Investigation I: Is Fish Safe To Eat, Or Is It A Toxic Risk?

Well...what do you think? Is fish safe to eat, or is it a toxic risk? Have you ever considered that when eating that tuna fish sandwich for lunch or enjoying a dinner of locally caught trout? Can what you eat make you sick? How can this happen? This unit will hopefully help you to answer some of these questions by the end.

In Part 1 of this Investigation, you will be asked to think about how fish can be considered "toxic" and what can possibly lead them to be described as so. You'll brainstorm individually and share with your classmates information that you may already know about this topic, as well as some questions you hope to have answered by the end of the unit.

In Part 2 of this Investigation, we'll look at a recent environmental catastrophe that will help us better set the stage for some of the upcoming investigations. The Gulf of Mexico oil spill that has finally come to an end will unfortunately impact the marine ecosystems of the region for many years to come. You will be asked to read a news article describing how scientists predict the oil spill will affect aquatic organisms within the Gulf.
Part 1: K-W-L

In this section you will fill out the following K-W-L chart with your classmates about the driving question to this Investigation. First, think about what you already know about fish being described as “toxic”. What would cause us to be able to describe them as such? How could they become “toxic”? Put your answers to these questions in the first column. Then, come up with some questions about the overall theme to the unit that you’d like to have answered and put them in the second column. We will leave the “L” portion of the chart blank until the end of the Investigation to see what questions you were able to actually answer and what new information you learned.

<table>
<thead>
<tr>
<th>What do we already know?</th>
<th>What do we want to know more about?</th>
<th>What have we learned?</th>
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Investigation I: Toxic Fish – Student Guide, Part 1 – 2 pages
Investigation I: Is Fish Safe To Eat, Or Is It A Toxic Risk?

Part 2: Toxic Fish in the News

On April 20, 2010 the Deepwater Horizon oil rig owned by BP exploded and sank into the Gulf of Mexico. During the months that followed, an estimated 207 million gallons of crude oil were released into the water. Fortunately, the leaking well was capped on July 15\textsuperscript{th} and stopped releasing oil into the Gulf. However, the impacts of such a large amount of oil being spilled into such a biologically diverse body of water will last for a long time.

In this part of the Investigation, you will be asked to read the following Associated Press article from early on in the spill to understand how scientists predict the oil spill will impact the marine ecosystems that exist in the Gulf of Mexico.

**Question:**

Q1. Before reading through the article, how do you think the oil spill in the Gulf of Mexico will affect the organisms that call it home? Will humans end up feeling the effects of these changes? Explain.
Scientists say Gulf spill altering food web

By MATTHEW BROWN and RAMIT PLUSHNICK-MASTI, Associated Press Writers

This June 15, 2010 photo provided by the University of California Santa Barbara, shows pyrosomes- cucumber-shaped, gelatinous organisms fed on by endangered sea turtles, pulled up after a deep cast in the vicinity of the oil spill in the Gulf of Mexico. Scientists are seeing early signs that the massive Gulf spill is altering the food web, by killing or tainting creatures that form the foundation of marine life and spurring the growth of others more suited to a fouled environment. (AP Photo/David L. Valentine, Department of Earth Science, University of California Santa Barbara)

Wed Jul 14, 9:04 am ET

NEW ORLEANS – Scientists are reporting early signs that the Gulf of Mexico oil spill is altering the marine food web by killing or tainting some creatures and spurring the growth of others more suited to a fouled environment.

Near the spill site, researchers have documented a massive die-off of pyrosomes — cucumber-shaped, gelatinous organisms fed on by endangered sea turtles.

Along the coast, droplets of oil are being found inside the shells of young crabs that are a mainstay in the diet of fish, turtles and shorebirds.

And at the base of the food web, tiny organisms that consume oil and gas are proliferating.
If such impacts continue, the scientists warn of a grim reshuffling of sealife that could over time cascade through the ecosystem and imperil the region’s multibillion-dollar fishing industry.

Federal wildlife officials say the impacts are not irreversible, and no tainted seafood has yet been found. But Rep. Ed Markey, D-Mass., who chairs a House committee investigating the spill, warned Tuesday that the problem is just unfolding and toxic oil could be entering seafood stocks as predators eat contaminated marine life.

"You change the base of the food web, it's going to ripple through the entire food web," said marine scientist Rob Condon, who found oil-loving bacteria off the Alabama coastline, more than 90 miles from BP's collapsed Deepwater Horizon drill rig. "Ultimately it's going to impact fishing and introduce a lot of contaminants into the food web."

The food web is the fundamental fabric of life in the Gulf. Once referred to as the food chain, the updated term reflects the cyclical nature of a process in which even the largest predator becomes a food source as it dies and decomposes.

What has emerged from research done to date are snapshots of disruption across a swath of the northern Gulf of Mexico. It stretches from the 5,000-feet deep waters at the spill site to the continental shelf off Alabama and the shallow coastal marshes of Louisiana.

Much of the spill — estimated at up to 182 million gallons of oil and around 12 billion cubic feet of natural gas — was broken into small droplets by chemical dispersants at the site of the leaking well head. That reduced the direct impact to the shoreline and kept much of the oil and natural gas suspended in the water.

But immature crabs born offshore are suspected to be bringing that oil — tucked into their shells — into coastal estuaries from Pensacola, Fla., to Galveston, Texas. Oil being carried by small organisms for long distances means the spill's effects could be wider than previously suspected, said Tulane professor Caz Taylor.

Chemical oceanographer John Kessler from Texas A&M University and geochemist David Valentine from the University of California-Santa Barbara recently spent about two weeks sampling the waters in a six-mile radius around the BP-operated Deepwater Horizon rig. More than 3,000 feet below the surface, they found natural gas levels have reached about 100,000 times normal, Kessler said.
Already those concentrations are pushing down oxygen levels as the gas gets broken down by bacteria, Kessler and Valentine said. When oxygen levels drop low enough, the breakdown of oil and gas grinds to a halt and most life can't be sustained.

The researchers also found dead pyrosomes covering the Gulf's surface in and around the spill site. "There were thousands of these guys dead on the surface, just a mass eradication of them," Kessler said.

Scientists said they believe the pyrosomes — six inches to a foot in length — have been killed by the toxins in the oil because there have no other explanation, though they plan further testing.

The researchers say the dead creatures probably are floating to the surface rather than sinking because they have absorbed gas bubbles as they filtered water for food.

The death of pyrosomes could set off a ripple effect. One species that could be directly affected by what is happening to the pyrosomes would be sea turtles, said Laurence Madin, a research director at the Woods Hole Oceanographic Institution in Cape Cod, Mass. Some larger fish, such as tuna, may also feed on pyrosomes.

"If the pyrosomes are dying because they've got hydrocarbons in their tissues and then they're getting eaten by turtles, it's going to get into the turtles," said Madin. It was uncertain whether that would kill or sicken the turtles.

The BP spill also is altering the food web by providing vast food for bacteria that consume oil and gas, allowing them to flourish.

At the same time, the surface slick is blocking sunlight needed to sustain plant-like phytoplankton, which under normal circumstances would be at the base of the food web.

Phytoplankton are food for small bait fish such as menhaden, and a decline in those fish could reduce tuna, red snapper and other populations important to the Gulf's fishing industries, said Condon, a researcher with Alabama's Dauphin Island Sea Lab.

Seafood safety tests on hundreds of fish, shrimp and other marine life that could make it into the food supply so far have turned up negative for dangerous oil contamination.

