Environmental Systems and Societies Name:

*Ecosystem Structure Practice*

**Learning goal:** I want you to use trophic levels, food chains, food webs, and pyramids of number, biomass and productivity to understand how ecosystems function.

**Success criteria:** You will make predictions about the results of the structure of ecosystems. You will then systematically explore the concepts which affect ecosystem structure. You will finish by revisiting the initial questions.

**Introduction:** As ecologists have studied ecosystems they have learned that ecosystems have a structure. The structure is largely dictated by the availability of energy in the system. This means concepts such as productivity are directly related to the structure of an ecosystem. How? There are three ways that productivity and ecosystem structure are related: Energy, biomass and population size.

Ecologists have calculated how much energy is stored in each level of an ecosystem, they call these levels *trophic* levels. Organisms in each trophic level must do their life processes (MRS. GREN) in order to stay alive so the amount of energy produced by autotrophs (GPP) or eaten by heterotrophs (GSP) is not the same as the amount available to the next level (NPP of NSP). As a result each trophic level has less energy available than the one before it. How much less? It turns out that only 10% of the available energy goes from one trophic level to the next. This means that you can structure the ecosystem like a pyramid with the most energy at the bottom and the least energy at the top. You can not have an infinite number of levels because there is not an infinite amount of energy available (which makes sense, because 90% of your energy is not available to your next level). *On average* you usually find a terrestrial ecosystem has only four trophic levels, an aquatic ecosystem, *on average*, will have five trophic levels.

Glucose can be used for energy (the cell converts it to ATP) or for biomass (glucose is combined with other nutrients to make lipids, amino acids—proteins, and carbohydrates, then they combine to make new cells). The paragraph above discusses how the available energy is measured and that information is used to illustrate the structure of an ecosystem. Biomass can also be used to illustrate the structure of an ecosystem. Each trophic level has a different amount of biomass (biomass is the mass of all the living things at that level). Just like with energy, the amount of biomass decreases as we go to the next trophic level. So this too makes a pyramid with the most biomass at the bottom and the least at the top. We can use the information from biomass to corroborate what we find from the information about energy. In other words, if you know the biomass of a trophic level you can infer the energy level in that trophic level.

The final area to explore concerning structure is the population size of different organisms. The first challenge in this task is to know what trophic level they exist in, for that we use a food chain. All food chains begin with an autotroph (okay caves and parts of the deep ocean don’t, but even they do in a round-a-bout way). Then we have a primary consumer which is a heterotroph that eats autotrophs. Next, we have a secondary consumer which is a heterotroph that eats primary consumers. The final level is usually a tertiary consumer which is a heterotroph that eats secondary consumers (sometimes there are 4th and 5th level consumers, but they are rare). The second task is to estimate the number of each population. When ecologists have done this they have noticed that typically the population size of all the populations in a trophic level are smaller than the level before it and larger than the population size in the trophic level after it. I say typically, because sometimes you get situations where the numbers don’t form a neat pyramid. For example if you are looking at just one tree, the population of the autotrophs is one, then the aphids that feed on the leaves might be 10,000 that makes a weird looking pyramid.

Clearly you can see that these ways of structuring an ecosystem are related to each other and to productivity. It makes sense that the more energy available (higher productivity) the more biomass and the more biomass the greater the population. However, as with most things there is lots of variation and the patterns I have described hold true *most* of the time, but there are often exceptions. So in general, we describe the structure of an ecosystem as a pyramid with more organisms, biomass, energy, and productivity at the bottom and less of each as we go up.

**Task one:** Answer the following questions; if you don’t know the answer make your best guess, but don’t look up the answer.

* Why does a chemical kill an organism at a higher trophic level, why doesn’t it have a detrimental affect on organisms at lower trophic levels?
* Animals like the Ospreys are at the top of a food chain, yet they have the lowest population of any organisms in their food chain. Why?
* Animals such as tigers and polar bears are top predators in their respective ecosystems. They are large and ferocious, yet are considered to be the most vulnerable to extinction. Why?
* Why are food chains limited in length? Typically terrestrial food chains have four links and aquatic food chains have five links, why do aquatic ecosystems have more trophic levels?

