Bears of the Moss (and Lichen) Activity #1
Adaptation is the Key to Survival

Overview: This cooperative learning activity introduces students to a taxon of microscopic organism that lives on epiphytes and the physiological changes that this organism undergoes when exposed to extreme environmental conditions. This activity is most effective as an introduction to the *Identifying Tardigrade* lesson plan.

Objectives: The students will learn about the four main states that tardigrades enter into due to environmental conditions. They will learn about: 1) normal tardigrade function; 2) *cryptobiosis*, a state the tardigrade enters into when there is a lack of water in the environment; 3) *anoxybiois*, the tardigrade's physical response to flooding or lack of oxygen in the environment; and 4) *osmobiosi*s, a tardigrade's physical reaction to high salinity in the environment.

Grades: 6-8

Time: Teacher Preparation- 40 minutes
Activity- 60 minutes (with *Exploring Epiphytes* (D-8)

Group size: Groups of four

Materials: A set of tardigrade cards for each group (D-3 and D-4)
An activity sheet for each group (D-5)
Activity Sheet answer page (D-6)
A copy of Exploring Epiphytes for each student (optional- D-7)

Background: Tardigrades are microscopic organisms that live on epiphytes; epiphytes are plants that live on plants. In the Pacific Northwest, common epiphytes are moss, lichen, liverworts, and some small shrubs like huckleberry or shade tolerant trees like Western hemlock. Epiphytes are important to the forest environment in that they create a habitat for organisms to live in the canopy.

One will find a plethora of microscopic organisms living on the epiphytes in the forest canopy. One of the most fascinating of these organisms is the tardigrade. A tardigrade is a microscopic aquatic animal that looks like a tiny bear (hence the name, "Bears of the Moss") or caterpillar. Tardigrades have five body-segments and 4 pairs of legs ending in claws. They range is size from 0.2-0.5 mm (the larger being about the same size as a fine-led pencil dot) (Miller 1997). Tardigrades are found in every biome including salt and freshwater environments, humid rain forests and dry deserts, low canyons and high altitude mountaintops.

Tardigrades are aquatic organisms and need to be in water to eat, breath, reproduce, and move. Tardigrades are commonly found in the interstitial environment (water between leaves) of moss and lichen. These organisms are made of 70% water and enter into a state of "cryptobiosis" when the habitat they live in dries up. In a state of cryptobiosis, they shrivel up into what is referred to as a "tun" and drastically slow down their metabolism. When tardigrades are in their cryptobiotic state, they can survive temperatures well below freezing, high above boiling, and under pressures of 27,000 psi for limited periods of time (Miller 1997). These creatures can live in a state of cryptobiosis for over a hundred years; one specimen, taken from a moss sample that was over 100 years old, showed signs of life upon rehydration (Kinchin 1994).

When there is too much salt (high salinity) in the tardigrades immediate environment, it cannot retain water and therefore has a difficult time functioning normally. When this occurs, the tardigrade enters into a state of "osmobiosis". The tardigrade dehydrates and goes into a similar state to that of cryptobiosis.

A third physical state that the tardigrade can enter into is called *anoxybiosis*. Because tardigrades cannot control the amount of water that is absorbed through their skin, they cannot function in an environment that has too much water. When their environment is too moist (e.g. flooding), the tardigrade will swell up like a balloon and float around on the water. When it is in an anoxybiotic state, the tardigrade cannot eat or reproduce. As the high water resides, the tardigrade deflates and returns to its normal behavior of eating, moving, and reproducing (Miller 1997).

These various states enable the tardigrade to live in extremely unpredictable environments. Though the active life of a tardigrade may only last a few months, their life span may be spread over several years if they enter into these various states for an extended period of time (Miller 1997).

Preparation: Make a set of cards for each group of four students and an activity sheet for all students in the class.

The Activity:
1. Introduce the concept of epiphytes and adaptations
2. Get students to start thinking about what lives on epiphytes by having them complete the *Exploring Epiphytes* preassessment page (optional). Inform the students that they are going to learn about an interesting organism that lives on moss and lichen.
3. Divide the class in groups of four
4. Pass out a set of cards to each group and an activity sheet to each student
5. Each student reads one card to the group (starting with the "normal state" card). There are four cards and four students, so each one should get an opportunity to read out-loud.
6. The students will work as a group to fill in the correct answers on the provided activity sheet.

Assessment: The activity sheets provide the teacher with an assessment tool to determine how well the students understand the tardigrade adaptations.

Extensions:
1. This activity can be made competitive. The teacher reads off the environmental conditions, each team flashes the card representing the correct physical response a tardigrade would undergo as a result of the specific environmental condition. The first group to raise the correct card gets a point.
2. Incorporate this lesson with the *Identifying Tardigrade* activity.
3. For younger students, simplify the information cards.

Glossary Terms (See Appendix II)**:**

Adaptations
Anoxybiosis
Biome
Cryptobiosis
Epiphyte
Organism
Osmobiosis
Osmosis
Salinity
Tardigrade

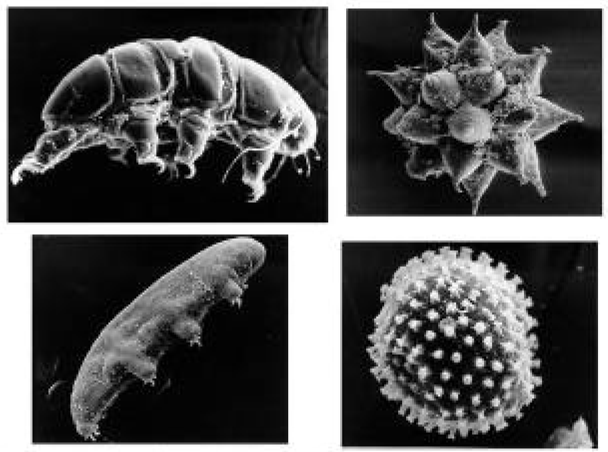
Other resources:

<u>Websites</u>

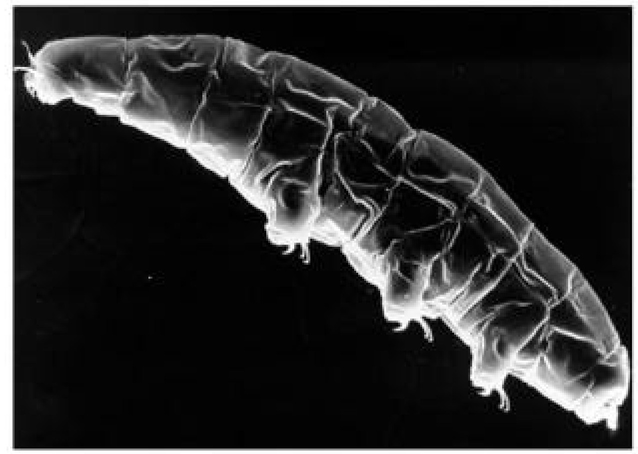
The Kan CRN website <<www.KanCRN.org>>
The Wonderful World of Tardigrades <<www.jsu.edu/depart/biology/tardy.htm>>
Tardigrade Appreciation Headquarters <<http://www.reed.edu/~vvichit/tardigrade.html>>

<u>Publications</u>

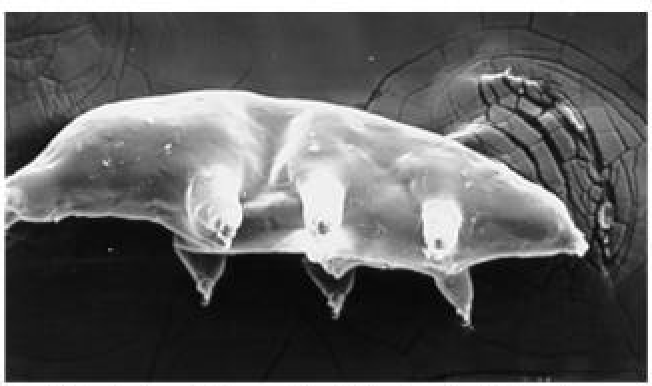
Miller, W.R. 1997. Tardigrades: Bears of the Moss. Kansas School Naturalist. Vol. 43:3 pp.1-14. (Available at:<< www.kancrn.org/tardigrades/cbackground>>).



Images of tardigrades in their "normal state" and eggs (Upper left-Echinsicus; lower left- Minibiotus; Upper right- egg of Macrobiotus or Minibiotus; lower right-egg of Macrobiotus); Photos by W.R. Miller, Phd.



A Milnesium tardigrade that has just emerged from the state of osmobiosis. Notice that its skin is shriveled from the salt. Photo by W.R. Miller, Phd.



A Hypsibius tadigrade in a state of Asphyxia. Notice how puffed up it is in this bloated condition. Photo by W.R. Miller, Phd.

A Hypsibius tardigrade that is coming out of the c ryptobiotic [illegible] state. A tardigrade that is shriveled up is called a tun. Photo by W.R. Miller, Phd.

Anoxybiosis

In an environment where there is too much water (e.g. flooding), the tardigrade cannot control the amount of water it absorbs and therefore gets bloated. When this occurs, the tardigrade swells up like a balloon and enters into a state called " anoxybiosis". When it is in an anoxybiotic state, the tardigrade cannot eat or reproduce. In this state, the tardigrade floats around on the water and waits for their environment to dry out. Once the water level decreases, the tardigrade deflates and returns to its normal behavior of eating, moving, and reproducing (Miller 1997).

Cryptobiosis

Tardigrades are made of 70% water and are commonly found on moss and lichen. When the tardigrade' s environment is extremely dry, it shrivels up and enters into a dormant state called "cryptobiosis". The tardigrade' s shriveled up body is referred to as a "tun". Whentardigrades are in a state of cryptobiosis, they can survive temperatures well below freezing, high above boiling, and under pressures of 27,000 psi (pounds/inch^2) for limited periods of time (Kinchin 1994; Miller 1997). These creatures can live in a state of cryptobiosis for over a century. One specimen, taken from a moss sample that was over 100 years old, showed signs of life upon rehydration (Kinchin 1994).

Normal State

A tardigrade is a microscopic aquatic animal that looks like a caterpillar. It has five body-segments and 4 pair of legs ending in claws. Tardigrades range in size from 0.2-0.5 mm (the larger being about the same size as a fine-led pencil dot) (Miller 1997). Tardigrades cover all trophic levels of the food chain; some tardigrades are carnivores, others are herbivores or omnivores. They feed on each other, as well as on other microscopic organisms (Miller 1997).

Tardigrades lack both lungs and eyes. They do not have a respiratory system with lungs but instead breathe via osmosis, pumping oxygen and fluids that are absorbed through the skin throughout their body. Tardigrades do not have eyes, but rather have a nervous system that responds to light sensitive spots.

Osmobiosis

Tardigrades are found in every environment in the world. They have been found in salt and freshwater environments, humid rain forests and dry deserts, low canyons and high altitude mountain-tops. These creatures, however, need a moist environment to function. A high amount of salt in the environment has a negative effect on the organism' s ability to function. When the environment is salty (high salinity), the tardigrade will enter into a state referred to as "osmobiosis". The reaction is for the tardigrade to shrivel up into a "tun", similar to what a tardigrade enters into during cryptobiosis. The tardigrade enters into the osmobiotic tun as a result of its body pushing all its moisture out into the surrounding environment.

Name:__________________
Date:____________________
Classroom_________________

The Tardigrade Game Activity Sheet

What is a Tardigrade?____

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Where does a tardigrade live?____

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What state would a tardigrade enter into under the following environmental conditions (your choices are "normal", "cryptobiosis", "anoxybiosis", and "osmobiosis"):

1. This summer was extremely dry, reaching drought conditions _____________________

2. Spring rain in the temperate rain forest is light and warm _________________________

3. Moss and lichen found in the coastal forests of the Pacific Northwest are exposed to oceanic fog that has a high salinity____

4. A tree branch falls into a forest lake, submerging moss mats under the water ________

5. A nesting bird grabbed a piece of moss from the lower canopy where it is moist and shady and carried it up to the upper canopy where it is sunny_____________________

6. Lichens located on rocks along the ocean's shoreline are covered in saltwater during the highest tides of the year____

7. Mild rain showers along the coastline gently wash the accumulated salts from moss and lichen mats that reside on the tree_______________________________________

8. A moss mat falls into large puddle on the forest floor, cutting off oxygen to all of the organisms that live on the mat ____

9. An old-growth Douglas-fir tree falls, exposing all surrounding tree trunks covered in moss to direct sunlight. During the summer the moss and lichen were exposed to high levels of direct sun exposure ______________________________________

10. Temperate rain forests in the Pacific Northwest receive over 100 inches of rain per year, drenching moss and lichen mats for a large part of the year __________________

The Tardigrade Game Activity Sheet-
Answer Page

What is a Tardigrade? See background ____

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Where does a tardigrade live? See background ____________________________________

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What state would a tardigrade enter into under the following environmental conditions (your choices are "normal", "cryptobiosis", "anoxybiosis", and "osmobiosis"):

1. This summer was extremely dry, reaching drought conditions______Cryptobiosis _____

2. Spring rain in the temperate rain forest is light and warm__________Normal ________

3. Moss and lichen found in the coastal forests of the Pacific Northwest are exposed to oceanic fog that has a high salinity_________________________ Osmobiosis ______

4. A tree branch falls into a forest lake, submerging moss mats under the water Anoxybiosis

5. A nesting bird grabbed a piece of moss from the lower canopy where it is moist and shady and carried it up to the upper canopy where it is sunny_____Cryptobiosis _____

6. Lichens located on rocks along the ocean's shoreline are covered in saltwater during the highest tides of the year____________________________Osmobiosis ______

7. Mild rain showers along the coastline gently wash the accumulated salts from moss and lichen mats that reside on the tree______________________Normal _________

8. A moss mat falls into large puddle on the forest floor, cutting off oxygen to all of the organisms that live on the mat______________________________Anoxybiosis _____

9. An old-growth Douglas-fir tree falls, exposing all surrounding tree trunks covered in moss to direct sunlight. During the summer the moss and lichen were exposed to high levels of direct sun exposure______________________________Cryptobiosis ______

10. Temperate rain forests in the Pacific Northwest receive over 100 inches of rain a year, drenching moss and lichen mats for a large part of the year ____Anoxybiosis

Name:__________________
Date:___________________
Classroom________________

Exploring Epiphytes- Preassessment

Do you think organisms live on the leaves of moss and lichen? ______________________

____

Why or why not?____

____

The moss and lichen environment is incredibly unpredictable. Sometimes is it wet like a soaked sponge and other times it is as dry as a desert. How do you think an organism could survive when the moss or lichen dries up (use your imagination)? ______

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____

What if the moss or lichen becomes flooded with water? ___________________________

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Draw a picture of what an organism living on moss or lichen would look like and list its adaptations that enable it to survive in extreme conditions of drought and flooding. Be Creative!

Its adaptations that enable it to survive in drought conditions are:

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____

Its adaptations that enable it to survive in flooding conditions are: _____

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Bears of the Moss (and Lichen)- Activity #2
Identifying Tardigrades

(This information and activity methodology is based on Dr. W.R. Miller's "Tardigrades: Bears of the Moss" (1997). It is adapted with permission by the author)

Overview: This activity guides the class through an exploration of a micro-community that lives on moss and lichen epiphytes. Students will be engaged through a microscopic examination of tardigrades, a phylum of unusually interesting organisms. Students will also learn scientific illustration techniques and how to use a dichotomous key to identify the specimen down to family.

