Invasion of the exotic worm!

(Building a forest ecosystem & making it work)

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- **Grade Level:**
Upper Elementary, Middle School (adaptable for older students)

- **Duration:**
Preparation time: 50 minutes
Activity time: one or two 50 minute periods

- **Setting:**
A large room of playing field

- **Materials:**
  - *5 large sheets of paper*
  - *copies of the "Forest Ecosystem Tables" and "Game Tiles"*
  - *markers, scissors & tape*
  - *9 boxes, about 4-6 inches on each side.* (Boxes are used to make dice for the game. Gift boxes for coffee mugs are a good size or ask at your local mailing outlet.) There will be 1 die (box) at each station. The labels for the sides of each die are listed in the "Forest Ecosystem Table". These labels represent the options for pathways that nutrients and energy can following in the ecosystem.
  - *a bell, whistle or some kind of sound maker* (optional)

Summary

With a roll of the die, students simulate the movement of nutrients in a forest ecosystem both before and after earthworms invade to see how & why change can occur in ecosystems as a result of exotic species invasion.

Objectives

Students will:

- Understand the basic components of a forest ecosystem
- Describe the movements of nutrients in that ecosystem
- Identify changes that can occur with earthworm invasion

Background

The movement of nutrients from one part of an ecosystem to another is critically important in determining what an ecosystem looks like. There are lots of processes that make this flow of nutrients possible and by role-playing a nutrient moving through the ecosystem, students begin to conceptualize how these complex systems work.

Scientists use "ecosystem models" to help them understand how an ecosystem works. Every ecosystem is composed of component parts. When building a model ecosystem it is best to start simply with general compartments like "trees, soil, animals, etc". After you learn what you can from your simple model you might discover a question that needs an even more realistic model. Then you might choose to create a slightly more detailed model. For example, our model is ideal for looking at general nutrient flow patterns for this ecosystem. But it can't tell us anything about the kinds of trees we would expect to find there. So, then we might divide the "tree" component up into "sugar maple", "paper birch" and "basswood" components. If the rates of nutrient flow are different for the different tree species then we will see the result when we play with our slightly more complex model. If you build a model in small steps, making it only as complex as you need to answer the question at hand then you won't get lost in a lot of confusing details.

In this game, the students will create a simple forest ecosystem model. Since there are no native earthworms in Minnesota our model doesn't have any either. Once students play with this system and understand how nutrients flow in it, then we add earthworms. Students can see how the changes caused by earthworms (or any exotic species) can change the rules of the ecosystem game and therefore, the ecosystem itself.

Important Concepts

Nutrients are the molecules that are needed to make plant & animal cells that together make the parts of plants and animals like leaves, muscle, etc. The some nutrients are less abundant than others or are needed in large quantities. Most plants need a lot of nitrogen and phosphorus to grow. If plants don't get enough of one of these ***limiting nutrients*** they may not grow as fast as they would if they had plenty of that nutrient. That's why farmers fertilize corn fields.

Earthworms change ***nutrient cycling*** in the forest by increasing the rate at which litter disappears.
Now, there are lots of nutrients in the forest floor but it is often in the form of leaves and twigs which plant roots can't absorb. In order for those nutrients to get to plant roots the nutrients that make up those dry leaves have to be converted into a form that plant roots can absorb (ammonium, nitrite or nitrate are the three most common forms that plants can use). In a worm-free forest, bacteria & fungi do the converting. It is a slow process, and the plant roots quickly absorb what is released as ***decomposition*** occurs. When earthworms invade they don't "create" more nutrients, but they increase the rate of decomposition so that the nutrients that were tied up in the dry leaves and twigs get converted to ***available forms*** really quickly. They do this in two ways. First, earthworms break up the litter into tiny pieces. Second, the earthworm mixes the leaf material with lots of bacteria as it passes through its gut. Then the bacteria do their job of conversion but they can do it a lot faster with the help of the worm. Imagine eating a tootsie roll sucker and your favorite part is the chewy center. To get to the chewy center, you would have to eat through the hard candy exterior. Bacteria prefer the "center" of the leaf litter (sugars and carbohydrates) but first have to get through the fiber (lignin and cellulose). If you imagine licking your way to the center of a tootsie roll, it would be much slower than biting through the hard candy exterior. Likewise, it takes time for bacteria to get through the fiber all by themselves. But, when earthworms are part of the system. Earthworms act as the teeth and expose the sugars and carbohydrates to the bacteria, allowing for a relatively quick breakdown of the litter compared to bacteria consuming the litter alone. The end result is leaf litter will be consumed at a rate faster than it is produced.