**Task two:** Watch the video over food chains, food webs, and trophic levels.

**Task three:** Build a food web. A food chain is a graphical way to illustrate the energy flow in an ecosystem. It shows the feeding relationship between species in an ecosystem. Arrows connect the species and the arrow points the direction the energy travels. If a bass eats a minnow then the arrow points toward the bass. You might have already realized that the arrow not only points in the direction of energy flow, but also in the direction of biomass flow (the biomass of the minnow is taken by the bass). The problem with food chains is ecosystems are almost never as simple as one food chain. You can make a separate food chain for each relationship, but that can be confusing and hard to see how the food chains relate to each other. In reality there is a complex network of interrelated food chains which create a food web. A food web shows all of the food chains connected to each other. For example on the African savannah acacia tree leaves feed giraffes, but they also feed impalas so we would have two arrows starting at the acacia tree, one going to the giraffe and one going to the impala. Impalas are eaten by leopards, lions, cheetahs and hunting dogs so there would be an arrow from the impala to each of these predators and so on. The result is a more complex and accurate picture of the energy and biomass flow in an ecosystem.

With a partner, use the information in the chart below to create a large food web based on the Ozarks temperate forest ecosystem.

|  |  |  |
| --- | --- | --- |
| Species | What it eats | What it makes |
| Aromatic Aster | n/a | Nectar for insects |
| Mud turtle | Worms, frogs, aquatic insects, slugs, snails, leeches and crayfish |  |
| Milk Snake | Rodents, lizards and insects. |  |
| Bleak (fish) | Insects, larvae, shellfish and dead plants. |  |
| Bladderwort (carnivorous plant—but still does photosynthesis) | Worms, aquatic fleas insect larvae. |  |
| Raccoon | Baby mice, birds, snakes, berries, nuts and seeds |  |
| Ozark Hellbender | Crayfish and small fish. |  |
| Northern Pike (fish) | Bass, trout and other fish |  |
| Earthworm | Dead grass and leaves, bacteria, fungi and algae. |  |
| Bluegill (fish) | Water fleas, honey bees, earthworms and insects. |  |
| Praying mantis | Insects, spiders, small tree frogs, lizards and mice. |  |
| Cottontail rabbit | Clover, crabgrass and tree bark. |  |
| Leopard frog | Insects, worms and spiders. |  |
| Barn owl | Mice, voles, moles and rats. |  |
| Leeches | Insects, snails, worms and blood. |  |
| Red tail hawk | Rodents, small birds and snakes. |  |
| Blue Heron (large bird) | Fish, salamanders, snakes, mice, insects and aquatic plants. |  |
| Grey bat | Mosquitoes, moths, mayflies, and beetles. |  |
| Honey bee | Nectar from flowers, bee larvae eat pollen from flowers. | honey |
| Skunk | Insects, acorns, fruit, mice and bird eggs. |  |
| Grass Carp (fish) | Bladderwort and other aquatic plants. |  |
| Tree frog | Insects, worms, small fish and spiders. |  |
| American dog tick | Blood of mammals |  |
| Mosquito | Nectar from flowers, females also eat blood. |  |
| Red oak tree |  | Acorns |
| American bittersweet (shrub) |  | Berries |
| Wild turkey | Acorns, nuts, seeds, insects, snakes and frogs. |  |
| White tailed deer | Twigs, buds, leaves of shrubs and trees, acorns and fruits. |  |
| Coyote | Deer, small mammals, snakes, eggs, lizards, frogs and berries. |  |
| Bluestem Indian grass |  | Seeds |
| Meadow vole | Grasses, sedges, and forbs, including many agricultural plant species. Also some snails and insects. |  |
|  |  |  |

How to make the food web:

1. Draw 30 squares in a circle on a large piece of paper. The squares should look like this:

Species

Autotroph or heterotroph

Producer, primary, secondary, tertiary consumer.

Omnivore, carnivore or herbivore,

1. Fill in each square with information from the chart (As much as you can at this point).
2. Connect each square to the other squares if energy and biomass are exchanged between them.
3. Draw an arrow to show which way the energy and biomass are transferred.
4. By following the arrows you should be able to ascertain if the consumer is primary, secondary or tertiary, fill in that part of the box.

