

Edvo-Kit #AP10

## Energy Dynamics

### Experiment Objective:

The objective of this activity is to model how energy flows through a meadow ecosystem with an emphasis on the concepts of trophic levels and energy loss.

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## Experiment Components and Requirements

### COMPONENTS *(included within this document)*

- Role cards
- Energy unit template
- Supply and Losses stations labels

### Check (✓)

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- 
- 

This experiment is designed for 20 students.

### REQUIREMENTS *(not included with this kit)*

- Scissors
- Containers (5" x 5" x 5" or larger)
- Sandwich bags or Envelopes

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## Background Information

Ecosystems maintain themselves by cycling energy and nutrients obtained from external sources. Organism can be either producers or consumers in terms of energy flow through an ecosystem. Producers convert energy from the environment into carbon bonds, such as those found in the sugar glucose. One of the most obvious examples of producers are plants as they obtain energy from sunlight and use it to convert carbon dioxide into glucose (or other sugars). Similarly, algae and cyanobacteria are also photosynthetic producers. Other producers include bacteria living around deep-sea vents. These bacteria take energy from chemicals coming from the Earth's interior and use it to make sugars. Other bacteria living deep in the oceanic crust can also produce sugars from such inorganic sources. Another word for producers is autotrophs.

| Consumer type | Trophic level       | Food source        |
|---------------|---------------------|--------------------|
| Herbivores    | Primary             | Plants             |
| Carnivores    | Secondary or higher | Animals            |
| Omnivores     | All levels          | Plants and Animals |
| Detritivores  | -----               | Detritus           |

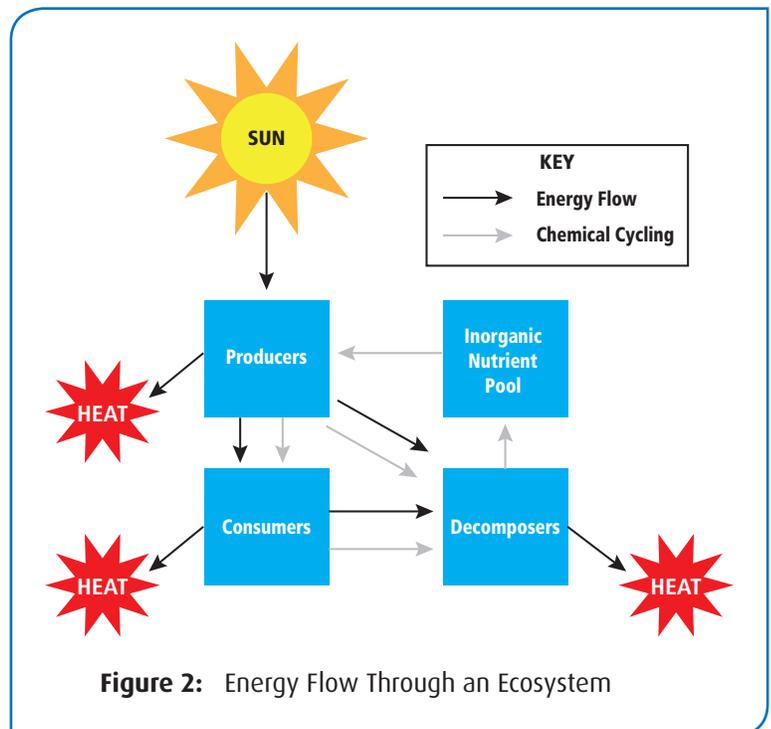
**Figure 1:** Different Types of Consumers.

Consumers do not produce energy, instead they obtain energy from the carbon sources produced by the producers. Another word for a consumer is a heterotroph. Based on what they eat, we can distinguish between four types of heterotrophs – herbivores, carnivores, omnivores, and detritivores. Consumers can also be described by trophic level.

A trophic level refers to the organism's position in the food chain. Food chains start at trophic level one where autotrophs produce their own complex compounds through photosynthesis or chemosynthesis. Next, at trophic level two, herbivores eat primary producers. These herbivores are sometimes referred to as primary consumers. Carnivores that eat herbivores make up trophic level three and carnivores that eat other carnivores make up trophic level four. Throughout this process detritivores are breaking down dead or decaying organisms. Because they consume organisms from all trophic levels they are often not incorporated into a specific trophic level although they remain a very important part of any ecosystem.

