Unit: Using Wyoming Wildlife Research to teach Biology: How will the pine bark beetle outbreak impact least chipmunks? – Grades 7-12

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The overall goal for this unit is to provide teachers with a set of lessons a.) that can be used together as a unit or individually, b.) that use actual data from current wildlife research in Wyoming, and c.) cover Wyoming State Science Standards. The lessons are unique in that they use actual data from an ongoing research project in the Laramie Mountain Range of Wyoming studying the impacts of mountain pine bark beetle on least chipmunk populations. The unit includes an introduction to the problem through a podcast and activity to teach students about population growth and the impact of the beetle on forest habitats. The unit also includes lessons that offer opportunities for field work and field data collection, creating figures/graphs based on data, and ample opportunities for hypothesis testing.

Copies of the hand-outs for students (no solutions) are included at the end of the unit.

Any questions about the material should be directed to Liz Flaherty (lizf@uwyo.edu).

Unit Overview:

- Lesson 1: Attack of the mountain pine bark beetles!
    - Introduction to the mountain pine bark beetle and the potential impacts on Wyoming wildlife, specifically the least chipmunk (*Tamias minimus*)
        - Podcast
    - Activity: Predicting pine bark beetle populations and their impact on our forest landscapes

- Lesson 2: Changing Wyoming forests: how the beetle impacts wildlife habitat and how habitat impacts wildlife populations
    - Introduction to habitat
    - Activity: Vegetation surveys to estimate chipmunk use of habitats
    - Activity: Estimating populations from live-trapping data and comparing population estimates to habitat variables

- Lesson 3: Using giving-up density experiments to estimate perceived predation risks and assess foraging behavior
    - Introduction to foraging behavior, optimal foraging theory, predation, predation risk, and giving-up density
    - Activity: estimating your foraging rate
    - Activity: Comparing giving-up density data for chipmunks in forest and sagebrush habitat
    - Optional activity: Giving-up density experiments in the school yard
    - Optional activity: Giving-up density experiments in Yellowstone: does predation risk by wolves influence elk foraging?

- Lesson 4: What does it all mean? Suggesting management decisions based on the results from the chipmunk research
    - Activity 1: Using the chipmunk data for further investigations and to suggesting management decisions.

Vocabulary List:

Adapt – to specialize the structure or behavior of an organism to increase survival in an environment.

Alternative hypothesis – also known as the research hypothesis, is an educated prediction or explanation.

Azimuth (AZ) – a measurement of position or direction.

Conifer – Cone-bearing trees and shrubs (spruce, hemlock, pine trees, etc.).

Coursing predators – predators that chase prey (like wolves and cheetahs) compared to sit-and-wait predators that hide and ambush prey (like lions and other big cats).

Dependent variable – a variable that changes in response to other factors.

Diameter at Breast Height (DBH) – a common measurement used in forestry and ecology to measure tree size. A tape, specially designed for this measurement, is wrapped around the trunk of a tree at breast height (about 1.3 m above the ground) to measure diameter.

Ecosystem – a biotic community and the abiotic environment.

Egg galleries – tunnels underneath the bark of a tree where pine bark beetles lay their eggs.

Escape cover – a habitat feature that will allow an organism to escape from possible predators. It may be a rock piles, shrubs, trees, etc.

Evolve/Evolution – gradual change over time.

Fitness – related to the ability of an organism to reproduce; the proportion of an organism's genes that is passed on to future generations.

Forage – to search for food.

Generalist – a species that does not specialize on a specific habitat characteristic or food and can generally adapt to new and varying conditions

Giving-up density – the point at which an animal will leave (give up) a foraging patch if the density of food becomes low, foraging involves more time spent searching, and their

perceived risk of predation is high (they think that the chance they will become prey is quite likely).

Glycerol – an organic compound with a very low freezing point that can be produced naturally in the body. Pine bark beetle larvae produce and use this compound as antifreeze to help survive the winter.

Habitat – the combined environmental conditions in which an organism, population, or community lives. This includes all the necessary resources needed to survive.

Immobilize – a term used when handling wildlife to describe a state in which the animal is unable to move, is unconscious, and in many cases cannot feel pain.

Independent variable – a variable that is not changed by other variables being measured.

Inhalant anesthesia – a liquid pharmaceutical that becomes a gas and induces a reversible state of unconsciousness and blocks pain.

Irruption – population growth with an explosive increase often followed by a large die-off when the population exceeds carrying capacity and quickly depletes necessary resources.

Larvae – juvenile form of an organism's life cycle that is different from the adult in its nutrition requirements, body structure, or habitat.

Line-transect survey – an observer walks a known distance and estimates the amount of that distance that intersects or crosses over specific vegetation types or other variables of interest.

Mark/recapture model – a method for estimating animal populations by live-trapping individuals and marking them. Recaptured animals are recorded and the relationship between the total number of trapped animals and the number of recaptured animals can be used to estimate a wild population.

Null hypothesis – proposes a relationship between variables or measurements of no difference or no relationship.

Pesticide – a substance or mixture used to kill a pest.

Physiology – the functioning of a living system (organism, organ, cell, etc.).

PIT tag – Passive integrative transponder tag – a tag implanted inside an animal with a unique identification number that can be read using a specific reading/scanning device. This is the same thing as a microchip implanted in a pet.

PIT tag reader – a scanner that sends a low frequency signal to the PIT tag (microchip) providing the power needed to send the tag's unique code or identification number back to the scanner and positively identify the animal.

Predation risk – the chance that an animal will be killed and eaten by another animal.

Prey – an animal or organism that becomes food for another animal or organism.

Pupate – occurs when an invertebrate goes through the pupa life stage which is the stage before becoming an adult invertebrate.

Optimal foraging theory – argues that an organism will forage in a way that maximizes energy intake/unit time. An animal will forage to maximize the amount of calories consumed while using as little energy as possible.

Outbreak – when a population or event occurs at a level greater than would otherwise be expected.

Replicate – to repeat a data collection or an experiment. Increases the confidence of your results if the results are the same with all experiments.

Soil macroinvertebrates – invertebrates that live in the soil and are large enough to view with the naked eye.

Specialist – a species that may have a limited diet or a restricted range of environmental conditions in which it can survive.

Spore – a haploid cell from a plant, fungi, or algae that divides mitotically resulting in a new individual organism.

Tomahawk live trap – a live animal metal box trap. Website: http://www.livetrap.com/

Variables – a factor, trait, condition that can exist in various states or quantities and can be dependent, independent , or controlled in research.

Vigilant – the act of being alert and aware of potential dangers.

X-axis – the horizontal axis in a graph that depicts the independent variable.

Y- axis – the vertical axis in a graph that depicts the dependent variable.

Lesson 1: Activity 1 – Modeling and predicting tree mortality by mountain pine bark beetle

Purpose:

Mountain pine bark beetle (*Dendroctonus ponderosae*) is native to the forests of the Rocky Mountains. Outbreaks have occurred in western forests throughout history but the current, wide-spread outbreak is a result of warmer average yearly temperatures and drought that have made the trees more susceptible to beetle infestation.

In late summer, adult beetles leave the now dead tree that the developed inside over the winter. Females fly to a living, large diameter tree and tunnel under the bark. Beetles reproduce inside the tree forming egg galleries (tunnels), the female lays eggs, and once hatched, the larvae begin tunneling away from the egg gallery feeding on the tree. The larvae develop under the bark over winter and survive by producing an anti-freeze (glycerol). The larvae pupate the next summer (June-July) and then exit the tree as an adult in late summer, completing the one-year life cycle. Each infected tree in a forest will produce enough beetles to infect at least 2 more trees the following year. Once infected, there is nothing that will save the tree. The cycle will continue either until all trees large enough for a beetle to infect are dead or the area experiences winters cold enough to kill the developing larvae.

In this activity, students will use information on pine bark beetles to evaluate tree mortality. This activity introduces the concept of exponential growth and also will provide students a stepping stone to begin thinking about broad-scale tree death and changes in wildlife habitat while gaining experience making and interpreting graphs.

Wyoming Science Standards Covered by Activity:

SC8.1.6 Interrelationships of Populations and Ecosystems

Materials:

- Podcast
- Worksheet
- Black board/white board to draw the population growth curve for class discussion

Procedure:

1. Play the podcast that describes the mountain pine bark beetle outbreak and least chipmunk project to introduce the students to the problem of bark beetles in western North American forests.
2. Have students complete both worksheets.

Podcast Script:

Hello, my name is Liz Flaherty and I am a research scientist at the University of Wyoming. Today I'm going to tell you about the mountain pine bark beetle, its impact on forests and forest wildlife in the Laramie Range of Wyoming, and about my research studying the potential impacts of the beetle outbreak on least chipmunks.

As most of you know, the forests of South Dakota, Wyoming, and Colorado are currently experiencing large-scale outbreaks of the mountain pine bark beetle. The mountain pine bark beetle, whose scientific name is *Dendroctonus ponderosae*, is native to this region of the United States and has caused some tree mortality and impacted forests for thousands of years. However, an extended drought in the late 1990's and early 2000's along with warmer winters triggered this recent irruption. Currently, the United States Forest Service predicts that by 2012, the beetles will have killed all mature lodgepole pine trees in southern Wyoming and northern Colorado. The beetle also prefers ponderosa and limber pine but occasionally attacks pinyon and bristlecone pine. So you can see, this is becoming quite a concern for many people.