Assuming the BP gusher is stopped and the cleanup successful, government and fishing industry scientists said the Gulf still could rebound to a healthy condition.

Ron Luken, chief scientist for Omega Protein, a Houston-based company that harvests menhaden to extract fish oil, says most adult fish could avoid the spill by swimming to
areas untainted by crude. Young fish and other small creatures already in those clean waters could later repopulate the impacted areas.

"I don't think anybody has documented wholesale changes," said Steve Murawski, chief scientist for the National Marine Fisheries Service. "If that actually occurs, that has a potentially great ramification for life at the higher end of the food web."

Questions:

Q2. How will the already visible impacts of oil contamination to a few organisms, such as pyrosomes and young crabs, have larger side effects?

Q3. What is the prediction for the seafood industry following this spill? Has this prediction been backed up by any evidence yet?

Q4. How has the base of the food web in the Gulf of Mexico already been changed by the oil spill? Is this a good change for the food web or a bad one? Explain.

Q5. How is phytoplankton being impacted by the oil spill? Will this change in conditions necessary for phytoplankton survival have a large side effect? Explain.

Q6. Are the conditions of the aquatic ecosystem of the Gulf of Mexico expected to return to normal over time or not? How so?
### Investigation II: Aquatic Food Chains, Food Webs, and Modeling

**Food Chain Anticipation/Reaction Guide**

**Directions:** Before we begin, in the Anticipation column, mark the statements true (t) or false (f) based on what you think or know now. When we are done, fold over or cover your initial responses in the Anticipation column and mark the statements in the Reaction column incorporating the information you learned. If the answer in the Reaction column is false (f), correct the statement to make it true.

<table>
<thead>
<tr>
<th>Anticipation</th>
<th>Reaction</th>
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<tbody>
<tr>
<td>1. __________ 1. A simple feeding pattern showing the transfer of energy is a food chain.</td>
<td>1. __________</td>
</tr>
<tr>
<td>2. __________ 2. Consumers that eat only plants are called carnivores.</td>
<td>2. __________</td>
</tr>
<tr>
<td>3. __________ 3. Aquatic organisms live on land.</td>
<td>3. __________</td>
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<tr>
<td>4. __________ 4. Periphyton are at the base of a food chain.</td>
<td>4. __________</td>
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<tr>
<td>5. __________ 5. There is a relationship between the number of predators and the number of prey.</td>
<td>5. __________</td>
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<tr>
<td>6. __________ 6. In a food chain, arrows point toward the organism being eaten.</td>
<td>6. __________</td>
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<tr>
<td>7. __________ 7. Crayfish can be both predators and prey.</td>
<td>7. __________</td>
</tr>
<tr>
<td>8. __________ 8. Producers are the source of all the energy in a food chain.</td>
<td>8. __________</td>
</tr>
<tr>
<td>9. __________ 9. Many food chains in an ecosystem make up a food web.</td>
<td>9. __________</td>
</tr>
<tr>
<td>10. __________ 10. When a smallmouth bass eats a crayfish, most of the energy from the crayfish is transferred.</td>
<td>10. __________</td>
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</table>
Part 1: Introduction to Aquatic Food Chains and Food Webs

Have you ever heard the expression, “It’s a dog eat dog world?” Is it really? Do dogs go around eating other dogs?!? If they did, we’d probably have few dogs left. In reality, the way organisms eat is more like that old children’s poem, “There Was an Old Lady Who Swallowed a Fly.” In that tale, a woman accidentally swallowed a fly. She then swallowed a spider to eat the fly, then a bird to eat the spider, then a cat to eat the bird, etc., etc., etc.

Living things eat other living things in order to get energy and to survive, but not every organism can eat any other organism. Every living thing has specific feeding requirements. The set of feeding relationships between different populations or organisms in an ecosystem is called a **food chain**. How much do you know about food chains?

The Calumet Harbor Aquatic Food Chain

The basic food chain in Lake Michigan’s Calumet Harbor consists of 3 trophic (feeding) levels. This ecosystem is experiencing stress from two major types of disturbances: invasive species and industrial pollution. A team of scientists from Illinois, Wisconsin and Michigan is studying this ecosystem to try to figure out how it is responding to these stressors. As you work through the investigations in this unit you’ll learn about the surprising results of their research, but let’s begin by learning about the basic food chain.

At the base of every food chain are producers or autotrophs. These are organisms that usually get their energy from the sun through photosynthesis. Algae, which belong to the Protist Kingdom, are usually the primary producers in aquatic (freshwater) ecosystems. In terrestrial (land) ecosystems, plants serve as the primary producers. **Periphyton** is a combination of algae along with bacteria, protozoa, and the remains of dead organisms (detritus), and serves as the base of the food chain in this part of the lake.
This periphyton coats the bottom of the harbor and clings in various amounts to the rocks and sandy bottom. If you've ever walked into a lake or pond and your feet sink into the “muck,” you have had an experience with periphyton.

The rest of the trophic levels in food chains consist of consumers or heterotrophs. These are organisms that eat other organisms in order to get the energy they need to survive. The first level of consumers are often called the **primary consumers** and are either herbivores (can only digest plants/algae) or omnivores (can digest either plants/algae or other animals). One of the main primary consumers in Calumet Harbor is the Northern Freshwater Crayfish, *Orconectes propinquus*. This is a native species of crayfish commonly found in these waters.

![Orconectes propinquus - University of Michigan](image)

This invertebrate (organism without a backbone) lives at the bottom and feeds primarily on periphyton, but it may feed on other smaller organisms as well. Crayfish are well adapted to living in Calumet Harbor. They are usually found under rocks or other debris. They also are covered by a very tough exoskeleton (outer skeleton) and have enlarged front claws.

An organism that eats the primary consumer is called a **secondary consumer** and is either an omnivore or carnivore (can only digest animals). In this food chain, the main secondary consumer is the smallmouth Bass, *Micropterus dolomieu*.

![Micropterus dolomieu – WI Dept. of Natural Resources](image)
If you have ever seen one of these fish, you might think its mouth is not very small – especially if you have caught one and have to try to take the hook out of it without getting bit. It is called a smallmouth bass because the hinge of its lower jaw is below and just in front of its eye (a largemouth bass’ jaw extends behind its eye).

This vertebrate (animal with a backbone) lives in rivers, streams and lakes and prefers cool, clear water with rocky or gravel bottoms and protective cover, like logs or large rocks. They are predators (organisms that hunt other organisms), and the crayfish is their prey (organism that is hunted). In Calumet Harbor, these fish are at the top of the natural food chain.

Questions:
Q1. Describe some of the characteristics or adaptations of both the crayfish and smallmouth bass that help them survive in Calumet Harbor.

Q2. Check your understanding of the following vocabulary terms by writing your own definitions/explanations and giving an example of each: producer, primary consumer, omnivore, autotroph, trophic level, secondary consumer, prey, heterotroph, omnivore, predator, carnivore, periphyton.

Q3. Do any of the terms in Question 2 mean the same thing? If so, which ones?
When scientists draw food chains, they “connect” the organisms with arrows as seen below:

You might think that it does not matter which direction an arrow is drawn, but that is incorrect. Arrows always point toward the organism that is doing the eating. If you get confused about which direction to draw the arrow, think of the arrow as meaning, “gives energy to.” So, in the aquatic food chain above, the periphyton “gives energy to” the crayfish, and the crayfish “gives energy to” the smallmouth bass. And remember, the sun is what gives energy to the periphyton and therefore to the entire ecosystem.

