. The students really got into their work and seemed to work as a team. The cooperation between the students was a pleasure to see, especially in weather that usually brings out a not so pleasant side of a young person's personality.

The conclusion of this ecology unit is that the unit was successful as an ending to the school year. The students academically achieved, and left with a positive attitude towards science. That positive attitude in the students is what all teachers strive for in a classroom. That's what really makes this unit a success.

POSSIBLE MODIFICATIONS FOR THE FUTURE

Being that this was the first year this unit was taught, this instructor would like to do the unit again in the fall as a comparison to this unit taught in the spring. Even though this unit was a success, it would be interesting to see how it affects scores if it was used as an introduction to biology. The unit itself would be expanded from a four week unit to a six week unit to include more field work and laboratories because that's what the students seemed to enjoy most. By beginning the school year with this unit, periodic follow-up studies could be done on the river to show the students how the river changes throughout the seasons.

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APPENDIX A

STUDENT HANDOUTS

FLOW OF ENERGY AND MATTER IN THE BIOSPHERE

One of the requirements of life is a constant flow of energy. Life involves activity, and activity requires energy. If the supply of energy stops, life stops. A constant flow of matter is also necessary, since matter is intimately involved in trapping energy and transporting it from one place to another within the living organism or from one organism to another. The food we eat, for example, consists of matter organized as carbohydrates, proteins, and lipids. These molecules contain usable energy, but when the same atoms are combined as carbon dioxide and water, they contain virtually no usable energy.

Color titles A through I, including the headings Carbon Dioxide and Water, and the corresponding parts of the plate. Choose a light color for C. Leave the oxygen and carbon dioxide next to the rabbit uncolored for now.

All the life processes on earth obtain their energy directly or indirectly from the *sun*. *Plants* absorb *light energy* and convert it into chemical energy in the process of photosynthesis. Plants conduct photosynthesis by combining carbon dioxide from the air with water and minerals taken up from the soil to make *carbohydrates*, *proteins*, and *lipids*. In the daytime, when the plant is photosynthesizing, the *oxygen* of the water molecules is a waste product as far as the plant is concerned, so it releases that oxygen into the atmosphere. The identical process goes on in plants and algae that live in lakes, streams, and oceans, except that they are immersed in water and don't have to depend on soil for it. (At night, photosynthetic organisms use oxygen just as animals do.)

Color title J, the animal, the oxygen it consumes, and the carbon dioxide it releases.

Although *animals* cannot carry out photosynthesis to obtain energy from light directly, they obtain it indirectly by eating plants or eating animals that eat plants (or eating animals that eat animals that eat plants, etc.). To extract the energy from the food they eat, animals must combine the food molecules with oxygen. This process is called oxidation and results in the production of carbon dioxide and water, which are released into the atmosphere when the animal exhales (although some of the water may be excreted in liquid or semisolid form). Plants carry on oxidation also, both to grow and to maintain themselves during the hours of darkness.

Color titles K and K^1 and the arrows representing heat energy gained and lost.

Anyone who has ever been out in the sun knows that the sun radiates *heat* as well as light, and that heat keeps the earth warm enough for living things to survive. What is not so obvious is that even light energy is sooner or later converted to heat. No chemical process is 100 percent efficient, and the reactions of photosynthesis lose a little of the trapped light energy as heat. Much more heat is produced by the oxidation of the products of photosynthesis as a plant grows or as an animal converts them into energy for its own life processes.

Eventually the heat energy received by the earth is radiated away into outer space. If you find this hard to believe, take notice in the winter how much colder it is on a morning following a night of clear skies than it is following a night with a heavy overcast to reflect radiating heat back to the earth. Energy, then, flows through the biosphere—the thin layer of our planet's surface that supports life—and back out into space. Matter, on the other hand, flows in constant cycles, and no significant amount of matter is added to the earth or lost from it. The cyclic flow of carbon from plants to animals and back to plants again is commonly called the "carbon cycle." Many other kinds of matter also flow in cycles, such as water, nitrogen, oxygen, and sulfur.

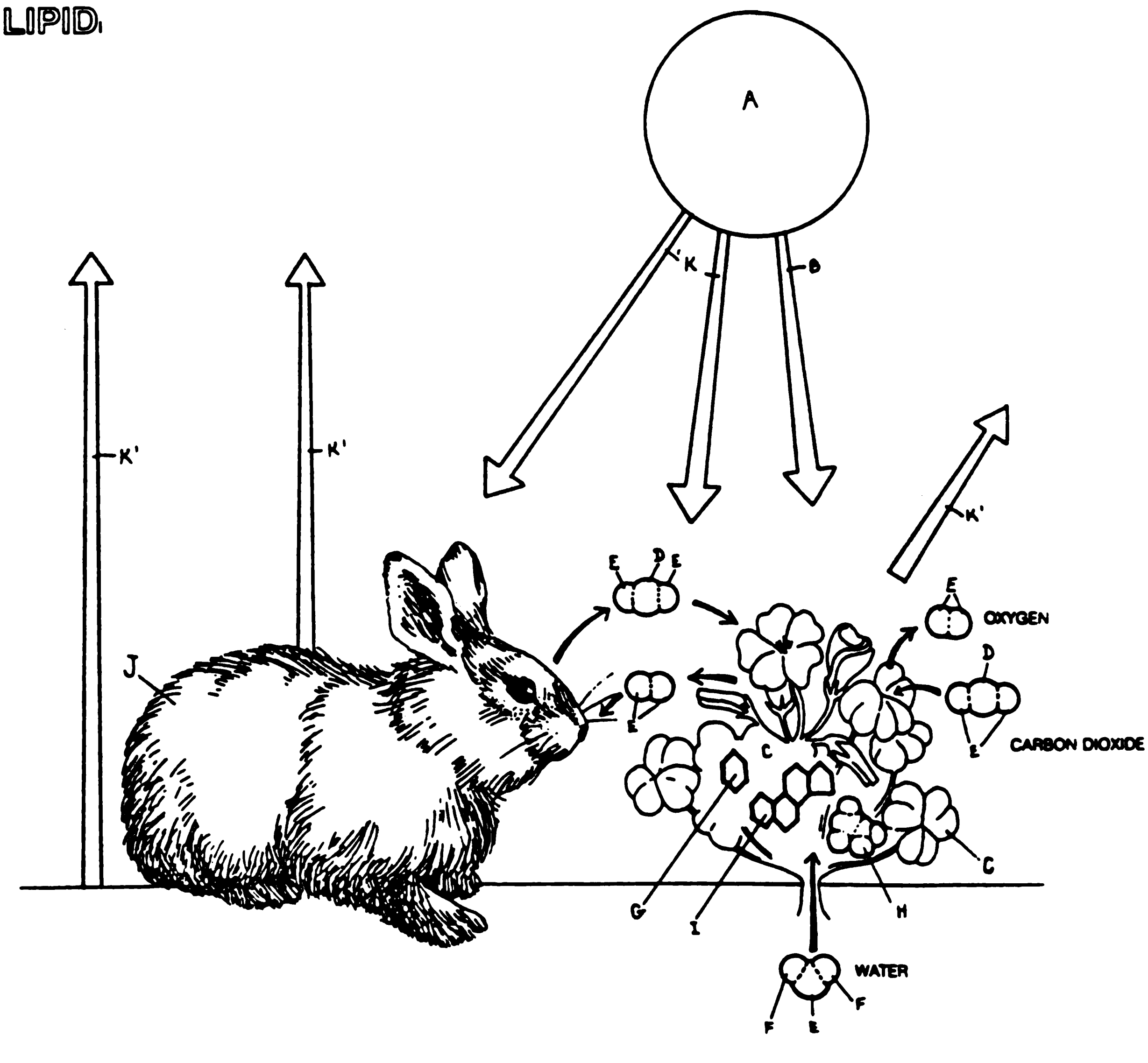
Source for Color Plates 43, 92 and 93:

Griffin, Robert D. The Biology Coloring Book. Oakville, CA: Coloring Concepts, Inc. 1986.

FLOW OF ENERGY AND MATTER IN THE BIOSPHERE.

SUN A
LIGHT ENERGY B
PLANT C
CARBON DIOXIDE (CO_2)*
CARBON ATOM D
OXYGEN ATOM E
WATER (H_2O)*
HYDROGEN ATOM F
CARBOHYDRATE G
PROTEIN H
LIPID I

ANIMAL J
HEAT ENERGY GAINED K
HEAT ENERGY LOST K'



COMMUNITIES

No living organism exists entirely by itself. It is always profoundly influenced by its environment. The branch of biology that studies the relationships between living organisms and their environments is known as ecology (Greek: *oikos*, "house"). Ecologists concentrate much of their study on communities and ecosystems. A community is defined as all of the organisms living in a given area and interacting with one another. An ecosystem is a community plus all of the nonliving components of its environment. This plate shows some of the components of a typical biological community and their relationships.

Color the heading "Trophic Levels," title A, and the corresponding part of the illustration.

Within a community, organisms are categorized into different "trophic levels" according to how they nourish themselves (Greek: *trophe*, "nourishment"). The most important organisms are the *producers*, the green plants that capture the energy of sunlight to make the energy-rich organic molecules on which all the rest of the community depends. (In some communities, algae or even certain bacteria may be the important producers.)

Color title B and the corresponding parts of the illustration.

Feeding directly on the producers are the *herbivores* (Latin: *herba*, "grass"; *vorare*, "to devour"), also known as *primary consumers*. Familiar members of this group include grasshoppers, butterflies, and other herbivorous insects, rabbits, squirrels, mice, and seed-eating birds.

Color title C and the corresponding parts of the illustration.

Animals that feed on the herbivores are called *primary carnivores* (Latin: *caro*, "flesh"). They are also called *secondary consumers*. It's unfortunate that they are "primary" one time and "secondary" another, but both naming systems are widely used. If you think about what the words actually mean, it really isn't too difficult to keep them straight. Included among the primary carnivores are such animals as foxes, owls, frogs, insectivorous (insect-eating) birds, and predatory insects such as the praying mantis.

Color title D and the corresponding parts of the illustration.

Animals that feed on primary carnivores are called *secondary carnivores* (or *tertiary consumers*). A snake that eats a frog is a secondary carnivore. So is a hawk that eats an insectivorous bird. Nature, of course, does not entirely cooperate with our desire for nice, neat categories. A fox may eat a frog, becoming a primary carnivore in the process; it may then eat a snake, becoming a tertiary carnivore in that process. Similarly, a mouse may eat an occasional insect, becoming thereby a primary or even a secondary carnivore, depending on what kind of insect it eats. Some animals, such as humans, baboons, and rats, routinely feed at all levels and are called omnivores (Latin: *omni*, "all"). Recognizing that the various categories of carnivores are oversimplifications, ecologists still find them useful, and carnivores and omnivores are traditionally assigned to the highest trophic level at which they feed.

