Biomagnification Through a Food Chain

Purpose:

The concepts of bioaccumulation and biomagnification (or biological magnification) are often confused. The former is the increase in the concentration of a *fat-soluble* toxin within the tissues of organisms; the latter describes the increase in that toxin as you move up through a food chain. Whereas water-soluble toxins will simply be excreted, fat-soluble toxins remain within the tissues and organs of an organism so that when that organism is eaten, the consumer ingests the toxin as well. Tertiary consumers, such as Bald Eagles and other birds-of-prey, are especially vulnerable to the effects of biomagnification. This activity will demonstrate the concepts of bioaccumulation and biomagnification using the classic example of DDT.

Background:

Shortly after WWII, a new super-pesticide was put into wide-spread use across the United States. Dichloro-diphenyl-trichloroethane (DDT), the first synthetic pesticide, had been used with massive success during World War II to combat malaria and other diseases carried by insects. In the baby-boom period right after the war this new technology was called upon to help keep America's agriculture healthy and prosperous and American families' houses idyllic abodes free of insects. No one knew that they were actually unleashing one of the most persistent toxic chemicals commercially available. Not until Rachel Carson's 1962 book *Silent Spring* did people start to question this chemical and the unforeseen negative effects ii was having on the environment

Carson's book outlined how DDT stayed within a food chain, building in toxicity as it was passed in the tissues from one trophic level lo the next This phenomenon, known as biomagnification, seemed to affect larger birds more than smaller ones and not by simply killing them, but by altering how they metabolized calcium. Because they could not process calcium properly, these birds could not build shells strong enough to last through incubation. Thus, by the late 1960's populations of Osprey, Brown Pelicans, and Bald Eagles were critically low and some species, such as the Peregrine Falcon, were extinct in certain regions. Fortunately the devastating effects of DDT were recognized relatively early on and in 1972 this organochloride pesticide was banned for commercial use in the United States. However in other parts of the world DDT was still widely used.

In 2001, the Stockholm Convention on Persistent Organic Pollutants (POPs) was introduced at the Conference of Plenipotentiariesn to try and eliminate and/or control the use of DDT and other POPs around the world. Ultimately signed by over 150 countries, the Convention limits the use of DDT to the prevention of malaria in select countries. The convention also places limitations on other long-lived, fat-soluable toxins, nicknamed "The Dirty Dozen", such as dioxin, aldrin, chlordane, and PCB's. While these POPs are still used in many countries and therefore still pose a risk globally due to their ease of transport both through the air and in water, efforts are being made to eliminate them and their environmental threat.

Vocabulary:

- Bioaccumulation – the process by which a fat-soluble toxin builds up within the tissues of an organism
- Biomagnification – the increase of a fat-soluble toxin at each successive level of a food chain
- Phytoplankton – microscopic plants that live in bodies of water, e.g. single celled algae like diatoms
- Persistent Organic Pollutants (POPs) – enduring chemicals that accumulate in the tissues of organisms, are passed up a food chain and pose a health risk to humans and the environment
- The Dirty Dozen – the twelve toxic chemicals initially named by the Stockholm Convention to be targeted for reduction/eradication; 9 of the 12 are pesticides
- Zooplankton – microscopic animals that live in bodies of water, e.g. copepods

Materials:

100–“phytoplankton”

20– "zooplankton"

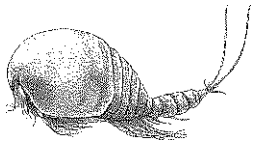
5– "minnow"

2 eels- "eel #1" and "eel #2"

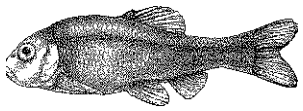
1– "osprey"

Procedure:

1. Cut up each individual square. The printed “D” on each slip represents the amount of DDT (in ppm) the algae ingested from pesticide runoff from a nearby agricultural area. Each box below represents one phytoplankton. Mark the amount of toxin each phytoplankton has ingested. If there is a full “D” on the slip then that phytoplankton has ingested 1 ppm of DDT, so write a “1” in one of the boxes below. If there is no “D” on the slip then that phytoplankton did not ingest any DDT so write a “0” in one of the boxes below.
   If there is a partial “M” on the slip then estimate how much of the “D” there is. For example, if there is only the top half of “D” then that would equal ½ of a unit of DDT ingested by that phytoplankton so you would fill in one of the boxes below with “½.”
2. Zooplankton in the lake (population size 20) each eat 5 phytoplankton. Move 5 squares o top each of the zooplankton. Record the amount of DDT each zooplankton has ingested using the instructions from step 1. Write the amount each ingested in the data able.



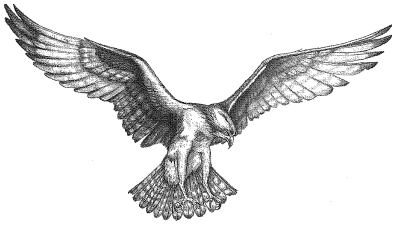
3. Minnows (population size of 5) in the lake each eat 4 zooplankton, ingesting the toxin that is stored in the zooplankton. Move the correct number zooplankton+squares on top of the minnow. Record the amount of DDT ingested by each of the small fish on the data table using instructions from step1 to calculate the total amount for each fish.



4. Two eels then come along for dinner. One eel eats 2 minnows and the other eel eats 3 minnows. Move the minnow+zooplankton+squares on top of the eel picture. Write the amount of DDT ingested by each eel on to the data table. Use the instructions from step 1 to calculate the total amount of DDT for each.