When the crayfish eats, about 90% of the energy from the periphyton gets “used up” by the crayfish or released as heat. Only 10% of the energy gets converted into “new” crayfish cells. The same is true when the smallmouth bass eats the crayfish. This fact also affects the number of predators and prey in an ecosystem.

Questions:
Q4. How does the energy from the periphyton get “used up” by the crayfish?

Q5. If it takes 3500 extra calories (kilocalories) to gain one pound, and you ate several fast food hamburgers and bags of cookies that added up to 3500 calories, would you gain exactly 1 pound?

Q6. Would it be possible to have more smallmouth bass than crayfish? Why or why not? What might happen?
Food Chains to Food Webs

Most of you have probably realized that there are a lot more organisms that live in any lake, pond, stream, or river than just three types, and that these organisms eat more than one kind of food. They do this because their main food source may not always be available, so they have to eat other organisms to survive. Imagine if you only ate one kind of food, such as pizza. If there was no way to order or make a pizza, you would starve, so you would eat something else – maybe even broccoli!

The way that all of the feeding relationships in an ecosystem are shown is by connecting all the possible food chains into a food web. A food web for all of Lake Michigan would look like this:

![Lake Michigan Food Web](image)

As you can see, a food web is highly complicated and has many different connections between organisms.

**Question:**

Q7. Trace 2-3 different food chains through this food web. How many trophic levels do they have? Could a food chain have 10 trophic levels? Why or why not? (Hint: Think about what you learned about energy transfer between organisms).
To practice constructing interactive food webs in 3 different ecosystems, access the Interactive Food Webs tool using the following link:
http://www.harcourtschool.com/activity/food/food_menu.html

**Question:**
Q8. Food webs are found in all ecosystems, including in the area where you live. Draw, sketch, use cut-out pictures, etc. a food web from a nearby ecosystem. Make sure to use at least 7-8 different organisms and include arrows. Label the organisms with the following terms: **producer, primary consumer, autotroph, trophic level, secondary consumer, prey, heterotroph, omnivore, predator, carnivore.**

Now that you have finished this part of Investigation II, check your understanding by completing the “Reaction” column of the **Food Chain Anticipation/Reaction Guide** on page 1. Make sure to cover up your answers in the Anticipation column If one of the answers is “false,” correct the statement to make it true.
Investigation II: Aquatic Food Chains, Food Webs, and Modeling

Part 2: Modeling an Aquatic Food Chain using NetLogo

In this investigation you will be looking at a model of an Aquatic Food Chain to see how the populations of organisms affect each other.

1. Open the Food Chain NetLogo model. This can be done in one of two ways:
   a. Launch the NetLogo software on your computer. Click on File → Open and select the Aquatic Food Chain model from the list.
   b. Or, open your internet browser and type in the following address: http://ecocasting.northwestern.edu/NetLogo/Food%20Chain.html

2. Notice the black box on the right side of the screen. In order to display the organisms that make up the food web in this region, you will need to click the button in the upper left corner of the screen.

   *NOTE:* This button will be helpful as you move through the rest of the investigation as it will always reset your model back to zero when clicked.

When the data loads, your model should look like this:
This model shows the 3 different organisms in the food chain:

periphyton  crayfish  smallmouth bass

The model also shows the initial Setup conditions and a population graph of the ecosystem:

**Question:**

Q1. Record the Setup conditions:

periphyton-start-amount  _______

crayfish-start-amount  _______

smallmouth-bass-start-amount  _______

3. Click the **go/stop** button and let the model run for a time interval of at least 500 (the time intervals do not represent any real generation times).

4. Click the **go/stop** button again to stop the run.
Question:

Q2. Sketch or print out your population graph. (It may look something like this):

![Population Graph](image)

Describe the changes in the 3 populations beginning at time 0 and ending at time 500. Be specific about any relationship between the populations.

5. Click the setup button to re-start the run from the beginning. Run the model again for a time interval of 500.

Question:

Q3. Compare your new population graph to your first one. Are the two the same or different? Why or why not?
6. While the model is stopped, Right Click (or command+click on a Mac) on a crayfish and scroll down to the specific crayfish number you have selected.

7. Click on ‘watch a-crayfish’, and the crayfish you chose will be highlighted in the population:

8. Click go/stop and follow what happens to the crayfish.

Question:

Q4. What happened to the crayfish you were following? Give an explanation. If it disappeared, what do you think that means?
9. Now it is time to use the NetLogo Aquatic Food Chain model to investigate what happens when certain conditions are changed. This may be done in a variety of ways.

   a) You can change the initial Setup conditions by sliding the start-amount buttons one direction or another:

   b) Or, you can change the “rules” by clicking the Change button and by typing in a new “rule” into the text box that pops up. When you are done, click Apply and OK.

10. Choose a new set of starting conditions either by changing the start amounts, the rules, or both. Click on the Setup button.

Questions:

Q5. Record the new Setup conditions:

   periphyton-start-amount ______
   crayfish-start-amount ______
   smallmouth-bass-start-amount ______

Rules: ____________________________________________________
       ____________________________________________________
       ____________________________________________________
Q6. Predict what you think might happen to each of the populations? Why might this happen?

11. Click the **go/stop** button and let the model run for a time interval of at least 500.

12. Click the **go/stop** button again to stop the run.

**Questions:**

Q7. Sketch your population graph below. Or, you can take a screenshot of the plot, save it, and print it out. Describe the changes in the 3 populations beginning at time 0 and ending at time 500. Be specific about any relationship between the populations.

Q8. Describe any differences between the populations during this run and your original run. What may be the reasons for these differences? How did these compare to your predictions?
During any of the runs, you may have a situation where “Bass went extinct locally.” This does not mean that these organisms are truly extinct, but that in this particular area, there are none left.

You can either click the Yes button to add an organism,

or at any time, you can click the buttons to add organisms. Or, click No and see what happens to the ecosystem without adding another bass.

13. Continue changing a variety of conditions in the model to see how changes in initial population numbers or having more members of a species enter a population affect the ecosystem.

14. Answer the final questions on the following page.
Questions:

Q9. Use the NetLogo model to answer some of the following: Can you get the populations to “crash?” Under what conditions? How long can the model run before a species goes locally extinct? Are there any “rules” that are impossible? Does setting up the same initial conditions guarantee that the model will run the same way? Why or why not?