Color title E and the corresponding part of the illustration.

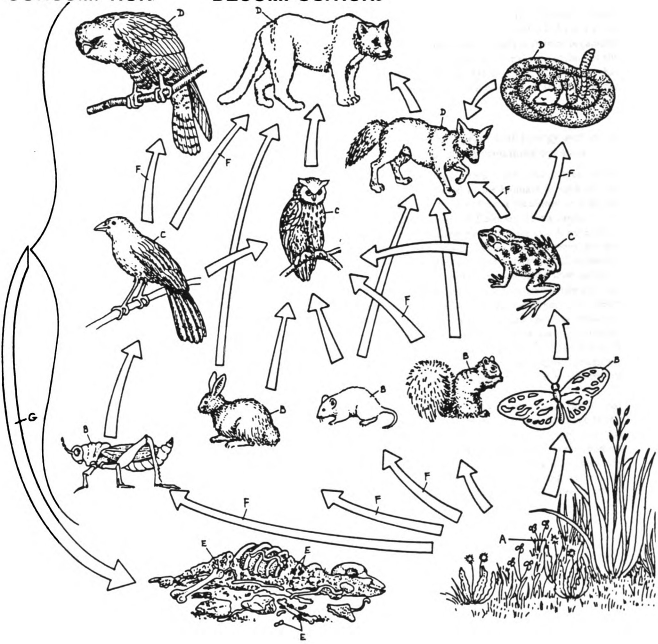
Feeding on all the other levels is the group called *decomposers*. (They are sometimes called reducers, but they do not reduce things in the chemical sense; they live by oxidation.) We don't apply the term "omnivore" to the members of this group, bacteria and fungi, because they do nearly all their feeding on dead organisms. The decomposers break down the dead remains of all species (including their own) into small, inorganic molecules that are released into the soil and water to be recycled as nutrients for the producers.

Color the heading "Food Web," titles F and G, and the associated parts of the illustration.

The pattern of the flow of energy and matter within a community is often referred to as a "food web." In the community illustrated here, that pattern is shown by the arrows, which indicate the transfer of energy and matter from one organism to the next. Only the direction of flow is shown, not the quantity of energy or matter. Those quantities are customarily shown by means of ecological pyramids, illustrated in the next plate.

COMMUNITIES.

TROPHIC LEVELS.
PRODUCER. A
HERBIVORE (PRIMARY CONSUMER). B
PRIMARY CARNIVORE (SECONDARY CONSUMER). C
SECONDARY CARNIVORE (TERTIARY CONSUMER). D
DECOMPOSER. E
FOOD WEB.
CONSUMPTION. F **DECOMPOSITION.** G



ECOLOGICAL PYRAMIDS

In trying to understand communities, ecologists find it useful to determine certain numeric values and convert them into graphs that give a pictorial representation of the relationships. Some of the most valuable of these are ecological pyramids. This plate shows the three kinds of pyramids in common use.

Color titles A through D, the heading Pyramid of Numbers, and the structures in the two pyramids in the first section.

One kind of ecological pyramid is the pyramid of numbers. The organisms in each trophic level are actually counted, where possible, or estimated from representative samples. In a very small forest, for example, it is entirely possible to count all the trees. Counting all the individual plants in even a tiny meadow would be a different matter.

A sort of pyramid is then constructed, making the area of each box proportional to the number of individuals in that community. The decomposers are usually not shown separately in ecological pyramids but are included as part of each level of consumer. If they were shown separately, in a pyramid of numbers, they would overwhelm the other trophic levels. One cubic centimeter of soil often contains more than a million bacteria, for instance. (How many cubic centimeters of soil are there in a small forest?)

A pyramid of numbers will take different shapes according to the sizes of the producers. In a grassland, each *producer* is very small, so their numbers are very considerable. An equal area in a forest will contain only a few large trees, so a pyramid of numbers for a forest will show a very small area for producers, although the trees might support just as many consumers as the grass does in the grassland.

Color the heading Pyramid of Biomass and the trophic levels in the two pyramids in that section.

"Biomass" means the actual mass (weight) of living matter in the organisms in each trophic level. Collecting the data from which to build this pyramid is even more tedious than for a pyramid of numbers, but it has been done for many communities. In a typical terrestrial community, a pyramid of biomass has the conventional pyramidlike shape, with a large base to represent the mass of plants necessary to support a smaller mass of *herbivores*, which in turn support a smaller mass of *primary carnivores*, and so on. However, since a pyramid of biomass shows the biomass at one particular point in time, the proportions can be distorted if one trophic level has a peculiar reproductive rate. This often happens in aquatic communities, where the producer level is dominated by algae that reproduce so rapidly that they replace the ones that are eaten as fast as they are consumed. At any given time, there is a smaller biomass of algae than of organisms feeding on them, but if we were to make a pyramid of the biomass produced over an extended period of time, that pyramid would closely resemble the pyramid of energy described below.

Color the heading Pyramid of Energy and structures A through D in the remaining pyramid.

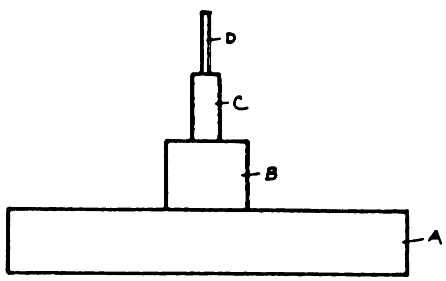
A pyramid of energy displays the total amount of energy captured and stored in the biomass of each trophic level over one year. (The energy is measured in kilocalories—what nutritionists call Calories, with a capital "c"—or in joules, a unit of energy from physics.) A pyramid of energy takes very nearly the same shape for every community. Each trophic level captures only about 10 percent of the energy contained in the biomass of the level below it. The remaining 90 percent is unassimilated (since even the most efficient digestive system cannot digest and absorb everything) or is used and dissipated as heat in the activities of life. Thus a *secondary carnivore* eating a primary carnivore takes in only about 1 percent (10 percent of 10 percent) of the energy present in the original producers and converts only about 0.1 percent of that energy into its own body mass.

The pyramid of energy shows very clearly that if food for feeding people is scarce, we can feed far more people on plant foods than we can on meat from plant-eating animals. It also shows why in nature the largest number of trophic levels normally found is five, and then usually only in aquatic communities where the big fish eat the little fish who eat the littler fish who eat the almost microscopic organisms who eat the algae.

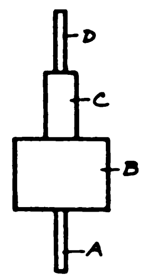
ECOLOGICAL PYRAMIDS.

PRODUCERS.A
HERBIVORES.B
PRIMARY CARNIVORES.C
SECONDARY CARNIVORES.D

PYRAMID OF NUMBERS.

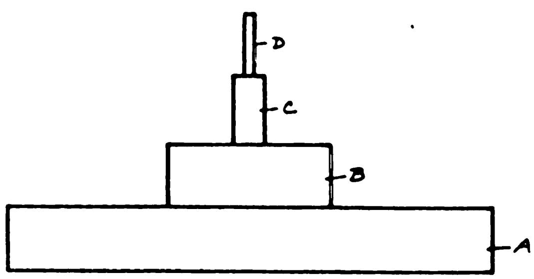


GRASSLAND

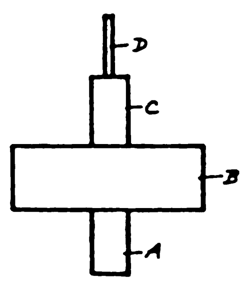


TEMPERATE FOREST

PYRAMID OF BIOMASS.

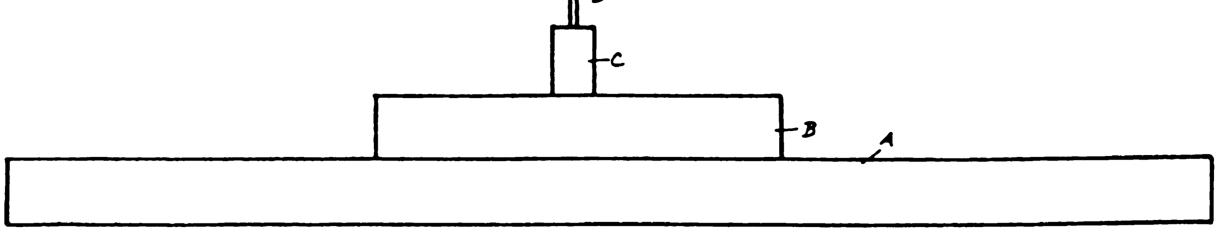


GRASSLAND



OPEN OCEAN

PYRAMID OF ENERGY.



NAME________________________________ DATE__________ HOUR_______
SITE:_____________________________________

DATA SHEET

BIOTIC FACTORS (IN WATER)

(N) NONE (S) SPARSE (M) MODERATE (A) ABUNDANT (P) PROFUSE

_____FLATWORMS	FISH TYPES:	MICROORGANISMS:
_____ROUNDWORMS	_____ ______________	_____ ______________
_____LEECHES	_____ ______________	_____ ______________
_____SNAILS	_____ ______________	_____ ______________
_____CLAMS	_____ ______________	_____ ______________
_____SOWBUGS	_____ ______________	_____ ______________
_____CRAYFISH		_____ ______________
_____MAYFLIES	PLANT TYPES:	_____ ______________
_____DRAGONFLIES	_____ ______________	_____ ______________
_____SPONGES	_____ ______________	_____ ______________
_____BEETLES	_____ ______________	_____ ______________
_____MITES	_____ ______________	_____ ______________
_____TRUE FLIES	_____ ______________	_____ ______________
_____STONEFLIES	_____ ______________	_____ ______________
_____SCUD	_____ ______________	_____ ______________
_____CRANE FLY		

ABIOTIC FACTORS

FILL IN AT SITE:	CIRCLE ONE:
______pH	**Phoshate**: present, not present
______D.O. ppm	**Nitrate**: present, not present
______CO_2 ppm	**Weather**: sunny, part. cloudy, part. sunny, cloudy
______Hardness (Ca & Mg)	
	Water: clear, cloudy, opaque
______Temp. 'C	

STREAM FLOW:

	STRAIGHT	INSIDE BEND	OUTSIDE BEND
TRIAL 1			
TRAIL 2			
TRIAL 3			
AVERAGE ft/s			

STREAM QUALITY ASSESSMENT OBSERVATIONS AND ANALYSIS

The organisms on page 6 are grouped into three categories:

GROUP 1 (pollution-intolerant or good quality indicators)
GROUP 2 (organisms that can exist in both extremes of quality)
GROUP 3 (pollution-tolerant or poor quality indicators)

The organisms in these three groups are assigned a group index value.