You can tell what level the organism is at by taking that strand out of the web and making it a food chain. Then just see where the organism is on the chain:

Producer

Tertiary Consumer

Secondary Consumer

Primary Consumer

**Task four:** Turn the food web into a pyramid of productivity. A pyramid of productivity shows the flow of energy through each trophic level of an ecosystem. A trophic level is the position an organism or a group of organisms in a community occupies in a food chain. Organisms are grouped into trophic (or feeding) levels. Trophic levels usually start with a primary producer and end with a carnivore at the top of the chain—a top carnivore.

Pyramid of productivity shows where the energy is generated and how much is available at each level, so by looking at the whole pyramid you can see the flow of energy from one trophic level to the next. The energy stored in each trophic level is measured in units of energy in a given area in a defined period of time. The most common unit of measure is joules per meter squared per year.

How to make a pyramid of productivity:

1. Look at your food web, make a list of producers, another list of primary consumers, a third list of secondary consumers, and a fourth list of tertiary consumers (if you have quaternary consumers make another list of them).
2. Here is where it gets tricky—you really have two types of productivity pyramids: the first is just organizing the organisms into trophic levels, so level one would have all the producers and it would be the largest. Level two would be primary consumers and it would be smaller than level one, but larger than level three. This trend would continue through all the levels. The second type of productivity pyramid will have actual numbers associated with it. To make this kind you would need to know the GPP and GSP of each trophic level. This is hard to find. If you did have those numbers you would build a pyramid with the same number of levels as there are trophic levels in your ecosystem and you would put the numbers in each level. Unless I give you those numbers, assume I want you to do it the first way. So make a box that you can write in all of the species names that are autotrophs. Next make a *proportionally* smaller box on top of the first and write all of the organisms that are primary consumers. Continue this process for all trophic levels.
3. Now add arrows that shows the efficiency of the system; what I mean is have two arrows, one that shows how much energy is lost to the atmosphere as heat (entropy) and how much is transferred to the next trophic level. If I don’t give you specific numbers to use assume the 10% rule: only 10% of the GPP or GSP goes to the next trophic level, 90% is eventually lost as heat to the universe. If I do give you numbers, then calculate the efficiency of each trophic level and put the appropriate numbers into the arrows.
4. Title your pyramid of productivity based on the ecosystem you are studying.

For this task I want you to make both types of productivity pyramids. Here is data for the numeric version:

|  |  |  |
| --- | --- | --- |
| Trophic Level | GPP or GSP (J/m2/year) | NPP or NSP (J/m2/year) |
| Producers | 20810 | 8833 |
| Primary consumers | 3368 | 1478 |
| Secondary consumers | 383 | 67 |
| Tertiary consumers | 21 | 6 |

Environmental Systems and Societies

*Estimating Animal Population Size*

**Learning Goal:** You will be able to utilize the Lincoln-Peterson method for estimating the population size of animals in the Ozarks ecosystem.

**Success Criteria:** You will formulate a data table of the animals in the different trophic levels of an ecosystem. One side of the data table will have a list of species, the other side will have the population estimate. Using these numbers you will complete your pyramid of numbers for the Ozarks ecosystem.

**Background:** A capture, mark, release and re-capture technique called the Lincoln Index is used to estimate the population size of animals which move about or do not appear during the day. The actual method of capture will depend on the size of the animals.

In an area, a sample of the population is captured and marked in some way that is non-harmful and does not expose them to higher predation levels than non-marked individuals. For example, dog whelks on a rocky shore or woodlice in a woodland can be marked with a spot of non-toxic paint. They are then released and allowed to remix with the population. Once they are mixed, a second sample is taken in the same way as the first and the proportion of marked and unmarked individuals is recorded. At least 10% of the marked sample should be recaptured if this estimate is going to be fairly accurate.

There are assumptions that are made when using this technique. If any of the following assumptions are shown to be untrue, the estimate is likely to be incorrect:

* The marked individuals have had time to remix into the population completely.
* The marks on the individuals do not come off.
* The marks on the individuals do not harm the individual or make it more likely they will become prey because the mark gives their location away.
* It is equally easy to catch every individual.
* There are no immigration (leaving), emigration (entering) of the members of the population. Also that there are no births or deaths in the population between sampling times.