Energy "flows" through the ecosystem in the form of carbon-carbon bonds. When respiration occurs, the carbon-carbon bonds are broken and the carbon is combined with oxygen to form carbon dioxide. This process releases the energy, which is either used by the organism (to move its muscles, digest food, excrete wastes, etc.) or lost as heat. Energy flow through an ecosystem is shown in Figure 2.

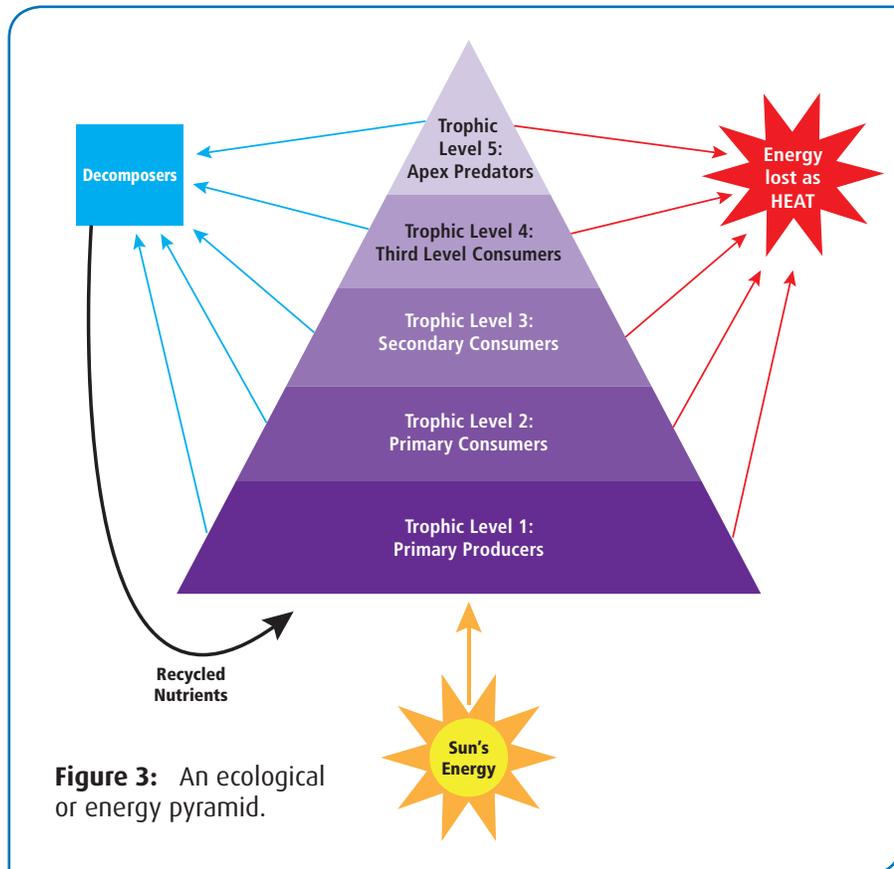
In Figure 2, the dark arrows represent the movement of energy through an ecosystem. Note that all energy comes from the sun, and that the ultimate fate of all energy



**Figure 2:** Energy Flow Through an Ecosystem

in ecosystems is to be lost as heat. The gray arrows represent the movement of inorganic nutrients. Inorganic nutrients are those that do not contain carbon-carbon bonds. Several inorganic nutrients are present in our body, such as phosphorous in teeth, bones, and cellular membranes; nitrogen in amino acids (the building blocks of protein); and iron in blood. These inorganic nutrients are passed from organism to organism as one organism is consumed by another. Ultimately, all organisms die and become detritus. At this stage, the last of the energy is extracted (and lost as heat) and the inorganic nutrients are returned to the soil or water to be taken up again.

In an ecosystem inorganic nutrients are recycled, but energy is not. The gradual loss of energy is often depicted as an ecological or energy pyramid (Figure 3). This is graphical representation of bio-productivity at each trophic level. Producers form the base of such pyramids and apex predators the top. Sometimes ecologists studying an area will measure biomass at a particular time as a proxy for bio-productivity. However, such measurements do not take into account differences in species life span which sometimes results in 'inverted' energy pyramids such as is often seen in aquatic ecosystems.