Producing lots of nutrients quickly sounds like a good thing, right? Well, if there is more nutrient available than the plants can take up, they can be washed away or ***leached*** when it rains. That's because ***ammonium, nitrate & nitrite*** can get absorbed by water molecules as well as plant roots. Two things increase the likelihood of ***nutrient leaching***. First, there are not enough plants or root systems to absorb the amount of nutrients available. Second, with all of those earthworm burrows, water can wash the dissolved nutrients down through the soil, below the plant roots or out into rivers and streams. Nutrients that would have been cycled within the hardwood forest ecosystem can either be lost underground or transferred out to another ecosystem. Leaching could also occur in worm-free forests because the same leachable forms of nutrients are being produced. But leaching rarely occurs because of the slow release by bacteria & fungi and the dense fine roots in the forest floor take them as fast as they are produced.

A ***native species*** is basically a species that naturally grew or existed in a particular location before humans began influencing the landscape in that spot. So, an ***exotic species*** is basically a species that did not grow or exist in a particular location before humans brought it there (either intentionally or unintentionally). Not all exotic species are bad. In fact, less than 10% of all exotic species have any impacts and even fewer have really big negative affects.

Important Concepts (continued)

Scientists are still trying to figure out exactly why some species have big affects and some don't. But, many of the ones that do have big impacts are species that affect ecosystem processes like nutrient cycling.

So, why can't the native hardwood forest plants just grow in worm worked soil? After all, there are lots of nutrients! Well, scientist are still working on figuring out the answers to that question but here are some theories…

- Many of the plants that grow in sugar maple forests are very finicky plants. They don't have seeds like the ones that you buy in the hardware store and plant in your gardens. These seeds have very complex ***germination*** and ***seed dormancy*** requirements. Many of them take 2-3 years, and several freeze thaw cycles to break seed dormancy and fully germinate. During that time, they must be protected from predation, drying out and freezing, which the forest floor does very well. When the worms remove the forest floor it changes the seeds environment in big ways.
- In worm-free forests, most of these plants root almost exclusively in the forest floor, since that's where most of the nutrients are. When worms invade they eat the forest floor out from under the plants which is a major ***disturbance*** resulting in lots of plant mortality.
- The changes that result from earthworm invasion may also affect other parts of the forest ecosystem in ways we haven't yet been able to document yet. Asking questions and then trying to find out the answers is what scientists do and most of the time we don't know the answer ahead of time. We make educated guesses (***hypotheses***) and then go out and design studies to help us answer those questions.

For more background information see the Great Lakes Worm Watch website at…

http://www.greatlakeswormwatch.org

Procedure

Warm-up

Ask students to brainstorm and identify the different parts of a forested ecosystem and how nutrients and energy move through that system. Write their responses on the board.

Activity

1. **Tell students they are going to become a nutrient molecule moving through the forest ecosystem. They will start in a *worm-free* ecosystem and then change to a *worm-invaded* one to see how things change.**
2. **Categorize the places a nutrient can move through into 5 stations: Trees, Understory Plants, Animals, Forest Floor and Soil. Write these names on a large piece of paper put them around the room or field (students may illustrate station labels).**
3. **Assign an even number of students to each station. Have the students identify the different places their nutrient molecule can go from that station in the forest ecosystem. Discuss the conditions that cause or allow the nutrient to move.** The fact that the Soil and Forest Floor are separate stations is confusing at first. Explain that when thinking about nutrient flow in a *worm-free* forest ecosystem that MOST of the nutrient is tied up in the *organic material* (leaves, twigs, wood, animals, etc.) very little is actually in the soil (which is mostly composed of weathered minerals). Explain that where they can move depends on the *form* of the nutrient. A nutrient can't go

Procedure (continued)

directly from a animal to a tree because the roots can't absorb animal tissue. The animal has to go to the forest floor and be broken down by bacteria and THEN can go to the trees. Sometimes the molecule won't go anywhere. After students have come up with lists, have each group share their work.