In late summer, adult beetles leave the now-dead tree it developed inside. Adults fly to a living, large diameter tree and tunnel under the bark. Beetles reproduce inside the tree forming egg galleries (tunnels). The female lays eggs, and once hatched, the larvae begin tunneling away from the egg gallery feeding on the tree. The larvae develop under the bark over winter and survive by producing an anti-freeze called glycerol. The larvae pupate the next summer in June and July, exit the tree as adults in late summer, and tunnel into another tree to reproduce, thus completing their one-year life cycle. Each tree infected by beetles will produce enough beetles to infect at least 2 more trees the following year. Spores of blue stain fungi, a fungi that grows within the tree following beetle infection and helps the beetle kill the tree, are transmitted between trees on the adult beetles. Once infected by the beetle, there is nothing that will save the tree.

Control methods for the beetle are very limited. Extremely cold winter temperatures that occur in the fall before the beetles have created their anti-freeze or in the spring when the beetles are pupating will kill the beetles. For weather in the middle of the winter to affect the larvae, temperatures need to drop below -30˚F for 5 consecutive days. Woodpeckers and clerid beetles that forage on the pine bark beetles under the bark also provide a small amount of natural control. Large areas of trees cannot be easily protected by non-natural controls but small areas of susceptible trees can be sprayed with a pesticide.

We can easily identify trees infected with pine bark beetles. When beetles initially tunnel under the bark in late summer, the tree tries to defend itself using sap. This creates pitch tubes on the tree that look like white, pink, or brown kernels of popcorn on the trunk. Often sawdust is present at the base of the tree created during tunneling. Eight to ten months following attack, the needles of the tree begin to turn red and die. Currently, the pine trees in forests in southern Wyoming and northern Colorado are dying quickly from the beetles. This tree loss will create a build-up of fuel for forest fires, impact roads, power lines, water flow, recreation areas, scenic views, and affect wildlife habitat.

How will this affect wildlife? Many wildlife species require forest habitats and ecosystems. Forest habitats are generally cooler because of the shade provided by the trees, which this creates habitat for many plants, invertebrates, and animals. When the trees die, all the other species of organisms will suffer. Additionally, pine forest habitat provides food for some species in the form of pine seeds found in the cones. For species like red squirrels, this is an incredibly important food source that they specialize on and eat very little of other kinds of food. Other animals living in forest habitat are not as specialized to the habitat, they eat a variety of foods, live in a variety of areas in the forest, and are considered generalists. The least chipmunk is a generalist and has been chosen as our monitoring species for our research studying the impacts of the bark beetle on forest habitats. The least chipmunk is the smallest of Wyoming's chipmunk species and is found throughout most of the forested habitats in Wyoming but will also use sagebrush and other habitats especially if there are large rocks and boulders. Its diet includes invertebrates, seeds, nuts, berries, plant stems and roots, and fungi.

For our research we hypothesized that as the trees die from the beetle attack, sagebrush habitat will expand, and chipmunks will need to begin using sagebrush habitat as forest habitat declines. To test our hypothesis, we have started a field study near Laramie, Wyoming.

To estimate chipmunk populations in forest and sagebrush habitat, we have been live-trapping chipmunks in both habitats. We create an 8 x 5 trap grid with each trap 50 m from another trap and use Tomahawk live-traps. For 5 consecutive days, we open and bait the live-traps each morning at approximately 6:30. Our bait is a mixture of oatmeal, peanut butter, and molasses and looks (and tastes) like unbaked cookie dough. We also include a small piece of apple in the trap so a trapped chipmunk will have access to water. Traps remain open until 4 PM. Any trapped chipmunks are first scanned with a passive integrative transponder or PIT tag reader to see if they have already been micro-chipped. If they are new, we briefly expose them to an inhalant anesthetic to immobilize them, and then using a needle and syringe, inject a PIT tag under the skin between their shoulder blades. This is exactly the same technique used to microchip

cats and dogs. The PIT tag contains a unique identification number so we can keep track of the different chipmunks that we catch. After we scan and PIT tag, we weigh the chipmunks, measure their body and tail length, and determine if they are a male or a female. Then the chipmunk is released. At the end of a 5 day trapping session, we use this data to estimate how many chipmunks live in the area we were trapping and compare the results between a forest and sagebrush grid.

We are also interested in the habitat characteristics of forest and the sagebrush areas. To evaluate habitat for chipmunks, we conduct vegetation surveys on the trapping grid. During these surveys, we estimate the available cover on the ground for a chipmunk to hide from predators. We also measure the distance to the nearest tree from the trap which also provides chipmunks escape cover. We also identify the tree to species and measure its size get an idea of how large the trees are on a site. To evaluate food availability, we count the number of pine cones in a specific area and we trap soil macroinvertebrates.

We have only just begun to analyze all the data we have collected in the field. Soon we hope to be able to determine whether sagebrush provides adequate habitat for chipmunks, if forest habitat has large populations of chipmunks, and provide information for forest and wildlife managers to better manage our natural resources.

Name:_____

Making graphs of tree mortality to predict impacts of the bark beetle on forests

Lesson 1 – Activity 1 - Worksheet 2

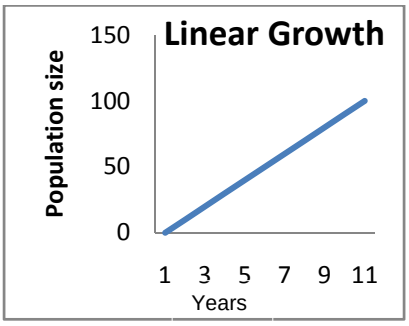
Using the data from your tree worksheet, create a figure depicting tree mortality resulting from the pine bark beetle infestations. You will label the x axis “years” which represents the years following the infestation of the first tree. The y-axis should be labeled as “number of trees infected”. Continue projecting your population out to 10 years to better understand the population growth of the beetles and the resulting tree mortality. Be sure to give your graph a title and to label the axes.

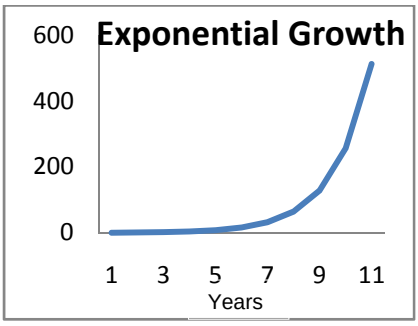
Title:

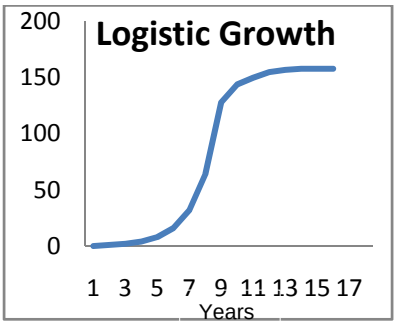
y-axis

x- axis

1. Now that you have finished making your figure, what kind of population growth do we see? Which of the below figures does yours best resemble:







2. If you examine the logistic growth curve in the graph above, you notice that eventually the population reaches a plateau and stops growing. Will this happen with the bark beetle populations? When will the beetles population plateau and the trees stop dying?

Eventually the beetles will kill all the infectable trees and the population will crash.

3. What do you think will happen to forest wildlife species that require trees for cover and food? What will happen to forest species, like woodpeckers, the eat bark beetles?

They may die or move to new habitats.

Woodpecker populations will increase.

Lesson 2: Activity 1- Changing Wyoming forests: how the pine bark beetle impacts wildlife habitat

Purpose:

Managing habitat and ensuring that animals have the necessary resources to survive is one of the most important and challenging tasks for a wildlife biologist. Animal species have adapted to their environment and require specific food and cover to survive. Often biologists use vegetation/habitat surveys to evaluate or predict habitat use for a species. At the University of Wyoming, scientists have been studying the impact of the mountain pine bark beetle on wildlife, using least chipmunks as monitoring species. They are interested in whether chipmunks will be able to use sagebrush habitat if the available forest habitat declines following the bark beetle tree kills. The vegetation surveys sample cover availability that allows chipmunks to hide and escape from predators. They also survey the availability of potential food items like pine seeds and soil macroinvertebrates.

This activity introduces students to habitat, habitat sampling, data collection, and data analysis to evaluate habitat requirements for wildlife species. Students will work as a team, learn to use various pieces of equipment and identify tree species. The activity can be done on a field trip outside of town or the students can collect vegetation data close to their school and compare it with the vegetation data for a forest habitat close to Laramie, WY, and determine whether chipmunks could survive around the their school and what habitat characteristics might be absent that would provide chipmunk habitat.

This activity can be quite lengthy if attempted in one class or field trip. It might be helpful to teach students the techniques at school before going into the field. It might also be helpful to have specific students assigned to one activity and be the expert for that measurement.