**Figure 3:** An ecological or energy pyramid.

In this activity you will model how energy moves through a food web made up of the following species:

- *Liatris scariosa* (Eastern Blazing Star) is a drought resistant perennial that blooms in late summer or fall. It is often found in oak or pine savannas and in prairies where wildfires limit woody vegetation.
- *Asclepias purpurascens* (Purple Milkweed) is a perennial whose distinct flowers turn from pink to dark purple as they mature. These flowers attract important pollinators. The species is usually found along prairie edges. Because of its high nutrient requirements scientists use it as an indicator of healthy ecosystems.
- *Brassica rapa* (Field Mustard) is an annual native to Eurasia. Several subspecies of the plant are cultivated in the U.S. including bok choy and turnips. In the wild the plant can grow up to a meter and can dominate fields, roadsides, and waste areas.
- *Pieris rapae* (Cabbage White Butterfly) is a Eurasian butterfly that was introduced to Canada around 1860 and has since spread to all of North America. The larva is a serious pest to several important crops.
- *Graphocephala coccinea* (Candy-striped Leafhopper) is a small (<7 mm) but brightly colored insect that can jump up to 28 cm. Its piercing-sucking mouthpart allows it to feed on many different plants and so it is found in both meadows and woodlands.

- *Tetraopes tetrophthalmus* (Red Longhorn Beetle) is an insect that specializes in feeding on milkweed – a plant that is too hairy, sticky, and toxic for many herbivores. The insect's Latin name, roughly translated to four eyes, is because its compound eyes are fully divided by the antennae.
- *Lithobates pipiens* (Northern Leopard Frog) is an amphibian found throughout the U.S. and Canada. During the spring they gather in communal breeding ponds but for the rest of the year they forage in a variety of habitats including meadows and grasslands.
- *Dolichonyx oryzivorus* (Bobolink) is a small songbird that migrates between the northern U.S. in the summer and the interior of South America in the winter. During the summer it forages in the grasslands for ground insects and seeds. While still common the population has declined 75% since the 1960s because of habitat loss.
- *Pooecetes gramineus* (Vesper Sparrow) is a grassland songbird that feeds on ground insects and seeds. It is found throughout North America migrating to southern U.S. states in the winter and northern U.S. states and Canada in the summer. The name refers to the male's evening songs.
- *Circus cyaneus* (Northern Harrier) is a long winged and long tailed bird of prey that is found in North America and in Eurasia. It hunts by flying low over open areas. It uses its keen hearing almost as much as its eyesight to locate prey.
- *Buteo jamaicensis* (Red-tailed Hawk) is a common bird of prey that has adapted to many types of habitats. It is found throughout North America except for areas of unbroken forest and the high Arctic. It is an opportunistic feeder that will eat small mammals, birds, reptiles and amphibians.

## Experiment Overview

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### EXPERIMENT OBJECTIVE:

The objective of this activity is to model how energy flows through a meadow ecosystem with an emphasis on the concepts of trophic levels and energy loss.

### LABORATORY NOTEBOOKS:

Scientists document everything that happens during an experiment, including experimental conditions, thoughts and observations while conducting the experiment, and, of course, any data collected. Today, you'll be documenting your experiment in a laboratory notebook or on a separate worksheet.

### Before starting the Experiment:

- Carefully read the introduction and the protocol. Use this information to form a hypothesis for this experiment.
- Predict the results of your experiment.

### During the Experiment:

- Record your observations.

### After the Experiment:

- Interpret the results – does your data support or contradict your hypothesis?
- If you repeated this experiment, what would you change? Revise your hypothesis



## Investigation - Modeling Energy Flow

1. Receive your role card and initial energy supply. Take note of what organisms you eat and what organisms can eat you.
2. Approach another classmate and reveal the identity of your organisms to each other. Exchange energy units based on the following:
  - If one organism can eat the other organism then: 1) the eaten organism gives five energy units to the eating organism and 2) the eating organism puts two energy units into the losses container.
  - If neither organism can eat each the other, then each organism places one unit in the losses container.
  - If both organisms are primary producers, then each organism removes ten units from the supply container and each organism puts one unit in the losses container.
3. Continue to exchange with other students until you lose all your energy units or until the teacher calls time.
4. As a class, count the number of energy units that each student had at the end of the activity and record your collective findings in Table 1 on page 8. Also record the final number of energy units in the losses station here: \_\_\_\_\_.
5. Use Table 1 on page 8 to answer the following questions:
  - Which organisms finished with the most units? Which with the least? Why do you think this happened?
  - How many units did the primary producers start and end with? What about the other three trophic levels: primary, secondary, and tertiary consumers?
  - The measurement of energy transfer efficiency between two successive trophic levels is termed the trophic level transfer efficiency (TLTE). Calculate the three TLTE for this ecosystem using the following formula:

$$\text{TLTE} = \frac{\text{Total energy units at the end in trophic level A} \times 100}{\text{Total energy units at the end in the trophic level immediately below A}}$$

|   | Trophic Level | Number of Organisms | Number of energy units at start (Total) | Number of energy units at end (Total) |
|---|---------------|---------------------|---|---------------------------------------|
| <i>Liatris scariosa</i><br>(Eastern Blazing Star)         | 1             |                     |   |                                       |
| <i>Asclepias purpurascens</i><br>(Purple Milkweed)        | 1             |                     |   |                                       |
| <i>Brassica rapa</i><br>(Field Mustard)                   | 1             |                     |   |                                       |
| <i>Pieris rapae</i><br>(Cabbage White Butterfly)          | 2             |                     |   |                                       |
| <i>Graphocephala coccinea</i><br>(Cadystriped Leafhopper) | 2             |                     |   |                                       |
| <i>Tetraopes tetrophthalmus</i><br>(Red Longhorn Beetle)  | 2             |                     |   |                                       |
| <i>Lithobates pipiens</i><br>(Northern Leopard Frog)      | 3             |                     |   |                                       |
| <i>Dolichonyx oryzivorus</i><br>(Bobolink)                | 3             |                     |   |                                       |
| <i>Pooecetes gramineus</i><br>(Vesper Sparrow)            | 3             |                     |   |                                       |
| <i>Circus cyaneus</i><br>(Northern Harrier)               | 4             |                     |   |                                       |
| <i>Buteo jamaicensis</i><br>(Red-tailed Hawk)             | 4             |                     |   |                                       |

**Table 1:** Organism and Energy Tally

## Study Questions

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1. Why is energy transfer between trophic levels an inefficient process?
2. Organisms often eat a variety of foods from different trophic levels. What do you think would have happened in the classroom simulation if one of the secondary consumers could have taken energy from the producers?
3. An invasive or introduced species is one that is not native to a specific location. One factor that can make invasive species successful is a lack of natural predators. What do you think would happen to *Pieris rapae* (Cabbage White Butterfly) if it was never eaten by any of the tertiary consumers?

# Instructor's Guide

## NOTES TO THE INSTRUCTOR & PRE-LAB PREPARATIONS:

### Overview of Laboratory Investigations

The laboratory experience is a very important component of science courses. Laboratory experiment activities allow students to identify assumptions, use critical and logical thinking, and consider alternative explanations, as well as help apply themes and concepts to biological processes.

EDVOTEK does not advocate the used of dangerous plant pests that can escape into the environmental and cause damage to valuable agriculture crops and ecosystems. To address this we have created a simulation to teach energy dynamics. To perform the experiment with living creatures, consult the AP manual at [http://media.colleg-eboard.com/digitalServices/pdf/ap/bio-manual/Bio\\_Lab10-EnergyDynamics.pdf](http://media.colleg-eboard.com/digitalServices/pdf/ap/bio-manual/Bio_Lab10-EnergyDynamics.pdf).

### Organizing and Implementing the Experiment

Class size, length of laboratory sessions, and availability of equipment are factors that must be considered in the planning and the implementation of this experiment with your students. These guidelines can be adapted to fit your specific set of circumstances.

If you do not find the answers to your questions in this section, a variety of resources are continuously being added to the EDVOTEK web site.

In addition, Technical Service is available from 9:00 am to 6:00 pm, Eastern time zone. Call for help from our knowledgeable technical staff at 1-800-EDVOTEK (1-800-338-6835).

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## Pre-Lab Preparations

### INVESTIGATION: MODELING ENERGY FLOW

- Before class print and cut out the role cards, energy units, and station labels. If these materials will be used by multiple classes or over multiple years consider laminating these cut-outs to save paper and time. The energy units page should be copied and printed 10 times to provide 800 units. Beans or similarly small items can also be used as an alternative to the provided energy units.
- Combine role card and energy units in a sandwich bag or envelope. Each organism should be provided with a starting number of energy units according to the information below. Also put 300 energy units in the supply station container.