*Note** this lab requires both dissecting microscopes (with 30x-40x magnification) and compound microscopes with refracted light (not a light source that comes from below the viewing plate). It can be adapted for classes that only have access to low magnification dissecting scopes, however most of the objectives will not be met without the use of high magnification dissecting or compound scopes.*

Objectives: Students will learn about a microscopic organism that lives on moss and lichens, including its adaptations that enable it to survive in an unpredictable environment. Students will learn how to use a dissecting and compound microscope and how to make slides for viewing on a compound microscope. The students will also become familiarized with the system of taxonomic identification and with using a taxanomic key to identify the tardigrades to family. They will learn about the importance of noticing and illustrating close detail.

Grades: 6-12

Time: Teacher preparation- 30 minutes for setting up scopes
Moss/lichen collection- 45 minutes
Microscope lab- 1-1.25 hours

Group size: 2-3 students per microscope

Materials:

Moss and lichen sample (see procedure below for tips on collecting samples)
Distilled water
Small plastic cups or containers for soaking moss
Micro-pipettes
Petri dishes
Microscopes (30x-40x dissecting, and if available, compound)
Black paper (if dissecting microscopes do not have a black view plate)
Glass slides and cover slips
Pen for marking slides
Hard copy of tardigrade dichotomous key and/or internet connection
Field notebook Entry Page (Appendix D-12)
Scientific Illustration sheets (Appendix D-14)
Assessment Page (Appendix D-13)
*Ethel alcohol (70% solution) or buffered formalin specimen (5% solution)
*Hand-held GPS unit for taking longitude and latitude readings
*Moss/lichen identification book

*mandatory if you are submitting your samples to the *International Tardigrade Survey*

Background: A tardigrade is a microscopic aquatic animal that looks like a caterpillar or small bear (hence, the name "Bears of the Moss") with five body-segments and 4 pair of legs ending in claws. Tardigrades range is size from 0.2-0.5 mm (the larger being about the same size as a fine-led pencil dot). Tardigrades are found in all biomes including salt and freshwater environments, humid rain forests and dry deserts, low canyons and high altitude mountain tops. Tardigrades reproduce sexually and asexually. Their eggs can look like small white or bright sparkles, Christmas tree ornaments, or sea mines. Some tardigrades have been documented as producing female offspring through asexual reproduction.

Tardigrades cover all trophic levels of the food chain; some tardigrades are carnivores, others are herbivores or omnivores. They feed on each other, as well as other microscopic organisms. They have a fully developed digestive and excretory system.

Tardigrades lack both lungs and eyes. They do not have a respiratory system with lungs but instead breathe via diffusion, pumping oxygen and fluids that are absorbed through the skin throughout their body (osmosis). Tardigrades do not have eyes, but rather have a nervous system that responds to light sensitive spots.

Tardigrades are aquatic organisms and need to be in water to eat, breath, reproduce, and move. Tardigrades are commonly found in the interstitial environment of moss and lichen (water between leaves). These organisms are made of 70% water and enter into a state of "cryptobiosis" when the habitat they live in dries up; they shrivel up into what is referred to as a "tun" and drastically slow down their metabolism. When tardigrades are in their cryptobiotic state they can survive temperatures well below freezing, high above boiling, and under pressures of 27,000 psi for limited periods of time. These creatures can live in a state of cryptobiosis for over a hundred years. One specimen taken from a moss sample that was over 100 years old showed sign of life when it was rehydrated (Kinchin 1994). The active life of a tardigrade may only last a few months, however their life span may be spread over several years if they enter into a cryptobiotic state.

Tardigrades do not have the ability to stop absorbing water and cannot function in a environment that is saturated for long periods of time. When their environment is too moist (i.e. in a state of flooding), the tardigrade swells up like a balloon, enters into a state called "anoxybiosis", and floats around on the water. When it is in an anoxybiotic state, the tardigrade cannot eat or reproduce. As the high water resides, the tardigrade deflates a little, and returns to its normal behavior of eating, moving, and reproducing.

These fascinating organisms are highly successful in harsh environments due to their ability to physiologically respond in several different ways to maximize their biological productivity in the face of unpredictable environmental circumstances.

Preparation: Introduce students to tardigrades and their physiological responses to lack of water and flooding (see *Background Information* and *Extensions*).

Moss collection and preparation: In teams of 2-3, the students will collect one specimen sample of moss and/or lichen from the local environment. Put <u>each individual species</u> sample in a <u>separate small paper bag</u> and write the students' names or a collection code on each bag. *It is important that each moss/lichen sample is stored separately and clearly marked as to who, what, where, and when the sample was collected*. Each student should fill out the *Field Notebook Entry Page* (D-12), which documents detailed information on their collections.

Note** It is best to take lichen and moss samples that have fallen on the ground and not disturb the natural presence of moss or lichen on a tree. However, if you are participating in the *International Tardigrade Survey* (see *Activity Variations*), you will need to know the tree from which your moss or lichen samples originated. If you cannot clearly determine the host of a fallen moss/lichen sample with absolute confidence, than take a sample from a host tree that is identifiable. To identify a common native deciduous or coniferous tree, see the dichotomous keys in the *Canopy Througfall Study (*B-10 and B-11*)*.

Your class will only need a small patch of lichen/moss per microscope so take a minimal amount. Students can share their specimens with each other while looking at them under the microscope. Dry the moss and/or lichen in a paper bag (not plastic). This will probably take 1-2 weeks if the bagged moss is stored in a warm and dry place.

Prior to classroom examination, soak each separate moss/lichen samples in 100ml distilled water for 24-36 hours. Avoid tap water for it often contains chlorine, which can inhibit the tardigrades from emerging out of cryptobiosis. Set up the microscope lab with the dissecting and compound microscopes. The dissecting microscopes will enable the students to see the tardigrades so they can pipette them onto a slide, where the tardigrades will be viewed up close. Tardigrades can be viewed in dissecting microscopes, however the student will be unable to identify them taxonomically without a compound microscope.

The Activity:

1. As instructed previously, soak moss in 100ml distilled water for 24-36 hours.
2. Pass out the soaked, clearly labeled samples. Each species of moss/lichen should be soaked separately.
3. Instruct each student to gently shake their sample in the water to dislodge any tardigrades that are clinging onto the moss or lichen specimen.
4. Keep moss or lichen sample for identification.
5. Students pipette some of the settled particles into the petri dish and begin examining the particles under the dissecting microscope (be sure the microscope viewing plate is black and not white. If you cannot change your viewing plate, put a black piece of paper under the petri dish).
6. Students search for tardigrade and egg specimens.
7. Once the students find a tardigrade or egg specimen, they can fix it on a slide for closer examination on the compound microscope.
8. To create a slide, using a pipette, drop the tardigrade sample on the slide and cover with a slide cover slip.
9. Observe the specimen at the lowest magnifying power and increase until the tardigrade specimen can be clearly identified.
10. Have the student scientifically illustrate the organism by following the directions on the *Scientific Illustration Sheet* (Appendix D-14).
11. Using the ID chart (http://www.kancrn.org/tardigrades/gidentify.cfm; or hard copy can be obtained via ICAN), classify the tardigrade down to family.
12. Label the taxonomic category of tardigrade.
13. Students can walk around the room and view each other's tardigrade samples. It is very important that if you are contributing to *the International Tardigrade Survey* that the students do not move the petri dish sample around the room. If they do so they might get the samples confused and therefore not be able to submit the sample to the survey.
14. Have students label their drawings, note any distinguishing characteristics that enable the identification of their tardigrade genus, and hang the illustrations up for viewing.
15. Have the student complete the assessment page (Appendix D-13)

**Note: Return all moss/lichen samples to their original location. It is important that when doing scientific research and observations, the scientists try their best to not disturb the natural environment and its processes.

Assessment: Have the students complete the assessment page. Evaluate the students' abilities to follow directions and work carefully; this can be assessed through careful observation of each student in lab as well as through their scientific illustrations and assessment page. For the younger students, compare the responses from the pre-assessment activity to the final assessment activity.

Extensions:

1. Older students can submit their samples to an international database. See *The International Tardigrade Survey* write up.
2. For younger students, introduce this activity with the *Exploring Epiphytes Activity Page* (D-7).
3. Use fresh moss instead of dry. You will find many other organisms (mites, spiders, arthropods, nematodes). However, you will probably not be able to find tardigrades because they will blend onto all the organism activity occurring on the fresh moss.
4. *The SO_2 Lichen project*- a global survey documenting the presence of lichen that are susceptible to high SO_2 levels in the atmosphere. This activity is another aspect of the *International Tardigrade Survey* and can be found at <<www.KanCRN.edu>> (grades 10-12).

G**lossary Terms** (see Appendix II):
Anoxybiosis
Biome
Cryptobiosis
Epiphyte
Interstices
Osmobiosis
Osmosis
Salinity
Taxonomy

Other Resources/Citations:

Websites
The Kan CRN website <<www.KanCRN.org>>
Lichen Land <<http://mgd.nacse.org/hyperSQL/lichenland/html>>
The Wonderful World of Tardigrades <<www.jsu.edu/depart/biology/tardy.htm>>
Tardigrade Appreciation Headquarters <<http://www.reed.edu/~vvichit/tardigrade.html>>

Publications
McInnes, S.J. and D.B. Norman. 1998. Tardigrade Biology. Zoological Journal Linnean Society London. Academic Press. London. Vol. 116: pp. 1-243

Miller, W.R. 1997. Tardigrades: Bears of the Moss. Kansas School Naturalist. Vol. 43:3 pp.1-14. (Available at: << www.kancrn.org/tardigrades/cbackground>>)

Pojar, J.MacKinnon, A., 1994. Plants of the Pacific Northwest Coast; Washington, Oregon, British Columbia, and Alaska. Lone Pine Publishing, Redmond, WA, 528 pp.

Vitt, D.H.,Marsh, J.E.,Bovey, R.B., 1988. Mosses, Lichens, and Ferns of Northwest North America. Lone Pine Publishing, Edmonton, Alberta, 296 pp.

Identifying Tardigrades Field Notebook Entry

(Note All this information must be taken if your class will be contributing to the International Tardigrade Survey)*

Name and/or collection code: ____________________

Date and Time of day: ____________________

Location (including place name, altitude, longitude, and latitude): ____________________

____

____

Type of habitat (i.e. old-growth, second–growth, single tree in a parking lot, etc.):

____

____

Other environmental factors that might influence the habitat (i.e. light exposure, roadside, dusty, high atmospheric salinity, high rainfall, etc): ____________________

____

____

Species name of moss/lichen sample: ____________________

Species of tree where moss/lichen sample was found: ____________________

Describe where your sample was found (i.e. on a branch on the ground, on the forest floor, hanging off of a live tree, species of tree, direction facing) ____________________

____

____

Draw a detailed picture of a single moss leaf or lichen thallus from your sample. Include detailed information on coloration and irregularities.

Name:__________________
Date:___________________
Classroom_______________

Identifying Tardigrades Assessment

List at least three things you learned from this activity:____________________________

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What did you like most about this activity? ______________________________________

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____

What did you dislike? ____

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____

How has this experience affected your thoughts of biodiversity and organisms in the environment? ____

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____

If you were to do this activity again, how might you change it? ______________________

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Scientific Illustration

Closely observing the characteristics of an organism is important in understanding how it behaves and functions. In this lesson you will examine and illustrate details of the microscopic specimen. Follow these simple guidelines:

1. Without drawing, look at the organism you are studying for one minute. How does it move? Does is have hair? Does it have moving mouth-parts?

2. Begin by drawing a straight line across the middle of the box. This will be your line of symmetry.

3. Next, notice if the organism has body segments. All insects have three body parts (head, thorax, and abdomen) and all Tardigrades (Bears of the Moss) have five. Are these body sements all the same size or are they different sizes? Draw lines perpendicular to the line of symmetry that represents the organisms body parts. Try to keep the lines in the same proportion as the organism's body parts are to one another.

4. Now you can begin to draw details relative to the proportionate grid pattern on your paper. Be sure to draw all hairs, pores, scales, or other objects on the organism's body. Take your time.

Bears of the Moss (and Lichen)- Activity #3
The International Tardigrade Survey

(This activity is based on Dr. W.R. Miller's research methodology as presented in the KanCRN Tardigrade Research Project at << http://www.kancrn.org/>>. Permission for reprinting this methodology has been granted by Dr. W.R. Miller).

Overview: As an enhancement activity to *Identifying Tardigrades*, students will contribute their tardigrade samples to an international database hosted by Dr. W.R. Miller and the KanCRN research network. The class will receive a booklet with drawings, descriptions, and pictures of the tardigrades discovered in their samples that are submitted to the survey.

Objectives: In small groups, the students will prepare specimens for lab identification by the project "mentor". The class will interact and communicate with the "mentor" on technique, questions, problems, and identification verification. The class will submit their data and information from the *Identifying Tardigrades Field Notebook Entry* to an on-line database.

Grades: 9-12

Time: 50 minutes- includes waiting around time while the samples settle

Group size: Entire class

Materials: Small glass vials (2" x 0.5"), with tight caps for each moss and lichen species
70% alcohol or 4% formalin solution for preservation of samples
Pipettes
Shipping box
Postage
Copy paper and pencil
Scissors

Background: See information on tardigrades in the *Identifying Tardigrades* activity. The goal of this survey is to document tardigrade species that exist around the world. Samples collected and preserved by the class and sent to the International Survey will be entered into a GIS database and made available to researchers and students around the world. The goal of the survey is to identify which species of tardigrades "live in a given area and to relate their habitat information to the tardigrade (species)". This database will support GIS mapping software and allow tardigrade data to be integrated as a layer onto other relative information such as weather, pollution, geological, vegetative, population, urbanization, altitude, etc." (http://dev.scrtec.org/!kancrndv/ku/su98-redesign/design4/tardigrade/rbackground.shtml).

Preparation: Introduce the students to tardigrades through the *Identifying Tardigrades* activity. Be sure students accurately complete all the information listed on the *Field Notebook Entry* sheet, as it is important information for the consistency of the International Survey. Collect all the above materials.