GROUP 1 = 3 GROUP 2 = 2 GROUP 3 = 1

The analysis procedure consists of counting the number of <u>types</u> of organisms in each category and multiplying the group index value.

EXAMPLE:	GROUP 1 TAXA		GROUP 2 TAXA		GROUP 3 TAXA	
	CADDISFLY(S)		DRAGONFLY(S)		BLACKFLY(S)	
	STONEFLY(S)		CRAYFISH		MIDGE(S)	
	MAYFLY(S)	3x3 = 9	CLAM(S)	3x2 = 6		2x1 = 2

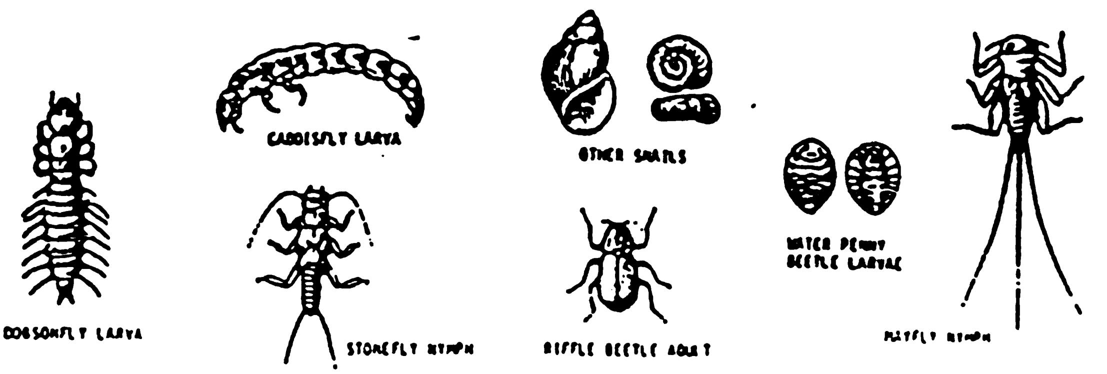
The respective group index values are then added together to find the cumulative index value (which in the above case would be 17). By referring to the following chart, the stream quality assessment can thus be determined.

STREAM QUALITY ASSESSMENT	CUMULATIVE INDEX VALUE
EXCELLENT	23 and above
GOOD	17 - 22
FAIR	11 - 16
POOR	10 or less (SEE ACTION PROCEDURE ON PAGE 8)

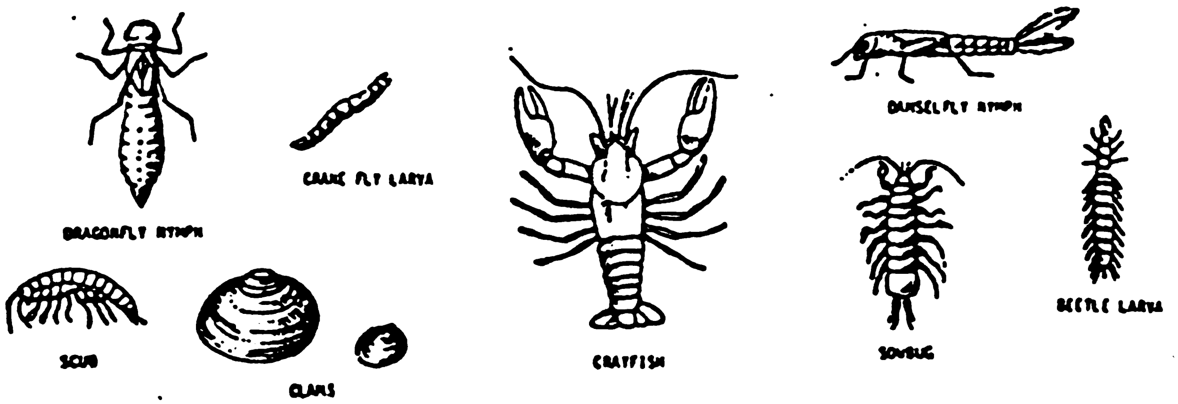
NOTE: The organisms listed on the stream quality assessment form used in the field are to be recorded by placing a letter code in the corresponding block. Each letter represents your estimated count.

MACROINVERTEBRATE TAXA GROUPS

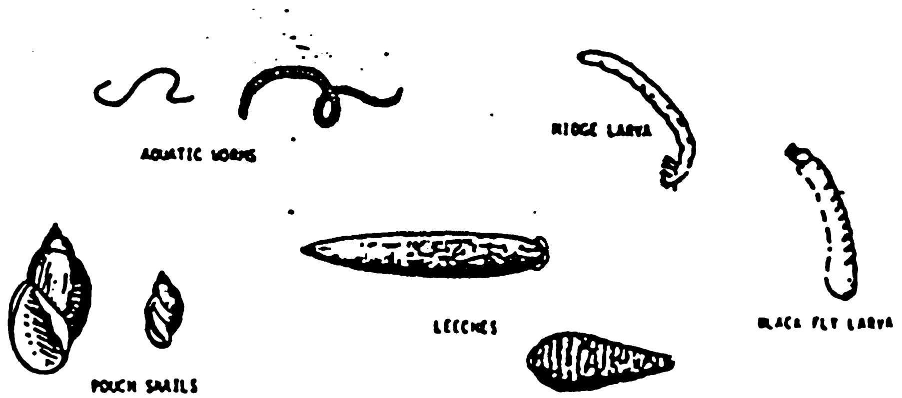
GROUP 1 (*These organisms are generally pollution-intolerant. Their dominance generally signifies* GOOD WATER QUALITY)



GROUP 2 (*These organisms can exist in a wide range of water quality conditions.*)



GROUP 3 (*These organisms are generally tolerant of pollution. Their dominance usually signifies* POOR WATER QUALITY.)



APPENDIX B

STUDENT LABORATORIES

ANALYSIS OF FEEDING GROUPS
STREAM MACROINVERTEBRATES

TAKEN FROM
CUMMINS AND WILZBACH

The objective of this exercise is to do a quick initial assessment of the food base of a stream ecosystem by focusing on the roles played by the macroinvertebrates present. Macro means larger than microscopic and invertebrates are those animals without backbones. According to the authors of the original lab, about 80-90% of the organisms that you will find can be classified accurately this way. This is good enough for our purposes, but for a more detailed study, we would need to use more complex keys.

Stream macroinvertebrates are separated into four FEEDING GROUPS. SHREDDERS are dependent on large pieces of organic matter such as leaves, needles, wood, and other plant parts. COLLECTORS use small particles of organic matter (generally less than 1 mm in size), either by filtering from the passing water or gathering from deposits in the sediments on the stream bottom. SCRAPERS are adapted for removing attached algae, especially where it grows on rocks or log surfaces in the current. PREDAOTRS are adpated through behavior and specialized body parts for the capture of prey.

We will take handfuls of organic materials from four areas of the stream as follows:

a. Coarse Particulate Organic Matter (CPOM) = litter accumulations of leaves, needles, bark, twigs, other plant parts, and coarse fragments of these materials from a riffle.

b. Fine Particulate Organic Matter (FPOM) = particles less than 1 mm in size from the fine organic-rich sediment of a pool.

c. Periphyton = Predominantly attached algae (diatoms) on rock and wood surfaces.

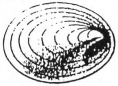
d. Large Wood = Branches and logs. Taken from soft punky wood fallen into the streams.

KEY TO FUNCTIONAL FEEDING GROUPS

|—| |——————| Indicates size or range of sizes

1. ANIMALS IN HARD SHELL (Phylum Mollusca)

   a. LIMPETS (Class Gastropoda)




SCRAPERS

   b. SNAILS (Class Gastropoda)



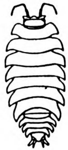
SCRAPERS

Snails are generalized (facultative) feeders and can also function as Shredders.

   c. CLAMS OR MUSSELS (Class Pelecypoda)

FILTERING COLLECTORS

2. SOW BUG OR SHRIMP-LIKE ANIMALS (Class Crustacea)




SHREDDERS

Generalized, can also function as Gathering Collectors.

3. LARVAE IN PORTABLE CASE OR "HOUSE"
Go to page 6.

4. LARVAE IN FIXED RETREAT WITH CAPTURE NET

   Note: Care must be taken when collecting to observe nets.

Go to page 8.

5. WITHOUT CASE OR FIXED RETREAT

   a. WORM-LIKE LARVAE WITHOUT JOINTED LEGS
   Go to page 10.

   b. NYMPHS OR ADULTS WITH JOINTED LEGS
   Go to page 12.

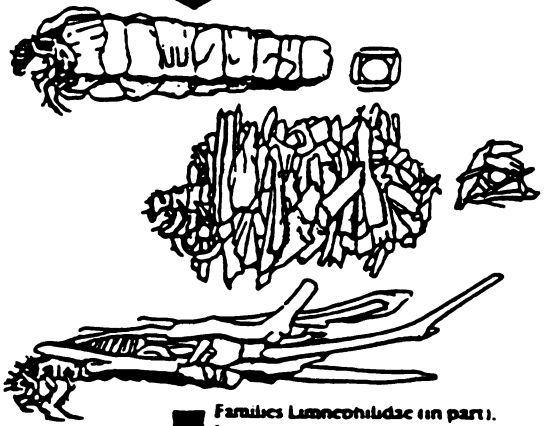
54

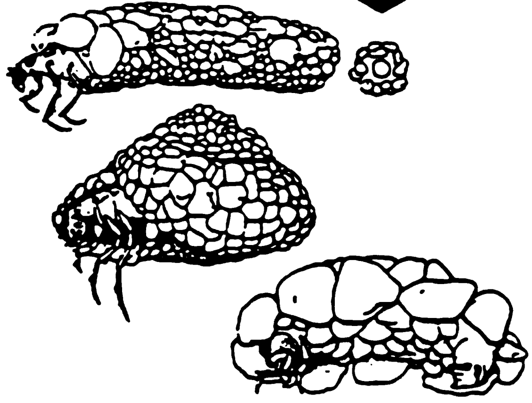
FIRST LEVEL OF RESOLUTION

LARVAE IN PORTABLE CASE
Caddisflies (Order Trichoptera)

CASES ORGANIC
Leaf, stick, needle, bark

CASES MINERAL
Sand, fine gravel





Families Limnephilidae (in part), Lepidostomatidae (in part), Phryganeidae, Leptoceridae (in part)

Families Glossosomatidae, Limnephilidae (in part), Helicopsychidae

SHREDDERS

SCRAPERS

SECOND LEVEL OF RESOLUTION considers a few fairly common caddisflies that would be misclassified above on the basis of case composition alone.