Q10. Using what you have learned about food chains, predators and prey, and food webs, predict what would happen to your populations if another organism was introduced into the ecosystem.
Name ____________________________ Date ___________ Class ________________

**Investigation III: Bioaccumulation**

**Part 1: What do I know about pollutants?**

<table>
<thead>
<tr>
<th>In the space below circle T for true or F for false</th>
<th>Question</th>
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<tbody>
<tr>
<td>T or F</td>
<td>1. What we eat/drink we eventually digest and then excrete.</td>
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<tr>
<td>T or F</td>
<td>2. Contaminants stay close to where they are spilled.</td>
</tr>
<tr>
<td>T or F</td>
<td>3. Rachel Carson started the environmental movement when she observed a particularly “Silent Spring”.</td>
</tr>
<tr>
<td>T or F</td>
<td>4. The most common exposure route for a toxin in humans is contaminated drinking water.</td>
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<tr>
<td>T or F</td>
<td>5. The “Dirty Dozen” was a movie in the early 1970’s starring Clint Eastwood.</td>
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<tr>
<td>T or F</td>
<td>6. We are exposed to chemicals in the womb before we are born.</td>
</tr>
<tr>
<td>T or F</td>
<td>7. If we do not wash our hands before we eat we are exposed to chemicals.</td>
</tr>
<tr>
<td>T or F</td>
<td>8. PCBs are a group of man-made chemicals.</td>
</tr>
<tr>
<td>T or F</td>
<td>9. PCBs are used in plastic water bottles and, when discarded, end up in the Great Lakes system.</td>
</tr>
<tr>
<td>T or F</td>
<td>10. Longer-lived animals have greater bioaccumulation.</td>
</tr>
<tr>
<td>T or F</td>
<td>11. PCBs can be absorbed through the skin into an organism</td>
</tr>
</tbody>
</table>
Investigation III: Bioaccumulation

Part 2: What is POP (don’t you mean soda)?

From the 1870s through much of the 20th century, Calumet Harbor, home to the ecosystem you are learning about, was one of the busiest ports in the Great Lakes. Steel mills, oil refineries and meat packing plants were a few of the big industries that established major facilities in what was to become Chicago's South Side. Chicago became a major international port in 1959 with the opening of the St. Lawrence Seaway, because ships could finally navigate all the way inland from the Atlantic Ocean.

Waste from these industries and Chicago’s sewers flowed freely into the Calumet River system, which polluted the local environment and contaminated Chicago’s drinking water. Though environmental regulations now prohibit the dumping of industrial waste, the pollutants from earlier in this century still persist in the sediments of Calumet Harbor and Lake Michigan.

Today you will read “Persistent Organic Pollutants: A Global Issue, A Global Response,” which was published by the U.S. Environmental Protection Agency (EPA publication EPA160-F-02-001). This reading will familiarize you with the environmental and human health impacts of persistent organic pollutants (POPs). You will also learn about the current legal and scientific actions taken by the United States and other countries to address these pollutants.

Use the following graphic organizer to identify important information as you read. Write what you learn in the bubbles in the glass of soda. In particular, read carefully the following sections:

- “What are POPs?”
- “What Domestic Actions Have Been Taken to Control POPs?”
- “How Do POPs Affect People and Wildlife?”
- “The Great Lakes: A Story of Trials and Triumphs”

You can read the document online at http://www.epa.gov/international/toxics/pop.html or you can download it from http://www.epa.gov/oia/toxics/brochure.html.
Name __________________ Date ___________ Class __________________
Group members’ names ____________________________________________

POP Graphic Organizer

As you read the EPA document, write down what you learn about POPs and their effects on the environment in the bubbles.
Investigation III: Bioaccumulation

Part 3: How are we exposed to chemicals?

Every day, we come into contact with chemicals such as water, oxygen, nitrogen, fructose etc. If we come into contact with these substances for a short time – less than 14 days – we call this exposure “acute.” If, however, our exposure lasts over a year it is called “chronic.” Anything in between is called “intermediate.”

Most of these substances have no adverse health effects, but some do. A toxin is a substance that has adverse acute (immediate) or chronic (long-term) health effects when it enters the body. Today, we will consider all the ways we expose ourselves to toxins.

For example, gasoline stations carry the following warning at the pump: “Avoid prolonged breathing of vapors as long term exposure to vapors has caused cancer in laboratory animals.” Merely spilling gasoline on your hand does not provide a pathway for its toxins to enter your body. Gasoline must volatilize (vaporize) and be inhaled into your lungs for the exposure pathway to be complete.

In this activity, you will work in groups of 4 to brainstorm routes of chemical exposure to humans using examples from everyday life.

Procedure

1. Write your name in the center oval of your map.
2. In each of the four squares on your map, write one way in which you think humans are exposed to chemicals in their environment.
3. Once everyone in your group has finished, pass your map to your neighbor on your left. Repeat this procedure until everyone in the group has read each other’s answers.
4. As a group, decide which activities could be grouped together. Use the highlighters provided to categorize the activities.
5. Once you think of three categories of activities, write them on the board at the front of the room under your group name.
6. Answer the questions on the following page.
Investigation III: Bioaccumulation

Part 3: How are we exposed to chemicals?

Exposure Pathways Concept Map
Once the class has shared their brainstorming, complete the following:

Q1. Write the three exposure pathways for humans by your class.

_________________________________  ___________________________________  ___________________________________

Q2. Now imagine you’re an organism living in a beautiful lake. Would your exposure pathways change?

Q3. Do exposure pathways change according to what type of aquatic organism you are: forage fish, a mussel, or a top predator? Think about where each one lives, what they eat, how they breathe, etc.

Q4. List the generalized exposure pathways for an aquatic organism.

___________________________________________________________________________________________________
Investigation III: Bioaccumulation

Part 4: What is a PCB?

In every workplace and home there are chemicals. In an office, it is common to have toners for the copier or cleaners for equipment. In a hair salon, there are hair dyes and chemical straighteners. Auto shops have coolants, oils, degreasers and gasoline. In your home, there may be cleaning fluids, pesticides, or herbicides. Each of these chemicals has potential adverse health effects. Some of them are immediately (acutely) apparent, like a chemical burn or shortness of breath, or it might take years for these effects to appear, as is the case with cancer.

In order to protect workers’ safety, the federal government passed a law in 1983 that created the Occupational Health and Safety Administration (OHSA). As part of this law, a Material Safety Data Sheet (MSDS) is “required for all shipments of hazardous chemicals leaving the manufacturer’s workplace and from all importers of such on all shipments,” as well as all “distributors and employers.”

The OHSA-formatted MSDS requires identification of the substance, as listed on the product label, followed by:

I. Manufacturer’s Name and Pertinent Information
II. Hazardous Ingredients/Identity Information
III. Physical/Chemical Characteristics
IV. Fire and Explosion Hazard Date
V. Reactivity Data
VI. Health Hazard Data
VII. Precautions for Safe Handling and Use
VIII. Control Measures

It is very easy to recognize the immediate adverse health effects of many chemicals; however, long term health effects can be easily dismissed. Think about smoking! Many people choose to smoke knowing that cancer or emphysema may occur years later. Someday, you will choose a career and/or start a family. It is very important to know the consequences of exposure to various substances so you can protect yourself and your family.
Today you will read a citizen’s guide developed by the U.S. Environmental Protection Agency (EPA). The purpose of this guide is to inform the general public of what PCBs are, and where and when they are used. Calumet Harbor in Chicago, IL has been heavily polluted with PCBs. As you have learned in this unit, toxins like PCBs are easily absorbed by aquatic organisms through feeding and direct exposure in their environment. Some of these organisms, like the smallmouth bass, are important sport fish and are eaten by humans. The EPA guide will detail what we now know about how PCBs can affect human health.

You will also do an internet search for a MSDS. As you read, complete the following questions and graphic organizer.

Access the following website site and answer the questions below.

http://www.epa.gov/epawaste/hazard/tsd/pcbs/pubs/about.htm

Q1. What are polychlorinated biphenyls (PCBs)?

Q2. Why were they once a desirable substance?

Q3. Name some locations where PCBs may exist in your community:

Q4. What is a common trade name for PCBs?