Wyoming Science Standards Covered by Activity:

Life Systems

SC8.1.5 Behavior and Adaptation
SC8.1.6 Interrelationships of Populations and Ecosystems
SC8.2.2 Students use inquiry to conduct scientific investigations
SC11.1.6 Interrelationships of Populations and Ecosystems
SC11.2.2 Students use inquiry to conduct scientific investigations

Materials:

- Measuring tapes
    - At least 2-3 per group
- DBH – diameter at breast height tape
    - A regular measuring tape will work too. Students will then be measuring circumference and can make the diameter calculation in the classroom.
- Meter stick
- Compass
- Plastic cups
- Paper plates
- Nails
- Clip boards
- Data sheet
- Field guide to identification of trees
- Ziploc baggies
- Dissecting microscope

Procedure:

1. Prep with students at the classroom/school before the activity. Explain the various measurements students will be making. Have students think about how different types of vegetation would be important to chipmunks while they are practicing the methods. For example, if you were a chipmunk and could escape from a predator by climbing a tree, would you want to look for food in area close to a tree or farther from a tree? If you like to eat pine seeds, would you want to live in an area with primarily aspen trees or sagebrush?
2. Using the line-transect method, students will estimate available cover for chipmunks. This method measures the amount of the tape (10 m in each direction) that intersects, travels over, etc. vegetation cover types.
    a. Using the compass, align one 50 m measuring tape with the N-S coordinates (use 2-3 people with one holding the compass and directing the others into a straight north-south line). The tape should extend 10 m in each direction with the 10 m mark located at the survey site.
    b. Using a second tape, align this tape with the E-W coordinates and repeat the previous step.
    c. You should now have two tapes crossing and extending in 10 m in each cardinal direction making a square X.

d. Along the tape, choose one very detail-oriented student to walk along the tape and estimate the distance intersecting bare ground (pine needles, duff, bare rock, soil, etc. – provides absolutely no cover), grass (grass, anything less than 4 inches high or the height of your hand held sideways), and shrub (sagebrush, juniper, no trees, etc., anything that would provide good cover for a chipmunk to hide under and is higher than 4 inches).
    i. Use notecards to make tally lists.
    ii. Measure the 2 most infrequent cover types, add those, subtract from 10 m, and you have the intersection distance for the 3rd.
    iii. Measure tape intersections to the nearest cm.
    iv. Your 3 estimates (bare ground, grass, shrub) for each direction should equal 10 m.

3. From the flag and in each of the 4 quadrats created by the tapes (NW, NE, SE, SW), measure the distance to the nearest <u>living</u> tree. The tree must be taller than you to qualify.
    a. Measure distance to the tree in m.
    b. Identify tree species – will be pines and aspens in the Laramie, WY area. Tree field guides will help with identifying trees in other locations.
        i. Lodgepole have a dark gray bark that looks like puzzle pieces on larger trees. They have medium length needles. Cones are small.
        ii. Ponderosa have dark gray bark when small. When larger, it is a cinnamon color with longitudinal cracks. Needles are very long compared to the other local pines. Cones are large.
        iii. Limber pine has a whitish gray bark that is smooth in places. Needles are very short. Cones are very larger and covered in sap. This tree is mostly found in more open areas.
    c. Measure diameter at breast height of the tree.
        i. To measure DBH, use the side of the DBH tape with the unusally large looking unit. The tape essentially takes the math out of measuring diameter. If you make sure to use the side of the tape that allows you to use the hook without the tape twisting, you are using the correct side. If using a regular tape measure, you will be measuring circumference and will need to convert the data to diameter.

4. In each of the 4 quadrats (think circle), students will count the number of pine trees wider than two fists (about 6 in) and also count the number of those trees that are already dead and those that appear to be infested with pine bark beetles.
    a. Signs of bark beetle infection are primarily pitch tubes on the trunk. These look like popcorn kernels and may be yellow, brown, red, and white. These are formed by resin leaking out of the site where a beetle tunneled into the tree. Look carefully and sometimes you may find an unsuccessful attempt of a beetle boring into the tree – the dead beetle may be enclosed in the pitch tube! You may also see sawdust around the base of the tree. Note: the needles may still be green and look healthy in infected trees. Needles do not turn yellow and then red until 8-10 months after the initial attack.
5. At the end of each line, students will also count the number of pine cones on the ground (do not dig into the duff, count the number of visible cones on the surface) in a 1 x 1 m square. This gives us an index of the availability of pine seeds as a food source for chipmunks.
    a. Use the meter stick to mark off a 1 x 1 m square.
6. Randomly choose either the N-S or E-W line transect. Every 5 m along the line, at the 0, 5, 10, 15, 20 m marks, dig a hole large enough to bury the plastic cup so that the lip is flush with the ground. Place a paper plate over the cup to keep the cup from filling with water if it rains. Use two nails or a rock to anchor the plate to the ground. This creates a pitfall trap to collect macro-soil invertebrates. Invertebrates will hide under the plate, fall in the cup, and become trapped in the cup. Cups should remain in the ground for at least 3 days in order to collect invertebrates.
7. At least 3 days after the survey, collect the pitfall traps.
    a. Remove the plate and nails and empty contents of cup into a Ziploc baggie.
    b. Freezing the baggies is a quick and humane method to kill the bugs.
    c. Use a dissecting microscope and an invertebrate key to identify the bugs captured in the traps.
8. Before going into the field, but after going over the methods described above, ask students to create hypotheses that they can test using the vegetation data they will collect. Explain null and alternative hypotheses or have students create one experimental hypothesis.
    Examples:
    H_A = Distance to nearest tree from survey point will be shorter in the forest than the sagebrush habitat.

H_0 = There will be no difference in distance to the nearest tree.

H_A = Available shrub cover will be great in the sagebrush than the forest habitat providing more escape cover for chipmunks.
H_0 = There is no difference in available shrub cover between the two habitats.

9. Choose at least 3 sites in your sampling area for the surveys. By surveying the habitat at several points, students collect data that better represents the entire area (replication). See Figure 1 at the end of the Procedures for a visual example of the surveys.
    a. If possible, survey a forested area with chipmunks or an area with your species of interest, and another area that may or may not be habitat suitable for chipmunks/your species. A forest habitat and a sagebrush habitat work well and can then be compared to the data file with the UW vegetation data.

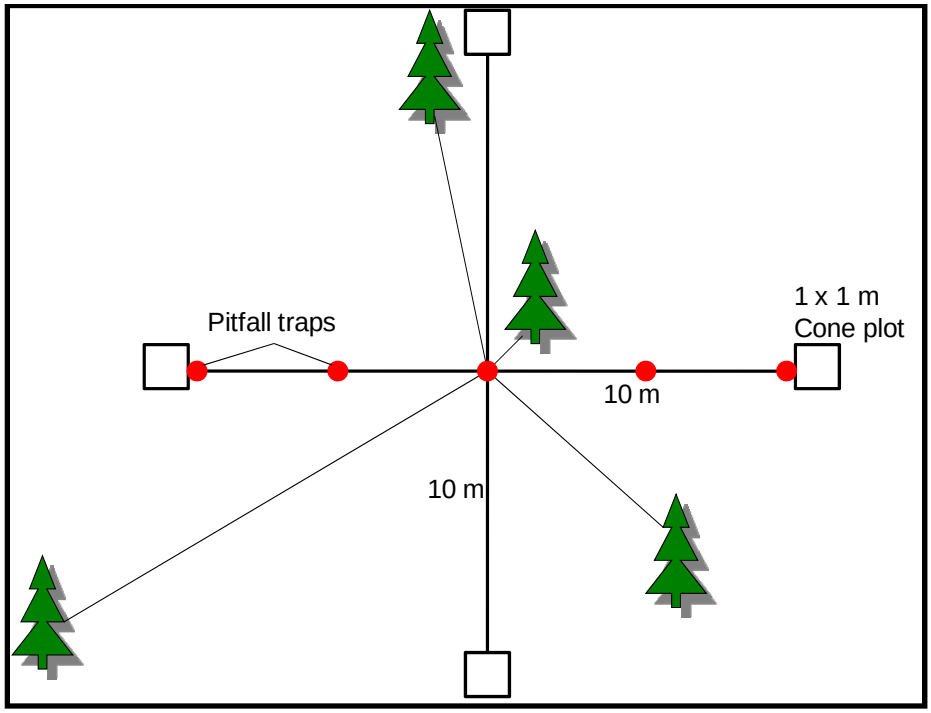


Figure 1. Diagram of the vegetation surveys.

Discussion Questions:

1. Which of the variables that you measured (shrub cover, the number of pine cones, distance to the nearest tree, etc.) differed the most between the two habitats you sampled?

2. Which variables differed the least (were the most similar between the two)?

3. Which of the variables that you measured (shrub cover, the number of pine cones, distance to the nearest tree, etc.) do you think is the best for determining optimal chipmunk habitat? Why?

Chipmunks, Bark Beetle Irruptions, and Climate Change Project Data Sheet
Vegetation Survey

Date:_____ Investigators:_____ Grid ID:_____

Trap #	AZ	Nearest tree species	Distance to the nearest tree	DBH of nearest tree	# Trees with beetle sign w/in 10 m of trap			AZ	Horizontal Cover			# cones in 1x1 m plot
			m	(cm or in)	Total trees	Dead Trees	Infected trees		Bare ground	Grass	Shrub	
	NW							N				
	NE							E				
	SE							S				
	SW							W				
	NW							N				
	NE							E				
	SE							S				
	SW							W				
	NW							N				
	NE							E				
	SE							S				
	SW							W				
	NW							N				
	NE							E				
	SE							S				
	SW							W				
	NW							N				
	NE							E				
	SE							S				
	SW							W				

Lesson 2: Activity 2 – How habitat impacts chipmunk populations

Purpose:

Often by comparing the vegetation in two different habitats, we can make predictions about how different species of wildlife will use those areas. In this activity, students will compare a few of the vegetation measurements collected at the Laramie sites. Students will also analyze the chipmunk trapping data to determine whether chipmunks will use sagebrush habitat following the loss of trees in forests infected with pine bark beetles. Students can also compare the data they collected between the two sites.