The Activity:

For each separate moss and lichen species sample

1. Shake moss or lichen sample in the 100ml cup of water to dislodge any last tardigrades
2. Let the debris settle for 10 minutes.
3. While the cup samples are settling, carefully empty the samples in the petri dish into the vial.
4. Tilt the petri dish ¼" and pipette the upper part of the dish (to ensure that no tardigrades are left on the dish). Be careful not to create currents to suck up the tardigrades.
5. Pour the petri dish sample into the vial and let settle for 10 minutes.
6. Now that the samples in the cups have settled, pipette off as much of the top water as possible without disturbing the settled matter. Again, be careful not to create currents that suck up the tardigrades.
7. Let the debris in the cup settle again.
8. Pipette water from the cup sample until it is small enough in volume to pour into one vial (or two).
9. If you have two vials, let the vials sit about 20 minutes to allow all the material to settle to the bottom.
10. Carefully, pipette off about 3/4 of the water in each vile. Then combine the debris of two vials into one and repeat the process until you have all the debris and tardigrades in one vial with little water.
11. Fill the vial with alcohol and let settle, pipette off and replace with alcohol again. This will establish the preservation concentration. Formalin can be used instead of alcohol.
12. Cut a label out of copier paper (1"x 0.5").
13. On the label write with a No. 2 pencil your school number, date of collection, and host plant).
14. Slide the label into the vial and put the lid on tight.
15. Next, place a strip of masking tape up one side, over the top, and down the other. Smooth out the tape to seal the top. The tape protects the vial from breakage.
16. Write the label information on the masking tape with a pencil or felt pen.
17. Pack the vials into a small box with paper towels, tissue, or small bubble wrap. Interlace the vials within the packaging materials and fill the space with extra material to create a tight package. Put an address inside the box before taping it closed.
18. Send to Tardigrade Mentor:

Dr. William R. Miller
Department of Biology
Chestnut Hill College
9601 Germantown Ave.
Philadelphia, PA 19118
<millerw@chc.edu>

Note on Returns:

The Mentor will acknowledge the receipt of the package to the class.
The Mentor will make microscope slides of and identify the tardigrades in the vials.
The Mentor will return a set of microscope slides with examples of each species found.
The Mentor will return data, drawings, descriptions, and pictures of each species found.
The Mentor will donate slides to the International Tardigrade Survey Collection.
The Mentor will enter class in the annual "First Records" competition.
The Mentor will notify the class of the verification of specimens.

19. The class will enter their data through the Data Submission Area @ << http://www.kancrn.org/tardigrades/cdata_sub.cfm>>. Note** all of the information listed on the *Field Notebook Entry* included in the *Identifying Tardigrades* activity must be filled in accurately or the data cannot be entered into the International Database.
20. Ask the students to complete the Assessment Page (Appendix D-18).

Assessment: Evaluate students on their learning by examining the assessment page and by observing their ability to follow through with the specific procedures for sending the specimens.

Extensions:
The SO_2 Lichen project- a global survey documenting the presence of lichen species that are susceptible to high SO_2 levels in the atmosphere. This activity is another aspect of the *International Tardigrade Survey* and can be found at <<www.KanCRN.org>>.

G**lossary Terms** (see Appendix II):
Anoxybiosis
Biome
Cryptobiosis
Epiphyte
Osmobiosis
Salinity

Other resources:
<u>Websites</u>
The Kan CRN website <<www.KanCRN.org>>
Lichen Land <<http://mgd.nacse.org/hyperSQL/lichenland/html>>
The Wonderful World of Tardigrades <<www.jsu.edu/depart/biology/tardy.htm>>
Tardigrade Appreciation Headquarters <<http://www.reed.edu/~vvichit/tardigrade.html>>

<u>Publications</u>
McInnes, S.J. and D.B. Norman. 1998. Tardigrade Biology. Zoological Journal Linnean Society London. Academic Press. London. Vol. 116: pp. 1-243

Miller, W.R. 1997. Tardigrades: Bears of the Moss. Kansas School Naturalist. Vol. 43:3 pp.1-14. (Available at: << www.kancrn.org/tardigrades/cbackground>>).

International Tardigrade Survey Activity Assessment

What did you learn from this activity? ____

____

____

____

____

What did you like best about this study? ____

____

____

____

What did you like least about the study? ____

____

____

____

____

What benefits do you think this survey will have towards global science? ______________

____

____

____

____

____

If you were to do this study again, how would you do it differently? __________________

____

____

____

____

On the back of this page or on a separate sheet of paper, spend ten minutes writing about the procedure you (and your class) underwent to obtain and submit these samples.

Canopy Poetry

Overview: By writing poetry, the student is able to express their knowledge of and feelings toward the canopy environment in a creative and imaginative way.

Objective: Students will learn how to write *a Diamante, Haiku, Cinquain, Acrostic, Picture*, and *Freestyle* poem. The students will be able to express their perspective of the forest environment through a creative exercise. The Students will present their favorite and analyze some of the class' poems.

Grades: 4-12

Time: 50 minutes

Group size: Not specific

Materials: Paper
Writing utensil
Writing board
Poem examples

Background: Poetry is an important form of expression and creative thought for people all over the world. It allows the mind to conceptualize on the surrounding environment in an intimate manner. There are numerous different styles of poetry. In this excercise a *Diamante, Haiku, Cinquain, Acrostic, Picture, and Freestyle* poem will be discussed. Guidelines for writing each of these poetry styles follow this lesson plan.

Preparation: Gather all the necessary materials for the class. Find a nice spot outside where the students can gaze into the canopy of a tree or forest.

The Activity:
1. Bring the class outside and ask them to sit (or lay) silently on the ground where they can listen.
2. Read a few nature-oriented poems by famous authors.
3. After reading each poem discuss what the poet is conveying through his or her words. What image is the poet creating? What feeling is the poet expressing? Do the students like the poem, why or why not?
4. Inform them that they will sit by themselves, and write poems about the canopy.
5. Pass out the poem descriptions and examples (Appendix E-3).
6. Ask the students to scatter themselves.
7. Give them 20 minutes to sit by themselves and write two poems of their choice. Walk around and observe if all the students are writing. Do not disturb them if they are content. If students are having a problem conceptualizing their poem, guide them. You can ask them what they like most about the forest canopy. How does that aspect of the canopy make them feel? What do they see in that aspect of the canopy?
8. When the time is up, call them together to share their poems.
9. Ask each student to share one of his/her poem.
10. After all the students have shared, ask the class which poems stuck out the most and why?

Assessment: The poems will serve as a means of assessment. Did the students understand how to write each poem? Did they express themselves creatively? Offer the students some constructive criticism about their writing.

Extension: Have the students paint a water color that accompanies their poem on a 3x5 card or piece of construction paper. The poem and watercolor can be mounted on a piece of colored construction paper and given to the parents for Mother's or Father's day or make this activity an Earth Day celebration. If your school is year round, celebrate Forest Canopy Week, July 20-25, as declared by Washington's State Governor Gary Locke in 1997.

Other Resources:

Bogen, Nancy. 1998. How to Write Poetry (3rd Ed). IDG Books Worldwide.
Higginson, William J. and Penny Harter. 1992. Haiku Handbook: How to Write, Share, and Teach Haiku. Kodansha International.
Humphries, Jeff. 1995. A Bestiary. Blue Pond Press.
Owens, Mary Beth. 1999. Be Blest: A Celebration of Seasons. Simon and Schuster.
Poet-tree pgs. 13-15 *in* Project Learning Tree. 1997. Environmental Education Activity Guide. American Forests Foundation.
Schnur, Steven. 1997. Autumn: An Alphabet Acrostic. Clarion Books.
Snyder, Gary.1997. Mountains and Rivers Without End. Counterpoint.
Yolen, Jane. 1991. Bird Watch: A Book of Poetry. Paper Star.

Poetry Styles and Examples

Diamante

noun
adjective, adjective
participle, participle, participle
noun, noun, noun, noun
participle, participle, participle
adjective, adjective
noun

Canopy
dense, foliose
sparkling, dancing, blowing
tree, branch, needle, scuzz
supporting, protecting, surviving
biodiverse, intricate
Forest

Haiku

Five syllables
Seven syllables
Five syllables

Trees tower above
offering a habitat
for life in the woods

Cinquain

The title in two syllables
A description of the title in four syllables
A description of action in six syllables
A description of feeling in eight syllables
Another word for a title in two syllables

Tree Vole
Mouse of the tree
Scurrying from shadows
Silently surviving the night
red mouse

Acrostic

The title is presented vertically and each letter of the title is the start of a line describing the title.

Colossal
Ancient
Never-ending
Openness
Protecting
Yew

Picture

Free form in the shape of something the poem is representing

T
Swaying branches a Evergreen
l
l
Ancient one T Silent one
r
e
e

Freestyle

No rules- anything goes

High above arms reach,
surpassing the view of one's eyes,
there is a world.

A world that we wish to understand,
a world that we wish to learn from,
a world that will forever hold secrets

A Council of Canopy Critters

Overview: In this activity, the students will take on the persona of a critter from the temperate rain forest canopy. They will research information on, create a mask that depicts, and represent the organism in an imaginary council of concerned forest citizens.

Objectives: The students will learn about the ecology of organisms in the forest canopy, focusing on a single organism of their choice. The students will create an artistic expression of the organism they represent. The student will express concerns that the organism might feel as a result of a loss of habitat. The students will become their organism and present in a council setting.

Grades: 4-12

Time:
Teacher Preparation- 40 minutes
Organism Research- varies depending on the availability of resources (i.e. library, Organism Profiles) and the students' research capabilities.
Mask Making- 1 hour
Council- 45 minutes (with the option of snacks following the presentations)

Materials:
Canopy Organism Profiles
Images of Organisms
Mask making materials
- paper plates
- string
- scissors
- construction paper
- markers
- various art materials
- glue
- hole punch

Guided Imagery

Background: The complex community of the old-growth temperate rain forest canopy is the result of thousands of years of evolution and adaptation. As a result of time, the forest canopy of an old-growth forest has high species diversity. In most scientific studies that compare the biodiversity of old-growth forests to that of second growth, the old-growth canopy shows far higher biodiversity. Some scientists claim that insect diversity within the old-growth forest canopies of temperate rain forests could possibly rival that of tropical rain forests (Kirk and Franklin 1992; Boegtlin 1982). It has been estimated that 1,500 (Franklin et al 1981) to 6,000 species (Lattin 1993) of arthropod species reside in a single mature stand of Pacific Northwest Douglas-fir forest, demonstrating the greatest diversity of arthropods of any temperate canopy system studied (Boegtlin 1982). Vertebrates, such as arboreal mammals, bats and birds, also find more diverse resources in older canopies, rather than younger ones (Shaw and Bible 1996). Some specifically rely on these healthy canopies (spotted owl, silver-haired bat, tree vole). Fungus is another organism found to contribute to high biodiversity in the old-growth forest canopy. A single conifer needle may host several dozen species, externally and internally, many of which are highly host specific (Stone, Sherwood, and Caroll 1996). Around 160 species of microfungi are specifically associated with old-growth Doug-fir trees (Farr et al 1989) and it is estimated that the biomass (total weight of dead and living plant material) of these foliar-fungus equals approximately 30kg/ha (Caroll 1979). These fungi play a critical role in maintaining high biodiversity of invertebrates as they are a grazing resource for microarthropods, such as orbatid mites. Some canopy microfungi also serve as mycorrhizal symbionts with canopy epiphytes.

Because it has only been in the last thirty years that scientists have begun researching the temperate rain forest canopy, new discoveries about its ecosystem function and organisms are constantly revealed. It is imperative that the remaining old-growth temperate rain forests are protected for future scientific inquiry. As of 1991, it was estimated that only 5% of old-growth forests in the lower forty-eight state of the U.S. remain standing. As well, approximately 20% of Alaska's old-growth forests still remain standing due to remoteness (Postel and Ryan 1991). There remains much potential in old-growth temperate rain forest canopies for new discoveries of medicines and species. It is also important that we recognize the complex ecological relationships that occur in the canopy, in order to manage forest stands to promote the occurrence of these species and ecosystem function in second growth stands. Old-growth forests are the elders from which we must learn; without them, the information and stories of the forest canopy will be forever lost.

This activity will allow the students to think about their organisms ecological niche in the forest canopy and represent the organism in a council of concerned canopy citizens.

Preparation: Print copies of the Canopy Organism Profiles, accompanying pictures, and the Guided Imagery . Gather mask-making materials.

The Activity:

1. Inform the students that they will become an organism in the forest canopy. Let them choose from the critters presented in the Organism Profiles.
2. Have them research their organism. Some of the books listed in the Resources and Information appendix also contain information that can be applied to their research.

Mask Making

1. Prior to making the masks, have the students lay on the floor or put their head down on the desk. Read the Guided Imagery (F-4) to them.
2. Working in teams of two, instruct the students to take a paper plate and hold it to their face. The student with the paper plate on their face puts their fingers on the spot where their eyes are located and pulls the mask from their face, not letting go of their eye spots. The student's partner then marks the two spots with a marker pen.
3. Once each student has marked their eye-spots, they can cut out holes in the plate where their eyes will look out.
5. Now they can creatively construct a mask that represents their organism.

The Council of Canopy Critters

1. The teacher begins by welcoming all the canopy critters to this important meeting. The teacher represents the judge. He/she explains that their habitat is soon to be lost because of housing development, unless the organisms can convince him/her that they have an important role in supporting the forest ecosystem. The teacher should also introduce a "Talking Stick". This is an instrument that has been used by many cultures in meeting environments. Whoever holds the talking stick has the right to speak- all should pay respect to the speaker by not talking while the speaker is talking.
2. The judge requests the first speaker.
3. Continue around the circle until all organisms have spoken. It is important that all creatures speak, so that their voice is heard.
4. Wrap up the exercise by pointing out the importance of the organisms in the ecosystem and declare the forest saved from development.
5. Ask the students to turn back into their human forms and have a final discussion based on the questions in the Assessment section of this write-up.

Assessment: Ask the students what this exercise meant to them and how it felt to become an animal or plant in the forest canopy. What was unusual about this activity? Do animals normally get representation in the decision making of habitat conversion and destruction? Ask them what they can do to protect the canopy environment and its organisms.

Extensions:
1. Precede this activity with Canopy Poetry.
2. Create a play based on the characters and the scenario. Act the play out for the students' parents or other classmates.
3. Create a canopy mural in the classroom. Have the students' create a picture of their organism to hang in a forest canopy mural on the classroom wall.

Glossary of Terms (see Appendix II):
Arthropod
Epiphyte
Fungus
Interconnectedness
Invertebrate
Lichen
Old-growth forest
Vertebrate

Resources:

Carroll, G.C., 1979. Forest canopies: complex and independent systems. In: R.H. Waring (Ed.)^(Eds.), Forests: Fresh Perspectives from Ecosystem Analysis. Proceedings from the 40th Annual Biology Colloquium. Oregon State University, 87-108 pp.

Farr, D.F.,Bills, G.F.,Chamuris, G.P.,Rossman, A.Y., 1989. Fungi on plants and plant products in the United States. APS Press, St. Paul, 1252 pp.

Franklin, J.F.,K. Cromack, J.,Denison, W.,McKee, A.,Maser, C.,Swanson, F.,Juday, G. (1981). Ecological characteristics of old-growth Douglas-fir forests, United States Department of Agriculture Report 56.

Kirk, R.Franklin, J., 1992. The Olympic Rain Forest: An Ecological Web. University of Washington Press, Seattle and London, 128 pp.

Lattin, J.D., 1993. Arthropod diversity and conservation in old-growth northwest forests. American Zoology **33:** 578-587.

Postel, S. and J.C. Ryan. 1991. Reforming Forestry. Worldwatch Institute Report: State of the World 1991. Washington D.C. Island Press.

Shaw, D.C. and K. Bible. 1996. An overview of forest canopy ecosystem functions with reference to urban and riparian systems. Northwest Science **70**:1-6.

Seed. J, J. Macy, P. Fleming, and A. Ness. 1988. Thinking Like a Mountain; Towards a Council of All Beings. New Society Publishers. Santa Cruz, California. 122 pp.

Stone, J.K.,Sherwood, M.A.,Carroll, G.C., 1996. Canopy Microfungi: function and diversity. Northwest Science **70:** 37-45.