Q5. How might PCBs be released?
Health Effects of PCB exposure

Go to: http://www.epa.gov/epawaste/hazard/tds/pcbs/pubs/effects.htm#Repro
Use the internet to search for 2 Material Safety Data Sheets for polychlorinated biphenyls (PCBs). Read the materials and attach them to this sheet. Then answer the following questions:

Q6. What are other names for polychlorinated biphenyls?

Q7. What are common uses of PCBs?

Q8. What are the sources, routes, and types of exposure to PCBs?

Q9. What are the effects of exposure to PCBs? (note if these are different from what the EPA states)

Q10. What are the safety guidelines for exposure to PCBs?
Investigation III: Bioaccumulation

Part 5: Modeling Bioaccumulation and Biomagnification with

What did you eat for dinner last night? Most of the food we eat is used up by our bodies for energy and growth, and some of it is excreted as waste. But this doesn't account for everything that enters our bodies. Sometimes there are chemicals present in our food, like pesticides from the farm on which it was grown, or compounds from the soil, that our bodies can't use up or get rid of. These substances are stored in our bodies and their amount increases over time. The same happens to organisms in the wild that live in contaminated environments.

In today's activity, you will model the bioaccumulation of PCBs in the freshwater organisms of the Calumet Harbor ecosystem. As you proceed through the activity, observe how PCBs biomagnify as the travel through the food web.

Materials

You will be provided with the following materials:

- Food chain diagrams
- 200 Skittles or M&Ms (each piece of candy represents 1 unit of caloric energy)
- 100 plastic beads (each bead represents 1 unit of PCB toxin)

Instructions

1. We will start by modeling bioaccumulation in a single periphyton.
2. Place ten candies (10 units of caloric energy) on one periphyton square.
3. When the periphyton respires, it will lose 9 units of caloric energy (remove 9 candies from the periphyton square). The single candy remaining represents energy converted into biomass. Fill out “Day 1” of the table.
4. Now, imagine the food source for the periphyton becomes contaminated with PCBs. As the periphyton consumes its daily 10 units of caloric energy (10 candies) it will also eat one bead (this plastic bead represents the PCBs in Lake Michigan). You cannot digest plastic, nor can you digest PCBs. But unlike the plastic bead, PCBs will get stored in your fat. So the more beads you eat, the more PCBs you will store.
5. Repeat Steps 3, 4, and 5, adding 10 candies and 1 bead. Then remove 9 of the candies, but leave the beads. Record the data on “Day 2” of the table.
6. Have the periphyton eat contaminated food for ten days. Remember that the periphyton will continue to respire each day.

<table>
<thead>
<tr>
<th>Day</th>
<th>PCBs (number of beads)</th>
<th>Number of candies (caloric energy → biomass)</th>
<th>Ratio of PCB to biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td></td>
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Questions:

Q1. Did the periphyton get “bigger” over the 10-day period?

Q2. What happened to the concentration of PCBs in the periphyton? Remember to use appropriate science vocabulary.
We will now model biomagnification in this food chain.

7. Before you start, give 100 units of caloric energy to the crayfish.
8. Add plastic beads and candies to the rest of the periphyton so that they each match the one you just modeled.
9. Have the crayfish eat 10 contaminated periphyton per day for 10 days. Remember that each day, the crayfish will respire 90 units of caloric energy after eating (remove 90 candies). The crayfish will continue to store plastic beads in its biomass.
10. After each day, fill in the table below.

<table>
<thead>
<tr>
<th>Day</th>
<th>PCBs (plastic beads)</th>
<th>Number of candies (caloric energy → biomass)</th>
<th>Ratio of PCB to biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</table>

11. Now bring your crayfish up to the teacher, who will feed them to a smallmouth bass that has 250 units of caloric energy.

**Question:**
Q3. Using your previous two models, what do you predict will happen to the PCB concentration in the smallmouth bass after ten days of eating this way?
Crayfish

periphyton  periphyton  periphyton  periphyton  periphyton

periphyton  periphyton  periphyton  periphyton  periphyton
Smallmouth Bass
Investigation III: Bioaccumulation

Part 6: Modeling bioaccumulation and biomagnification using NetLogo

In Part 5, you physically modeled bioaccumulation and biomagnification. Now, you will use the NetLogo Bioaccumulation model to explore these concepts in a simulated ecosystem.

Materials

• Computers (1 computer for each student preferred) with NetLogo or Internet access and a Java-enabled web browser
• NetLogo Aquatic Bioaccumulation model
• Student Guide
• Graph paper

The Crayfish

First, we will take a look at bioaccumulation within one organism—in this case, a crayfish. Crayfish are in the second trophic level because they consume the primary producers of this ecosystem, the periphyton. In this model, the periphyton have been contaminated with a toxin. This toxin is a POP (persistent organic pollutant). We will examine how this affects energy and toxicity in a crayfish.

Procedure

1. Open the Aquatic Bioaccumulation model. You can do this in one of two ways:
   a. Open the NetLogo modeling software and click on File → Open. Select the Aquatic Bioaccumulation model from the list.
   b. Or, launch your internet browser and go to: http://ecocasting.northwestern.edu/NetLogo/Bioaccumulation.html

2. Notice the black box on the right side of the screen. In order to display the organisms that make up the food web in this region, you will need to click the button in the upper left corner of the screen.

*NOTE: This button will be helpful as you move through the rest of the investigation as it will always reset your model back to zero when clicked.*
When the data loads, your model should look like this:

3. Click...
4. Right-click (ctrl+click on a Mac) on a crayfish. A pull down menu will pop up. (hint: for this exercise, select a crayfish near a lot of periphyton but not near a smallmouth bass.)
5. Scroll down to the bottom of the pull down menu and select “a-crayfish ####”. A pop up menu will open.
6. Select **watch a-crayfish #**. You will see values appear in the boxes labeled **Energy/Toxicity of watched/followed creature.**

```
Energy/Toxicity of watched/followed creature
```

```
Energy  19
Toxicity 132
```

7. Write down the number of your crayfish here: __________ (in this example, 1357)

8. Record the values for energy and toxicity next to Step 1 in the table provided below.

9. Click **Go One Step** again and record energy and toxicity for Step 2 in your table. Repeat this in a step-wise fashion until 20 steps are complete. If your crayfish dies, go back to Step 6 and begin again.

---

<table>
<thead>
<tr>
<th>Step</th>
<th>Energy</th>
<th>Toxicity</th>
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<tbody>
<tr>
<td>1</td>
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<td>20</td>
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</tbody>
</table>
Analysis
10. On a sheet of graph paper, create a plot of step (x-axis) versus energy (left y-axis) and on the same graph plot step (x-axis) versus toxicity (right y-axis).

Questions:
Before answering the following questions, form groups of four. Record your name and the names of your three group members in the name column in the table below.

<table>
<thead>
<tr>
<th>Names</th>
<th>Step in which crayfish had the most energy</th>
<th>Step in which crayfish had the most toxicity</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

Q1. Look at your step versus energy plot and those of your group members. Is there a connection between step and energy? Explain your reasoning citing specific steps from your graph.

Q2. Look at your step versus toxicity plot and those of your group members. Is there a connection between step and toxicity? Explain your reasoning citing specific steps from your graph.

Q3. Use your data set to give a specific example of where bioaccumulation is occurring. Explain your reasoning citing specific steps from your graph.
The smallmouth bass

Next, we will explore bioaccumulation at the third trophic level of this ecosystem by measuring toxin increase in the smallmouth bass.