If all of the above conditions are met then to estimate the population size of an animal you plug in your counts into this equation:

n1 X n2

N = ---------------------

m2

n1 = number of animals first marked and released.

n2 = number of total animals captured in second sample

m2= number of marked animals in the second sample

N = total population of species

Example:

100 water snails were captured from a pond and marked with a small spot of paint on the undersides of their shells; they were then returned to the pond. One week later, a second sample of 100 was captured, of which 25 had paint spots on their shells. What is the estimated number of snails in the pond?

n1 was 100, n2 was also 100, m2 was 25 so 100 x 100 = 10,000 divided by m2 or 25 gives you a total snail population of 400.

**So what do you do?** It is a labor intensive process to estimate the population of animals in an ecosystem so be patient and follow the steps.

1. Make a data table. You will need 6 columns and 25 rows: 1) species name (there are about 25 species) 2) n1 (number of animals caught and marked the first time) 3) n2 (total number of animals captured in the second sample) 4) m2 (number of animals marked in the second sample) 5) N (population estimate for that species) 6) Adjusted population estimate for that species.
2. Get a Ziplog bag with the three trophic level baggies inside from your teacher.
3. Take the baggie marked “primary consumers” out.
4. Reach in the bag and grab a fist full of objects. Spread out on table.
5. Using the guide below identify each object and list its name in the species column of your table.
6. Count how many of each species you have in your sample (not the whole baggie—just your fist full) and write the number down in column two for each species.
7. Mark each species (object) with a marker or colored pencil—make sure it won’t come off.
8. Put it back in the baggie and mix it up for one minute.
9. Take out another fist full and spread it out.
10. Count how many of each species you have this time and enter it in column three of your data table.
11. Examine the objects closely look for your mark you made earlier, separate the species into two piles 1) no mark and 2) with a mark. Count the number of each species with a mark and enter it into column 4 of your data table.
12. Use the numbers from columns 2-3-4 to calculate your population estimate, enter it in column 5.
13. Multiply the number from column 5 by 100, this is your final estimated population size for that species that we will use in your pyramid of numbers.
14. Put all of the objects back in your baggie and put back into the Ziploc bag.
15. Stretch.
16. Repeat steps 4-12 with the baggie marked secondary consumers.
17. For the final column of the secondary consumers multiply the numbers in column 5 by 10.
18. Put objects back in baggie and put back into the Ziploc bag.
19. Stretch
20. Repeat steps 4-12 with the baggie marked tertiary consumers.
21. For the final column of the tertiary consumers, multiply the numbers in column 5 by 5.
22. Put objects back in baggie and put back into the Ziploc bag.
23. Return Ziploc bag to your teacher.
24. Add the population estimates from column 6 for each trophic level together. Add that level to your pyramid of numbers.
25. Rest.

Primary Consumers

|  |  |
| --- | --- |
| Species | Object that represents it. |
| Earth worm | Spaghetti pieces |
| Cottontail rabbit | Fluff balls |
| Honey Bee | White rice |
| Grass Carp | White plastic balls |
| Mosquito (male) | Green Lentils |
| White tailed deer | Foam pellets |

Secondary Consumers

|  |  |
| --- | --- |
| Species | Object that represents it. |
| Mud turtle | Beads |
| Bleak | Marbles |
| Ozark’s Hellbender | Cork |
| Northern Pike | Paper towel squares |
| Bluegill | Brass thingys |
| Praying Mantis | Rocks |
| Leopard frog | Pumpkin seeds |
| Grey bat | Red beans |
| Skunk | Rotini pasta |
| Tree frog | Shinny metal shapes |
| American dog tick | White bean |
| Mosquito (female) | Brown rice |
| Wild turkey | Popcorn |

Tertiary Consumers

|  |  |
| --- | --- |
| Species | Object that represents it. |
| Milk snake | Blue square |
| Raccoon | Red square |
| Barn owl | Green square |
| Red tail hawk | Pink square |
| Blue heron | Yellow square |
| Coyote | Black square |