Council of Canopy Critters
Guided Imagery

1. Have students lay on the floor or put their head on a desk.

2. Read the following prose.

   Close your eyes. Feel them softly resting. Your eyelids are so light that you cannot feel the top lid touching the bottom lid. Listen to the soft raindrops as they fall around you. Pitter patter, pitter patter. You are in the temperate rain forest. You are just waking from a nice sleep. Notice your surrounding environment. What do you see around you? Are you in the lower-, mid-, high-, or emergent canopy layer? What is to your right? Is it moss, lichen, an animal? What is to your left? Begin to see yourself move. Do you sway in the wind? Do you walk on four legs? Do you fly? What does it feel like to move? How does the scenery change as you move? What does the canopy feel like at your feet or roots? You are feeling a bit hungry? You are looking for food? How do you get your food? Do you photosynthesize or do you prey on other organisms? Notice the other organisms that are around you. What kind of relationships do you share with each other? You hear something going on below…on the forest floor. You look down to see two unusual looking figures. They seem to be standing on two feet and wearing really strange fur that is all different colors. You try to listen and hear a few words they are exchanging…"perfect site for building a set of condominiums"…."lots of big trees to make the houses from"….."some controversy about this being the last patch of old-growth trees". You realize that the forest you live in is going to be cut down. How can you defend it? Immediately you are startled by a small mouse who has called together a "Council of All Canopy Beings". This meeting will give you a chance to express your need for the old-growth forest. You must make the preparations…………softly open your eyes.

3. Instruct the students that they will become a canopy critter of their choice.

4. Explain the mask making directions

Appendices

Common name: Douglas-fir

Scientific Name: *Psuedotsuga menziesii*
"Psuedo"= false; "tsuga"= hemlock
"menziesii"= name of first person to identify the tree

Description: This tree grows to 70m (210 feet) tall on average, occasionally reaching heights of 80-90m (240-270 feet). The crown of the Douglas-fir is pointy, like a pyramid, while the lower half of the tree skirts out in an irregular pattern. The branches are spreading with a slight droop. The bark is thick, rough, gray-brown, with deep crevasses in between ridges. The bark can be up to 12 inches thick. The needles spiral around the central branch in a bottle brush structure. Each individual needle is flat, bright green, with two lobes on the tip (not pointy). A single groove that runs the length of the needle can be seen on the upper side of each needle and two white grooves on the underneath side (Pojar and Makinnon 1994). When the needles are removed, a flat, circular scar is left behind. Cones point downward and have three forked bracts that resemble the feet and tail of a mouse protruding from beneath each seed shield.

Geographical range: The geographical range of this tree extends along the coastline and slightly interior from British Columbia, Canada, to the coastline of Northern California, U.S. Patches of the Douglas-fir also exist through the western region of the U.S.

Habitat: This tree inhabits a multitude of climates from dry lowland forests, to moist upland forests. However, it does primarily establish in an environment with direct sunlight and moist soils.

Reproduction: Both male and female cones are present on one tree. Pollen from the male cone is wind dispersed and pollinates the female cone. When the female cone is fertilized, the cone develops seeds and matures on the tree. The seeds are spread when either a small animal rips the cone open to eat the seeds and accidentally drops or stashes a viable seed or when the cone opens naturally and drops the seeds upon the forest floor.

Input requirements (food supply): Like all plants, the Douglas fir tree depends on photosynthesis for its survival. Using the energy of the sun, the tree chemically converts nutrients, water, and air into sugars and carbohydrates on which it feeds. This process is called photosynthesis.

Role in the ecosystem: This tree creates a habitat for insects, small mammals (including Northern flying squirrels and red tree voles), and many epiphytic plants (like lichens and mosses). This tree is also important for supporting thousands of species of microscopic fungi and Scuzz. Scuzz in an compound comprised of fungus, yeast, and bacteria. Scuzz lives on top of and inside the needles of the fir and supports an intricate food web of insects and mammals.

Use as a Human Resource: Douglas-fir has been historically used by humans as a vital resource. The wood was used by Native American tribes to make spears, spoons harpoon shafts, salmon weirs, fire tongs, caskets, and fishhooks. The pitch (sap) was used as a medicinal salve for wounds and skin irritations. The Nuxalk, Quinalt, and other tribes made torches using the pitch of the Douglas-fir (Pojar and Makinnon 1994).

Douglas-fir is probably the most sought after tree for present day timber harvesting. According to Franklin *et al* (1981), Douglas fir is a relatively fast growing tree, maturing in 60-70 years. It is also highly demanded as timber because it grows straight up due to the direct exposure and has straight fibers, thus making it easier to process and a more dependable timber product.

Notes: The Douglas-fir can live to be 1000 years old. Its thick bark protects the tree from fire. Most old-growth Douglas-firs in the temperate rain forest show a legacy of fires through their burn scars. This tree arrived in our region approximately 7,000 years ago, shortly after the retreating of the ice sheets that ended with the Pleistocene era (the Ice Age) (Pojar and Makinnon 1994).

Resources:

Pojar, J. and A. MacKinnon. 1994. Plants of the Pacific Northwest Coast; Washington, Oregon, British Columbia, and Alaska. Lone Pine Publishing, Redmond, WA, 528 pp.

Common name: Western dwarf mistletoe

Scientific Name: *Arceuthobium tsugense*

Description: This perennial plant is small, leafless, and yellowish to greenish-brown in color. It is parasitic on the branches of conifers (mostly Western hemlock), and its stems emerge from the host branch. The stems of the mistletoe are 2-20cm long, 1-3mm thick, and segmented. This plant's leaves are reduced to tiny, opposite scales. The flowers are yellowish-orange to green, small and inconspicuous. The male flowers lack a stalk and are usually found in pairs at the node of the plant segment. The female flowers are also found 1-2 at a node, sometimes with a stalk up to 1mm long and sometimes without a stalk. The fruit of this mistletoe are greenish or bluish, sticky, egg-shaped berries. Each berry consists of one seed that is explosively ejected from the berry. The seed is also covered in a slimy, sticky substance so that it clings onto wherever it lands within the canopy (Pojar and Mackinnon 1994).

Geographical range:

Habitat: This dwarf mistletoe is parasitic on many different coniferous trees including: *Abies* sp. (Firs), *Juniperus* sp. (Junipers), *Larix* sp. (Larch), *Picea* sp. (Spruce), *Pinus* sp. (Pines), and *Tsuga* sp. (Hemlocks). However, it is most commonly found specifically on Western Hemlock, *Tsuga heterophylla*. It is often not noticed because is occurs extremely high up in the canopy (Pojar and Mackinnon 1994). It is found in young and mature forests, however it best establishes in second growth forests because of the high density of western hemlocks, therefore encouraging easy distribution to its preferred host.

Reproduction: This flowering plant is wind pollinated. Its seeds are spread through the forest canopy via expulsion. A seed can shoot at an initial velocity of 27m/sec and can fly as far as 15 meters (45 feet). Sticks onto a branch and slides down into bifurcation (where a branch begins to extend from a stem). If the moisture and light environment in the branch bifurcation is just right, the seed will send "sinker roots" into the tree. The portion of the mistletoe plant embedded in the host is called the endophytic system and is composed of longitudinally oriented cortical strands and radial sinkers. The radial sinkers embed in the xylem. Scientists have documented that a direct cellular connection between the vascular elements of the mistletoe sinkers and the trachieds of the host does occur. Only about 5% of seeds expelled actually land on a branch and only 1-2% establishes a successful infection. The entire lifecycle of a dwarf mistletoe takes 4-7 years (depending on species) to establish and reproduce (Knutson and Tinnon 1980).

Input requirements (food supply): Dwarf Mistletoes (*Arceuthobium sp.)* are primarily heterotrophic. They tap into the host plants vasculatory system and take in phloem for carbon compounds. This has a negative effect the host causing a reduction in tree growth, distortion of growth, reduction in wood quality, predisposition of trees to secondary attack (by insect or fungus), and reduction of tree seed yield.

Role in the ecosystem: Dwarf Mistletoes play an important role in the mature forest ecosystem. This parasite contributes to the death of western hemlock trees. In a climax forest where there is not dwarf mistletoe, the western hemlock trees can take over and block all light from penetrating the canopy. As a result, the only trees that could grow under the dark canopy would be western hemlocks and western-red cedars. Western hemlocks grow taller than western red cedars, and thus the forest would eventually become predominantly western hemlock. If almost all the trees in the forest were western hemlock, the biodiversity would decrease. It is important that natural pests, like Dwarf mistletoe, kill some of the western hemlocks, so that they will open up the canopy and allow "light-dependent" species of plants to grow in the understory and tree-canopy.

Use as a Human Resource: Western dwarf mistletoe appears to have not beneficial inputs for humans. If anything, it has a negative impact on the quality and quantity of wood that the hemlock tree can produce when infected. Thus the mistletoe is viewed by resource managers as pest and as having a negative impact on wood quality.

Notes: In a climax forest with tree species diversity, Western dwarf mistletoe does not destroy all the trees in the forest stand. Because it is predominantly parasitic on Western hemlock, it does not infest other trees like Douglas-fir (*Psuedotsuga menziesii*) or Western red cedar (*Thuja plicata*), only the western hemlock trees.

Resources:

Knutson, D. and M.R.Tinnin. 1980. Dwarf mistletoe and host tree interactions in managed forest of the Pacific Northwest. Olympia, USDA Pacific Northwest Forest and Range Experiment Station.

Pojar, J. and A. MacKinnon. 1994. Plants of the Pacific Northwest Coast; Washington, Oregon, British Columbia, and Alaska. Lone Pine Publishing, Redmond, WA, 528 pp.

Common name: Licorice Fern

Scientific Name: *Polypodium glycyrrhiza*
"Polypodi"= many-footed fern; Greek
"glyc"= sweet; "rhiza"= root; Greek

Description: The long, pointed-triangle fronds of this evergreen fern range in size from 10-70cm on average. Its leathery leaves are once pinnately divided, with a light brown stipe; they are usually shorter than 50cm (20 inches) long. Its rhizome (root-like structure) has a scaly, reddish-brown outer covering, with a sweet, succulent inside that resembles the taste of licorice. Its sori (seed-like sack) of 3mm across or larger, are oval to round and located in a single file row on either side of a main vein on the underside part of the leaf. The sori (sack of spores) lack an indusium (a membrane that covers the sori) (Pojar and MacKinnon 1994).

Geographical range: This fern is found throughout coastal regions of the Pacific Northwest, extending from Northern California to Northern Alaska.

Habitat: *Polypodium glycyrrhiza* is found on wet, mossy ground, logs, rocks, and most commonly as an epiphyte on trees. It is predominantly found on Big leaf maple trees in the lowland, coastal forests of the Pacific Northwest (Pojar and Makinnon 1994).

Reproduction: Ferns reproduce both by seed-like structures called spores and vegetatively. Most ferns have spores on the underside of their leaves. These spores are stored in sacks called sori. When the climate and moisture are right, the fern releases its spores; some are blown through the wind, some travel on animals, and others fall to the ground. Each spore contains only one set of chromosomes (haploid) that are found in the fern cells. Thus, a spore itself cannot grow into a plant, but must undergo a process of growth called "alternate generation". A spore will grow into a gametophyte plant. A gametophyte is a premature fern that produces separate male and female parts of the plant. The gametophyte tends to be a small (1cm), heartshaped plant with fine hair-like roots called rhizoids. In this stage, the gametophyte produces tiny reproductive structures; the spherical antheridia which holds the sperm and the archegonia, which holds a single egg. The sperm swims in the water on the prothallus and finds a archegonia, which it fertilizes. The fertilized egg forms a zygote from which a new plant grows. The plant incubates inside the prothallus for a short period of time until it is developed enough to sink its roots into the soil and grow (Keater and Heady 1981).

Input requirements (food supply): Like all plants, the Licorice fern depends on photosynthesis for its survival. It takes nutrients (from the soil that has accumulated in the moss mats in which the fern resides), air, and water, and using the energy of the sun, converts these elements into useful sugars.

Role in the ecosystem: The licorice fern stabilizes forest canopy soil and substrate with its extensive network of rhizomes, supporting a place for other epiphytes (moss and lichen) to grow. It also provides food for herbivorous insects.

Use as a Human Resource: Licorice fern rhizoids were historically chewed as a snack by the Squamish, Sechelt, Comox, Haida, Nuxalk, and Kwakwaka'wakw tribes. Occasionally the rhizomes were eaten raw or cooked by coastal Native American tribes. The rhizomes are also important as medicine for sore throats and coughs, and as a sweetener for cooking (Pojar and Makinnon 1994).

Notes: This fern is often mistaken for its cousin, *Polyposium scouleri* (leather fern), which is located strictly on the coast in high saline, foggy, environments. However, *Polyposium scouleri* has incredibly leathery leaves and does not taste like licorice (Pojar and Mackinnon 1994).

Resources:

Keater and Heady. 1981. Ferns of the Pacific Northwest.

Pojar, J. and A. MacKinnon. 1994. Plants of the Pacific Northwest Coast; Washington, Oregon, British Columbia, and Alaska. Lone Pine Publishing, Redmond, WA, 528 pp.

Common name: Dragon skin lichen, Lettuce lung

Scientific Name: *Loberia oregana*

Description: *Loberia oregana* is a large-leaf foliose lichen that resembles a piece of lettuce. Its broad lobes (thallus) are 20-35mm wide, frilly on the edges, and textured with a vein like structure made up of depressions and ridges. The upper surface of the lichen is gray-green to yellowish-green; the bottom surface is brown-white to gray-white with patches of fine hair (Pojar and Mackinnon 1994).

Geographical range: Throughout the Pacific Northwest from northern California throughout British Columbia, Canada and Alaska, USA. Mostly restricted to west of the Cascades, except for a small population that resides in south-eastern British Columbia, Canada.

Habitat: This lichen is found on trees in well shaded, cool, and humid forests at low- and mid-elevations. *Loberia oregana* is incredibly sensitive to light exposure and grows best in a mid-canopy environment. This lichen is primarily restricted to old-growth forests because of its specific light and moisture requirements. *Loberia oregana* is only found in old-growth forests, and accounts for half of the epiphyte biomass in western Oregon lowland Douglas-fir forests. This lichen is metabolically active when its water content is 70% or higher. Below this level, and during drought times, this lichen ceases to photosynthesize. Thus, it is limited to habitats with moist and cool conditions (Vitt et al 1988).

Reproduction: Lichens reproduce by producing small propagules or by fragmentation. Propagules contain both the algal and fungal cells of the plant and are stored in specialized structures call "soredia". The soredia erupt and propel the cells of algae and fungi througout the forest. If both cells land in an adequate habitat, they begin to lichenize (form a lichen) and grow (Vitt *et al* 1988). However, most reproduction occurs through fragmentation. Little pieces of lichen, containing both the fungal and algal component, fall off the lichen thallus and establish in the appropriate habitat. Reproduction by fragmentation uses much less energy than reproduction by propagules.