4. **Give the students the appropriate die for each ***worm-free*** station.** The students can check to see if they covered all the places the nutrient can go. The *Forest Ecosystem Table* gives an explanation of movements for each station.
5. **Students should discuss the form in which molecules move from one location to another.** For the plants, everything must come from the forest floor because it needs to be in an absorbable form. But animals can take from plants directly by eating them. Most of the movement will flow through the Forest Floor compartment because that's where nutrient transformations occurs.
6. **Tell students they will be demonstrating nutrients movement from one location to another. In this game, a roll of the die determines where the nutrient molecule will go.** Students line up behind the die at their station. Students roll the die and go to the location indicated by the label facing up. If they roll **STAY**, they move to the back of the line. When students arrive at the next station, they get in line. When they reach the front of the line, they roll the die and move to the next station (or STAY).
7. **Students should keep track of their movements.** This can be done by having them keep a journal or a notepad to record each move they make, including STAYS. Another approach has half of the class playing the game and the other half watches. Onlookers can be assigned to track movements of their classmates. In the next round the onlookers play the game and the other half of the class can record their movements.
8. **Tell the students the game will begin and end at the sound of the bell (or buzzer or whistle). Begin the ***worm-free*** part of the game!**
9. **Let the students play the game for 15-20 minutes, or until you start to see patterns develop where students (nutrients) are beginning to cluster. Blow the whistle to stop the ***worm-free*** round.** Ask the student to discuss when nutrients flow and what patterns they are seeing as they move through the game. Where do they (as nutrients) spend a lot of their time?

SWITCHING TO *WORM-INVADED:*

10. **Tell the students that now earthworms are going to invade this ecosystem and they will play the game just as they did in the ***worm-free*** round.**
11. **Ask students to brainstorm on how this might change how nutrients move through the ecosystem.** Explain that earthworms eat the Forest Floor and mix it into the Soil compartment in the form of *cast material* (worm poop).
12. **Replace the ***worm-free*** station dice with the ***worm-invaded*** station dice (only the "tree" dice remains the same).** Have students see if they predicted all of the changes. If a student rolls *leach* at the soil station they leave the game and stand on the side until it is completed.
13. **Play the ***worm-invaded*** round of the game!** Have students continue to record their movements. Have them discuss how the patterns of nutrient flow changed as a result of worm invasion and how that might change what lives & grows in the ecosystem. What might be the long term implications of the introduction of leaching into a system that previously had no leaching?

Wrap-Up

Have students use their travel record to write stories about the places the nutrient molecule has been. They should include a description of what conditions were necessary for the nutrient to move from one station to the next. Discuss the cycling that took place during the game (that is, if any student returned to the same station).

Game Alternatives:

To even more clearly bring home how nutrients will accumulate in different parts of the ecosystem you may want to have the kids move tootsie rolls (representing nutrient packets) from each station as they move. Start with 10 or 20 Hershey kisses (of different colors for each station for an even more visual impression of how things flow between stations) at each station. As each student moves to another station they take one Hershey kiss (nutrient packet) with them and deposit it there. As the game progresses you will quickly see an accumulation on the forest floor when worm free and then a shift to soil when worm worked.

You could spread the playing of the game out over many days or even weeks using the tootsie rolls as nutrient packets, with the stations spread out around the room. Every day, and for each class period, the students make one move. Over many days or weeks the students can monitor the accumulations and changes in where nutrients are in the ecosystem. This strategy could include students from multiple class periods and provides a more realistic time step for nutrient movements. The Hershey kisses give students the opportunity to track the changes that happen in their absence (not unlike how scientists measure such things in the field – though we don't use Hershey kisses).

Extensions

Have student compare the movement of nutrients in other types of ecosystems like prairies, suburban woodlots and urban areas. They can adapt the game by creating new faces for the die for the new ecosystem types and the different conditions that exist in each. Students can also investigate how human influences can move through the ecosystem. For example, if you were to fertilize the ecosystem how would those additional nutrients move? Will there be enough plant material to take it up or will it run off or leach away?