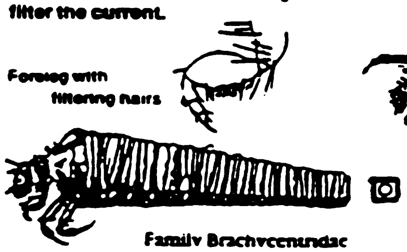
CASES ORGANIC

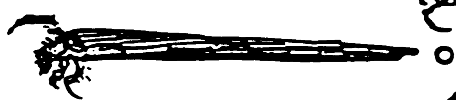
CASES MINERAL

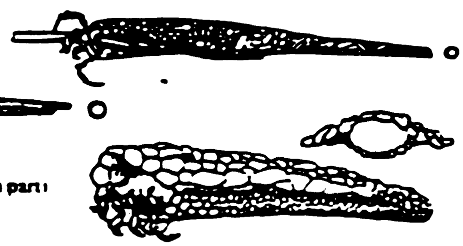
Cases square in cross section and tapered, with no bark or flat leaf pieces included. Front attached to substrate. Larvae extend legs and filter the current.

Cases long, slender, and tapered, made of plant material

Cases long, slender, and tapered (mostly fine sand) or cases ovoid and very flat in cross section







Family Brachycentridae

Family Leptoceridae (in part)

Family Leptoceridae (in part)

FILTERING COLLECTORS

GATHERING COLLECTORS

GATHERING COLLECTORS

FIRST LEVEL OF RESOLUTION

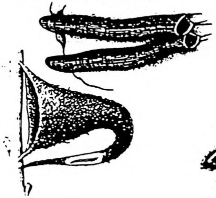
LARVAE WITH FIXED RETREAT AND CAPTURE NET

Note: Care must be taken when collecting to observe nets.

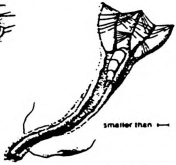
Caddisflies (Order Trichoptera) | True Flies (Order Diptera)

COARSE NET IN "SCAFFOLDING"

FLATTENED SOCK-LIKE OR TRUMPET-SHAPED NET OF FINE MESH



TUBE WITH SILK STRANDS STRUNG BETWEEN TERMINAL PRONGS



True Midges (Family Chironomidae)

Families Hydropsychidae, Philopotamidae, Polycentropodidae

FILTERING COLLECTORS

SECOND LEVEL OF RESOLUTION separates from free living larvae those net spinning caddisflies that may have been inadvertently collected without being associated with their nets.

NET SPINNING CADDISFLIES
Frequently separated from their nets

HEAD AS WIDE AS THORAX

Especially Philopotamidae (bright yellow) and Hydropsychidae (bright green or brown)

FILTERING COLLECTORS

FREE LIVING CADDISFLIES
Non net spinning

HEAD LONG, SMALL, AND NARROWER THAN THORAX

Rhyacophilidae (often bright green)

PREDATORS

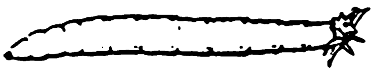
FIRST LEVEL OF RESOLUTION

WORM-LIKE LARVAE WITHOUT JOINTED LEGS

LARGE

larger than

Head retractile and poorly developed
Caudal lobes with eye-like spiracles



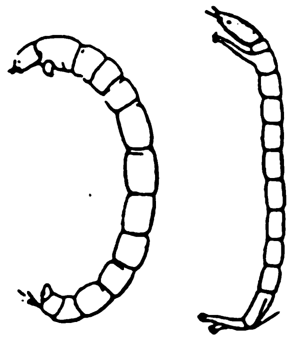
Craneflies (Family Tipulidae in part)

SHREDDERS

SMALL

smaller than

LONG AND SLENDER



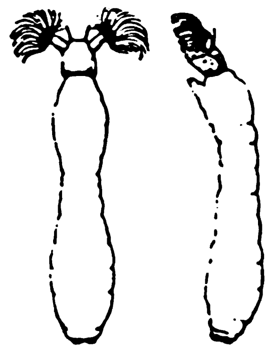
True Midges (Family Chironomidae)

Note: Subtract 10% of count for Predators.

GATHERING COLLECTORS

BOWLING PIN SHAPE

Bulbous base usually fastened tightly to substrate



Blackflies (Family Simuliidae)

FILTERING COLLECTORS

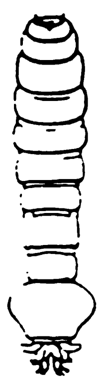
SECOND LEVEL OF RESOLUTION

SECOND LEVEL OF RESOLUTION considers some common worm-like Predators that would be misclassified in the above key.

WORM-LIKE LARVAE WITHOUT JOINTED LEGS

LARGE

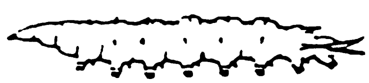
Posterior segment swollen
Head retractile



Family Tipulidae (*Eriocera* type)

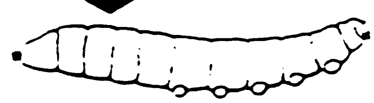
SMALL

Prolegs along entire length
Head visible



Family Athericidae (*Atherix*)

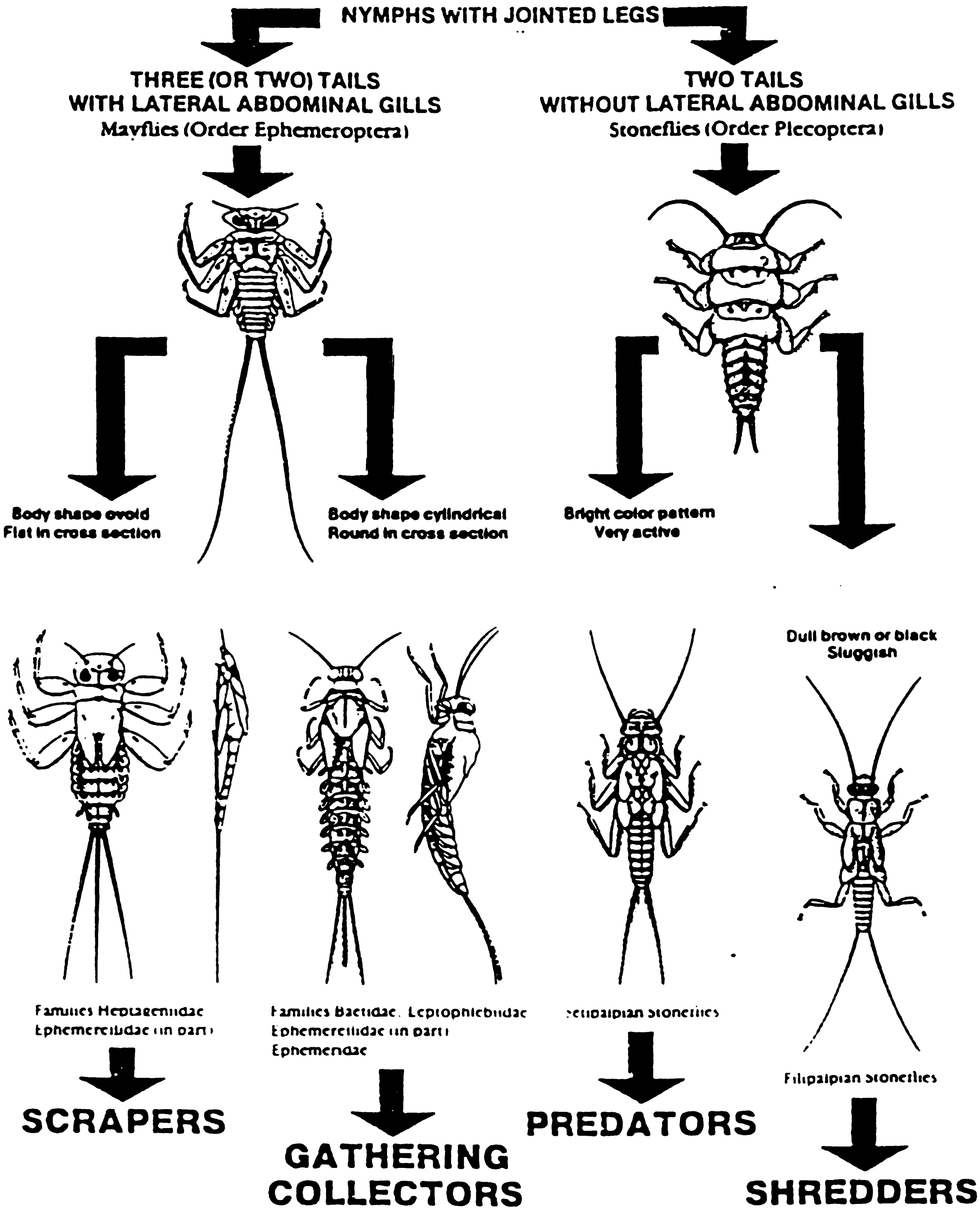
Prolegs poorly developed or absent
Jaws well developed
Very active



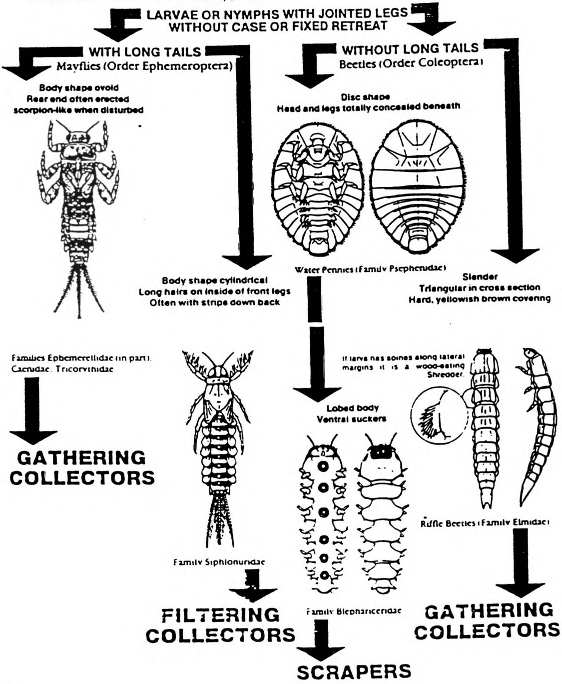
Family Tipulidae (*Dicranota* type)

PREDATORS

FIRST LEVEL OF RESOLUTION



SECOND LEVEL OF RESOLUTION considers some fairly common insects that do not fit in the above key or would be misclassified on the basis of body shape alone.



SCHOOLING BEHAVIOR IN FISH

TO THE STUDENT:

One of the purposes of this lab is to develop an understanding of the scientific method and an appreciation of its practical applications to everyday problem solving.

INTRODUCTION:

Animals may gather in a group for different reasons. If they are attracted to the same spot by the presence of food, light, or some external stimulus, the group is called the aggregate. If, however, they form a group because they are mutually attracted to one another, the group is called a school in the case of fish, and a herd, or flock, in the case of mammals or birds. In fish, vision, swimming movements in the water, and olfaction (sense of smell) may all contribute to keeping the members of the schools together, but vision is the most important cue. Schooling fish seem to be attracted to each other mainly by their appearance, and the attraction is the strongest for other members of the same species. Schooling is a form of communication between members of the same species, but fish of different species do sometimes school together as well.