Input requirements (food supply): Lichens are specialized flora that result from a mutualistic symbiotic bond between fungus and algae. The fungal part of the lichen (called the mycobiont) forms the structure of the lichen, giving it shape and a medium for water absorption. It also provides the plants with nutrients absorbed from the substrate. The algal component (called the photobiont), is responsible for providing carbohydrates to the fungus through the process of photosynthesis. In the case of *Loberia oregana*, which is a nitrogen fixing lichen, little cyanobacteria called *Nostoc* live on the surface of the lichen. These bacteria change atmospheric nitrogen (N_2), which a plant is not able to consume, to ammonium (NH_4^+), which the plant can consume. *Loberia* is only active when temperatures are below 60º and 70% moisture content within the lichen thalli (Kirk and Franklin 1992).

Role in the ecosystem: In a healthy old-growth forest canopy nitrogen-fixing lichens (cyanolichens) are the most dominant epiphytes, where they constitute over half of the total epiphytic mass (Pike et al 1997). Once nitrogen is fixed by the cyanobacteria on the lichen, the nitrogen ultimately ends up on the forest floor via leeching from rain. It is estimated that cyanolichens fix 2.5-4.5 pounds of N per acre of old-growth forest (3-5 kg/ha) per year (Franklin et al. 1981).

Lichens that fall to the forest floor play an important role in supplying deer, elk, and small mammals with winter food.

Use as a Human Resource: This lichen was used by the Hesquit to treat coughs and tuberculosis. Its cousin *Loberia pulmonaria* was used by early Europeans to treat pneumonia and other lung diseases (Pojar and MacKinnon 1994).

Notes: These cyanolichens are scarce in young forests. The lack of cyanolichens in second-growth forests is possibly due to dispersal limitations, unsuitable substrates and/or unsuitable climate (low moisture/proper light requirements) (Sillet and Neitlich 1996). Researchers have attempted to transplant *Loberia oregana* into second growth stands, where it rapidly died and decomposed. It is presumed that they did not survive due to the low moisture and higher temperatures found in second growth canopies (Franklin et al. 1981). The presence of *Loberia oregana* indicates a healthy forest ecosystem with high nitrogen presence.

Resources:

Franklin, J.F.,K. Cromack, J.,Denison, W.,McKee, A.,Maser, C.,Swanson, F.,Juday, G. 1981. Ecological characteristics of old-growth Douglas-fir forests, United States Department of Agriculture: 56.

Kirk, R.Franklin, J., 1992. The Olympic Rain Forest: an ecological web. University of Washington Press, Seattle and London, 128 pp

Pojar, J. and A. MacKinnon. 1994. Plants of the Pacific Northwest Coast; Washington, Oregon, British Columbia, and Alaska. Lone Pine Publishing, Redmond, WA, 528 pp.

Pike, L.H.,Rydell, R.A.,Denison, W.C., 1977. A 400 year old Douglas-fir tree and its epiphytes: biomass, surface area, and their distributions. Canadian Journal of Forest Research. **7**:680-699.

Sillett, S. and C. Neitlich.1996. Emerging themes in epiphyte research in westside forests with special reference to cyanolichens. Northwest Science. **70**:54-60.

Sillett, S.C., 1998. Survival and growth of cyanolichen transplants in Douglas-fir forest canopies. The Bryologist. **101**:20-31.

Vitt, D.H.,Marsh, J.E.,Bovey, R.B., 1988. Mosses, Lichens, and Ferns of Northwest North America. Lone Pine Publishing, Edmonton, Alberta, 296 pp.

Common name: Bigleaf Maple Tree

Scientific Name: *Acer macrophyllum*;
Aceraceae= Maple family
"macro"= large; "phyllum"= leaf

Description: This deciduous tree can grow up to 35m (120 feet) tall, and is multi-stemmed. The Bark changes in appearance with age. When the bark is young, it is green and smooth; when it is old, the bark is gray-brown and ridged. In a humid environment, epiphytes commonly grow abundantly on the bark. The tree's leaves are opposite, with 5 lobes and 15-30 cm across. The flowers of this tree are greenish-yellow, about 3mm across, and hang in a cylindrical cluster from an individual stem off one central main stem. The tree's fruits are a pair of golden-brown seeds, about 3mm across, with wings in the shape of a V (Pojar and Mackinnon 1994).

Geographical range: This tree's range extends from coastal, central British Columbia, Canada, all the way south to Southern California, U.S.

Habitat: Bigleaf maples tend to be found in dry to moist sites that suffer from fire, erosion, logging, and other disturbances. They are found in low to middle elevation forests in monoculture stands or within Douglas-fir/Hemlock forests (Pojar and Mackinnon 1994).

Reproduction: A maple tree is a flowering plant containing both male and female reproductive organs in its flowers. The pollen from the stamen (male part) of the flower fertilizes the pistil (female part). As a result of fertilization, a seed is developed. The seed falls to the earth and if exposed to the right conditions, sprouts and grows into a small maple tree seedling.

Input requirements (food supply): Like all plants, the Bigleaf maple depends on photosynthesis for its survival. Using the energy of the sun, the plant converts nutrients, air, and water into sugars and carbohydrates. Bigleaf maples have developed a special means of getting nutrients from with thick moss mats that accumulate on its branches. Within the lower part of the moss mat, plant material and particles from the air accumulate to form soil. This canopy soil is full of nutrients and minerals. The Bigleaf maple accesses these nutrients by sending out aerial roots (adventitious roots) from its branches directly into the moss mat where it sucks up nutrients and water (Nadkarni 1981).

Use as a Human Resource: Historically, Bigleaf maples were an incredibly important resource to the First Nations people. Leaves were used by the Skagit, Lummi, and Snohomish to cover food while it was cooking in the steam pit. The Squaxin used the leaves as mats on which they cleaned fish. The Swinomish, Chehalis, and Quinalt used cured wood for smoking salmon. The Haida, Tlinglet, and Tsimshiam regarded maple wood as the finest for carving. The Quinalt, Lummi, and Swinomish also used this wood for bowls, dishes, platters, and spoons. The S'klallam, Snohomish, and Skagit made canoe paddles form it. The only medicinal use documented is by the S'klallam, who boiled the bark and drank the tea as a cure for tuberculosis. Currently it is used to make furniture and as fire wood (Gunther 1973).

Resources:

Gunther, E., 1973. Ethnobotany of Western Washington; The Knowledge and Use of Indigenous Plants by Native Americans. University of Washington Press, Seattle, WA., pp.

Nadkarni, N.M., 1981. Canopy roots: convergent evolution in rain forest nutrient cycles. Science. **214**:1023-1024.

Common name: Step moss, Feather moss, Fern moss

Scientific Name: *Hylocomium splendens*

Description: The gametophyte (leafy part) of this fern is large and robust compared to other mosses. It is shiny green in color and has a twice-pinnate stem that is covered in abundant, small, green filaments (visible with a hand lens). Annual growth segments are visible, arising just behind the tip of the previous year's growth. Individual leaves are 2-4mm long, elliptic at the base and tapering into a sharp point at the tip. Two midribs run along the middle of each leaf. The ferns sporophytes are smooth, curved and cylindrical (Pojar and Mackinnon 1994).

Geographical range: This species of moss is found across Canada and along western parts of the Pacific Northwest coast from Alaska to Northern California (Vitt et al 1988).

Habitat: *Hylocomium splendens* is commonly found in lowland to middle elevation forests often found in the lower canopy or on the forest floor on humus rich in calcium (Pojar and Mackinnon 1994).

Reproduction: Mosses, like ferns, reproduce through a method of alternate generation. On the branch of a moss gametophyte (the vegetative part of the plant), male and female sex organs produce sperm and eggs. The sperm swims to the eggs to fertilize them; the fertilized egg then forms into a sporophyte. The sporophyte consists of a capsule on a stalk (seta), which grows out of the gametophyte. Spores are released from the sporophyte and grow into gametophytes. The lifecycle continues in these alternate generation stages of gametophyte and sporophyte. Moss can also grow vegetatively, where it does not require sexual reproduction but rather grows new gametophytes from the plant's rhizoid (root) (Pojar and Mackinnon 1994).

Input requirements (food supply): Like all plants, moss depends on photosynthesis for its survival. It obtains its nutrients from particles in the air or rain that settles on the moss leaves and rhizoids. The nutrients and dead plant material that fall onto the moss roots decompose and become soil. The moss uses nutrients from the soil rhizoids, and using the energy of the sun, chemically converts the nutrients, water, and air into sugars and carbohydrates.

Role in the ecosystem: All mosses lack "true roots", but instead have root-like structures called rhizoids. These rhizoids enable the plant to secure itself to a substrate (tree bark, needle, rock). When moss establishes itself, its rhizoids trap dust particles and vegetative matter (Pojar and Mackinnon 1994). This organic matter is decomposed by mites and nematodes and creates canopy soil from which the moss obtains its nutrients. The canopy soil also nourishes the licorice fern and lichens that are also growing within the tree canopy. Nutrients that are not absorbed by other epiphytes, eventually leeches onto the forest floor when the moss mats become saturated with water.

Use as a Human Resource: Moss releases oxygen as a waste product from photosynthesis. Humans need oxygen to survive and thus moss plays an important role in supplying humans with air. During the process of photosythesis, moss also cleans the air of pollutants.

Mosses, liverworts, and hornworts are currently being screened for antitumor agents. Some documented as effective anti-tumor agents include: *Polytrichum sp, Claopodium crispifolium, Plagiomnium venustum, Hylocomium splendens* (Spjut et al 1986).

Moss is also an important non-timber resource that is experiencing a strong demand on the floral market. It is harvested and used in planters and wire hanging baskets. Little research has been conducted to determine the long-term impact of extensive moss harvest on the forest environment.

Notes: The age of the step moss may be estimated by counting the number of leaf-cluster increments.

Resources:

Pojar, J. and A. MacKinnon. 1994. Plants of the Pacific Northwest Coast; Washington, Oregon, British Columbia, and Alaska. Lone Pine Publishing, Redmond, WA, 528 pp.

Spjut, R.W., M. Suffnesss, G.M. Cragg, and D.H.Norris. 1986. Mosses, liverworts, and hornworts screened for antitumor agents. Economic Botany. **40**:310-338.

Vitt, D.H.,Marsh, J.E.,Bovey, R.B., 1988. Mosses, Lichens, and Ferns of Northwest North America. Lone Pine Publishing, Edmonton, Alberta, 296 pp.

Common name: Marbled murrelet

Scientific Name: *Brachyramphus marmoratus*;
“Brachyramphus”= short billed
“marmoratus”= refers to the mottled brown plummage appearing during breeding season

Description: This bird is compact and 9-10.5 inches long, weighing 7-10 ounces (Scott 1987). It has small wings, a big head, short neck, and an upturned tail. In the winter, the murrelet’s coloration is prominent, with a dark brown upper body and a pure white lower body. A small shaft of white runs along the top of the wing, appearing as a wing patch in flight. During breeding season, its distinctly colored feathers molt to a mottled brown and white coloration, with a darker upper body. In either plumage, this murrelet has a distinguishing white circle around its eyes.

Geographical range: Found all along the Pacific Coast from Asia to Russia, and south along the North American coast from Alaska to Northern California (Scott 1987; Environment Canada, www.speciesatrisk.gc.ca).

Habitat: Marbled murrelets are incredibly habitat specific birds. The spend foraging hours on the open waters of the Pacific Ocean, but rear their young on the large, mossy limbs of coniferous trees. This species resides within 40 miles of the Pacific shoreline as it must travel from the ocean to the forest on a daily basis during breeding season (FEMAT 1993).

Reproduction characteristics: A pair of murrelets will nest solitarily. Suitable trees for nesting are within 70km (46 miles) from the ocean. Tall trees with mossy platforms or cavities on thick branches where they can form a simple cup nests 20-40 m above the forest floor are ideal for nesting. A clutch contains only one egg. The murrelet parents visits the nest only at night. Both male and female share the food foraging and incubation; while one is incubating the eggs, the other is foraging for food for the parent who is incubating. When a sufficient forest is unavailable, the murrelet will lay its eggs on rocky ground leaving the eggs susceptible to predators (Environment Canada, www.speciesatrisk.gc.ca).

Feeding characteristics: The murrelet’s “torpedo” shape and short wings enable it to swim underwater as it feeds on small fish, mollusks, and crustaceans.

Role in the ecosystem: Provides the forest ecosystem with marine derived nutrients via the excretion of its feces.

Notes (limiting factors, population status, etc.): The marbled murrelet populations are threatened by many human induced causes. Clear-cut logging contributes to a decline of suitable nesting habitat. Fishing nets along the coast are also a leading cause of murrelet death, as they are caught in the net from diving in the water to hunt for fish. Another cause of death is due to oil spills. In recent spills off the coast of Alaska and Canada, murrelets comprised a large number of total bird mortality. Lastly, near shore boats that create wake can disturb any nests that are on the shoreline. On the Pacific Northwest, however, murrelets tend to nest in forests and this is not as big a concern.

Resources:

Environment Canada, www.speciesatrisk/gc.ca/

FEMAT.1993. Forest Ecosystem Management: An Ecological, Economical, and Social Assessment. Portland, Or, Interagency SEIS Team.

Scott, S.L. 1987. Birds of North America. National Geographic Society. 464 pp.

Common name: Northern spotted owl

Scientific Name: *Strix occidentalis caurina*
"Strix" = to screech; referring to its call (Greek)
"occidentalis"= western (Latin)

Description: The spotted owl is about the size of a crow and has a large round head with black eyes and a spotted head, neck, and underside. Its chest is barred with brown. Its ears are not visible. Its main call is a series of three or four hesitant, dog-like barks and cries (Scott 1987).

Geographical range: The Northern spotted owl is a resident from Northern California, to western Oregon and Washington, and southwestern British Columbia, Canada.

Habitat: The Northern spotted owl inhabits dense, humid coniferous forests with canopy closures of at least 80% or on mixed woodlands and deeply shaded canyons in coastal and mountain ranges on the west coast. It requires a large forested environment with a multi-layered canopy, large crowned old-growth trees, and snags. Its habitat is usually found at less than 4,200 feet elevation (DeGraaf et al. 1991).

Reproduction: This owl requires 2,700-4,500 acres of dense old-growth forest or deep, narrow, heavily wooded canyons per breeding pair (Kirk and Franklin 1992). It generally nests in cool, shaded areas with a well-developed understory. It prefers to nest on the broken top of a snag or on platforms created by Dwarf Mistletoe or hollowed out logs or snags. It rarely builds its own nest in a branch node (DeGraaf et al. 1991). Its breeding season is from early March to mid-April. These owls start breeding when they are 2-3 years old and do not reproduce every year. They have 2-4 eggs per clutch. The chicks hatch after 28-30 days of incubation. The female sits on the nest and incubates the egg while the male brings the female food. Only 11% of the offspring survive from birth to breeding age and on average each breeding pair has .49 offspring throughout their lifetime (Kirk and Franklin 1992).

Input requirements (food supply): Preys on a wide variety of animals, but mostly eats small mammals like mice, squirrels, or voles (DeGraaf et al. 1991). It relies heavily on eating Northern Flying squirrels.

Role in the ecosystem: Maintains small mammal populations.

Use as a Human Resource: The northern spotted owl is considered an "Indicator species". When its populations cease to reproduce or are declining in numbers, it is an indication that the forest ecosystem is suffering from fragmentation.

Notes: This owl is strictly nocturnal and lives up to 15 years (Kirk and Franklin 1992).