Wyoming Science Standards Covered by Activity:

SC8.1.6 Interrelationships of Populations and Ecosystems
SC11.1.6 Interrelationships of Populations and Ecosystems

Materials:

- Student vegetation data
- Data from chipmunk trapping
- Calculators

Procedure:

1. The students will use data collected by wildlife scientists at UW to compare chipmunk populations in sagebrush and forest habitats near Laramie using the provided worksheet.
2. Students will then use vegetation data to determine if there is a habitat difference that might explain any differences in the populations.

Name: _____

Do chipmunks prefer forest or sagebrush habitat? Using live-trapping data for least chipmunks near Laramie to estimate populations in 2 different habitats

Lesson 2 – Activity 2 – Worksheet 1

As you may know, scientists at the University of Wyoming live-trapped least chipmunks in a forest and a sagebrush habitat to estimate populations in these two habitats. Using their actual data and a mark/recapture model, you will determine how many chipmunks likely live in the area of their trapping grids. Then you will combine this information with vegetation data collected during vegetation surveys to determine if there is a habitat variable that can be used to predict habitat use by a chipmunk.

Here is data from two days of trapping near Laramie for two different grids. The chipmunks are given unique identification numbers when PIT tagged the first time they are trapped. Using the mark recapture equation, estimate how many chipmunks were living in the forest grid.

Date	Grid	Chipmunk I.D.
9/25/2009	For 1	88
9/25/2009	For 1	551
9/25/2009	For 1	561
9/25/2009	For 1	D5B
9/26/2009	For 1	200
9/26/2009	For 1	D5B
9/26/2009	For 1	399
9/26/2009	For 1	630
9/26/2009	For 1	910
9/26/2009	For 1	719
9/26/2009	For 1	777
9/26/2009	For 1	551
9/25/2009	Sage 1	451
9/25/2009	Sage 1	362
9/26/2009	Sage 1	499

1.) Count the total number of individual chipmunks trapped the first day (9/26/2009) in forest 1 (for 1):

n_1 = ____4_____

2.) Add 1 to your n_1 (step 1) value: $n_1 + 1$ =___5_____

3.) Count the total number of chipmunks trapped the second day (9/26/2009) in for 1:

n_2 = _____8_____

4). Add 1 to your n_2 (step 3) value: $n_2 + 1$ = _____9_____

5.) Count the total number of chipmunks that were trapped both days.

m = _____2_____

6.) Add 1 to you m value (step 5):

$m + 1$ = _____3_____

7.) Multiply your $n_1 + 1$ value (step 2) to your $n_2 + 1$ value (step 4)

$(n_1 + 1) \times (n_2 + 1)$ = __5 x 9 = 45_____

8. Divide you value in step 7 $[(n_1 + 1) \times (n_2 + 1)]$ by your $m + 1$ value:

$[(n_1 + 1) \times (n_2 + 1)] \div (m + 1)$ = __45/3 = 15_____

9. Finally, subtract 1 from your answer in step 8: N = _____15-1_____

Your answer is the number of chipmunks we would expect to find in the area we trapped if we were able to catch each and every chipmunk that lived there. The work you did above can be abbreviated into the equation below:

$$N = \left[\frac{(n_1 + 1) * (n_2 + 1)}{(m + 1)}\right] - 1$$

In this equation, N = your population estimate, n_1 = total number of individual chipmunks caught the first day, n_2 = total number of chipmunks caught the second day, and m = the number of recaptures (look to see if any of the chipmunks were caught both days.

10.) How many chipmunks do you estimate live in this area of the forest?

14

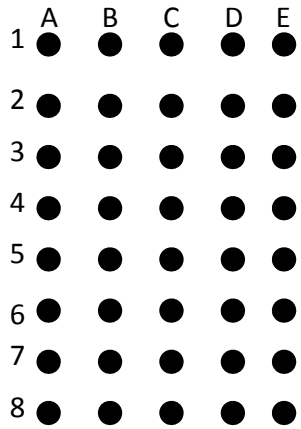
11.) Because we did not recapture any chipmunks in the sagebrush habitat, we will estimate Minimum Number Known Alive (MNKA) for both habitats. This is calculated by counting the number of individual chipmunks in both habitats. What were your results?

Forest = 11

Sagebrush = 3

Chipmunks prefer to live in areas with food and cover to hide from predators. On the next page are results from vegetation surveys near Laramie, WY. To evaluate habitat differences, we are going to compare available food for chipmunks in the form of seeds found in pine cones, available cover related to distance from the trap site to the nearest tree and the size of the tree, and the available shrub cover that was estimate using a 10 m line transect.

In the table on the next page, the first column, location, tells us which habitat type was surveyed, sagebrush or forest habitat. The next column tells us which trap site was used. The traps are arranged in a 5 × 8 trap grid and labeled with a number and a letter like this:



The column labeled AZ (short for azimuth) tells us in which direction from the trap the vegetation was measured. Distance to the nearest tree is the straight-line distance from the trap to the nearest tree. The tree had to be taller than the person measuring it. DBH is the diameter at breast height which is a way of measuring the size of the tree. Shrub cover in a 10 m survey is the amount of a 10 m line that was intersected (or crossed over) shrub, usually sagebrush or juniper shrub. Shrubs provide chipmunks with a place to hide from predators. Finally, in a 1 x 1 m plot, the number of cones lying on the ground was counted as an index of food for chipmunks. Chipmunks like to eat pine seeds found inside the cones.

How do you predict that the population numbers you calculated above will compare to the vegetation results?

Will chipmunks prefer forest or sagebrush habitat? Why?

Do you think would rather live in areas with bigger trees (bigger DBH measurements)? Why?

Would chipmunks rather live in areas with more shrub cover that would provide places to hide? Why?

Write at least 2 hypotheses below that you will test with the vegetation data.

Using the data in the table on the next page, complete the following table:

	Forest	Sagebrush
Average number of pine cones		
Average distance to the nearest tree		
Average DBH		
Average available shrub cover in 10 m		

Location	Trap #	AZ	Distance to nearest tree m	DBH of nearest tree cm	Shrub cover in 10 m survey m	Number of pine cones in 1 x 1 m plot
Sagebrush	A2	NW	6.18	9.3	5.1	0
Sagebrush	A2	NE	25.5	9.8	3.1	0
Sagebrush	A2	SE	30	6.7	3.8	0
Sagebrush	A2	SW	55.5	8.2	0.7	0
Sagebrush	B2	NW	41.5	21.1	4.8	0
Sagebrush	B2	NE	53.5	16.4	1.8	0
Sagebrush	B2	SE	46.5	9.3	4.5	0
Sagebrush	B2	SW	89.5	9.5	3.5	0
Sagebrush	B4	NW	25.5	5.5	4.7	0
Sagebrush	B4	NE	9.6	4.5	2.3	0
Sagebrush	B4	SE	44.5	24.3	5.1	0
Sagebrush	B4	SW	18	6.3	5.3	0
Sagebrush	E5	NW	22.3	4.5	1.5	0
Sagebrush	E5	NE	30.7	15.9	3.1	0
Sagebrush	E5	SE	20.9	3.3	2.7	0
Sagebrush	E5	SW	17.45	20.9	3.5	0
Forest	B1	NW	1.08	2.74	0	16
Forest	B1	NE	1.6	4.06	0	4
Forest	B1	SE	1.07	2.72	2.4	23
Forest	B1	SW	2.18	5.54	0	18
Forest	B3	NW	6.3	16	2.3	32
Forest	B3	NE	1.3	3.3	1.4	27
Forest	B3	SE	5.75	14.61	0.1	8
Forest	B3	SW	5.4	13.72	1.1	5
Forest	B6	NW	2.85	7.24	0	10
Forest	B6	NE	4.5	11.43	4.5	4
Forest	B6	SE	2.9	7.37	0.2	38
Forest	B6	SW	4.6	11.68	4.5	6
Forest	E8	NW	10.5	26.67	0	0
Forest	E8	NE	24.5	62.23	0	0
Forest	E8	SE	2.1	5.33	1.5	33
Forest	E8	SW	1.9	4.83	9.4	6

Lesson 3: Activity 1 – Estimating your optimal foraging strategies

Purpose:

Animals have evolved to forage or search for food in a way that maximizes their physiology, fitness, and survival. Therefore an animal is going to minimize its costs (energetic expenses, chance of predation, etc.) and maximize its gain (leave a foraging patch when the time spent searching food becomes too long and go to a new patch with a higher density of food).

This activity introduces the students to optimal foraging theory by allowing them to forage and assess each other's foraging strategies.

Wyoming Science Standards Covered by Activity:

Life Systems
SC8.1.5 Behavior and Adaptation
SC8.1.6 Interrelationships of Populations and Ecosystems
SC8.2.2 Students use inquiry to conduct scientific investigations
SC11.1.6 Interrelationships of Populations and Ecosystems
SC11.2.2 Students use inquiry to conduct scientific investigations

Materials:

- 5 buckets
- Shredded newspaper - Enough to fill the 5 buckets at least ½ full
- 25 plastic Easter eggs, film canisters, or something that candy can go inside.
- Candy, at least 105 pieces, with different colored wrappers but approximately of the same size
    - For example:
        - 15 pieces of green
        - 15 pieces of purple
        - 25 pieces of blue
        - 25 pieces of yellow
        - 40 pieces of red
- Stop watch

Procedure:

1. Number each bucket 1-5.
2. Fill the buckets at least half full of the shredded newspaper.
3. After creating the different foraging patches (buckets of candy) described below, you will arrange the buckets in a hallway or classroom so that a student forager will begin at one end of the foraging course, and move towards the buckets – similar to an obstacle course although the student can first go to whichever bucket they would like. Students will be timed and will have 60 seconds to visit buckets collecting candy.