Schooling is very prevalent among all sorts of fish, from very primitive ones to more advanced species. The members of the school may be better protected from predators than single fish, and they seem to be able to swim more efficiently. A predator in a school has a greater chance of locating food than does a lone predator. For plankton-feeding fish, however, food is always present, and there will be less food for each fish in a school than there would be for a single fish. Members of a school can learn from each other more quickly than a single fish can learn, and they do not have to spend energy locating mates for reproduction.

However, one big disadvantage of schooling behavior is that it has made the human fishing industry very successful and efficient and may ultimately lead to the decline or even extinction of many fish species.

In this experiment you will be testing the role of the visual component in schooling behavior. Because the fish will be separated by a glass barrier, there can be no communication by sound or chemical signals. In many fish vision is the prime factor in the attraction of schooling fish toward each other, but olfaction and sound seem to help maintain the cohesion of an established school. In this lab the problem you will be dealing with specifically is whether brightly marked fish depend more on vision for their schooling cues than do unmarked fish.

HYPOTHESIS:

Write three or more hypotheses dealing with the relationship between dependence on vision and markings on fish. Choose the one which you feel is the best.

MATERIALS:

2 large aquaria per group
4 large beakers per group
10 fish with markings
10 fish without markings
cheesecloth--enough to cover 4 beakers
large rubber bands

CAUTIONS AND PITFALLS

BEHAVIOR EXPERIMENTS WILL NOT WORK UNLESS THE ANIMALS ARE TREATED WITH CARE AND PATIENCE.

DO:

1. Always use a net to transfer the fish.

2. Allow time for the fish to adjust to new conditions before beginning your observations.

3. Wash and rinse your hands before reaching into the experimental tanks to place beakers.

4. Treat fish with care.

5. Report any sick-looking or dead fish to the instructor.

6. Return all fish to the proper tanks when you are finished.

DON'T:

1. Disturb the fish more than necessary for the experiments.

2. Expect the fish to respond instantaneously to a new stimulus.

3. Reach into the stock tanks where the fish are kept.

4. Leave the fish in the experimental apparatus or tanks.

PROCEDURE:

Part 1

Work with a partner and try these tests of schooling behavior. The experimental set-ups are shown in Figure 1 and Figure 2.

Test 1 (Figure 1)

1. Place several fish with markings in a beaker. Cover the beaker with cheesecloth, secure with a rubber band, and immerse the entire beaker slowly in the aquarium. Place it into position on side A of the aquarium.

2. Place an empty beaker on side B to serve as a control.

3. Place a single test fish of the same species in the tank.

4. Use a stopwatch to time the number of seconds spent by the test fish in each half of the tank during a 5 minute period (300 seconds). Record the results on your data sheet.

5. Calculate the percentage of time the test fish spent on side A and on side B.

Question: Did the fish spend more time on side A or side B?

Test 2 (Figure 1)

1. Place two fish in the beaker and repeat the experiment using aa different single test fish of the same species. Record the results.

2. Calculate the percentage of the test period that the fish spent on each side of the tank.

If you have time, repeat the test using different numbers of fish in the beaker and using a different test fish each time.

3. Calculate the percentage of the test period that the fish spent with the school and the percentage that it spent alone.

Question: Did the number of fish in the school affect the tendency of the single test fish to spend time with the school?

Test 3 (Figure 2)

1. Place 3 fish with markings in a beaker on side A of the aquarium and 3 fish of another species without markings in a beaker on side B. Be sure to put the same number of fish in each beaker.

2. Place a single test fish with markings in the center of the aquarium.

3. Use a stopwatch to time how many seconds in a 5 minute period the test fish spends with its own species (section A), with the other species (section B), and alone (section C).

4. Calculate the percentage of time that the test fish spent in each section of the tank.

Question: In which of the 3 sections did the fish spend the most time?

Is there a big difference in the percentaage of time spent with the two species?

Part 2 Visual markings may help fish to identify other members of the same species, but not all schooling fish have prominent markings. Test the schooling tendency of fish without prominent markings in the following experiments and compare your results to those you obtained for the fish with markings.

Test 4 (Figure 1)

1. Place several fish without markings in a beaker on side A of the aquarium, an empty beaker on side B, and a single test fish of the same species free in the aquarium.

2. Use a stopwatch to time the number of seconds spent in each half of the aquarium during the 5 minute period. Record the results.

3. Calculate the percentage of time the test fish spent on side A and on side B.

Question: On which side did the test fish spend more time?

Test 5 (Figure 1)

1. Place 2 fish in the beaker, and repeat the experiments using a different fish of the same species. Record the results.

2. Calculate the percentage of the test period that the fish spent on each side.

If you have time, repeat the test using a different number of fish in the beaker and using a different single fish each time.

3. Calculate the percentage of time the fish spent with the school and alone for each test.

Question: Did the number of fish in the school effect the tendency of the single test fish to swim with the school?

Test 6 (Figure 2)

1. Place 3 fish with markings in a beaker on side A of the aquarium and 3 fish without markings on side B. Be sure to put the same number of fish in each beaker.

2. Place a single test fish without markings in the center of the tank.

3. Use a stopwatch to time how many seconds in a 5 minute period the test fish spends with its own species (section B), with the other species (section A), and alone (section C). Record your results.

4. Calculate the percentage of time that the test fish spent in each section of the tank.

Question:
In which of the 3 sections did the fish spend the most time?

Is there a big difference in the percentage of time spent with each of the 2 species?

Was the test fish more attracted to visual markings or to members of its own species?

RETURN ALL FISH TO THE PROPER TANKS WHEN YOU ARE FINISHED.

DATA:

Construct a data table to record all six tests. Include time spent in zones A, B, and C and the percent time spent in zones A, B, and C.

CONCLUSIONS:

Carefully analyze the data collected. Accept or reject your chosen hypothesis on the basis of the class data. Be sure to explain your accepting or rejecting the hypotheses on the basis of observable and tabulated data.

KEY: $= test fish
&= marked fish
#= unmarked fish

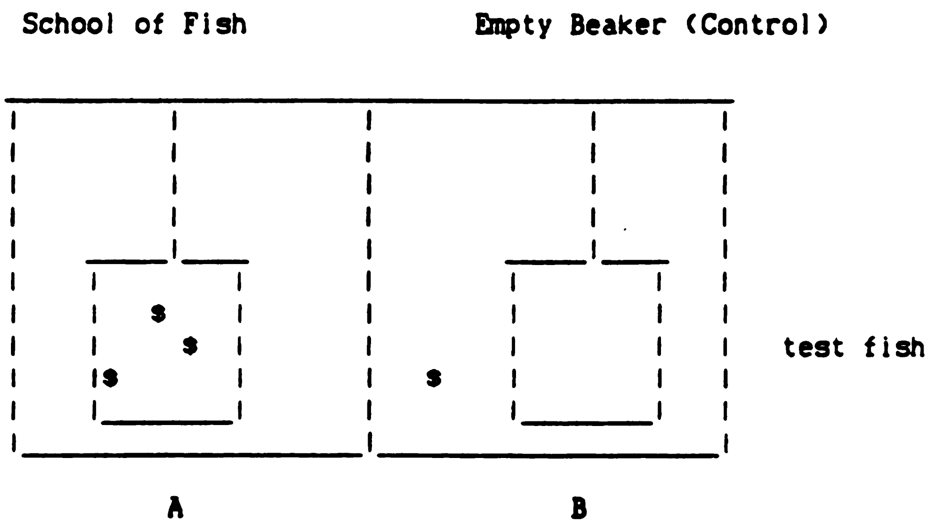


Figure One: Schooling Behavior. In the aquarium setup for testing with one school, a beaker with fish is placed an side A and an empty beaker on side B to serve as an control. The test fish is free to swim throughout the aquarium

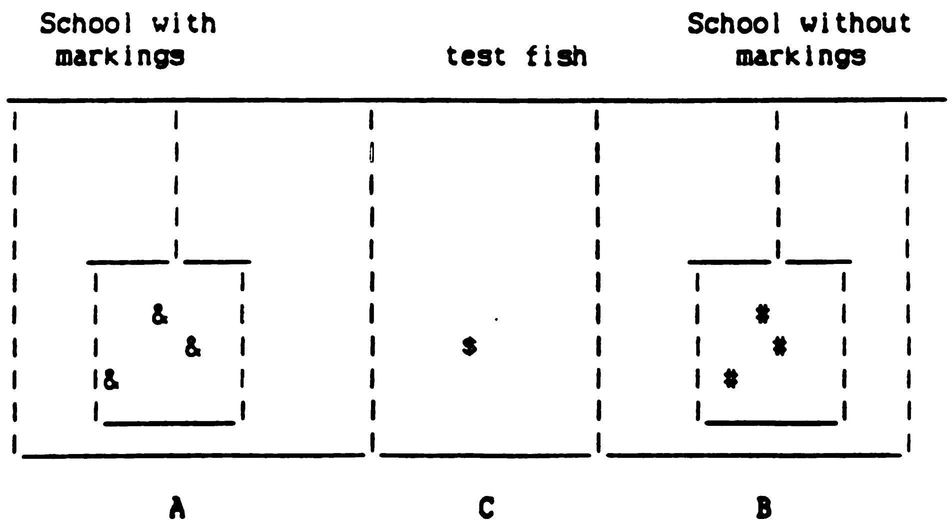


Figure Two: Schooling behavior. When two schools are used, the aquarium is divided into three parts. A school of one species is placed on side A and a school of another species on side B. The free test fish can choose school A, school B, or neither school.

LIMITING FACTORS FOR ALGAE

TO THE STUDENT:

One of the purposes of this lab is to develop an understanding of the scientific method and an appreciation of its practical applications to everyday problem solving.

INTRODUCTION:

Phosphorus (P) and nitrogen (N) are necessary nutrients for the growth of any plant life. The production of carbohydrates, through photosynthesis, does not in itself satisfy the needs of plant cells. Various fats and proteins must be formed from carbohydrates to furnish the additional components needed for life. Phosphorus and nitrogen enable this to take place. But, if either of these nutrients is in short supply, it becomes a limiting factor, retarding further growth. This is Liebig's Law of the Minimum.

In this experiment you will be testing this law using a solution of nutrient fertilizer in varying concentrations and a suspension of algal cells from an aquarium. The problem you will be dealing with is the amount of growth in each concentration of fertilizer (containing both P and N). You will be graphing your results.

HYPOTHESIS:

Write three or more hypotheses dealing with the relationship between the growth of the population of algae and the concentration of fertilizer. Choose the one which you feel is the best.