Its close relative and subspecies, the Southern spotted owl (*Strix occidentalis*) ranges throughout the mountains of southern Utah, central Colorado, Arizona, New Mexico, western Texas, south into Mexico (DeGraaf et al. 1991).

This Northern spotted owl is considered rare as its populations have severely declined over the last century due to the clearcutting of old-growth coniferous forests. As of 1992, approximately 500 pairs existed in Washington and fewer than 100 in Canada (Environment Canada, www.speciesatrisk.gc.ca/Species/English/SearchDetail.cfm/). In the U.S., the Northern spotted owl is federally listed as a threatened species. Both the US and Canada have developed long-term studies and forest management to eliminate the extinction of this species, however, its populations are still in decline.

The spotted owl is also threatened by another species in its same genus, *Strix varia,* the Barred Owl. The Barred owl looks incredibly similar to the spotted owl, except that it is a slight bit bigger in size. The Barred owl feeds on the same food as the spotted owl and can live on the edges of clearcuts and in disturbed forests, therefore directly competing with the availability of resources. The Barred owl is also more aggressive than the Northern spotted owl and literally chases the spotted owl out of its habitat (Kirk and Franklin 1992).

Resources:

DeGraaf, R.M.,Scott, V.E.,Hamre, R.H.,Ernst, L.,Anderson, S.H., 1983. Forest and Rangeland Birds of the United States. U.S. Department of Agriculture, Washington, D.C., 625 pp.
Environment Canada, www.speciesatrisk.gc.ca/Species/English/SearchDetail.cfm/).
Kirk, R.Franklin, J., 1992. The Olympic Rain Forest: an ecological web. University of Washington Press, Seattle and London, 128 pp.
Scott, S.L. 1987. Birds of North America. National Geographic Society. 464 pp.

Common name: Pileated woodpecker

Scientific Name: *Dryocopus pileatus*

Description: The Pileated woodpecker is the second largest woodpecker in North America, reaching an average length of 15 inches (38 cm). It has a long whitish beak and a white head with stripes. In the male, a red stripe extends off of the beginning of the beak to the neck, where it becomes a black streak and continues down the neck. On the female, this red stripe is replaced with a black. It has a red tuft of feathers that ride from the upper beginning of the beak to the back-edge of the head. It also has a black streak that runs from the beginning of the beak, through the eye, and to the upper back of the head where its meets with the red-tuft of feathers, giving the bird a masked appearance. The rest of its upper body is almost entirely black with the exception of a small white spot on the edge of the middle of its wing (Scott 1987).

Geographical range: This woodpecker is found from the south-western part of British Columbia, to most of Eastern Canada and all the eastern US states. Its populations extend down from British Columbia along the Pacific Northwest coast. Its populations do not appear East of the Pacific Northwest until the Great Lakes (Scott 1987).

Habitat: This species of woodpecker generally prefers densely forested areas, but also seems to adapt to living near surburban edges when large tracks of mature forest are present in close range. Its habitat requires the presence of snags and downed wood, where it carves a nest and gathers food (Scott 1987).

Reproduction: This woodpecker makes nests in snags by excavating a large hollowed out den 4.5-20m (15-70 feet) up a tree. It requires that the snags be greater than 38cm (15 inches) in diameter for nest cavities (DeGraaf et al 1991). The female lays 3-4 white eggs in spring. The eggs are incubated for 18 days by both parents.

Input requirements (food supply): The Pileated woodpecker consumes a diet that is about 70% insects. It mainly eats carpenter ants and bark beetle grubs (Scott 1987), but will also consume other insects, wild fruit, and seeds (DeGraaf et al 1991).

Role in the ecosystem: Abandoned woodpecker nests provide a nesting site for saw-whet owls, bats, martins, and flying squirrels (Kirk and Franklin 1992).

Use as a Human Resource: The Pileated woodpecker plays an important role in maintaining populations of pests, such as wood-boring beetles. In second growth forests where Pileated woodpeckers are not present due to a lack of nesting sites, populations of wood-boring beetles can get out of control and destroy or weaken the entire forest.

Notes: This bird is locally common in regions with large patches of old-growth forest. However, in areas of extensive agriculture or clearcutting they are not seen as commonly.

Resources:

DeGraaf, R.M.,Scott, V.E.,Hamre, R.H.,Ernst, L.,Anderson, S.H., 1983. Forest and Rangeland Birds of the United States. U.S. Department of Agriculture, Washington, D.C., 625 pp.

Kirk, R.Franklin, J., 1992. The Olympic Rain Forest: an ecological web. University of Washington Press, Seattle and London, 128 pp.

Scott, S.L. 1987. Birds of North America. National Geographic Society. 464 pp.

Common name: Silver-haired bat

Scientific Name: *Lasionycteris noctivagans*
"Lasios" =hairy; "nykteros" = nocturnal (Greek)
"Nocti" ="night"; "vagus" = wandering (Latin)

Description: The silver-haired bat is glossy black and has silver-gray tipped hair on its backside. Its underside is dull black in color. This bat is 92-108 mm (3 5/8-4 1/4 inches) long, has a wingspan of 25-27cm (10-11 inches), and weighs 9-13 grams (1/4-1/2 oz.) . Its hairless ears are short and round and its tail is almost completely covered with a small amount of fur (Whitaker 1980). This bat can be seen twisting and gliding at approximately 11 mph over water and through the forest. The sonar of this bat, because it has a lower pitch, can be heard by humans and resembles squeaks and chatters (Christy and West 1993).

Geographical range: This species of bat is found throughout North America and Canada. Some silver-haired bats migrate while others do not. Those that do not migrate south for the winter, but are instead permanent residents, must go into hibernation from November to March (Maser et al 1981; Christy and West 1993). In mountainous regions, the silver-haired bat migrates for the winter to lower elevations where the temperatures are not as cold, and then returns to the higher elevations in the spring when temperatures are warmer. Though this species is widespread, its populations are scarce where it is found (Whitaker 1980).

Habitat: The Silver-haired bat is mostly found in old-growth forests. The silver-frosted color on its back allows it to blend in with the lichen-coated bark of an old-growth Douglas-fir. It also finds refuge in holes created by old tree limbs that have since rotted and in the abandoned nests of woodpeckers and small mammals in the trunk of a snag (Christy and West 1993). Silver-haired bats have been known to live in young forests, however their populations are much larger in old-growth forests as there are more places for them to roost and more insects for them to eat (Grindal 1998; Perkins and Cross 1988). There are accounts of silver-haired bats roosting in caves as well, however these occurrences are few (Christy and West 1993).

Reproduction: The silver-haired bat tends to mate in autumn or winter (September-February), but the female stores the sperm until spring (March -May) when her body releases an egg. This is called "delayed implantation". The bat offspring are born from May to July. The silver-haired bat generally has two babies, but can have from one to four per litter. The female bat raises her young in the high forest canopy away from male bats and non-breeding females. In the high canopy, the female and babies are safer from predation than if they were in the lower- or mid-canopy (Christy and West 1993).

Input requirements (food supply): Bats use "echolocation" to find their prey. A bat emits a pulse of electronic sound that bounces off of the objects in its path. These reflected sound waves are received by the bat and provide information on the location, size, and nature of the object in the path of their ultrasonic emissions (Christy and West 1993). The silver-haired bat mostly feeds over bodies of fresh water, before sunrise and just at dusk. The silver-haried bat eats a variety of insects but mostly consumes flies and moths (Christy and West 1993). Bats that live near farms that use pesticides on their fields accumulate pesticides in their bodies from eating exposed insects (Christy and West 1993). This could have a severe effect on their health and growth.

Role in the ecosystem: Bats are important to the ecosystem for many reasons. Since they often feed on insects that live around water, they transfer aquatic nutrients that were stored in the insects to the inner forest where the bat roosts. Bats also contribute phosphorous into the forest ecosystem through their excrement. Phosphorous is an extremely important forest nutrient because it is needed by plants to help them absorb Nitrogen. All plants are dependent on Nitrogen to grow, and are also therefore dependent on Phosphorous. The silver-haired bat also serves as an important regulator of pest populations, eating insects that might otherwise eat plants. Bats are not commonly predated, however there are a few accounts of silver-haired bats being eaten by raptors, domestic cats, large fish, bullfrogs, and snakes have been documented (Christy and West 1993).

Notes: Twelve species of bat live in Douglas-fir forests of the Pacific Northwest (Christy and West 1993). All bats belong to the taxanomical order of Chiroptera, which translates as "hand-wing". The bat's wings are actually hands with each finger functioning as a part of the wing. The thumb bone has a claw at the tip, which enables the bat to grasp onto tree bark and limbs when it is roosting. The silver-haired bat can live to be twelve years old (Christy and West 1993). Many biologists believe that bat populations have declined in the last several years, however this is hard to determine because of the little research that has been done on bat populations. It is estimated that only 3% of bat populations worldwide are actually documented. Of the forty species that occur in North America, seven are listed as endangered species (Christy and West 1993).

Resources:

Christy, R.E.West, S.D., 1993. Biology of bats in Douglas-fir forests. U.S.D.A, Portland, pp.

Grindal, S.D., 1998. Habitat use by bats in second- and old-growth stands in Nimpkish Valley, Vancouver Island. Northwest Science. 72, 116-118.

Maser, C., 1998. Mammals of the Pacific Northwest; from the Coast to the High Cascades. Oregon State University Press, Corvallis, Oregon, 406 pp.

Perkins, J.M.Cross, S.P., 1988. Differential use of some coniferous forest habitats by Hoary and Silver-haired bats in Oregon. The Murrelet. 69, 21-24.

Whitaker, J.O., Jr.,Maser, C.,Keller, L.E., 1977. Food habits of bats of western Oregon. Northwest Science. 51, 46-55.

Common name: Northern Flying Squirrel

Scientific Name: *Glaucomys sabrinus*
"Glaucomys" = grey mouse (Greek)
"sabrinus" = Sabrinus is a river nymph from Greco-Roman myth; this name also refers to the Severn River of Ontario, Canada, where the first Northern flying squirrel was found. The Severn River is named after the Severn River of England, which was previously named the Sabrinus River by the Romans (Mathews 1988).

Description: The Northern flying squirrel is soft gray in color on its upper parts and white on its underside. It is 24 to 36 cm (10-15 inches) long, including its tail and weights 70 to 140 grams. The eyes of the flying squirrel have a reddish-brown over-brow and a gray under-brow. Flying squirrels have a large flap of skin that stretches from their hind-leg to forearm on both sides of their body. These squirrels can be heard at dusk and dawn giving off a soft bird-like chirp and rustling and thudding as they land onto a branch following a glide (Mathews 1988).

Geographical range: Found throughout the United States and Canada in northern regions, including north and south of Washington, Oregon, Idaho, Montana, the Great Lakes region south through the Appalachians (Squirrel Almanac, spot.colorado.edu/~halloran/sq_nofly.html).

Habitat: The northern flying squirrel likes heavily wooded coniferous and deciduous forests. It lives in trees such as cedar, spruce, and Douglas-fir. During nesting season, the mother squirrel occupies a hollowed out snag where she rears her offspring (Mathews 1988).

Reproduction: Northern flying squirrels either nest in abandoned bird nests in hollowed out snags or they make a nest on the tree branches using moss, lichen, sticks, and soft plant fibers as building materials. Flying squirrels tend to have one litter (aggregate) of 2-5 offspring a year. They mate in late winter to early spring and gestation lasts for approximately 40 days (Squirrel Almanac, spot.colorado.edu/~halloran/sq_nofly.html). In the Pacific Northwest, the northern flying has its offspring May-June. The young are born hairless and are unable to hear or see unti they are four weeks old. The mother nurses the babies with milk for about five weeks. At two months old (in midsummer), the young are taught how to fly (Mathews 1988).

Input requirements (food supply): In the Pacific Northwest, Northern flying squirrels mostly eat fungi and lichen. However, they are omnivorous and will therefore eat seeds, plants, and various other foods. These squirrels do not store a large amount of winter food like other species of squirrels. Instead, they forage for lichens and underground fungi all year round (Mathews 1988).

Role in the ecosystem: Owl, weasel, martin, bobcat, wolf, hawk, lynx, and domestic cat all prey on the Northern flying squirrel (The Squirrel Rehabilitation Center, www.squirrel-rehab.org). It is a primary food source for the Northern spotted owl.

Flying squirrels play an important role in distributing the spores (seeds) of truffles. Truffles are the fruiting body of a kind of mychorrizae fungi. Mycorrhizae fungi grow around (and sometimes inside) the roots of a tree (or other plant) and help the plant find nutrients and water. When a flying squirrel eats a truffle, the spores of the truffle are stored in the squirrel's digestive track for approximately one month. Inside the squirrels intestines, the fungal spores mix with a nitrogen-fixing bacteria and yeast. When the squirrel goes to the bathroom, it drops its feces, which contain both spores and nitrogen-fixing organisms. Thus, the spores have immediate access to accessible nitrogen, which aides in their survival and proliferation (The Squirrel Rehabilitation Center, www.squirrel-rehab.org).

Use as a Human Resource: Mycorrhizae is important to humans because it helps trees grow big and strong. In a clearcut that has been burned, there tend to be few mycorrhizal fungi and therefore trees grow slower and less healthy. If humans want healthy trees it is important that they protect the mycorrhizal fungi, and therefore protect flying squirrels.

Humans also like to eat truffles and other fungus that depend on the Northern flying squirrel for their dispersal. Thus, the flying squirrel is an incredibly important resource for humans who use forest trees, plants, or fungus.

Notes: The northern flying squirrel is nocturnal; this means it is only active at night. These squirrels live for about three to four years in the wild. Flying squirrels do not really "fly", but rather glide through the air. The squirrel uses a large tree as a launching pad, jumps into the air, and glides downward at about a 45-degree angle. They can control their movements left or right by moving their wing-flaps or make a sudden turn by shifting their tail. They can glide up to 80 yards and land in a tree or on the ground (The Squirrel Rehabilitation Center, www.squirrel-rehab.org; Squirrel Almanac, spot.colorado.edu/~halloran/sq_nofly.html).

Flying squirrels have an aerodynamic wing structure that NASA is modeling their airplanes after. The flying squirrel has tiny "winglets" attached to the tips of their wings that point upwards. According to NASA researchers, this wing structure cuts down air-drag by 20%. NASA has spent millions of dollars trying to perfect what the flying squirrel has had all along, efficient flight (Anonymous BBC News, May 18, 1998).

Resources:

Anonymous BBC News, May 18, 1998, www.bbcnews.com

Mathews, D.1980. Cascade and Olympic Natural History; A Trailside Reference. Raven Editions, 625 pp.

Squirrel Almanac, spot.colorado.edu/~halloran/sq_nofly.html

The Squirrel Rehabilitation Center, www.squirrel-rehab.org

Common name: Vaux's swift

Scientific Name: *Chaetura vauxi*

Description: The Vaux's swift is a small, 5 inch, swallow-like bird that is shaped like a cigar and flies through the canopy at speeds of 65 km/hour (40mph). Its upper body is dark sooty brown with a slight gloss, the rump being pale black. Its underside is light gray on the throat and abdomen, blending into a sooty brown color two-thirds of the way from the head to the tail (Godfrey 1966). It has dark eyes and a white brow over its eye.