   Foraging patches with low travel time
4. Hide 15 pieces of candy (green and purple) in 2 of the buckets. Place the buckets close to each other (within 2-3 feet).

   High predation/risky foraging patch
5. In another bucket, mix in 25 pieces of candy (blue). Choose one student to act as a predator. They will sit next to the bucket, barely within arms reach, and attempt to touch the forager if they visit this patch. If touched, the forager became prey and the time will end.

   Foraging patch with increased handling time to harvest food
6. The other bucket with 25 pieces of candy (yellow) can be placed anywhere. Hide each piece of candy inside the Easter eggs or film canisters. A forager visiting this patch will have to spend more time harvest the candy from the bucket.

   Foraging patch with increased travel time
7. The last bucket with the most amount of candy, 40 pieces, will be placed the farthest distance from the starting line. This bucket is an example of a foraging patch with a large travel time but with a higher rate of return.

   Beginning the game
8. Choose a student to act as the forager. Tell them their goal is to try and retrieve as much candy as possible to share with the class in 1 min. They must be back across the line before the end of 1 min. Give the student a warning when they have 15 seconds remaining and then count down from 10. Explain to them that at the bucket with the predator, if they are touched, their time ends. Do NOT tell them how much candy is in each bucket or the potential obstacles in the buckets. This allows the students to be naïve foragers. Have the other students watch and take notes on foraging behavior at the different buckets.
9. When finished, count the number of pieces of candy collected at each foraging patch.

Optional activities:

- Choose 3 foragers. Do not let the foragers watch each other run the obstacle course. This should result in 3 replicates of the experiment. Record the results of the experiments (how much food was foraged from each patch) and return candy to the appropriate foraging patches (buckets) after each student. The students observing should stay quiet and record observations to see if different foragers develop different strategies.
- Choose 3 foragers. Allow these students to watch the other students. Record the results of the experiments (how much food was foraged from each patch) and return candy to the appropriate foraging patches (buckets) after each student. The students observing should determine if these students modify their behavior to maximize the rate of return.
- Have students create additional modifications and predict how a naïve forager will run the course. Students can make hypotheses and test these using another class and develop their own data sheets for collecting observations.

Discussion Questions:

These can be incorporated into a worksheet or discussed as a class.

1. Which bucket did the forager collect the most pieces of candy? Why?

2. Which bucket seemed the most risky or had the biggest cost?

3. Which bucket seemed to have the biggest gain?

4. If they were going to forage a second time, which bucket would they return to first? Is there a specific strategy they would employ – spend some time at one patch, then move to a second etc. - or what would be their optimal foraging strategy?

5. Wildlife Conservation Implications - Think about this as though you were an animal. Animals only have a certain amount of energy they can spend traveling and harvesting food and they need to forage to replace their energy stores.

   As a forager, what do you predict would happen if the number of predators increased? What if the amount of available food in a patch decreased?

Lesson 3: Activity 2 – Estimating perceived predation risks by least chipmunks in forest and sagebrush habitat

Purpose:

Because mountain pine bark beetles are quickly changing the forest landscape in many parts of Wyoming, wildlife species will need to adapt to the new landscape or will disappear. The least chipmunk is a forest species that is considered a generalist species (does not specialize on a specific habitat characteristic or food and can generally adapt to new and varying conditions) that is closely associated with conifer forests in Wyoming but also occupies sagebrush and dry rocky outcrops. As pine trees die following attack by the beetles, the forests habitats are going to change. To survive, least chipmunks will need to survive in sagebrush habitats. Whether this species can do this depends on several aspects of their ecology including predation. Prey species are aware of various habitat characteristics that leave them more susceptible to predation and will avoid these habitats or modify their behaviors to use these habitats and survive. When foraging, it is difficult for the animal to be both completely vigilant and aware of its surroundings while also feeding. Therefore, many animals will give up a foraging patch if the density of food becomes low, foraging involves more time spent searching, and their perceived risk of predation is high (they think that the chance they will become prey is quite likely).

In this activity students will assess results from a giving-up density experiment on least chipmunks in sagebrush and forest habitat to determine if chipmunks perceive greater risks to predation in sagebrush vs. forest.

Wyoming Science Standards Covered by Activity:

Life Systems

SC8.1.5 Behavior and Adaptation
SC8.1.6 Interrelationships of Populations and Ecosystems
SC8.3.2 Students explore how scientific information is used to make decisions
SC11.1.6 Interrelationships of Populations and Ecosystems
SC11.3.2. Students explore how scientific information is used to make decisions

Materials:

- Least chipmunk data
- Worksheets
- Graphing paper

Procedure:

1. Explain to students that the mountain pine bark beetle outbreak is going to result in changes in the forest habitats in Wyoming and explain how this will affect chipmunk habitat. Explain that a change in the forest is going to result in a more open habitat with less cover and that chipmunks will likely need to use sagebrush habitat to survive. Lead their thinking about the problem to the issue of predators. Remember that the data we're using is not direct predation event data (we didn't count the number of chipmunks that died in each habitat) but instead, how the animals actually behave in response to sensing predators in a habitat. Least chipmunks likely prefer to have a lot of horizontal cover (bushes, trees, etc.) for hiding to avoid becoming prey for an avian or terrestrial carnivore.
2. Describe the field experiment:
    a. Plastic trays were filled with 1 liter of sand and 500 black oil sunflower seeds were mixed into each tray.
    b. The tray was covered by chicken wire to keep out birds and red squirrels. The holes in the wire allowed easy access to the tray by chipmunks.
    c. The tray was then left in sagebrush or forest habitat to allow chipmunks to visit the tray and potentially eat the seeds.
    d. We placed 500 black oil sunflower seeds in a tray each morning and each evening, we counted how many seeds remained.
3. Ask students to develop a hypothesis to test with the giving-up density data.
    For example:
    H_A = Chipmunks in sagebrush habitat (habitat with less cover for a chipmunk to hide) will perceive a greater predation risk to predation than chipmunks in forest habitat leaving more sunflower seeds in the trays.
    H_0 = There will be no difference in chipmunks' perception of predation risk between the two habitats.
    - This is the hypothesis set we have been testing at UW with the GUD experiments.
4. Students will follow the worksheet to calculate mean seeds left behind in the feeding trays (similar to Activity 1).

5. Discuss the results. Does the data support or refute their hypotheses? Were they surprised by the results?

Optional activity:

Scientists from the University of Wyoming studying the potential ecosystem impacts in Yellowstone following the reintroduction of wolves were interested in determining if elk would change their foraging behaviors in response to perceived predation risk. Over the last 50-100 years, aspen stands have seen very little replacement of adult trees because new shoots are being grazed by elk before they grow very tall. Another study on wolf kill sites indicates that aspen stands are considered “risky” habitat because many kill sites occurred in open areas with a water supply which in the winter have deep snow. These are the areas containing aspen habitat. Because wolves are inefficient hunters with low hunting success (~20%), they take advantage of these areas. Wolves are coursing predators meaning that they chase prey so they prefer hunting in more open habitats. The deep snow also makes it more difficult for elk to escape in the winter.

To determine if elk would continue to forage in these risky areas, the scientists used giving-up density experiments to assess perceived predation risk by elk.

Procedure:

1. Describe research questions (scenario above) to students.
2. Ask students to develop a hypothesis to test with the giving-up density data.
3. Have students enter the elk data into an excel spreadsheet following the instructions on the worksheet.
4. Discuss the results. Does the data support or refute their hypotheses? Were they surprised by the results?

Name:_____

Do chipmunks sense more predators in different habitats? Using giving-up data to estimate perceived predation risks by least chipmunks

Lesson 3, Activity 2, Worksheet 1

Because of the current outbreak of mountain pine bark beetles, the forests in southeastern Wyoming are likely going to change, becoming more open with less cover for least chipmunks to hide from predators. Sagebrush habitat may also expand into areas that were once forested. If chipmunks sense a greater risk of becoming prey for a predator, they are less likely to use a habitat and will avoid it.

Scientists at the University of Wyoming are interested in determining if chipmunks sense a greater risk from predators in forest or sagebrush habitat because with less forest habitat, chipmunks may begin using sagebrush habitat more.

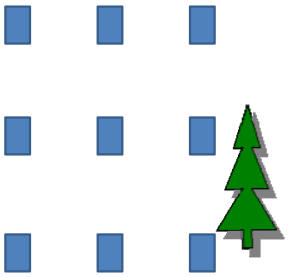
1. What do you think is the scientists' research/alternative hypothesis? Write it below.

H_A = Chipmunks will perceive greater predation risk in sagebrush than forest habitats.

2. What do you think is the scientists' null hypothesis? Remember, the null hypothesis predicts no difference or change.

H_0 = There will be no difference in perceived predation risk by chipmunks between forest and sagebrush habitats.

To test their hypothesis, the scientists used giving-up density experiments. These experiments use an experimental food patch to determine how much food a chipmunk will eat before it gives up the food patch because it senses predators. The experimental food patches were made from a plastic tray filled with 1 L of sand with 500 black oil sunflower seeds mixed into the sand. The trays were set at 9 different sites in 2 forest and 2 sagebrush grids like in the figure below.