In this game we treated all worms as the same, but in reality different worms have different habits and ecological niches (see the website for details). Students can discuss how the affects of worms might be different with different species or ecological groups. For example, the litter dwelling species may directly affect the plants because they eat the forest floor where the plants are rooted. The soil dwelling species may not have direct affects on the plants, because they don't eat the forest floor, but they might increase leaching more because they create deep burrows.

Resources

Minnesota's Natural Heritage – an ecological perspective : John R. Tester. 1995. University of Minnesota Press, Minneapolis, MN

(see the website for more)

Forest Ecosystem Table 1: Worm-Free Conditions

STATION	DIE SIDE LABELS	EXPLANATION
Trees	4 sides *trees (stay)*	If a nutrient gets put into the trunk or limbs of a tree, it can stay there for a very long time
	2 sides *forest floor*	If a nutrient gets put into a leaf it returns to the forest floor at the end of the year and there are LOTS of leaves. So, a lot of nutrients move from the trees to the forest floor every year.
Understory	2 sides *understory (stay)*	If a nutrient gets put into the roots or stems of a perennial plant it can stay there for many years.
	2 sides *forest floor*	If a nutrient gets put into the leaf of a plant, then it goes to the forest floor at the end of the year.
	2 sides *animal*	A plant, or part of a plant, might be eaten by an animal.
Animals	3 sides a*nimals (stay)*	If a nutrient gets put into an animal it can stay in that animal as muscle or bone for a long time OR it can get moved to another animal if a small animal gets eaten by a bigger one. Either way the nutrient stays in the animal box.
	3 sides *forest floor*	When an animal defecates or dies it transfers those nutrients to the forest floor.
Forest Floor	2 sides *forest floor (stay)*	If a nutrient finds it's way to the forest floor as a leaf or dead animal, it will stay there for some period of time until it changes into a form that plant roots can take up. In a worm-free forest the leaves, twigs and other stuff that make up the forest floor are broken down by fungi and bacteria which is a very slow process, so things accumulate and nutrients are released slowly.
	2 sides *understory*	Understory plants root almost exclusively in the forest, so they take up available nutrients that are there.
	1 side *trees*	The fine roots of trees also take up nutrients from the forest floor.
	1 side *soil*	A small amount of nutrient leaches into the soil beneath.
Soil	2 sides *soil (stay)*	Some nutrients get bound up with soil particles and stay there.
	1 side *tree*	A few tree roots that are capable of taking up nutrients grow here (most of the roots in soil are for anchoring & taking up water).
	3 sides *forest floor*	Fungi & bacteria take up nutrients & move them back to the forest floor to help break down the fresh litter that accumulates there.

Forest Ecosystem Table 2: Worm-invaded Conditions

STATION	DIE SIDE LABELS	EXPLANATION
Trees	same as Table 1	Trees are the one part of the forest that does not show obvious changes following earthworm invasion. However, the long term impacts are yet to be fully appreciated.
Understory	same as Table 1	The number of plant species and abundance has changed, so the image does too
Animals	same as Table 1	The small mammal population changes from small shrews and red-backed voles to mouse and vole species. The implications of this change are not yet known.
Forest Floor	1 side *forest floor (stay)* 5 sides *soil*	Earthworms eat the litter so very little nutrient stays in this part. When earthworms eat the litter they produce lots of "cast material" (worm poop) which becomes part of the soil. The processing that happens in the earthworm gut breaks down the litter in the same way that bacteria & fungi did in the worm-free forest floor but they do it a LOT faster so the litter doesn't accumulate and the nutrients are rapidly converted to forms that can be taken up by plant roots. *(there is no *animal* link here because the actual amount of nutrient that is in the bodies of the worms is so tiny compared to the amount they convert to soil that it isn't important. This is an example of how what the worms DO is more important than what they are made of, at least when we are talking about nutrients).
Soil	1 sides *soil (stay)* 2 side *tree* 1 side *understory* 2 side *leach (leave)*	Some nutrients get bound up with soil particles and stay there. The fine roots of trees take up nutrients from the soil. Now that there is no forest floor, the few plants that can get established root in the soil. When worms eat litter, they convert all of the litter to available forms of nutrients very quickly, the plants can't take it up as fast as it is being produced so when it rains the water washes those nutrients down deeply into the soil below the plant roots or may wash them out into the adjacent wetlands, creeks & rivers. This process is called "leaching" and it removes the nutrient from this ecosystem.