Procedure, continued

11. Click **Setup** to reset your model.

12. Click **Go One Step**.

13. Right-click (or ctrl+click on a Mac) on a smallmouth bass (hint: make sure it is near a few crayfish). A pop-up menu will appear.

14. Scroll down to the bottom of the menu and select **a-smallmouth_bass ####**. A second pop-up menu will appear.

15. Select **watch a-smallmouth_bass ####**. Values will appear in the boxes labeled **Energy/Toxicity of watched/followed creature**.

16. Record the values for energy and toxicity next to Step 1 in the table provided on the next page.

17. Write the number of the smallmouth bass you selected here:

   **a-small-mouth-bass ___________**.

18. Click **Go One Step** again and record the new values for energy and toxicity next to Step 2 in your table. Repeat this in a step-wise fashion until 20 steps are complete in the table below. If your smallmouth bass dies go back to Step 11 and begin again.
Analysis
19. On a sheet of graph paper, create a plot of energy (x-axis) versus toxicity (y-axis).

Questions:
Q4. When the slope is horizontal what is occurring? Explain and support your answer with specific data.
The Community

We will now shift our focus from individual organisms to the whole community. We will explore how a persistent organic pollutant (POP) behaves within a complex food web.

Procedure, continued

20. Click on Setup to reset your model.

21. Move your cursor over the top of the first bar on the left (green bar) in the Average Energy Level by Species graph. The left bar is the average energy level of the periphyton. A cross hair will show up. Align the horizontal axis of the cross hair with the top of the column. You will note two numbers show up. The only one we are interested in is the number to the left (y-value), which is the average energy level.

22. Record the average energy for the periphyton.

23. Repeat this procedure for the crayfish, which is represented by the red middle bar, and the smallmouth bass, which is represented by the black right bar.

24. Move the cursor to the Toxin Level by Species bar graph and record the average toxin levels for each of the species in the below graph using the procedure outlined above.

25. Click Go One Step 20 times.

26. Repeat steps 21-25 three times and fill in the table below as you go.

<table>
<thead>
<tr>
<th>Step</th>
<th>periphyton</th>
<th>crayfish</th>
<th>smallmouth bass</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>20</td>
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<td>60</td>
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</table>

Analysis

27. On one graph, create a plot for step (x-axis) versus average toxicity level per average energy level energy (y-axis) for all three species.
Questions:

Q5. Compare the three graphs you made in steps 10, 19, and 27. Which has the steepest slope and which has the shallowest? Use data from your graphs and tables to support your answer.
Investigation IV: Invasive Species

Introduction

“AHHHH!!! We’re being invaded! Save yourself!” When you hear statements like these, you may think of either a castle being stormed by an enemy army during the medieval time period, or instead you might imagine a sky filling up with disc-shaped UFOs. Either way, what you’re picturing probably isn’t all that positive of a situation for the person who would be making those initial comments. But is this how non-human organisms feel when a new species makes its way into an ecosystem? Would those little critters want to yell warnings to the other organisms they share resources with? Or would it be more like a new neighbor quietly moving into the house next door, not really bothering anyone as they settle into their new environment?

When we look at our Great Lakes freshwater ecosystems, we know we aren’t looking at pristine bodies of water that have remained untouched by the human hand. Investigation III should have taught you how polychlorinated biphenyls (PCBs) came to appear in the waters of the Calumet Harbor. We have also influenced the dynamics of native aquatic ecosystems within the Great Lakes through the introduction of invasive species, starting around the early 1800s. According to the United States Environmental Protection Agency’s (US EPA) Great Lakes invasive species website, this includes approximately 25 different types of fish, mollusks, plants, and crustaceans. The particular aquatic ecosystem you’ve been looking at throughout Investigations II & III has been invaded by two different types of mussels (the zebra and quagga mussels) and the round goby. In this model, we will be mainly focusing our attention on the impact of the round goby on a portion of the Calumet Harbor aquatic ecosystem.
Mussels

The first invasive species to have worked its way into Calumet Harbor was the zebra mussel. The zebra mussel is a small shellfish (mollusk) that is commonly found attached to hard objects in water such as water intake pipes, piers, and boat bottoms. This species is named for the striped pattern that runs across the surface of its shell. Zebra mussels are filter feeders that can remove large amounts of phytoplankton from an ecosystem, significantly changing properties including water clarity and algae content.

These mussels came from bodies of water in Eurasia such as the Black and Caspian Seas. According to the United States Geological Survey’s (USGS) Nonindigenous Aquatic Species Database, zebra mussels most likely were introduced to the Great Lakes as young, developing mussels held in the ballast water of a cargo ship from Europe or Asia. They were first found in the Great Lakes in 1988 in the waters connecting Lake Huron and Lake Erie, and by 1990 were detected in all of the Great Lakes.

However, the zebra mussel has been out-invaded (also known as succeeded) by another mussel in the Calumet Harbor: the quagga mussel. The quagga mussel is a close
cousin to the zebra mussel, getting its name from the “quagga”, an extinct ancestor of the zebra (USGS Nonindigenous Aquatic Species Database, 2010). As you can see in the picture on the next page, quagga mussels are mollusks just like the zebra mussels, but they are larger in size and rounder. Their impacts on aquatic ecosystems are very similar to that of zebra mussels; however, they can be found on both hard and soft underwater surfaces.

Quagga mussels are native to the Ponto-Caspian Sea and the Dneiper River watershed of the Ukraine. This species is thought to have entered the Great Lakes from the ballast waters of transoceanic ships. Quagga mussels were first found in Lake Erie in 1989 and by 2005 had spread to the remaining Great Lakes (USGS Nonindigenous Aquatic Species Database, 2010).

Round Goby

The final invasive species looked at in this investigation is the round goby. The round goby is a small brown fish that is native to the same bodies of water in Eurasia as the zebra mussels. They prefer shallower waters and perch themselves on rocks using their small, front fins; however, they can travel to deeper waters to feed. Round gobies are aggressive eaters who enjoy diets of smaller fish, fish eggs and fry (early life stage of fish), aquatic insects, and zebra mussels. They can out-compete for food with native species within an ecosystem because they have the ability to feed in total darkness (USGS Nonindigenous Aquatic Species Database, 2010).
Just like the zebra and quagga mussels, the round goby was introduced to the Great Lakes waterways via the ballast water found in freighter ships from Europe or Asia. They were first found within the Great Lakes near the Michigan-Ontario, Canada border in 1990. By 1994 the round goby had been detected in southern Lake Michigan, in places like Calumet Harbor and other ports around Chicago, IL. They can now be found in all five of the Great Lakes (USGS Nonindigenous Aquatic Species Database, 2010).

What is an invasive species and how can it affect a food web?

In this section, you will start off working with a partner to share ideas about what an invasive species is and how it could potentially affect an ecosystem. You will then put your ideas to the test by using the NetLogo modeling software to see how an invasive species can impact a food web.

Part 1: Getting started – Brainstorming

Questions:

Q1. When you hear the term “invasive species”, what do you think of? List as many thoughts as you can in the time provided to you. Compare lists with a partner to see if any common ideas emerge. Using these common ideas, create your own definition of an invasive species with your partner and write it in the space below.
Q2. How do you think invasive species affect the environment in which they exist? Are they positive or negative influences? Working together with your partner, come to a consensus as to how invasive species affect their new home environments.