Each day for 4 consecutive days the sunflower seeds were mixed into the trays each morning by 8 AM and then sieved from the sand at 4 PM and the remaining seeds were counted. The scientists used 9 trays in each habitat and ran their experiment for 4 days to replicate the experiment. Their results are in the table below. To compare their results and determine if there was a difference in the number of sunflower seeds consumed each day, you will need to calculate the average number of seeds consumed in each habitat each day. **Remember, to calculate an average, you add all of the seeds left in each tray and divide by the number of trays.**

FOREST 1	Day 1	Day 2	Day 3	Day 4
Tray 1	500	451	362	254
2	485	486	402	296
3	477	452	391	222
4	500	434	399	101
5	432	430	321	7
6	498	475	376	219
7	488	444	318	178
8	467	459	423	321
9	496	468	412	377
Average				
FOREST 2	Day 1	Day 2	Day 3	Day 4
Tray 1	398	301	196	94
2	444	463	332	299
3	419	407	265	178
4	374	366	188	51
5	495	412	319	217
6	409	389	245	253
7	478	416	367	321
8	452	321	204	87
9	407	287	112	0
Average				
SAGEBRUSH 1	Day 1	Day 2	Day 3	Day 4
Tray 1	492	500	491	489
2	498	481	475	447
3	476	462	463	426

4	484	480	422	396
5	500	488	457	421
6	490	492	497	491
7	500	479	441	422
8	479	468	439	408
9	481	472	466	412
Average				

SAGEBRUSH 2	Day 1	Day 2	Day 3	Day 4
Tray 1	488	451	447	421
2	497	490	489	412
3	499	476	482	452
4	451	432	431	387
5	486	451	453	400
6	500	487	476	432
7	462	451	462	392
8	494	448	436	367
9	487	461	449	370
Average				

Next, using graphing paper, make a line graph of your data to further analyze the response of chipmunks to the 2 habitats. When making a line graph, remember that the x-axis is the independent variable which is the “Date” and your y-axis is the dependant variable, the number of seeds left. Use 4 different colors of pencil or 4 different symbols so you can graph all four lines (Forest 1, Forest 2, Sagebrush 1, and Sagebrush 2) on one graph to compare the habitats.

Now using your graph, answer the following questions:

1. In which of the 2 habitats did chipmunks consume the most seeds in a tray?

2. Look at your lines for Forest 1 and Forest 2, do they look similar (does the line follow the same trend)? Do the lines increase or decrease?

3. Look at your lines for Sagebrush 1 and Sagebrush 2, do they look similar? Do the lines increase or decrease?

4. Why do you think the number of seeds consumed increased as the number of days of the experiment increased?

5. If the chipmunks eat fewer seeds in the habitat they think has more predators, in which of the two habitats did these chipmunks sense more predators?

6. Did this support your alternative or your null hypothesis?

Name:_____

Did elk in Yellowstone stop using risky aspen habitat to avoid predation following the reintroduction of wolves?

Lesson 3, Activity 2, Worksheet 2

Over the last 50-100 years, biologists in Yellowstone National Park noticed that no new aspen trees were growing. Older aspen continued to grow but none of the new sprouts survived after growing about as high as your knee. Upon further inspection, scientists noticed that these young aspen were being eaten by elk. When wolves were reintroduced into Yellowstone in 1995, scientists predicted that elk would stop using these areas that grew aspen because it was easier for them to become prey for wolves. These areas were more open than forests with conifer trees. Wolves are not very good hunters and need open areas to successfully chase and kill an elk which makes these aspen stands perfect for hunting.

1. What do you think is the scientists' research/alternative hypothesis? Write it below.

H_A = After the wolf reintroduction, new aspen trees will begin growing as elk use those habitats less.

2. What do you think is the scientists' null hypothesis? Remember, the null hypothesis predicts no difference or change.

H_0 = There will be no difference in aspen growth before or after the wolf reintroduction.

To test their hypothesis, the scientists used giving-up density experiments with the elk just like the experiments with chipmunks! To do this, they used livestock feed buckets with blocks of wood (the elk will not eat the wood and it works like the sand in the chipmunk experiments) and alfalfa cubes (instead of sunflower seeds). They chose 20 different sites in Yellowstone which allowed for replication of their experiments. At each site they used 8 trays set in a straight line with 20 m between each tray. During the experiments, they would set out the feeding trays for 5 days. They would mix in 60 alfalfa cubes in the morning and then at the end of the day count how many cubes remained.

Here are the results from their experiment:

	Average number of alfalfa cubes remaining	
Date	Risky habitat (aspen)	Safe habitat (forest)
Dec 11-19	39	21
Jan 6-14	15	20
Jan 27-Feb 3	7	21
Feb 18-25	6	14
Mar 9-17	9	30
Nov 11-21	49	58
Dec 10-15	36	35
Jan 6-11	31	49
Jan 26-31	20	4
Feb 17-22	31	13
Mar 10-15	29	35

Often trying to determine what our data actually means is difficult if we just look at the numbers. We can make this easier by making a figure. Using graph paper and the data table above, make a bar graph. The date will go on the x-axis and you should have two bars at each date, a risky and a safe bar depicting the average number of alfalfa cubes remaining in the tray.

Now using your graph, answer the following questions:

1. In which of the 2 habitats does it look like elk consumed the most alfalfa cubes in a tray? Is it easy to decide which habitat the elk preferred or does it appear that they used each about the same?

2. Do you think that based on your data, elk avoided the risky habitat?

3. Did this support your alternative or your null hypothesis?

For an elk, successfully surviving the winter means finding food. If an elk cannot eat, it will not survive until spring. The elk know that the aspen areas are risky because the wolves prefer to hunt in those areas but they are willing to take the risk to survive the winter and not starve. Therefore they have to make a trade-off maximizing finding food and minimizing predation. One way to minimize predation is to forage in a herd. In a herd, there are more eyes and ears look for predators so the elk are more likely to detect a wolf before the wolves can successfully hunt then. There's also less of a chance of being the one eaten if you are in a big herd of animals if the wolves make a successful hunt.

Lesson 3: Activity 3 – Giving-up density experiments in the schoolyard

Purpose:

In this activity, students will investigate perceived predation risk by animals using a non-invasive research project that estimates giving-up density, or the point when an animal decides that foraging is no longer worth the risk of being eaten by a predator. Student activities will include creating data sheets, developing hypotheses, basic data analysis, and presenting results in the form of tables or graphs. By repeating the experiment over several days and using multiple trays/patches at each treatment level, students will learn the importance of replication in experimental design.

Note: if a student is interested in using this experiment or any experiment involving live animals for a school science fair, they will need to complete and follow guidelines for the use of vertebrate animals in research. More information can be found at: http://www.societyforscience.org/Page.aspx?pid=312.

Wyoming Science Standards Covered by Activity:

Life Systems

SC8.1.5 Behavior and Adaptation
SC8.1.6 Interrelationships of Populations and Ecosystems
SC8.2.2 Students use inquiry to conduct scientific investigations
SC11.1.4 Interdependence of organisms
SC11.1.6 Interrelationships of Populations and Ecosystems
SC11.2.2 Students use inquiry to conduct scientific investigations

Materials:

- Cake pans, plastic trays, or anything similar with a 1-2 in. edge that will keep sand contained in the “patch.”
- Playground sand
- Black oil sunflower seeds
- Ziploc baggies for storing seed samples
- Sharpie for labeling baggies
- Chicken wire (optional – can be placed loosely over the top of tray to exclude birds. If experiment involves tree squirrels, create a dome with the chicken wire that will allow the squirrels to enter from either end but will not allow birds to land directly on the tray.)

- Colander or sieve for separating the seeds from the sand at the end of each day

Procedure:

1. Before beginning, students will need to determine the research questions and their hypotheses. Are they interested in testing whether the distance from an escape structure (tree), distance from a busy road or sidewalk, weather, etc. influences foraging.
2. Students should create a research hypothesis to test with the experiment.

   For example:

   H_A = As distance from a tree increases, squirrels will perceive greater predation risk and giving-up density will increase resulting in a greater number of seeds remaining in the patch.

   H_0 = There will be no difference in giving-up density in relation to distance from a tree.
3. Add 1 L of sand to each tray
4. Add a known number of sunflower seeds to each tray (300-500).
5. If using chicken wire, make an open-ended dome over the tray.
6. Place trays at selected sites in the morning.
7. At the end of the day, collect the trays and sieve the seeds from each tray.
8. Count the remaining seeds.
9. Remember - the number of seeds remaining indicates the point when the animals determined the predation risk outweighed food (energy) gain.
10. Have the students create a data sheet for recording data from multiple days. Column titles can include data, distance from tree, number of seeds remaining, weather, etc.
11. Ask students to graph their data either on paper or in Excel.

Discussion Questions:

1. Does the number of seeds differ between habitat, distance from cover, etc.?
2. Did your study animal perceive a risk to predation at the various treatment levels?
3. Did giving-up density change over time (when you left the trays out on the second or third day, did the squirrels eat more seeds)?
4. Were your hypotheses supported by the data?
5. Conservation Implications: How do you think timber harvest/logging affects foraging of squirrels?

Additional Resources:

Brown, J.S. 1988. Patch use as an indicator of habitat preference, predation risk, and competition. Behavioral Ecology and Sociobiology 22:37-47.

Brown, J.S. 1992. Patch use under predation risk: I. Models and predictions. Annales Zoologici Fennici 29:301-309.

Charnov, E.L. 1976. Optimal foraging: the marginal value theorem. Theoretical Population Biology 9:129-136.

Lesson 4: Activity 1- What does it all mean? Suggesting management decisions based on the results from the chipmunk research

Purpose:

One priority in science is to use the data to make recommendations to the appropriate people and agencies about the management of a species. The students should now be familiar enough with least chipmunks, pine bark beetles, and the research to create some suggestions for future management of forests and small forest mammals.