MATERIALS:

Dropper
7 bottles
teaspoon
tablespoon
suspension of green aquarium scum
liquid plant fertilizer
distilled water
half-inch pieces of chalk
Spec 20 and cuvettes

CAUTIONS AND PITFALLS:

1. Be sure to mark the bottles and tubes accurately with numbers 1--7 and DO NOT mix them up.

2. It will help if each week you will rotate the bottles so that all sides are exposed to sunlight.

PROCEDURE:

1. Set up 7 bottles each containing a piece of chalk and 10 drops of the aquarium scum. This scum is the source of the algae colonies. Label eacn bottle with 1-7.

2. Fill the bottles according to the following chart:

BOTTLE	AMT FERTILIZER	AMT. H_2O
1	full	none
2	5 tablespoons	fill
3	1 tablespoon	fill
4	1 teaspoon	fill
5	20 drops	fill
6	2 drops	fill
7	none	fill

3. Place a cover over each bottle and place them in the sun.

4. At the end of each week swirl each bottle and withdraw enough of the colony to fill a cuvette tube which is marked with the same number as the bottle.

5. Using the Spec 20, measure the absorbance/ transmittance of each tube and record in your data table. Use a wavelength setting of 430.

6. Return the material from each tube to the bottle from which it came. BE SURE NOT TO GET THE TUBES AND BOTTLES MIXED UP.

7. At the end of five weeks graph the absorbance against the time for eacn colony. Use a different color for each colony (bottle).

CONCLUSIONS:

Carefully analyze the data collected. Accept or reject your chosen hypothesis on the basis of the class data. Be sure to explain your accepting or rejecting the hypothesis on the basis of observable and tabulated data.

TEMPERATURE AS A FACTOR IN DETERMINING DISSOLVED OXYGEN

TO THE STUDENT:

One of the purposes of this lab is to develop an understanding of the scientific method and an appreciation of its practical applications to everyday problem solving.

INTRODUCTION:

Water quality is essential to many forms of life other than mankind. Land and aquatic organisms all depend on water for survival. There are many ways to test for water quality, just as there are many different kinds of water systems to test, such as lakes, rivers, and streams. In doing this laboratory exercise you will be performing a task similar to those used by water researchers and scientists: collecting data and interpreting the results.

You will be testing for the amount of dissolved oxygen, abbreviated D.O. Dissolved oxygen is essential to the metabolism of all aerobic aquatic organisms. Therefore, the concentration of DO is a direct indicator of the distribution, behavior, and growth of aquatic organisms.

The factors that control dissolved oxygen concentration are important in determining oxygen availability to these creatures. The rates of oxygen input (atmospheric, photosynthetic, and wave action) are counterbalanced by oxygen output (metabolism and respiration). The rate of this oxygen use allows for the evaluation of the metabolism of fresh water organisms.

The problem you will deal with in this lab is the effect of water temperature on the concentration of dissolved oxygen.

HYPOTHESIS:

Write three or more hypotheses for the problem of the relationship between temperature and concentration of dissolved oxygen. Choose the one which you feel is the best.

MATERIALS:

Ring stand
Ring
Wire gauze
Bunsen burner
Beaker tongs
1 beaker 400-500 ml
2 beakers 100 ml
Thermometer
DO Hach kit

CAUTIONS AND PITFALLS:

Be sure to eliminate all air bubbles in bottles before shaking.

Bottles must be thoroughly rinsed before continuing.

Keep PAO dropper vertical to maintain proper drop size.

PROCEDURE:

1. Follow all steps according to the Hach kit manual for each sample to determine DO. All readings will be taken at 10 C intervals. The flocculent (woolly) precipitate may be flushed down the sink with copious amounts of water.

2. Remove 350 ml of the sample to be tested. Place the thermometer in the beaker: wait one minute and record the temperature. Re-read "Cautions and Pitfalls". Now take the concentration of dissolved oxygen. Record. Rinse bottle thoroughly.

3. Heat the remaining sample on the ring stand until a temperature increase of 10 C is achieved. Take the DO concentration and record both temperature and DO. This is trial 2.

4. Repeat step 3 until you have 6 readings. Be sure to rinse bottle thoroughly between each step.

DATA:

Make a data table to include the temperature and concentration of DO for each of the 6 trials.

Graph your results using temperature on the X axis (horizontal) and DO concentration on the Y axis (vertical).

CONCLUSIONS:

Carefully analyze the data collected. Accept or reject your chosen hypothesis on the basis of the class data. Be sure to explain your accepting or rejecting the hypotheses on the basis of observable and tabulated data.

QUESTIONS:

1. Why is it important to be sure there are no air bubbles in the sample bottle?

2. What is the purpose of rinsing the bottle thoroughly before making more tests?

3. According to your data and graph, was there one 10 C interval that had a much greater/smaller change than the other 5? Suggest a reason for this.

4. By extrapolation of your graph, determine the concentration of DO at the boiling point (100 C)

5. Suggest two other inorganic factors that may influence the level of DO and discuss how they might effect the DO content. (Hint: most inorganic factors are also in the water.)

APPENDIX C

STUDENT TESTS

PRETEST-ECOLOGY NAME________________
TOWNSEND

1. _____OF ALL THE SUN'S ENERGY THAT REACHES THE EARTH. THE AMOUNT USED BY LIVING THINGS IS APPROXIMATELY (A) 0.1 PERCENT (B) 1.0 PERCENT (C) 5.0 PERCENT (D) 10. PERCENT

2. _____THE SERIES IN WHICH A LARGE FISH HAS EATEN A SMALLER FISH THAT HAS EATEN ALGAE IS A (A) FOOD CHAIN (B) FOOD WEB (C) ENERGY PYRAMID (D) BIOMASS PYRAMID

3. _____DECOMPOSERS CAUSE THINGS TO ROT. ARE THEY BENEFICIAL OR HARMFUL TO THE ENVIRONMENT? (A) BENEFICIAL (B) HARMFUL (C) (D)

4. _____WHICH OF THE FOLLOWING WOULD MOST LIMIT THE GROWTH OR NUMBERS OF ORGANISMS THAT LIVE IN WATER? (A) OXYGEN (B) CARBON DIOXIDE (C) LIGHT (D) TEMPERATURE CHANGES

5. _____ WHICH WOULD CONTAIN MORE DISSOLVED OXYGEN? (A) FAST-FLOWING BROOK (B) SLOW-MOVING STREAM (C) POND (D) LAKE

6. _____WHICH WATER TYPE WOULD HAVE MORE OXYGEN? (A) COLD WATER (B) WARM WATER (C) HOT WATER (D) ALL THE SAME

7. _____WHICH ORGANISM WOULD BE MOST AFFECTED BY A LACK OF CALCIUM? (A) CLAM (B) FISH (C) LEECH (D) ALGAE

8. _____THE COMBINATION OF ALL THE LIVING AND NONLIVING THINGS WITHIN AN ENVIRONMENT IS KNOWN AS A(N) (A) ECOSYSTEM (B) BIOSPHERE (C) ABIOTC (D) BIOTIC

9. _____WHICH OF THE FOLLOWING PROCESSES IS INVOLVED WITH OXYGEN PRODUCTION? (A) RESPIRATION (B) PHOTOSYNTHESIS (C) DIGESTION (D) FERMENTATION

10. _____WHAT TYPE OF ORGANISM PRODUCES OXYGEN (A) BACTERIA (B) ANIMAL (C) PLANT (D) ALL OF THESE

11. _____PHOTOSYNTHESIS IS AN ESSENTIAL STAGE IN (A) THE CARBON CYCLE ONLY (B) THE OXYGEN CYCLE ONLY (C) BOTH THE CARBON AND OXYGEN CYCLE (D) NEITHER CARBON NOR OXYGEN CYCLE

12. _____WHICH ORGANISM WOULD YOU EXPECT TO FIND IN WATER THAT IS LOW IN OXYGEN? (A) TROUT (B) PERCH (C) CARP (D) SNAILS

13. _____UNLIKE MATTER, ENERGY (A) CAN BE RECYCLED (B) CAN NOT BE RECYCLED (C) CAN BE TRANSFERRED (D) CAN NOT BE TRANSFERRED

14. _____OF THE FOOD A PERCH EATS, WHAT PERCENT BECOMES ACTUAL STORED ENERGY? (A) 1 (B) 5 (C) 10 (D) 50

15. _____WHEN MOVING THROUGH A FOOD CHAIN, THE ANIMAL FARTHEST FROM THE PRODUCER USUALLY (A) HAVE THE MOST BIOMASS (B) ARE LARGEST IN NUMBER (C) RECEIVE THE MOST ENERGY (D) RECEIVE THE LEAST ENERGY

16. _____THE MOST COMMOM PROCESS FOR PRODUCING CARBON DIOXIDE IS (A) RESPIRATION (B) PHOTOSYNTHESIS (C) FERMENTATION (D) DIGESTION

17. _____WHICH WOULD YOU EXPECT TO FIND IN WATER THAT IS HIGH IN OXYGEN? (A) TROUT (B) PERCH (C) CARP (D) SNAILS

18. _____WHEN AN ORGANISM DIES, ITS MATTER (A) DISAPPEARS (B) IS LOST (C) IS RECYCLED (D) REMAINS TRAPPED

19. _____WHICH OF THE FOLLOWING WOULD BE A PRIMARY CONSUMER? (A) OAK TREE (B) FOX (C) COW (D) BACTERIA

20. _____WHAT IS THE ORIGINAL SOURCE OF ENERGY FOR ALL LIVING THINGS? (A) FOOD (B) LIGHT (C) HEAT (D) ELECTRICITY

21. _____WHAT KIND OF ORGANISM PRODUCES CARBONDIOXIDE? (A) PLANTS (B) ANIMALS (C) BACTERIA (D) ALL OF THESE

22. _____WHICH ONE OF THE FOLLOWING WOULD BE CONSIDERED A SECONDARY CONSUMER? (A) MAPLE TREE (B) RABBIT (C) FOX (D) BACTERIA

23. _____WHICH OF THE FOLLOWING WOULD HAVE MORE BIOMASS IN THE SAME ECOSYSTEM? (A) PRODUCERS (B) PRIMARY CONSUMERS (C) SECONDARY CONSUMERS (D) TERTIARY CONSUMERS

24. _____WHICH OF THE FOLLOWING IS A PRODUCER? (A) OAK TREE (B) SQUIRREL (C) HORSE (D) BACTERIA

25. _____ALL NUTRIENTS MOVE THROUGH THE ECOSYSTEM IN (A) BIOGEOCHEMICAL CYCLES (B) WATER CYCLES (C) CARBON CYCLES (D) OXYGEN CYCLES

26. _____PCB, A TOXIC WASTE, HAS BEEN FOUND IN FRESH WATER ORGANISMS. WHICH OF THE FOLLOWING WOULD MOST LIKELY HAVE THE HIGHEST CONCENTRATION? (A) BASS (B) WATER FLEA (DAPHNIA) (C) MAYFLY (D) MINNOW