Part 2: Exploring the Effects of a New Trophic Level on the Food Web

If you’ve been working through Investigations I, II, & III of this unit, you’ve already been introduced to one type of relationship that can exist within an ecosystem: predator-prey. You should also have seen how humans can impact the health of an ecosystem through the addition of toxins, specifically PCBs, into the environment. Now it’s time to expand upon both of those investigations by looking at how a new species introduced to an ecosystem can change both the initial predator-prey relationships AND change how a pollutant moves through a food web.

The scientists who are studying Calumet Harbor set out to answer those same questions: How do new species affect predator-prey relationships and toxin transfer in a food web? You might ask, “How did they do this?” They went fishing! They collected lots and lots of fish and examined samples of their tissues and stomach contents to see what kinds of organisms they had been eating. They used this information to create computer models that could help them predict the effects of invasive species and POPs on the ecosystem.

In this investigation, you will examine how an invasive species can affect the transfer of a pollutant through an ecosystem. Recall from Investigation III that **bioaccumulation** is the buildup of a toxin in the tissues of an individual organism during its lifespan, while **biomagnification** is the increasing concentration of a toxin in the tissues of organisms in successive (higher) trophic levels. As you complete this activity, you will want to focus on both the accumulation of PCBs within each species as well as how the toxin biomagnifies as it moves from one trophic level to the next.

**Procedure**

1. Open the NetLogo Aquatic Invasive Species model. This can be done in one of two ways:
   a. Open the NetLogo software on your computer. Click on **File → Open** and select the **Aquatic Invasive Species** model from the list.
   b. Or, open your internet browser and type in the following address:  
      [http://ecocasting.northwestern.edu/NetLogo/Invasive%20Species.html](http://ecocasting.northwestern.edu/NetLogo/Invasive%20Species.html)
2. Notice the black box on the right side of the screen. In order to display the organisms that make up the food web in this region, click the **setup** button in the upper left corner of the screen.

*NOTE:* The setup button will be helpful as you move through the rest of the investigation as it will always reset your model back to zero when clicked.*

When the data loads, your model should look like this:

Notice the **Food-Web** box on the left-hand side of the model. These rules govern how the model runs. They were written based on how the scientists predicted the food web would be structured, with larger organisms eating the smaller ones.

**Question:**

Q3. Which of the organisms listed in the **Food-Web** box is missing from the model frame? Why is this?
Q4. Now that you know what an invasive species is and how it can adapt to living in a new ecosystem, predict how you think a round goby invasion will affect the population size of each of the organisms that make up this aquatic ecosystem model.

Q5. How do you think the round goby will fare in its new environment? Provide a prediction about how you think its population will react.

3. Click on the go/stop button in the upper left corner of the screen to start the model running. This button will both start and stop the model run.

4. Let the model run to 100 on the time axis. Begin to invade your ecosystem model with round goby. In order to do this, click on the “Start Invasion” button on the upper left side of the screen.

Once your invasion begins, you should see a few round gobies appear in the ecosystem image as small brown fish:

Watch what happens to the population size for each of the organisms as you let the model run. Focus your attention on the line graph labeled “Population Size” on the left of the screen.
**NOTE:** Let the model run to *at least* 300 on the time axis in the “Population Size” graph before stopping it or recording any observations.* Run the model 3 times to identify general trends

If the model is changing too quickly for you as it runs, you can adjust the speed using the slider bar at the top of the model:

Questions:

Q6. Were your predictions about the round goby’s impact on the food web supported by the model? Describe any differences between your predictions and what you saw happening AND provide some possible explanations for any differences you saw.

Q7. How did the round goby population fare? Was this what you predicted? Describe any differences between your predictions and what you saw happening AND provide some possible explanations for any differences you saw.

Q8. How would your ecosystem react to multiple invasions of the round goby? Write a hypothesis about how the populations of each of the organisms in this ecosystem might react to more than one invasion of the round goby.

5. Test your prediction! Reset your model using the button, get it running, and then re-invade the ecosystem as many times as you would like.
Questions:

Q9. How many times did you press the “Start Invasion” button? Were your invasions evenly distributed or not? Why did you choose to invade the ecosystem this way?

Q10. How did the pre-existing organisms in the ecosystem react to more than one invasion of the round goby? Describe your observations.

Q11. Could multiple invasions of an invasive species into an ecosystem actually happen in nature? Explain your answer.

Part 3: Different Species, Different Adaptations

Q12. As was stated in the reading at the start of this investigation, zebra and quagga mussels are additional invasive species found within the Calumet Harbor ecosystem and are represented by the mussel image in the model. In tissue samples, zebra mussels have been found to be more contaminated than their quagga counterparts. What do you think could be the reason for this?
Q13. Scientists have found that between 1999 and 2005, quagga mussels became the dominant mussel species within Calumet Harbor. How do you think this mussel succession could affect PCB biomagnification throughout the food web?

Part 4: Exploring the Effects of a New Trophic Level on Toxin Transfer

You will now run the model to examine how biomagnification in the Calumet Harbor ecosystem is affected by an invasion of round goby. Round gobies become contaminated with polychlorinated biphenyls (PCBs) due to their diet. They eat organisms in their new ecosystems, such as zebra and quagga mussels, that cause PCBs to be directly passed on to them.

Question:

Q14. How do you think an invasion of round goby will affect the bioaccumulation of PCBs in each of the species in this ecosystem model?

6. Reset your model and click \(\text{go/stop}\). After 100 units of time has passed, click \(\text{Start Invasion}\) to invade your ecosystem. This time, follow what is happening in the toxicity graphs. Allow the model to run for at least another 200 units of time before recording any observations. Run the model 3 times.

Here are some sample toxicity graphs. Yours may look slightly different.
Questions:

Q15. Looking back to the answers you provided for Question 14, did the model’s results support your prediction about the round goby’s impact on bioaccumulation and biomagnification? Describe any differences between your predictions and what you saw happening AND provide some possible explanations for these differences.

Q16. You may have observed that the Toxicity History levels fluctuate over time, particularly for the round goby and smallmouth bass. What do you think is happening in the model when the average toxin level of a species decreases?
Part 5: Reading Real Data from the Scientists

To test their models against the real data, the scientists collected samples of each species in the ecosystem. They took tissue samples from each species and calculated their trophic level. This graph was created using the real data from Calumet Harbor. Each sample the scientists measured is represented by a point on the graph. The black vertical lines above and below the sample are error bars—they represent the amount of uncertainty in each data point. Look carefully at the trophic levels of the round goby and the smallmouth bass.

Figure 1. Trophic position of organisms in Calumet Harbor ecosystem. Reproduced from Ng, et al. 2008. Chemical amplification in an invaded food web: seasonality and ontogeny in a high-biomass, low-diversity ecosystem. Environ. Toxicol. Chem. 27L 2186-2195.

Q17. What is this graph saying about the trophic positions of the round goby and the smallmouth bass?

As you have observed, the introduction of invasive species to the Calumet Harbor ecosystem has added a new trophic level to the mix. The smallmouth bass have a new source of food, and the crayfish now have a new predator to avoid. However, what scientists have learned about the round goby is that they aren’t just prey to the smallmouth bass, but the smallmouth bass can be prey to them too! This means that the round goby can occupy two different trophic levels in the same food web.
Question:

Q18. Develop a hypothesis as to how a smallmouth bass can be prey to the round goby. Remember... the smallmouth bass is a larger fish than the round goby and when we look at simple food chains, the bigger organism typically eats the smaller one. How is a smaller species able to be a predator to a larger one?