Primary Producers – 30 energy units to each organism  
 Primary Consumers – 15 energy units to each organism  
 Secondary Consumers – 10 energy units to each organism  
 Tertiary Consumers – 5 energy units to each organism

- Set up containers for supply and loss stations. Place labeled containers in easily accessible locations.

#### NOTE:

Twenty role cards are provided but you can increase or decrease the number of players depending on class size. For best results maintain a general pyramid structure where trophic level 1 organisms represent the largest group and trophic level 4 organisms represent the smallest group.

## Experiment Results and Analysis

The results on the right represent an example run of the activity. Your class results may vary.

|   | Trophic Level | Number of Organisms | Number of energy units at start (Total) | Number of energy units at end (Total) |
|---|---------------|---------------------|---|---------------------------------------|
| <i>Liatris scariosa</i><br>(Eastern Blazing Star)         | 1             | 4                   | 120                                     | 152                                   |
| <i>Asclepias purpurascens</i><br>(Purple Milkweed)        | 1             | 4                   | 120                                     | 160                                   |
| <i>Brassica rapa</i><br>(Field Mustard)                   | 1             | 4                   | 120                                     | 147                                   |
| <i>Pieris rapae</i><br>(Cabbage White Butterfly)          | 2             | 1                   | 15                                      | 21                                    |
| <i>Graphocephala coccinea</i><br>(Cadystriped Leafhopper) | 2             | 1                   | 15                                      | 28                                    |
| <i>Tetraopes tetraphthalmus</i><br>(Red Longhorn Beetle)  | 2             | 1                   | 15                                      | 0                                     |
| <i>Lithobates pipiens</i><br>(Northern Leopard Frog)      | 3             | 1                   | 10                                      | 11                                    |
| <i>Dolichonyx oryzivorus</i><br>(Bobolink)                | 3             | 1                   | 10                                      | 2                                     |
| <i>Pooecetes gramineus</i><br>(Vesper Sparrow)            | 3             | 1                   | 10                                      | 3                                     |
| <i>Circus cyaneus</i><br>(Northern Harrier)               | 4             | 1                   | 5                                       | 0                                     |
| <i>Buteo jamaicensis</i><br>(Red-tailed Hawk)             | 4             | 1                   | 5                                       | 0                                     |

**Table 1 with example results.**

## Experiment Results and Analysis

- **Which organisms finished with the most units? Which with the least? Why do you think this happened?**

*Asclepias purpurascens* (Purple Milkweed) finished with the most while *Buteo jamaicensis* (Red-tailed Hawk), *Circus cyaneus* (Northern Harrier), and *Tetraopes tetraphthalmus* (Red Longhorn Beetle) tied for the least. This is because *A. purpurascens* gained three times as many energy units per positive interaction and also because there were more opportunities for *A. purpurascens* to interact with other primary producers – an exchange that led to a net energy gain for both.

- **How many units did the primary producers start and end with? What about the primary, secondary and tertiary consumers?**

Primary Producers - Start: 360 End: 459  
 Primary Consumers – Start: 45, End: 49  
 Secondary Consumers – Start: 30, End: 16  
 Tertiary Consumers – Start: 10, End 0

- **The measurement of energy transfer efficiency between two successive trophic levels is termed the trophic level transfer efficiency (TLTE). Calculate the three TLTE for this ecosystem using the following formula:**

$$\text{TLTE} = \frac{\text{Total beans at the end in trophic level A} \times 100}{\text{Total beans at the end in the trophic level immediately below A}}$$

$$\text{Trophic Levels 1 \& 2: } \frac{49 \times 100}{459} = 10.68\%$$

$$\text{Trophic Levels 2 \& 3: } \frac{16 \times 100}{49} = 32.65\%$$

$$\text{Trophic Levels 3 \& 4: } \frac{0 \times 100}{16} = 0\%$$

**Please refer to the kit  
insert for the Answers to  
Study Questions**

# Role Play Cards



***Liatris Scariosa* (Blazing Star)**

Trophic Level 1 (Primary Producer)

Eaten by: Cabbage White Butterfly, Candystriped Leafhopper, Red Longhorn Beetle.



***Liatris Scariosa* (Blazing Star)**

Trophic Level 1 (Primary Producer)

Eaten by: Cabbage White Butterfly, Candystriped Leafhopper, Red Longhorn Beetle.