27. _____THE POINT OF ORIGIN OF A RIVER IS KNOWN AS (A) WATERSHED (B) GROUNDWATER (C) TROPHIC LEVEL (D) BIOSPHERE

28. _____A SHREW, THAT HAS EATEN A GRASSHOPPER AND SOME GRAIN, WAS EATEN BY A FOX THAT HAS ALSO EATEN A RABBIT. THIS IS AN EXAMPLE OF A (A) FOOD WEB (B) FOOD CHAIN (C) ENERGY PYRAMID (D) ECOSYSTEM

POST-TEST ECOLOGY NAME________________
TOWNSEND

1. _____ONE OF THE FOLLOWING IS NOT AN ECOLOGICAL PYRAMID (A) CONSUMER (B) BIOMASS (C) ENERGY (D) NUMBER

2. _____AS THE TEMPERATURE INCREASES, THE AMOUNT OF DISSOLVED OXYGEN (A) INCREASES (B) STAYS THE SAME (C) DECREASES (D) FLUCTUATES BACK AND FORTH

3. _____ALL NUTRIENTS MOVE THROUGH THE ECOSYSTEM IN (A) WATER CYCLES (B) BIOGEOCHEMICAL CYCLES (C) CARBON CYCLES (D) OXYGEN CYCLES

4. _____PCB, A TOXIC WASTE, HAS BEEN FOUND IN FRESH WATER ORGANISMS. WHICH OF THE FOLLOWING WOULD MOST LIKELY HAVE THE HIGHEST CONCENTRATION? (A) MINNOW (B) WATER FLEA (DAPHNIA) (C) MAYFLY (D) BASS

5. _____WHICH OF THE FOLLOWING WOULD HAVE MORE BIOMASS IN THE SAME ECOSYSTEM? (A) PRIMARY CONSUMERS (B) PRODUCERS (C) SECONDARY CONSUMERS (D) TERTIARY CONSUMERS

6. _____WHEN MOVING THROUGH A FOOD CHAIN, THE ANIMAL FARTHEST FROM THE PRODUCER USUALLY (A) HAVE THE MOST BIOMASS (B) ARE LARGEST IN NUMBER (C) RECEIVE THE LEAST ENERGY (D) RECEIVE THE MOST ENERGY

7. _____ WHICH WOULD CONTAIN MORE DISSOLVED OXYGEN? (A) LAKE (B) SLOW-MOVING STREAM (C) POND (D) FAST-FLOWING BROOK

8. _____OF THE FOOD A PERCH EATS, WHAT PERCENT BECOMES ACTUAL STORED ENERGY? (A) 1 (B) 10 (C) 5 (D) 50

9. _____THE SERIES IN WHICH A LARGE FISH HAS EATEN A SMALLER FISH THAT HAS EATEN ALGAE IS A (A) BIOMASS PYRAMID (B) FOOD WEB (C) ENERGY PYRAMID (D) FOOD CHAIN

10. _____THE PROCESS BY WHICH BACTERIA IN THE ROOTS OF PEAS AND BEANS CHANGE FREE NITROGEN INTO NITROGEN COMPOUNDS IS (A) NITROGEN FIXATION (B) THE NITROGEN PYRAMID (C) DENITRIFICATION (D) THE NITROGEN CYCLE

11. _____THE COMBINATION OF ALL THE LIVING AND NONLIVING THINGS WITHIN AN ENVIRONMENT IS KNOWN AS A(N) (A) BIOSPHERE (B) ECOSYSTEM (C) ABIOTC (D) BIOTIC

12. _____WHICH OF THE FOLLOWING WOULD BE A PRIMARY CONSUMER? (A) OAK TREE (B) FOX (C) BACTERIA (D) COW

13. _____WHAT IS THE ORIGINAL SOURCE OF ENERGY FOR ALL LIVING THINGS? (A) FOOD (B) HEAT (C) LIGHT (D) ELECTRICITY

POST-TEST ECOLOGY
TOWNSEND

14. _____THE MOST COMMOM PROCESS FOR PRODUCING CARBON DIOXIDE IS (A) DIGESTION (B) PHOTOSYNTHESIS (C) FERMENTATION (D) RESPIRATION

15. _____WHICH OF THE FOLLOWING IS A PRODUCER? (A) SQUIRREL (B) OAK TREE (C) HORSE (D) BACTERIA

16. _____DECOMPOSERS CAUSE THINGS TO ROT. ARE THEY BENEFICIAL OR HARMFUL TO THE ENVIRONMENT? (A) (B) HARMFUL (C) (D) BENEFICIAL

17. _____WHICH OF THE FOLLOWING PROCESSES IS INVOLVED WITH OXYGEN PRODUCTION? (A) RESPIRATION (B) DIGESTION (C) PHOTOSYNTHESIS (D) FERMENTATION

18. ______FOR ORGANISMS TO SURVIVE IN THE THORNAPPLE RIVER. THE pH SHOULD BE AROUND (A) 5 (B) 9 (C) 7 (D) 10

19. ____A PRODUCER-CONSUMER RELATIOSHIP IS BEST ILLUSTRATED BY (A) FOXES EATING MICE (B) LEAVES GROWING ON TREES (C) RABBITS EATING CLOVER (D) TAPEWORM LIVING IN FOXES

20. _____PLANT-EATING ANIMALS ARE KNOWN AS (A) HERBAVORES (B) CARNIVORES (C) DECOMPOSERS (D) PRODUCERS

21. _____THE POINT OF ORIGIN OF A RIVER IS KNOWN AS (A) GROUNDWATER (B) WATERSHED (C) TROPHIC LEVEL (D) BIOSPHERE

22. _____WHICH ONE OF THE FOLLOWING WOULD BE CONSIDERED A SECONDARY CONSUMER? (A) MAPLE TREE (B) RABBIT (C) BACTERIA (D) FOX

23. _____WHICH OF THE FOLLOWING IS NOT AN ABIOTIC FACTOR (A) RAINFALL (B) TEMPERATURE (C) WATER (D) DECOMPOSERS

24. _____OF ALL THE SUN'S ENERGY THAT REACHES THE EARTH. THE AMOUNT USED BY LIVING THINGS IS APPROXIMATELY (A) 10. PERCENT (B) 1.0 PERCENT (C) 5.0 PERCENT (D) 0.1 PERCENT

25. _____PHOTOSYNTHESIS IS AN ESSENTIAL STAGE IN (A) THE CARBON CYCLE ONLY (B) THE OXYGEN CYCLE ONLY (C) NEITHER CARBON NOR OXYGEN CYCLE (D) BOTH THE CARBON AND OXYGEN CYCLE

26. _____WHEN AN ORGANISM DIES. ITS MATTER (A) DISAPPEARS (B) IS RECYCLED (C) IS LOST (D) REMAINS TRAPPED

27. _____ANOTHER NAME FOR AN AUTOTROPH WOULD BE (A) BIOTIC (B) CONSUMER (C) DECOMPOSER (D) PRODUCER

POST-TEST ECOLOGY
TOWNSEND

28. _____A SHREW. THAT HAS EATEN A GRASSHOPPER AND SOME GRAIN. WAS EATEN BY A FOX THAT HAS ALSO EATEN A RABBIT. THIS IS AN EXAMPLE OF A (A) FOOD CHAIN (B) FOOD WEB (C) ENERGY PYRAMID (D) ECOSYSTEM

29. _____WHICH ORGANISM WOULD BE MOST AFFECTED BY A LACK OF CALCIUM? (A) FISH (B) CLAM (C) LEECH (D) ALGAE

30. _____WHAT KIND OF ORGANISM PRODUCES CARBONDIOXIDE? (A) PLANTS (B) ANIMALS (C) ALL OF THESE (D) BACTERIA

31. _____WHICH OF THE FOLLOWING IS THE CORRECT FLOW OF ENERGY THROUGH AN ECOSYSTEM? (A) CONSUMER->SUN->PRODUCER (B) SUN->PRODUCER->CONSUMER (C) SUN->CONSUMER->DECOMPOSER (D) DECOMPOSER->PRODUCER->CONSUMER

32. _____IN THE NITROGEN CYCLE. BACTERIA THAT LIVE ON THE ROOTS OF LEGUMES (A) BREAK DOWN NITROGEN COMPOUNDS INTO FREE NITROGEN (B) DENITRIFY NITROGEN COMPOUNDS (C) CHANGE FREE NITROGEN INTO NITROGEN COMPOUNDS (D) CHANGE FREE NITROGEN INTO PLANT PROTEINS

33. _____A CLIMAX COMMUNITY IS DETERMINED BY THE (A) TEMPERATURE AND RAINFALL (B) LATITUDE AND CLIMATE (C) MAJOR FORMS OF PLANT LIFE (D) MAJOR FORMS OF ANIMAL LIFE

34. _____UNLIKE MATTER. ENERGY (A) CAN BE RECYCLED (B) CAN BE TRANSFERRED (C) CAN NOT BE RECYCLED (D) CAN NOT BE TRANSFERRED

35. _____WHAT TYPE OF ORGANISM PRODUCES OXYGEN (A) BACTERIA (B) ANIMAL (C) ALL OF THESE (D) PLANT

36. _____IN A FOOD CHAIN. HERBIVORES ARE KNOWN AS (A) SECONDARY CONSUMERS (B) PRODUCERS (C) CARNIVORES (D) PRIMARY CONSUMERS

37. _____WHICH WATER TYPE WOULD HAVE MORE OXYGEN? (A) ALL THE SAME (B) WARM WATER (C) HOT WATER (D) COLD WATER

38. _____WHICH OF THE FOLLOWING WOULD MOST LIMIT THE GROWTH OR NUMBERS OF ORGANISMS THAT LIVE IN WATER? (A) CARBON DIOXIDE (B) OXYGEN (C) LIGHT (D) TEMPERATURE CHANGES

39. _____WHICH WOULD YOU EXPECT TO FIND IN WATER THAT IS HIGH IN OXYGEN? (A) SNAILS (B) PERCH (C) CARP (D) TROUT

40. _____WHICH ORGANISM WOULD YOU EXPECT TO FIND IN WATER THAT IS LOW IN OXYGEN? (A) TROUT (B) PERCH (C) SNAILS (D) CARP

MATCHING NAME________________

1. _____THE PLANTS AND THE ANIMALS OF AN ECOSYSTEM MAKE UP WHICH KIND OF FACTORS?

2. _____CONSISTS OF ALL THE LIVING AND NONLIVING FACTORS THAT SURROUND AN ORGANISM

3. _____THE PATHWAY OF FOOD IN AN ECOSYSTEM

4. _____NUTRIENTS MOVE THROUGH THE BIOSPHERE IN A SERIES OF PHYSICAL AND BIOLOGICAL PROCESSES CALLED THIS.