In addition to collecting fish and analyzing samples in the lab, the scientists wanted to observe how the fish behaved in their own environment. To do this, they went diving in the harbor with a video camera. Open your internet browser and navigate to Dr. John Janssen’s website, http://www.glwi.uwm.edu/people/jjanssen/goby/index.html, where you can watch a short video clip of a round goby invasion in action!

Questions:

Q19. What did you learn about how the round goby can be a predator to the smallmouth bass?

Q20. How do you think the ability of the round goby to feed at two different trophic levels will change what you saw happen earlier to the populations of other species following your initial round goby invasion?
Let’s see what happens!

7. Stop your model if it is still running by clicking [go/stop].

8. Find the **Food-Web** box at the top of the model. In order to add a new food chain to the model, click on the **Change** button on the **Food-Web** box.

![Food-Web box with change button highlighted]

Once you do that, a new **Food-Web pop up window** will appear. Here is where you will be able to enter a new food chain.

9. In the new **Food-Web** window, add in a new food chain demonstrating that smallmouth bass are now prey to the round goby.

![Food-Web window with new food chain]

10. When you are done typing in the new food chain click the **Apply** button. Notice that after you clicked the button, in the original **Food-Web** box at the top of the model a new food chain has been added.
11. Click OK in the **Food-Web** window to close the pop up.

12. Click **setup** in the upper left corner of the model to reset the ecosystem.

13. Click **go/stop** to start the model running. Remember... if you want to stop the model from running at any time, click this button again.

14. After 100 units of time have passed, click **Start Invasion** to introduce the round goby into the ecosystem. Allow the model to run for *at least* another 200 units of time on the “Population Size” graph before recording any observations. **Run the model 3 times.**

Questions:

Q21. Did the model support your prediction from Question 20? Describe any differences between your predictions and what you saw happening in the model AND provide some possible explanations for these differences.

Q22. Were any of the organisms from this portion of the ecosystem eliminated after the round goby invasion? Is this realistic? Explain your answer.

Q23. What did you choose to do once this portion of the ecosystem was absent of a particular species? Explain your choice AND describe how the ecosystem reacted.
Here’s the same trophic level graph you saw earlier. This time, however, the round goby data points are grouped according to the size of the fish the sample came from.

Figure 2. Trophic position of organisms in Calumet Harbor ecosystem with small (S), medium (M) and large (L) size classifications. Reproduced from Ng, et al. 2008. Chemical amplification in an invaded food web: seasonality and ontogeny in a high-biomass, low-diversity ecosystem. Environ. Toxicol. Chem. 27L 2186-2195.

Q24. What is the relationship between size of round goby and trophic level on this graph?

The scientists discovered that small round gobies are better at invading smallmouth bass nests than larger round gobies. Therefore, small round gobies are at a higher trophic level than larger round gobies because they are the ones eating smallmouth bass eggs. Eggs are a rich source of lipids (fats), but they are also a rich source of PCBs because these toxins are stored in the fatty tissues of organisms. We will now investigate how the ability of the round goby to feed at two trophic levels impacts biomagnification of PCBs through the food web.
Q25. Do you think the ability of the round goby to feed at two trophic levels will change the toxicity levels throughout the food web that you observed earlier? Write your prediction below.

15. If your model is still running, click to stop it. Reset your model to clear the graphs- this should not change the new rule you have added to the Food-Web box.

16. Click in the upper left corner of the screen to start the model running.

After 100 units of time have elapsed, click .

Focus your attention this time on the “Average Toxin Level by Species” and the “Toxicity History” graphs.

*NOTE: Let the model run to at least 300 before stopping it or recording any observations. Run the model 3 times.*

Questions:

Q26. Looking back to Question 25, was your prediction supported by the model? Describe any differences between your prediction and what you saw happening AND provide some possible explanations for these differences. How is this graph different from the Toxicity History graph in Part 4 (before you changed the Food-Chain rules)?

Q27. Are there other factors (besides feeding at two different trophic levels) that could be playing a role in how the round goby affects the biomagnification of PCBs through the Calumet Harbor ecosystem? Explain.
Part 6: A Twist on Bioaccumulation

As you have probably realized, Calumet Harbor is a unique example of what happens to an ecosystem when it is invaded by new species. The scientists studying this ecosystem have learned a great deal about the potential impacts of invasive species on population sizes and toxin transfer within a food web.

In the beginning of their study, scientists expected that round gobies would have greater concentrations of PCBs in their tissues than mussels, but smaller concentrations than the smallmouth bass. They predicted this because, initially, they thought smallmouth bass were the predator of round gobies. When this team of scientists collected fish to study, however, they had two surprises. The first was that some round gobies had greater concentrations of PCBs than smallmouth bass. The second surprise was that most small round gobies had a higher concentration of PCBs than larger round gobies. Both of these findings contradict typical patterns within ecosystems. A big question remains: How will this impact the smallmouth bass population, which is a much more desirable sport fish to humans than the round goby?

The study had other interesting results, too. They learned that small round gobies have an equal trophic position or PCB concentration to the smallmouth bass only during certain times of the year. It actually varies by season. Round gobies can only eat fish eggs when fish are spawning, right? Therefore, they will only have an elevated trophic position and higher PCB levels during spawning season. For round gobies, that’s May to September and for smallmouth bass it’s only during the month of June. Round gobies will eat the eggs of smallmouth bass in addition to eggs of other round gobies.
Figure 3. Changes in round goby 15-N stable isotope signature over the course of a calendar year. On the x-axis, time is measured in days, where January 1 is day 0 and December 31 is day 365. Graph reproduced from Ng, et al. 2008. Chemical amplification in an invaded food web: seasonality and ontogeny in a high-biomass, low-diversity ecosystem. *Environ. Toxicol. Chem.* 27: 2186-2195.

$^{15}$N is an isotope of nitrogen (a variant of an atom that has a different number of protons than neutrons) that scientists use as a way to measure an organism's place in a food web. The non-isotope form of nitrogen is $^{14}$N. The greater the ratio of $^{15}$N:$^{14}$N in an organism, the higher up on the food chain it is. This ratio is represented as δ$^{15}$N. The graph you see above shows that the round goby’s trophic position rises during the summer months (days 120-213) when smallmouth bass and other round gobys are spawning. The different lines indicate that the amount of increase in δ$^{15}$N depends on how many eggs are eaten by round gobies.

Scientists use this information to better guide consumers about when it is safe to eat fish. While round gobies are not a popular fish eaten in the Great Lakes region, smallmouth bass are a favorite. If their food source – the round gobies – have a higher toxicity level during certain times of the year because they are feeding on fish eggs, anglers need to know. The complicated nature of this food web shows that there may be more going on in an ecosystem than meets the eye. To have the best guidelines, we need to know a lot about how all the different fish interact. Science research is an ongoing process to better understand the complexities of our world and how we interact with it.
Questions:

Q28. Based on these new findings, how would you change the model to better represent the food web?

Q29. Is this ecosystem unique? Why or why not?

Q30. Make a policy statement regarding what we should do about invasive species in the Great Lakes.

Q31. Based on what you have learned in this investigation cut out the images on the next page and use them to construct a diagram of the Calumet Harbor food web. Paste this new diagram onto the back of this sheet and draw arrows that better represent the feeding habits of the species in Calumet Harbor.
Smallmouth bass

Periphyton

Round goby

Crayfish

Mussels