This activity also allows students to do additional research, synthesize information, and communicate their results.

Wyoming Science Standards Covered by Activity:

SC8.1.5 Behavior and Adaptation
SC8.1.6 Interrelationships of Populations and Ecosystems
SC8.2.1 Students research scientific information and present findings through appropriate means
SC8.2.2 Students use inquiry to conduct scientific investigations
SC8.2.3 Students clearly and accurately communicate the result of their own work, as well as information obtained from other sources
SC8.3.2 Students explore how scientific information is used to make decisions.
SC 11.1.4 Interdependence of Organisms
SC 11.1.6 Behavior and Adaptation
SC 11.2.1 Students research scientific information and present findings through appropriate means
SC 11.2.2 Students use inquiry to conduct scientific investigations
SC11.2.3 Students clearly and accurately communicate the result of their own work, as well as information obtained from other sources
SC11.3.2 Students explore how scientific information is used to make decisions.

Materials:

- Data files used in previous activities
- Extra data files available from Liz Flaherty at UW
- Computers for internet research

Procedure:

1. Students will break up into small groups and use the data files they have and additional data or internet resources to write reports to the Wyoming Game and Fish and other agencies with management suggestions and to prepare agencies in terms of what to expect from the beetle kill.

2. Additional questions for students can include:
    a. How will other wildlife species respond to the loss of forest habitat?
    b. How will other wildlife species (predators) respond to the loss of least chipmunks?
    c. How will bark beetles impact recreational activities by killing pine trees (i.e. skiing, camping, hunting, etc.)?

3. Liz Flaherty, at the University of Wyoming, has a large library of data files that are available for class projects. Files include vegetation surveys on chipmunk trapping grids from 2 locations in Wyoming, chipmunk live-trapping data, giving-up density data, body size measurements for chipmunks, and more. Email requests to lizf@uwyo.edu.

4. Students will draft a report and present their recommendations to the class.

Name:_____

Making graphs of tree mortality to predict impacts of the bark beetle on forests

Lesson 1 – Activity 1 - Worksheet 2

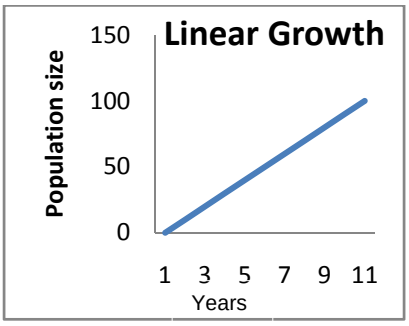
Using the data from your tree worksheet, create a figure depicting tree mortality resulting from the pine bark beetle infestations. You will label the x axis “years” which represents the years following the infestation of the first tree. The y-axis should be labeled as “number of trees infected”. Continue projecting your population out to 10 years to better understand the population growth of the beetles and the resulting tree mortality. Be sure to give your graph a title and to label the axes.

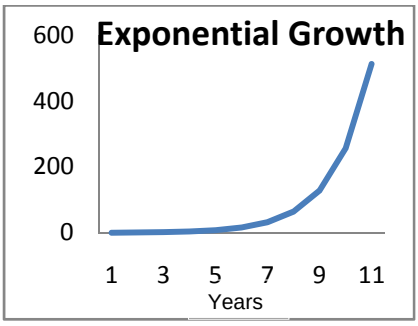
Title:

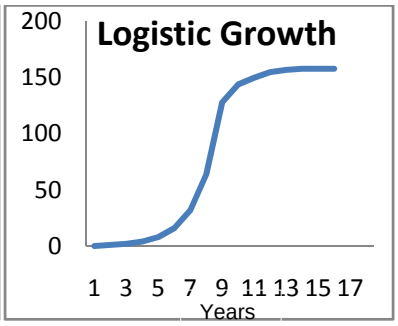
y-axis

x- axis

1. Now that you have finished making your figure, what kind of population growth do we see? Which of the below figures does yours best resemble:







2. If you examine the logistic growth curve in the graph above, you notice that eventually the population reaches a plateau and stops growing. Will this happen with the bark beetle populations? When will the beetles population plateau and the trees stop dying?

3. What do you think will happen to forest wildlife species that require trees for cover and food? What will happen to forest species, like woodpeckers, the eat bark beetles?

Name: _____

Do chipmunks prefer forest or sagebrush habitat? Using live-trapping data for least chipmunks near Laramie to estimate populations in 2 different habitats

Lesson 2 – Activity 2 – Worksheet 1

As you may know, scientists at the University of Wyoming live-trapped least chipmunks in a forest and a sagebrush habitat to estimate populations in these two habitats. Using their actual data and a mark/recapture model, you will determine how many chipmunks likely live in the area of their trapping grids. Then you will combine this information with vegetation data collected during vegetation surveys to determine if there is a habitat variable that can be used to predict habitat use by a chipmunk.

Here is data from two days of trapping near Laramie for two different grids. The chipmunks are given unique identification numbers when PIT tagged the first time they are trapped. Using the mark recapture equation, estimate how many chipmunks were living in the forest grid.

Date	Grid	Chipmunk I.D.
9/25/2009	For 1	88
9/25/2009	For 1	551
9/25/2009	For 1	561
9/25/2009	For 1	D5B
9/26/2009	For 1	200
9/26/2009	For 1	D5B
9/26/2009	For 1	399
9/26/2009	For 1	630
9/26/2009	For 1	910
9/26/2009	For 1	719
9/26/2009	For 1	777
9/26/2009	For 1	551
9/25/2009	Sage 1	451
9/25/2009	Sage 1	362
9/26/2009	Sage 1	499

1.) Count the total number of individual chipmunks trapped the first day (9/26/2009) in forest 1 (for 1):

n_1 = _____

2.) Add 1 to your n_1 (step 1) value: $n_1 + 1$ =_____

3.) Count the total number of chipmunks trapped the second day (9/26/2009) in for 1:

n_2 = _____

4). Add 1 to your n_2 (step 3) value: $n_2 + 1$ = _____

5.) Count the total number of chipmunks that were trapped both days.

m = _____

6.) Add 1 to you m value (step 5):

$m + 1$ = _____

7.) Multiply your $n_1 + 1$ value (step 2) to your $n_2 + 1$ value (step 4)

$(n_1 + 1) \times (n_2 + 1)$ = _____

8. Divide you value in step 7 $[(n_1 + 1) \times (n_2 + 1)]$ by your $m + 1$ value:

$[(n_1 + 1) \times (n_2 + 1)] \div (m + 1)$ = _____

9. Finally, subtract 1 from your answer in step 8: N = _____

Your answer is the number of chipmunks we would expect to find in the area we trapped if we were able to catch each and every chipmunk that lived there. The work you did above can be abbreviated into the equation below:

$$N = \left[\frac{(n_1 + 1) * (n_2 + 1)}{(m + 1)}\right] - 1$$

In this equation, N = your population estimate, n_1 = total number of individual chipmunks caught the first day, n_2 = total number of chipmunks caught the second day, and m = the number of recaptures (look to see if any of the chipmunks were caught both days.

10.) How many chipmunks do you estimate live in this area of the forest?

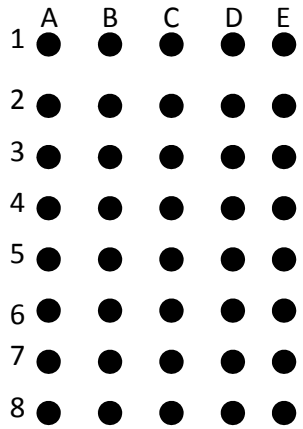
11.) Because we did not recapture any chipmunks in the sagebrush habitat, we will estimate Minimum Number Known Alive (MNKA) for both habitats. This is calculated by counting the number of individual chipmunks in both habitats. What were your results?

Forest =

Sagebrush =

Chipmunks prefer to live in areas with food and cover to hide from predators. On the next page are results from vegetation surveys near Laramie, WY. To evaluate habitat differences, we are going to compare available food for chipmunks in the form of seeds found in pine cones, available cover related to distance from the trap site to the nearest tree and the size of the tree, and the available shrub cover that was estimate using a 10 m line transect.

In the table on the next page, the first column, location, tells us which habitat type was surveyed, sagebrush or forest habitat. The next column tells us which trap site was used. The traps are arranged in a 5 × 8 trap grid and labeled with a number and a letter like this:



The column labeled AZ (short for azimuth) tells us in which direction from the trap the vegetation was measured. Distance to the nearest tree is the straight-line distance from the trap to the nearest tree. The tree had to be taller than the person measuring it. DBH is the diameter at breast height which is a way of measuring the size of the tree. Shrub cover in a 10 m survey is the amount of a 10 m line that was intersected (or crossed over) shrub, usually sagebrush or juniper shrub. Shrubs provide chipmunks with a place to hide from predators. Finally, in a 1 x 1 m plot, the number of cones lying on the ground was counted as an index of food for chipmunks. Chipmunks like to eat pine seeds found inside the cones.

How do you predict that the population numbers you calculated above will compare to the vegetation results?

Will chipmunks prefer forest or sagebrush habitat? Why?

Do you think would rather live in areas with bigger trees (bigger DBH measurements)? Why?

Would chipmunks rather live in areas with more shrub cover that would provide places to hide? Why?

Write at least 2 hypotheses below that you will test with the vegetation data.