Geographical range: This bird is found in southeastern Alaska and northern British Columbia to central California (mainly west of the Cascades and Sierra Nevadas). It is also found throughout western Mexico to northern Venezuela (Godfrey 1966).

Habitat: This bird inhabits forested areas with large trees (DeGraaf 1991). It is found in woodlands near lakes and rivers (National Geographic 1987)

Reproduction: The nest of Vaux's swift is a narrow bracket of twigs, stems, and/or conifer needles, cemented together and mounted on the inside of a hollowed out snag. It nests in snags that are tall and at least two feet in diameter, requiring thick walls to maintain a warm environment (Kirk and Franklin 1992). The Vaux's swift has 4-6 dull white eggs per clutch. The eggs are incubated for 18-20 days (Godfrey 1966).

Input requirements (food supply): The Vaux's swift feeds exclusively on canopy insects captured while in flight (Kirk and Franklin 1992).

Role in the ecosystem:

Use as a Human Resource:

Notes: Vaux's swift are uncommonly seen.

Resources:

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Kirk, R.Franklin, J., 1992. The Olympic Rain Forest: an ecological web. University of Washington Press, Seattle and London, 128 pp.

Scott, S.L. 1987. Birds of North America. National Geographic Society. 464 pp.

Common name: Water bears

Scientific Name: Phylum- Tardigrada.
“Tardigrada” = slow walker

Description:A tardigrade is a microscopic aquatic animal. It looks like a caterpillar that has 4 pair of legs ending in claws and five body-segments. Tardigrades range is size from 0.2-0.5 mm (about the same size as a fine-led pencil dot) (Miller 1997).

Geographical range: Tardigrades are commonly found on every continent (McInnes 1994).

Habitat: Tardigrades are found in every biome including salt and freshwater environments, in humid rain forests and dry deserts, in low canyons and high altitude mountain tops. However, tardigrades are aquatic and do need to be in water to eat, breath, reproduce, and move (Miller 1997). Tardigrades are commonly found in the interstitial (water between leaves) environment of moss and lichen.

Reproduction: Tardigrades reproduce sexually and asexually. Their eggs can look like small white or bright sparkles, Christmas tree ornaments, or sea mines. It has been documented that tardigrades can produce female offspring through asexual reproduction (Miller 1997).

Input requirements (food supply): Some tardigrades are carnivores, others are herbivores or omnivores. They feed on each other, as well as mites, aphids, nematodes, and other microscopic organisms. They have a fully developed digestive and excretory system. Tardigrades do not feed during their molting periods, from a few hours to a few days (Miller 1997).

Role in the ecosystem: These microscopic creatures play a role in the cycling of nutrients.

Use as a Human Resource: To this day, no human resource use has been identified (Miller 1997).

Notes: This phylum of organism is phylogenetically located between the phylum of roundworms (nematodes) and the arthropods (crustacean, insects, ticks, and mites). In the last 200 years, since these organisms were first discovered, 3 classes, 5 orders, 15 families, 94 genera, and over 750 species have been discovered (Miller 1997).

Tardigrades are unlike any other organism because of several unusual characteristics. Tardigrades do not have a respiratory system with lungs. Instead, they breathe through their skin and pump oxygen and fluids throughout their body.

Tardigrades do not have eyes, but instead have a nervous system that responds to light sensitive spots. Tardigrades are made of 70% water. When their environment is too dry, they enter into a state of “cryptobiosis”. The tardigrade shrivels up into “tun” and drastically slows down its metabolism. When tardigrades are in their cryptobiosis state they can survive temperature well below freezing, high above boiling, and under pressures of 27,000 psi for limited time periods. These creatures can live in a state of cryptobiosis for over a hundred years (Miller 1997). One specimen from a sample of moss that was over 100 years old showed sign of life when rehydrated (Kinchin 1994). The active life of a tardigrade may only last a few months, however their lifespan may be spread over several years if they enter into a cryptobiotic state.

The tardigrade is unable to control the amount of water it absorbs through its skin. Therefore, when the tardigrade's environment is too moist, it swells up and enters into a state called "anoxybiosis". In this state the tardigrade swells up like a balloon and floats around on the water. When the high water resides, the tardigrade deflates a little, and returns to its normal behavior of eating, moving, and reproducing (Miller 1997).

Resources:

McInnes, S.J. and D.B. Norman. 1998. Tardigrade Biology. Zoological Journal Linnean Society London. Academic Press. London. Vol. 116: pp. 1-243

Miller, W.R. 1997. Tardigrades: Bears of the Moss. Kansas School Naturalist. Vol. 43:3 pp.1-14.

Common name: Oregon red tree vole, Tree mouse

Scientific Name: *Arborimus longicaudus*
"Arbor"= tree; "mus"= mouse
"longus"=long; "caudus"= tail

Description: This vole is 16-20 cm (6-8 inches) in length, including a tail that is over one-third its total body length.. The tree vole weighs between 1-1.5 ounces (25-47 grams). Its coloration varies from dark reddish brown along the northern coast to lighter reddish brown along the middle of its range, to orangish red along the southern coast and western flank of the Cascade Mountain range. The underside of the tree vole is light gray and the tail varies in color from rich medium brown to black (Maser 1998).

Geographical range: This vole is found in Western Oregon from South of the Columbia River to just south of the Smith River, just below the Southwestern Oregon boarder in California. It has never been found North of the Columbia River, in Washington, British Columbia, or Alaska (Maser 1998).

Habitat: The Oregon red tree vole usually inhabits coniferous forests, although they have been documented to live in mixed-coniferous/deciduous forests. They mostly reside in the mid-to upper-canopy of Douglas fir trees (*Psuedotsuga menziesii),* but occasionally on the coastal regions are found in the canopies of Sitka Spruce (*Picea sitchensis)* and old-growth Western hemlock (*Tsuga heterophylla)* trees. These voles can only inhabit trees that are at least 25-30 years old because immature trees are not structurally developed to support the voles nesting requirements or to protect them from severe weather (Maser 1998).

Reproduction: Male and female tree voles build separate nests and live in them year round, only to encounter when the female is fertile. The female has a litter size of one to four offspring. The babies are born naked, blind, and helpless. A female can become fertile within 24 hours of giving birth to her babies, thus sometime more than one litter occupy a nest at a given time. The offspring remain in the nest until they are at least one month old, at which time the move to another part of the same tree and construct their own nest (Maser 1998).

Input requirements (food supply): Oregon tree voles are one of the most specialized tree-dwelling organisms in the world. They feed primarily on the needles of Douglas fir trees and to a lesser extent on the soft bark or pithy center of a small twig. They also sometimes eat the needles of Sitka spruce, Grand fir (*Abies grandis*), and Western hemlock trees. The voles cut their twigs at night, drag them back to the nest, and consume them in or on top of their nest site or store them for future consumption. When a tree vole eats a coniferous needle, it bites along the edge of the needle and removes a part of the needle called the "resin duct". Once both resin ducts are removed, it consumes the entire needle. Young needles are often consumed without the removal of their resin ducts (Maser 1998). It has been estimated that tree voles eat an average of 100 Douglas-fir needles per hour (Kritzman 1977) Tree voles obtain their water from their food and from licking dew drops off of the coniferous needles (Maser 1998).

Role in the ecosystem: Oregon tree voles are an important food source for raccoons, weasels, martens, and various other owl species. Northern spotted owls are their most common predator (Maser 1998).

Use as a Human Resource: The Oregon red tree vole is important to humans because it is an indicator species. Tree vole populations are threatened when forests are fragmented. Thus, when their populations decline it is an indication that the forest where their population is declining is under great environmental stress.

Notes: In an old-growth forest, many generations of tree voles can live in a single Douglas fir tree. Nests are built over 150 feet above the forest floor in ancient forests and 60-70 feet above the forest floor in second growth forests. As a tree grows, its lower branches become shaded and die. Thus, the red tree vole will leave the lower nest atop dead branches and make a new nest higher in the canopy on live branches. In order to maximize its foraging efficiency and protect itself from predators, the vole tends to build its nest on branches with live needles where it can obtain food in close range (Maser 1998).

Oregon tree voles build nests out of harvested twigs, sometimes building atop of an already preexisting, but abandoned, bird or small mammal nest. Their nest begins as a pile of twigs and needle resin ducts. As the nest debris accumulates, the vole begins to burrow a hole, pushing nesting debris to the side and overhead as if to create a small dome. As the vole feed on top of the nest and inside of the nest, it adds to the accumulation of debris and its nest grows ever so larger. The nest is passed down to generations as the parents die, and in effect the nest grows larger and larger. In order for the tree vole to access the exterior of the nest, it creates various tunnels. All tree vole nests have an escape route that leads from the interior of the nest to below the nest. There is also at least one tunnel that leads from the interior of the nest to the roof, where the vole feeds on its stash. These tunnels are usually situated so that the vole does not have to be exposed to the outside for long periods of time when it is getting its food. Sometimes a nest can be so large, it surrounds the entire trunk of the tree (Maser 1998).

If a tree vole is being attached by its predator it via a tunnel that leads to the bottom side of the nest and onto the tree trunk. The vole then scurries, head first, down the trunk of the tree and hides under leaves or bushes on the forest floor. Another way it escapes is by running onto the branches of nearby trees, scurrying into a dense patch of branches and standing still. The tree vole's reddish coat enables it to blend in nicely with the bark of the tree or it appears to resemble a Douglas-fir cone. The third way a tree vole can escape a predator is by jumping from the tree into the air and falling to the ground. The tree vole can fall from a height of 60 feet and almost always lands on its feet, unharmed. They appear to spread their legs and tail which aids them for a softer landing and allows them to cling onto any underbrush they may fall upon (Maser 1998).

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Common name: Methuselah's Beard, Oldman's Beard

Scientific Name: *Usnea longissima*

Description: As its common name suggests, this lichen resembles hanging strands of pale yellowish-green hair. Each strand of lichen can grow up to from 15cm (6 inches)- 6m (19 feet) long. Each strand consists of a single main unbranched strand (or sparsely branched) with numerous short branchlets growing from the main strand. *Usnea longissima* has an elastic central cord that when the lichen is stretched, it can easily be identified by this feature (Pojar and Makinnon 1994).

Geographical range: This lichen is found from California along the western region, all the way through northern Alaska. However, it is not found East of the Cascades, Rockies, and Northern California mountain ranges (Pojar and Makinnon 1994).

Habitat: This lichen is found draped over various trees and shrubs in well-ventilated, semi-open canopy forests. This species is not frequently found, but when it is, its population tends to be abundant. Its healthiest populations are found in old-growth forests (Pojar and Makinnon 1994).

Reproduction: Lichens reproduce by producing small propagules (seed-like part of the plant) or by dispersal of fragments of the mother plant. Propagules contain both the algal and fungal cells of the plant and are stored in specialized structures call "soredia". The soredia erupt and propel the cells of algae and fungi througout the forest. If both kinds of cells land in an adequate habitat, they begin to lichenize (form a lichen) and grow (Vitt *et al* 1988). However, most reproduction occurs by fragmentation. Small pieces of lichen that contain both the fungal and alga component fall off the mother lichen and get established somewhere else in the canopy. Much less the lichen expends energy when it reproduces by fragmentation. *Usnea longissima* disperses mostly, if not entirely, from small pieces fragmenting from the main plant and being carried off in the wind, by an animal, or by simply falling onto another plant (Pojar and Makinnon 1994).

Input requirements: Lichens are specialized organisms formed from a mutualistic symbiotic bond between fungus and algae. The fungal part of the lichen (called the mycobiont) forms the structure of the lichen, giving it shape and a medium for water absorption. It also provides the plants with nutrients absorbed from the substrate. The algal component (called the photobiont), is responsible for providing carbohydrates to the fungus through the process of photosynthesis (Vitt *et al* 1988).

Role in the ecosystem: This lichen serves an important role as food for various insects, as nest material for birds, and as a winter food source for deer, elk, and small mammals.

Use as a Human Resource: The Haida people of Northern British Columbia, Canada, used this lichen to strain impurities from hot tree pitch. Tree pitch was used as a sealant on the outside of the canoe or as medicine (Pojar and Makinnon 1994).

Notes: This lichen has a hard time establishing itself in managed forests, as it requires a multi-leveled canopy to propagate most readily. It has already disappeared from most of its range in Europe (Pojar and Makinnon 1994).

Resources:

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Vitt, D.H., J.E. Marsh, and R.B. Bovey. 1988. Mosses, Lichens, and Ferns of Northwest North America. Lone Pine Publishing, Edmonton, Alberta, 296 pp.

Common name: Pacific Yew; Western Yew

Scientific Name: *Taxus brevifolia*

Description: The Pacific Yew is an evergreen tree that grows 2-15m (6-45 feet) in height, with a trunk diameter of up to 30 cm (11 inches). Its branches tend to droop and its trunk and branches are often gnarly and twisted. The bark is reddish-brown and scaly, with some scales shedding to reveal a bright red under bark. The needles are dull- to dark-green, flat, alternate one another, and 1 inch (2-3 cm) long with a sharp tip. The bottom side of the needle is white with a light green central line running the length of the needle (Pojar and Makinnon 1994). A bright red, fleshy fruit with a belly button-like hole on the tip surrounds the seeds of the Yew.

Geographical range: Found throughout the western region of northern California, Oregon, Washington, British Columbia, Canada, and Alaska. This tree is restricted to very western forests of northern British Columbia and Alaska (Pojar and Makinnon 1994).

Habitat: This tree is found in low- to middle-elevation old-growth Douglas-fir/ Western hemlock forests. It requires moist soil and a high shade environment with occasional sunflecks penetrating through the canopy (Pojar and Makinnon 1994).

Reproduction: Yew trees are either male or female. Pollen from the male cone is wind dispersed and pollinates the female cone. When the female cone is fertilized, it forms a fleshy red cup encasing a single seed. The seeds are spread via birds or by dropping onto the forest floor. The Yew tree is unlike all other conifers in that it forms a berry with seeds, rather than a cone (Pojar and Makinnon 1994).

Input requirements (food supply): Like all plants, the Yew tree depends on photosynthesis for its survival. Using the energy of the sun, the Yew chemically converts nutrients, water, and air into sugars and carbohydrates.

Role in the ecosystem: The bright red berries serve as an important food source for birds (Pojar and Makinnon 1994).

Use as a Human Resource: The hard and durable wood from the Yew tree was a primary resource for coastal Native American tribes. Tribes used this wood to make bows, wedges, clubs, paddles, digging sticks, adze handles, harpoon shafts, spears, sewing needles, awes, knives, dishes, spoons, boxes, drum frames, bark scrapers, combs and many other useful tools. Yew wood is still sought today by wood carvers, as its beautiful wood changes in color from yellow to deep-red the deeper it is carved into the heartwood (Gunther 1973).

Medicinally, the Yew tree is also an incredibly important resource for human beings. For centuries Native American tribes all over the Pacific Northwest made a tea from the needles to combat a cold or flu sickness (Gunther 1973). In the last decade, Yew trees have become an important resource in western medicine. A chemical called taxol, derived from under the bark layer of the Yew tree, is currently used as an anti-cancer agent. It has proven to suppress tumor growth in ovarian, breast, and kidney cancers. However, only one ounce of taxol can be obtained from a 100 year-old tree. Yew trees are incredibly slow growing and are endangered by over-harvesting for the taxol. To overcome this problem of endangering populations of yew trees in the region, tree farms are currently being established and pharmacists are perfecting a synthetic replication of taxol. Taxol is currently being used on cancer patients.