5. _____BACTERIA AND FUNGI ACT AS THESE IN A FOOD WEB

6. _____A TURTLE ATE A MINNOW THAT ATE SOME ALGAE. THE MINNOW IS A

7. _____THE STUDY OF THE INTERACTIONS OF ORGANISMS WITH ONE ANOTHER AND THEIR PHYSICAL SURROUNDINGS.

8. _____THE NITROGEN CYCLE. THE WATER CYCLE AND THE CO_2-O_2 CYCLE ARE ALL WHAT KIND OF FACTORS?

9. _____TROPHIC LEVEL THAT UNDERGOES PHOTOSYNTHESIS TO MAKE THEIR OWN FOOD

10. _____ALSO KNOWN AS A FEEDING LEVEL

11. _____THE INTERACTION OF PRODUCERS AND MANY DIFFERENT COMSUMERS

12. _____A SNAKE EATS A FROG THAT HAS EATEN A GRASSHOPPER. THE SNAKE IS A

13. _____A NUTRIENT THAT CAN PREVENT THE GROWTH OF AN ORGANISM

14. _____AN OWL ATE A RAT THAT ATE A GRASSHOPPER. THE RAT IS A

15. _____THE PROCESS OF AN EXISTING COMMUNITY BEING GRADUALLY REPLACED BY ANOTHER COMMMUNITY

MATCHING

1. TROPHIC LEVEL
2. LIMITING FACTOR
3. ECOSYSTEM
4. FOOD CHAIN
5. BIOTIC
6. ECOLOGY
7. DECOMPOSER
8. ABIOTIC
9. PRODUCERS
10. FOOD WEB
11. BIOGEOCHEMICAL CYCLES
12. PRIMARY CONSUMER
13. TERTIARY CONSUMER
14. SECONDARY CONSUMER
15. ECOLOGICAL SUCCESSION

ESSAY/SHORT ANSWER
PUT ON SEP. SHEET

NAME________________

1. WHY IS SUNLIGHT NEEDED TO MAINTAIN AN ECOSYSTEM?

2. DISCUSS SOME LIMITING FACTORS IN THE THORNAPPLE RIVER.

3. TRACE THE PATH OF NITROGEN THROUGH THE NITROGEN CYCLE.

4. EXPLAIN WHY EACH TROPHIC LEVEL IN A FOOD CHAIN CONTAINS LESS ENERGY THAN THE LEVEL BELOW IT.

5. DESCRIBE THE WATER CYCLE.

6. WHAT IS THE IMPORTANCE OF THE WATERSHED FOR THORNAPPLE RIVER?

7. GIVE AT LEAST FIVE BIOTIC FACTORS AND DESCRIBE THREE ABIOTIC FACTORS IN THE THORNAPPLE RIVER.

8. WHY IS IT MORE ENERGY EFFICIENT FOR PEOPLE TO EAT PLANTS INSTEAD OF ANIMALS?

9. DESCRIBE THE RELATIONSHIP BETWEEN THE CARBON AND OXYGEN CYCLES.

10. AFTER ALL WE HAVE LEARNED IN CLASS ABOUT POLLUTION INDICATORS. GIVE ME YOUR INFORMED OPINION ON HOW POLLUTED THE THORNAPPLE RIVER IS.

APPENDIX D

ATTITUDE SURVEY

OPINION SURVEY ABOUT SCIENCE

Science							
1.	Strange	1	2	3	4	5	Familiar
2.	Good	1	2	3	4	5	Bad
3.	Dull	1	2	3	4	5	Fun
4.	Interesting	1	2	3	4	5	Boring
5.	Easy	1	2	3	4	5	Difficult
6.	Unimportant	1	2	3	4	5	Important
7.	Career	1	2	3	4	5	Hobby
Laboratory Activities							
8.	Strange	1	2	3	4	5	Familiar
9.	Good	1	2	3	4	5	Bad
10.	Dull	1	2	3	4	5	Fun
11.	Interesting	1	2	3	4	5	Boring
12.	Easy	1	2	3	4	5	Difficult
13.	Unimportant	1	2	3	4	5	Important
14.	Dangerous	1	2	3	4	5	Safe
Working in Teams to Solve Problems in Class							
15.	Good	1	2	3	4	5	Bad
16.	Strange	1	2	3	4	5	Familiar
17.	Unimportant	1	2	3	4	5	Important
18.	Dull	1	2	3	4	5	Fun
19.	Useful	1	2	3	4	5	Wasteful
20.	Busy	1	2	3	4	5	Quiet
21.	Difficult	1	2	3	4	5	Easy
Scientific Method							
22.	Strange	1	2	3	4	5	Familiar
23.	Good	1	2	3	4	5	Bad
24.	Dull	1	2	3	4	5	Fun
25.	Interesting	1	2	3	4	5	Boring
26.	Easy	1	2	3	4	5	Difficult
27.	Unimportant	1	2	3	4	5	Important
28.	Useful	1	2	3	4	5	Unnecessary
Waste Recycling							
29.	Strange	1	2	3	4	5	Familiar
30.	Good	1	2	3	4	5	Bad
31.	Important	1	2	3	4	5	Unimportant
32.	Easy	1	2	3	4	5	Difficult
33.	Necessary	1	2	3	4	5	Unnecessary

Lawn Fertilizing

34.	Strange	1	2	3	4	5	Familiar
35.	Good	1	2	3	4	5	Bad
36.	Permanent	1	2	3	4	5	Temporary
37.	Easy	1	2	3	4	5	Difficult
38.	Necessary	1	2	3	4	5	Unnecessary
39.	Dangerous	1	2	3	4	5	Safe

Hunting

40.	Strange	1	2	3	4	5	Familiar
41.	Good	1	2	3	4	5	Bad
42.	Dull	1	2	3	4	5	Fun
43.	Interesting	1	2	3	4	5	Boring
44.	Easy	1	2	3	4	5	Difficult
45.	Unimportant	1	2	3	4	5	Important
46.	Career	1	2	3	4	5	Hobby

Wildlife Management

47.	Strange	1	2	3	4	5	Familiar
48.	Good	1	2	3	4	5	Bad
49.	Dull	1	2	3	4	5	Fun
50.	Interesting	1	2	3	4	5	Boring
51.	Easy	1	2	3	4	5	Difficult
52.	Unimportant	1	2	3	4	5	Important
53.	Career	1	2	3	4	5	Hobby

Clearcutting forests (this means clearing part of a forest by cutting all the trees down.)

54.	Good	1	2	3	4	5	Bad
55.	Strange	1	2	3	4	5	Familiar
56.	Unnecessary	1	2	3	4	5	Necessary
57.	Ugly	1	2	3	4	5	Beautiful
58.	Useful	1	2	3	4	5	Wasteful
59.	Permanent	1	2	3	4	5	Temporary
60.	Safe	1	2	3	4	5	Dangerous

Our Local Rivers

61.	Polluted	1	2	3	4	5	Clean
62.	Beautiful	1	2	3	4	5	Ugly
63.	Important	1	2	3	4	5	Unimportant
64.	Drinkable	1	2	3	4	5	Undrinkable
65.	Uninhabited	1	2	3	4	5	Inhabited

APPENDIX E

STUDENT SIMULATION HANDOUTS

BIOLOGY PREDATOR-PREY GAME
OWLS AND MICE

INTRODUCTION:

Animals spend much of their time looking for and consuming food. Some eat plants, some eat meat, and some eat both. Many meat-eating animals obtain their meat by hunting other animals. The hunters are known as predators and the hunted animals are known as prey.

In this activity you will do a simulation of a predator-prey relationship, with owls as predators and mice as prey. In nature, owls and mice are often found living in forests. The forest in your simulation will be HOOT WOODS.

Owls are excellent hunters. The various kinds of owls eat many different kinds of animals, including rabbits, squirrels, rats, mice, shrews, birds, fish. and insects. To simplify the simulation, you will limit the owls' food supply to mice.

PROCEDURE:

Using masking tape, mark off a square approximately 50 cm on a side on the surface of your lab table. This square represents Hoot Woods, where the mice and owls live.

You will simulate 25 generations of owls and mice. The mice can be eaten and the owls can starve. Surviving mice and owls can reproduce. To make calculations easier, each surviving mouse will be considered capable of producing one offspring. In each generation, the surviving mouse population will double to form the next generation. For example, if six mice are living in the woods and two are caught by an owl, then four mice will survive. These four mice will each produce one offspring, and the next generation will begin with eight mice. Remember, the number of offspring is always the same as the number of surviving mice. At any one time, the maximum mouse capacity of Hoot Woods is 400 mice.

In order to survive, each owl must catch at least three mice in every generation. If an owl does not catch three mice, it will starve. For each three mice that an owl catches, it will reproduce one offspring. For example, if an owl catches eight mice it will reproduce two new owls, making a total of three owls to begin the next generation.

At the beginning of EACH generation there must be at least three mice and one owl in the woods. If the populations drop below these numbers (by being eaten or starving), new mice and owls will migrate in. For example, if just one mouse survives the first generation, just one offspring will be produced, for a total of two mice. One mouse must migrate in to bring the mice total to three. If all owls die, one owl must migrate in.

PLAY:

Place the mouse squares at random in Hoot Woods. Then, from a height of about 30 cm, drop the owl square into the woods. Try to hit as many mice as you can in one drop. When an owl square fully or partly covers a mouse square(s), that is a "catch". If there is more than one owl in a generation, drop the owl square once for each owl.

Remove and count the number of mice CAUGHT BY EACH OWL AT EACH DROP. Keep all mice from each owl catch in separate stacks. Record the data on your chart. You will want to have different people do the dropping and the recording.

EXAMPLE:

Suppose generation 3 begins with 20 mice and 2 owls. You make a drop for the first owl and catch 7 mice. On the second drop, the second owl catches only 2 mice. The owls have caught a total of 9 mice. There are 11 mice left in Hoot Woods, and they reproduce 11 mice. The next generation will start with 22 mice. Because the first owl caught 7 mice, it reproduces 2 offspring for the next generation. The second owl caught only 2 mice; it starves and does not survive or reproduce. The data chart line for that generation would look like this:

Gen.	No. Mice Start	No. Owls Start	No. Mice Caught	No. Owls Starved	No. Surviving Mice + Offspring	No. Surviving Owls + Offspring
3	20	2	9	1	11+11=22	1+2=3
4	22	3				

ANALYSIS:

1. Which population first increases in size?

2. Describe the pattern of the fluctuations in the sizes of the two populations.

3. By looking ONLY at the graph, can you tell which species is the prey and which species is the predator? How can you tell?

4. Which species gets to the largest number of individuals? Why?

5. What do you think would happen to the mouse population in Hoot Woods if the owls were all hunted to extinction? Why?

6. Prepare a line graph of the number of mice in each generation and in a different color the number of owls in each generation