Using the data in the table on the next page, complete the following table:

	Forest	Sagebrush
Average number of pine cones		
Average distance to the nearest tree		
Average DBH		
Average available shrub cover in 10 m		

Location	Trap #	AZ	Distance to nearest tree m	DBH of nearest tree cm	Shrub cover in 10 m survey m	Number of pine cones in 1 x 1 m plot
Sagebrush	A2	NW	6.18	9.3	5.1	0
Sagebrush	A2	NE	25.5	9.8	3.1	0
Sagebrush	A2	SE	30	6.7	3.8	0
Sagebrush	A2	SW	55.5	8.2	0.7	0
Sagebrush	B2	NW	41.5	21.1	4.8	0
Sagebrush	B2	NE	53.5	16.4	1.8	0
Sagebrush	B2	SE	46.5	9.3	4.5	0
Sagebrush	B2	SW	89.5	9.5	3.5	0
Sagebrush	B4	NW	25.5	5.5	4.7	0
Sagebrush	B4	NE	9.6	4.5	2.3	0
Sagebrush	B4	SE	44.5	24.3	5.1	0
Sagebrush	B4	SW	18	6.3	5.3	0
Sagebrush	E5	NW	22.3	4.5	1.5	0
Sagebrush	E5	NE	30.7	15.9	3.1	0
Sagebrush	E5	SE	20.9	3.3	2.7	0
Sagebrush	E5	SW	17.45	20.9	3.5	0
Forest	B1	NW	1.08	2.74	0	16
Forest	B1	NE	1.6	4.06	0	4
Forest	B1	SE	1.07	2.72	2.4	23
Forest	B1	SW	2.18	5.54	0	18
Forest	B3	NW	6.3	16	2.3	32
Forest	B3	NE	1.3	3.3	1.4	27
Forest	B3	SE	5.75	14.61	0.1	8
Forest	B3	SW	5.4	13.72	1.1	5
Forest	B6	NW	2.85	7.24	0	10
Forest	B6	NE	4.5	11.43	4.5	4
Forest	B6	SE	2.9	7.37	0.2	38
Forest	B6	SW	4.6	11.68	4.5	6
Forest	E8	NW	10.5	26.67	0	0
Forest	E8	NE	24.5	62.23	0	0
Forest	E8	SE	2.1	5.33	1.5	33
Forest	E8	SW	1.9	4.83	9.4	6

Name:_____

Do chipmunks sense more predators in different habitats? Using giving-up data to estimate perceived predation risks by least chipmunks

Lesson 3, Activity 2, Worksheet 1

Because of the current outbreak of mountain pine bark beetles, the forests in southeastern Wyoming are likely going to change, becoming more open with less cover for least chipmunks to hide from predators. Sagebrush habitat may also expand into areas that were once forested. If chipmunks sense a greater risk of becoming prey for a predator, they are less likely to use a habitat and will avoid it.

Scientists at the University of Wyoming are interested in determining if chipmunks sense a greater risk from predators in forest or sagebrush habitat because with less forest habitat, chipmunks may begin using sagebrush habitat more.

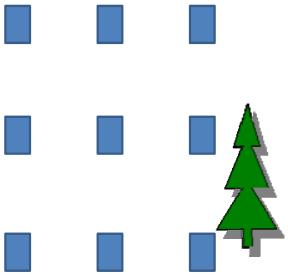
1. What do you think is the scientists' research/alternative hypothesis? Write it below.

H_A =

2. What do you think is the scientists' null hypothesis? Remember, the null hypothesis predicts no difference or change.

H_0 =

To test their hypothesis, the scientists used giving-up density experiments. These experiments use an experimental food patch to determine how much food a chipmunk will eat before it gives up the food patch because it senses predators. The experimental food patches were made from a plastic tray filled with 1 L of sand with 500 black oil sunflower seeds mixed into the sand. The trays were set at 9 different sites in 2 forest and 2 sagebrush grids like in the figure below.



Each day for 4 consecutive days the sunflower seeds were mixed into the trays each morning by 8 AM and then sieved from the sand at 4 PM and the remaining seeds were counted. The scientists used 9 trays in each habitat and ran their experiment for 4 days to replicate the experiment. Their results are in the table below. To compare their results and determine if there was a difference in the number of sunflower seeds consumed each day, you will need to calculate the average number of seeds consumed in each habitat each day. **Remember, to calculate an average, you add all of the seeds left in each tray and divide by the number of trays.**

FOREST 1	Day 1	Day 2	Day 3	Day 4
Tray 1	500	451	362	254
2	485	486	402	296
3	477	452	391	222
4	500	434	399	101
5	432	430	321	7
6	498	475	376	219
7	488	444	318	178
8	467	459	423	321
9	496	468	412	377
Average				
FOREST 2	Day 1	Day 2	Day 3	Day 4
Tray 1	398	301	196	94
2	444	463	332	299
3	419	407	265	178
4	374	366	188	51
5	495	412	319	217
6	409	389	245	253
7	478	416	367	321
8	452	321	204	87
9	407	287	112	0
Average				
SAGEBRUSH 1	Day 1	Day 2	Day 3	Day 4
Tray 1	492	500	491	489
2	498	481	475	447
3	476	462	463	426
4	484	480	422	396
5	500	488	457	421
6	490	492	497	491
7	500	479	441	422
8	479	468	439	408
9	481	472	466	412
Average				

SAGEBRUSH 2	Day 1	Day 2	Day 3	Day 4
Tray 1	488	451	447	421
2	497	490	489	412
3	499	476	482	452
4	451	432	431	387
5	486	451	453	400
6	500	487	476	432
7	462	451	462	392
8	494	448	436	367
9	487	461	449	370
Average				

Next, using graphing paper, make a line graph of your data to further analyze the response of chipmunks to the 2 habitats. When making a line graph, remember that the x-axis is the independent variable which is the “Date” and your y-axis is the dependant variable, the number of seeds left. Use 4 different colors of pencil or 4 different symbols so you can graph all four lines (Forest 1, Forest 2, Sagebrush 1, and Sagebrush 2) on one graph to compare the habitats.

Now using your graph, answer the following questions:

1. In which of the 2 habitats did chipmunks consume the most seeds in a tray?

2. Look at your lines for Forest 1 and Forest 2, do they look similar (does the line follow the same trend)? Do the lines increase or decrease?

3. Look at your lines for Sagebrush 1 and Sagebrush 2, do they look similar? Do the lines increase or decrease?

4. Why do you think the number of seeds consumed increased as the number of days of the experiment increased?

5. If the chipmunks eat fewer seeds in the habitat they think has more predators, in which of the two habitats did these chipmunks sense more predators?

6. Did this support your alternative or your null hypothesis?

Name:_____

Did elk in Yellowstone stop using risky aspen habitat to avoid predation following the reintroduction of wolves?

Lesson 3, Activity 2, Worksheet 2

Over the last 50-100 years, biologists in Yellowstone National Park noticed that no new aspen trees were growing. Older aspen continued to grow but none of the new sprouts survived after growing about as high as your knee. Upon further inspection, scientists noticed that these young aspen were being eaten by elk. When wolves were reintroduced into Yellowstone in 1995, scientists predicted that elk would stop using these areas that grew aspen because it was easier for them to become prey for wolves. These areas were more open than forests with conifer trees. Wolves are not very good hunters and need open areas to successfully chase and kill an elk which makes these aspen stands perfect for hunting.

1. What do you think is the scientists' research/alternative hypothesis? Write it below.

H_A =

2. What do you think is the scientists' null hypothesis? Remember, the null hypothesis predicts no difference or change.

H_0 =

To test their hypothesis, the scientists used giving-up density experiments with the elk just like the experiments with chipmunks! To do this, they used livestock feed buckets with blocks of wood (the elk will not eat the wood and it works like the sand in the chipmunk experiments) and alfalfa cubes (instead of sunflower seeds). They chose 20 different sites in Yellowstone which allowed for replication of their experiments. At each site they used 8 trays set in a straight line with 20 m between each tray. During the experiments, they would set out the feeding trays for 5 days. They would mix in 60 alfalfa cubes in the morning and then at the end of the day count how many cubes remained.

Here are the results from their experiment:

	Average number of alfalfa cubes remaining	
Date	Risky habitat (aspen)	Safe habitat (forest)
Dec 11-19	39	21
Jan 6-14	15	20
Jan 27-Feb 3	7	21
Feb 18-25	6	14
Mar 9-17	9	30
Nov 11-21	49	58
Dec 10-15	36	35
Jan 6-11	31	49
Jan 26-31	20	4
Feb 17-22	31	13
Mar 10-15	29	35

Often trying to determine what our data actually means is difficult if we just look at the numbers. We can make this easier by making a figure. Using graph paper and the data table above, make a bar graph. The date will go on the x-axis and you should have two bars at each date, a risky and a safe bar depicting the average number of alfalfa cubes remaining in the tray.

Now using your graph, answer the following questions:

1. In which of the 2 habitats does it look like elk consumed the most alfalfa cubes in a tray? Is it easy to decide which habitat the elk preferred or does it appear that they used each about the same?

2. Do you think that based on your data, elk avoided the risky habitat?

3. Did this support your alternative or your null hypothesis?

For an elk, successfully surviving the winter means finding food. If an elk cannot eat, it will not survive until spring. The elk know that the aspen areas are risky because the wolves prefer to hunt in those areas but they are willing to take the risk to survive the winter and not starve. Therefore they have to make a trade-off maximizing finding food and minimizing predation. One way to minimize predation is to forage in a herd. In a herd, there are more eyes and ears look for predators so the elk are more likely to detect a wolf before the wolves can successfully hunt then. There's also less of a chance of being the one eaten if you are in a big herd of animals if the wolves make a successful hunt.