Notes: The bright red berries are poisonous to humans. This tree is only found in old-growth forests as it takes numerous years to establish itself and grows incredibly slow.

Resources:

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Glossary

Adaptation- the act or process of adjusting or changing

Aesthetic- of or pertaining to beauty

Allelopathy- when a plant releases a chemical into the soil in which discourages other plants from growing

Amensalism- a relationship where the health of one organism declines while the other's health is left unchanged.

Anoxybiois- the tardigrade's physical response to flooding or lack of oxygen in the environment

Arthropod- a large group of invertebrates that have segmented bodies and joints, including insects and crustaceans

Autotroph- an organism that creates its own food; plants are autotrophic. They create sugars through the process of photosynthesis

Biome- a general classification of ecosystems around the world that share relatively the same characteristics (e.g. climate, soil, animal and plant species). Some examples of biomes are desert, savanna, chaparral, tropical forest, temperate forest, montane forest, marsh, grassland, etc.

Biodiversity- the number and variety of organisms, including genetic diversity, species diversity, and ecological diversity- also called, biological diversity

Canopy- the area of the forest above the understory brush layer; the combination of leaves, branches, twigs, epiphytes, organisms, and interstices

Canopy spread- the area over which a tree's canopy shades the ground

Commensalism- a relationship between two organisms where one benefits while the other is not affected at all

Coniferous tree- a cone bearing evergreen tree, tend to be softwood

Cryptobiosis- the state a tardigrade enters into when there is a lack of water in the environment

Dbh- diameter at breast height; the measurement of a tree's cross section 1.4m (4.5 feet) meters from the ground

Deciduous tree- a tree that annually produces leaves that fall in the autumn, tend to be hardwood

Decomposition- the process by which dead organic matter is broken down into soil

Ecology- the biological field of study on how plants and animals interact in an ecosystem

Ecosystem- the interacting system of a community of living organisms and non-living elements in an environment

Epiphytes- plants that grow on plants

Fauna- a common scientific term for animal

Flora- a common scientific term for plants

Fog-drip- water vapor that accumulates on a plants leaves/branches and falls to the ground in the form of rain

Fungus- a group of organism that does not contain chlorophyll and photosynthesize (includes mold, yeast, mushrooms, and smuts). This plural form of the word is fungi.

Habitat- a plant/animal's environment; area that supplies a plant/animal with food, water, shelter, and space

Heterotroph- an organism that cannot synthesize its own organic compounds, but rather obtains nutrients by either feeding on autotrophs, other heterotrophs, or dead organic matter

Hydrological interaction- water functions that occur between plants and the atmosphere, including plant transpiration, evapotranspiration, and leaf absorption.

Hydrology- the study of water

Hypothesis- an educated assumption used as a basis for scientific inquiry and to draw conclusions

Interconnectedness- the intimate relationships of organisms who are affected by each other and mutual changes in the environment

Invertebrate- an animal that lacks a backbone- insects and mollusks (slugs and snails)

Lichen- an organism composed of fungi and algae

Mammal- A type of vertebrate whose offspring is nourished off of milk from the mother's mammary glands

Methodology- the protocol or structure for procedure, especially used in scientific inquiry

Microclimate- a climate that occurs within the forest canopy as a result of light, wind occurrence, and temperature. The microclimate within a canopy can be significantly different from the atmospheric climate due to the influence of these other factors.

Neutralism- when two organisms experience a relationship where neither is affected positively or negatively

Nutrient Cycling- the processing of inorganic matter through the food chain; from absorption by plants, consumption by herbivores, omnivores, and carnivores, to decomposition by organisms, inorganic matter travels through organisms and is eternally recycled and utilized

Old-growth forest- a matured forest with multiple canopy layers, trees over 200 years old, snags, and large fallen logs (Franklin *et al.* 1981)

Organism- any living thing

Osmobiosis- a tardigrade's physical reaction to high salinity in the environment

Parasite- an organism that feeds off of another organism but does not kill the organism on which it feeds.

Photosynthesis- the process by which a plant creates its own food. Using the energy of the sun, the plant converts air, water, and nutrients from the soil into sugars and carbohydrates

Precipitation- when water in the atmosphere condenses and falls in the form of rain or snow

Predation/ Parasitism- one organism benefits from the other organism's loss

Protocooperation/ Mutualism- two or more organisms that benefit from living together.

Salinity- salt content

Scientific Method- a structured set of steps that guide scientific inquiry, research, and processing of data

Snag- a dead, but standing tree

Symbiotic relationship- two or more organisms that live together and do not harm one another

Tardigrade- a microscopic organism that lives on all continents and biomes of the world

Taxonomy- the classification of organisms into categories based on their similar characteristics

Throughfall- the amount of precipitation that falls through the canopy

Tree-crown projection- the circumference area of canopy spread

Vertebrate- all animals with backbones

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Swingin' in the rain: Life in forest treetops. 1997. Frontiers: Newsletter of the National Science Foundation. (Available at http://www.nsf.gov/od/lpa/news/publicat/frontier/12-97/12treetop.htm).

Videos

(These videos can be borrowed from the ICAN for a minimal fee that covers postage and handline)

Exploring the High Frontier, National Geographic, 1999 – an adventure with four scientists through the tropical rain forest canopy (available at www.nationalgeographic.com).

Valley of the Giants, by Anyplace Wild TV. Episode #111, First aired Oct. 9, 1998- a journey through the temperate rain forests of Olympic National Park

Voyage of the Mimi, Episodes #10 and #11. A young girl climbs a tree in the tropical rain forest with Dr. Nalini Nadkarni and learns about epiphytes.

Websites

The International Canopy Network (ICAN), <<www.evergreen.edu/ican>>.

The Temperate Rain Forest Canopy Website,
<<http://192.211.16.13/individuals/nadkarnn/TRFwebsite/TRFhome.htm>>

Research at the Wind River Canopy Crane,
<<http://sequoia.fsl.orst.edu/lter/about/environs/pictures/windpic.htm>>.

The Lester B. Pearson College Forest Canopy Research Station,
<<http://www.uwc.ca/pearson/CANOPY/pcserv6.htm>>.

Rain forest canopy on the ceiling of the classroom,
<<http://www.uk-dso.odedodea.edu/wruislip/rainfrst.html>>.

Olympic National Park, <<http://www.fs.fed.us/r6/olympic/ecomgt/unecosys/canopy.htm>>.

An activity for grades 4-6 on forest succession following a fire,
<<http://www.northmason.wednet.edu/NMHSonline/student_gallery/fire/mural_cards.html>>.

Trees of the Pacific Northwest- information and dichotomous key for trees in Northwest Forests,
<<http://www.orst.edu/instruct/for241/>>.

A virtual research activity about epiphytes,
<<http://heg-school.aw.com/bc/companion/cmr2e/activity/rf/RFCBiolo.htm>>.

Lichen Land -an interactive key to determining species of lichens. This site also includes other information on lichens, including species profiles, <<http://mgd.nacse.org/hyperSQL/lichenland/html>>.

North American Lichen Project, <<http://www.lichen.com>>.

The KanCRN website-for tardigrade and lichen research activities,
<<www.KanCRN.org>>.

The Wonderful World of Tardigrades, <<www.jsu.edu/depart/biology/tardy.htm>>

Tardigrade Appreciation Headquarters, <<http://www.reed.edu/~vvichit/tardigrade.html>>

Washington State Essential Academic Learning Requirement Components

Critter of the Canopy

Science:

1.2- The student will identify, describe, and categorize living things based on their characteristics
1.4- The student will recognize the components, structure, and organization or systems and the interconnections within and among them.
4.1- The student will use listening, observing, and reading skills to obtain science information.

Social Studies/ Geography:

1.2- The student will recognize spatial patterns on Earth's surface and understand the processes that create these patterns.

Communication:

1.1-The student will focus attention
1.2- The student will listen and observe to gain and interpret information
2.3- The student will use effective delivery
3.2- The student will work cooperatively as a member of a group
3.3- The student will seek agreement and solutions through discussion.

Canopy Throughfall Field Study

Science:

1.3-The student will measure properties and characteristics
1.6- The student will construct and use models to predict, test, and understand scientific phenomena
2.1- The student will plan and implement scientific investigations
2.2- The student will think logically, analytically, and creatively
2.3- The student will practice the principles of scientific inquiry
4.1- The student will use observing skills to obtain science information
4.2- The student will use writing and speaking skills to organize and express scientific ideas
4.3- The student will use effective communication strategies to prepare and present science information
5.1- The student will use mathematics to enhance scientific understanding

Writing:

1.1- The student will develop concept and design
1.3- The student will apply writing conventions
2.2- The student will write for different purposes
2.3- The student will write in a variety of forms
2.4- The student will write for career applications
3.1- The student will pre-write
3.2- The student will draft
3.3- The student will revise
3.4- The student will edit
4.1- The student will assess own strengths and weaknesses and need for improvement
4.2- The student will seek and offer feedback

Mathematics-

2.1- The student will investigate situations
2.2- The student will formulate questions and define the problem
3.1- The student will analyze information
3.2- The student will predict results and make inferences
3.3- The student will draw conclusions and verify results

Communications:

- 3.2- The student will work cooperatively as a member of a group
- 3.3- The student will seek agreement and solutions through discussion
- 4.1- The student will assess strengths and need for improvement

Social studies/Geography-

- 1.1- The student will use and construct charts and other resources
- 1.2- The student will recognize spatial patterns on Earth's surface and understand the processes that create these patterns
- 2.1- The student will describe the natural characteristics of places and regions
- 2.3- The student will identify the characteristics that define the PNW

Mathematics:

- 1.1- The student will understand and apply concepts and procedures from number sense
- 1.2- The student will understand and apply concepts and procedures from measuring
- 1.3- The student will understand and apply concepts and procedures from geometric sense
- 1.5- The student will understand and apply concepts from algebraic sense

The Canopy Web of Life

Science:

- 1.4- The student will recognize the components
- 1.5- The student will understand that interactions within and among systems cause changes in matter and energy
- 4.2- The student will use writing and speaking skills to organize and express science ideas

Reading:

- 1.2- The student will build vocabulary through reading
- 3.1- The student will read and learn new information
- 3.2- The student will read and perform a task

Social Studies/ Geography:

- 3.1- identify and examine people's interaction with and impact on the environment
- 3.2- The student will analyze how the environment and environmental changes affect people.

The Tardigrade Game

Science:

- 1.2- The student will identify, describe, and categorize living things based on their characteristics
- 1.5- The student will understand that interactions within and among systems cause changes in matter and energy
- 2.2- The student will think logically and analytically
- 4.1- The student will use listening and reading skills to obtain science information

Communication:

- 1.1- The student will focus attention
- 1.2- The student will listen and observe to gain and interpret information
- 3.1- The student will use language to interact effectively and responsibly with others
- 3.2- The student will work cooperatively as a member of a group
- 3.3- The student will seek agreement and solutions through discussion

Reading:

- 1.2- The student will build vocabulary through reading
- 2.1- The student will comprehend important ideas and details
- 2.2- The student will expand comprehension by analyzing, interpreting, and synthesizing information and ideas
- 3.1- The student will read and learn new information

3.2- The student will read and perform a task

Identifying Tardigrades

Science:

1.1- The student will use properties to identify, describe, and categorize organisms

1.2- The student will identify, describe, and categorize living things based on their characteristics

1.3- The student will measure characteristics

1.4- The student will recognize the components, structure, and organization of systems and the interconnections within and among them.

Communications:

1.1- The student will focus attention

1.2- The student will listen and observe to gain and interpret information

3.2- The student will work cooperatively as a member of a group

Arts:

1.1- The student will understand and apply art concepts and vocabulary to communicate ideas

4.1- The student will use art skills and knowledge in other subject areas

Social Science/ Geography

2.1- The student will describe the natural characteristics of places and regions

The International Survey

Science:

2.1- The student will plan and implement scientific investigations

4.1- The student will use listening and reading skills to obtain science information

4.2- The student will use writing and speaking skills to organize and express science ideas

4.3- The student will use effective communications strategies and tools to prepare and present science information

5.4- The student will examine the relationships among science, society, and the workplace

Communications:

2.1- The student will communicate clearly to a range of audiences for different purposes

2.3- The student will use effective delivery

3.2- The student will work cooperatively as a member of a group

Social Studies/ Geography

1.1- The student will use and construct maps, charts, and other resources

2.1- The student will describe the natural characteristics of places and regions

Canopy Poetry

Science:

2.2- The student will think logically, analytically, and creatively

Art:

1.1- The student will understand and apply art concepts and vocabulary to communicate ideas.

1.3- The student will use and develop arts skills and techniques to express ideas.

3.1- The student will use image, through the arts to express individual ideas

4.1- The student will use arts and skills in other subject areas

Writing:

1.2- The student will use style appropriate to the audience and purpose

1.3- The student will apply writing conventions

2.2- The student will write for different purposes

2.3- The student will write in a variety of forms

4.2- The student will seek and offer feedback

Communications:

1.1- The student will focus attention

1.2- The student will listen and observe to gain and interpret information

2.1- The student will communicate clearly to an audience
2.3- The student will use effective delivery
2.4- The student will use effective language and style
2.5- The student will effectively use images to support presentations
4.2- The student will seek and offer feedback

Council of Canopy Critters

Science:

1.4- The student will recognize the components, structure, and organization of systems and the interconnections within and among them.

1.5- The student will understand that interactions within and among systems cause changes in matter and energy.

2.2- The student will think logically, analytically, and creatively.

3.3- The student will evaluate solutions and consequences.

Art:

1.1- The student will understand and apply art concepts and vocabulary to communicate ideas.
1.3- The student will use and develop arts skills and techniques to express ideas.
1.4- The student will use skills and craftsmanship to produce quality work
3.1- The student will use image, through the arts to express individual ideas
4.3- The student will demonstrate an ability to use artistic knowledge in personal and community decision making.

Communications:

1.1- The student will focus attention
2.1- The student will communicate clearly to an audience
2.3- The student will use effective delivery
2.5- The student will effectively use images to support presentations

Reading:

2.1- The student will comprehend important ideas and details
2.2- The student will expand comprehension by analyzing, interpreting, and synthesizing information and ideas
3.1- The student will read to learn new information
3.2- The student will read to perform a task
3.3- read for literary experience

Exploring the Temperate Rain Forest Canopy
Curriculum Evaluation

Grade level(s) taught____________________

Special notes regarding the structure or learning level of your class
(i.e. integrated class, special ed., advance science)_______________________________________

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Do you currently teach about temperate rain forests? ____________________________________

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How useful is this curriculum as a supplemental resource? ________________________________

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What did you like most about the curriculum and why? __________________________________

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What did you like least about the curriculum and why?__________________________________

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Are the activities and resources useful for your grade-level/class? If not, given the information, can the activities be easily adapted to meet your needs? ___________________________________

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How can we improve this curriculum?____

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Comments: ____

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Thank you for your participation in this evaluation,
we appreciate your input!

Mail to: The International Canopy Network-Curriculum Survey
PMB 612, 2103 Harrison Ave, Suite 2, Olympia, Wa. 98502-2607
<canopy@elwha.evergreen.edu>