***Liatris Scariosa* (Blazing Star)**

Trophic Level 1 (Primary Producer)

Eaten by: Cabbage White Butterfly, Candystriped Leafhopper, Red Longhorn Beetle.



***Liatris Scariosa* (Blazing Star)**

Trophic Level 1 (Primary Producer)

Eaten by: Cabbage White Butterfly, Candystriped Leafhopper, Red Longhorn Beetle.

# Role Play Cards



*Asclepias purpurascens* (Purple Milkweed)

Trophic Level 1 (Primary Producer)

Eaten by: Cabbage White Butterfly, Candystriped Leafhopper, Red Longhorn Beetle.



*Asclepias purpurascens* (Purple Milkweed)

Trophic Level 1 (Primary Producer)

Eaten by: Cabbage White Butterfly, Candystriped Leafhopper, Red Longhorn Beetle.



*Asclepias purpurascens* (Purple Milkweed)

Trophic Level 1 (Primary Producer)

Eaten by: Cabbage White Butterfly, Candystriped Leafhopper, Red Longhorn Beetle.



*Asclepias purpurascens* (Purple Milkweed)

Trophic Level 1 (Primary Producer)

Eaten by: Cabbage White Butterfly, Candystriped Leafhopper, Red Longhorn Beetle.

# Role Play Cards



***Brassica rapa (Field Mustard)***

Trophic Level 1 (Primary Producer)

Eaten by: Cabbage White Butterfly, Candystriped Leafhopper, Red Longhorn Beetle.



***Brassica rapa (Field Mustard)***

Trophic Level 1 (Primary Producer)

Eaten by: Cabbage White Butterfly, Candystriped Leafhopper, Red Longhorn Beetle.



***Brassica rapa (Field Mustard)***

Trophic Level 1 (Primary Producer)

Eaten by: Cabbage White Butterfly, Candystriped Leafhopper, Red Longhorn Beetle.



***Brassica rapa (Field Mustard)***

Trophic Level 1 (Primary Producer)

Eaten by: Cabbage White Butterfly, Candystriped Leafhopper, Red Longhorn Beetle.

# Role Play Cards



***Pieris rapae* (Cabbage White Butterfly)**

Trophic Level 2 (Primary Consumer)

Eats: Eastern Blazing Star, Purple Milkweed, Field Mustard.

Eaten by: Northern Leopard Frog, Bobolink, Vesper Sparrow.



***Graphocephala coccinea* (Candystriped leafhopper)**

Trophic Level 2 (Primary Consumer)

Eats: Eastern Blazing Star, Purple Milkweed, Field Mustard.

Eaten by: Northern Leopard Frog, Bobolink, Vesper Sparrow.



***Tetraopes tetraphthalmus* (Red Longhorn Beetle)**

Trophic Level 2 (Primary Consumer)

Eats: Eastern Blazing Star, Purple Milkweed, Field Mustard.

Eaten by: Northern Leopard Frog, Bobolink, Vesper Sparrow.



***Lithobates pipiens* (Northern Leopard Frog)**

Trophic Level 3 (Secondary Consumer)

Eats: Cabbage White Butterfly, Candystriped Leafhopper, Red Longhorn Beetle.

Eaten by: Northern Harrier, Red-tailed Hawk.

# Role Play Cards



***Dolichonyx oryzivorus* (Bobolink)**

Trophic Level 3 (Secondary Consumer)

Eats: Cabbage White Butterfly, Candystriped Leafhopper, Red Longhorn Beetle.

Eaten by: Northern Harrier, Red-tailed Hawk.



***Pooecetes gramineus* (Vesper Sparrow)**

Trophic Level 3 (Secondary Consumer)

Eats: Cabbage White Butterfly, Candystriped Leafhopper, Red Longhorn Beetle.

Eaten by: Northern Harrier, Red-tailed Hawk.



***Circus cyaneus* (Northern Harrier)**

Trophic Level 4 (Tertiary Consumer)

Eats: Northern Leopard Frog, Bobolink, Vesper Sparrow.



***Buteo jamaicensis* (Red-tailed Hawk)**

Trophic Level 4 (Tertiary Consumer)

Eats: Northern Leopard Frog, Bobolink, Vesper Sparrow.

# Station Labels

Losses Station



Supply Station



Losses Station



Supply Station



# Energy Units

(Print 10 copies)