5. Finally, an osprey flies by and eats both eels. Move the correct number of slips from the eel cups into the osprey bowl. Calculate and then write the total amount of DDT ingested by the osprey onto the picture below:



Data Collection:

1. Data Table.
   a. Fill in the population of organisms at each level of the food chain.

b. During the activity, calculate the average amount of DDT ingested at each level of the food chain. Show all your work below. Write the final averages into the data table.

	Population of Organisms	DDT Ingested (ppm)
Phytoplankton		
Zooplankton		
Minnows		
Eels		
Osprey		

Data Analysis:

1. Show your calculations for the average DDT at each level in the food chain:

2. Draw a pyramid of numbers representing the populations and a pyramid showing the relative concentrations of DDT at each level of the food chain using the values from the data table.

3. Summary of Data Trends.
    a. Compare the amount of DDT found in the osprey with the amount of toxin found in one phytoplankton. Be specific. Discuss numerical evidence.

b. Compare and contrast what your pyramids tell you. Discuss similarities and differences between the pyramids, above and beyond the obvious. Do the various shapes make sense, given what you know about food chains in general and biomagnifications? Why or why not?

Conclusion:

1. Summarize what you have learned through doing this lab.

2. Do you think the purpose of the lab was achieved? Why or why not?

3. Are there any biases or assumptions behind the collection of data or the experimental design? If so, did they how did they impact the outcome of the experiment?

4. Are there any other sources of error that impacted the final calculations? If so, what are they and what could be done to negate their effect?

You will need to do some outside research to answer these last two questions

5. Is the amount of DDT at each level in this model is accurate compared to the "real world"?

6. Would the amount calculated for the osprey in this situation be detrimental to a real osprey?

7. Choose one to complete on a separate paper and staple to this paper.
   a. Research the following pesticides: alachlor, metalachlor, cyanazine, atrazine, methoxychlor, pyrethrin. Create a table that compares their toxicity levels. Include effects on humans, half-life in the environment, persistence level, mobility level, impact on groundwater, and effects on aquatic life. Include an overall ranking of most toxic to least toxic.
   b. Flame-retardant chemicals have been used for years in common household products such as electronics, polyurethane foam furniture cushions and children's flame-resistant clothing. Recently attention has been focused on the toxicity and bioaccumulative properties of this group of chemicals, the polybrominated diphenyl ethers (PBDEs), namely decabromodiphenyl ether (decaBDE), pentaBDE, and octaBDE. PBDEs have been found in concerning levels in human blood, fat, breast milk, and in the brain. While their exact effects are not accurately known, they are believed to cause damage to the liver, thyroid and slow neurological development in infants. Humans typically inhale PBDEs from their environment but also ingest them in the food they eat, namely fish and poultry which have been exposed to the chemicals through non-point pollution from landfills. Given this background information, design an experiment which would help demonstrate that PBDEs are bioaccumulative in humans.

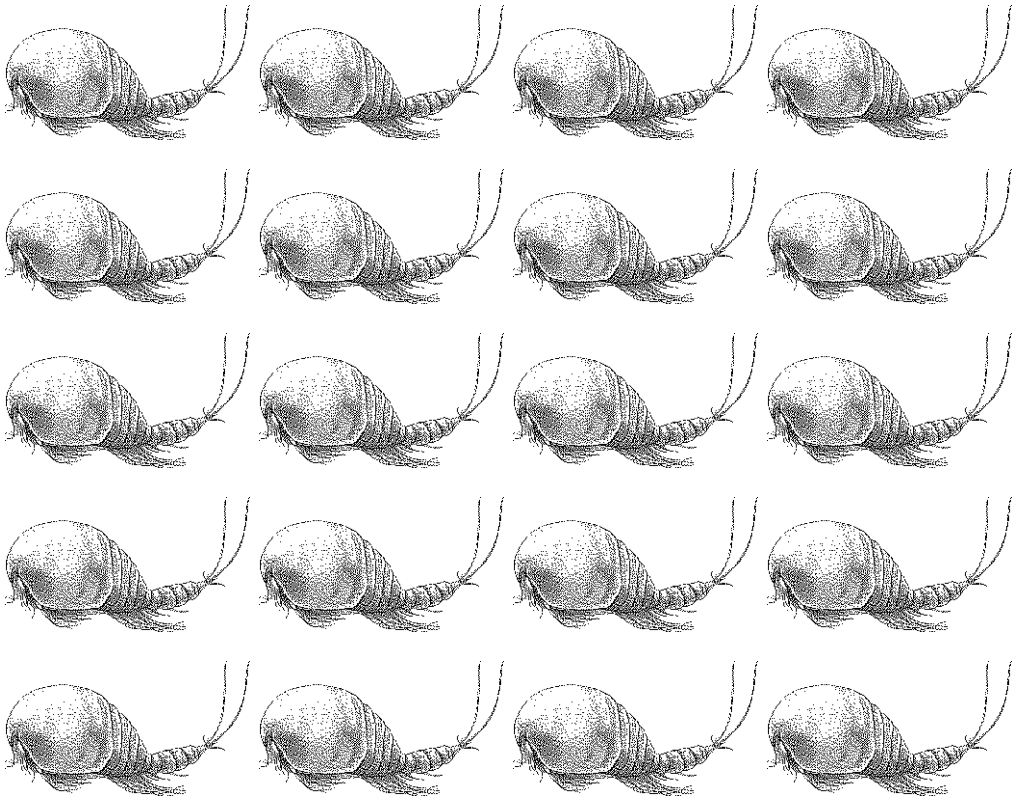
Suggestions for Further Investigation:

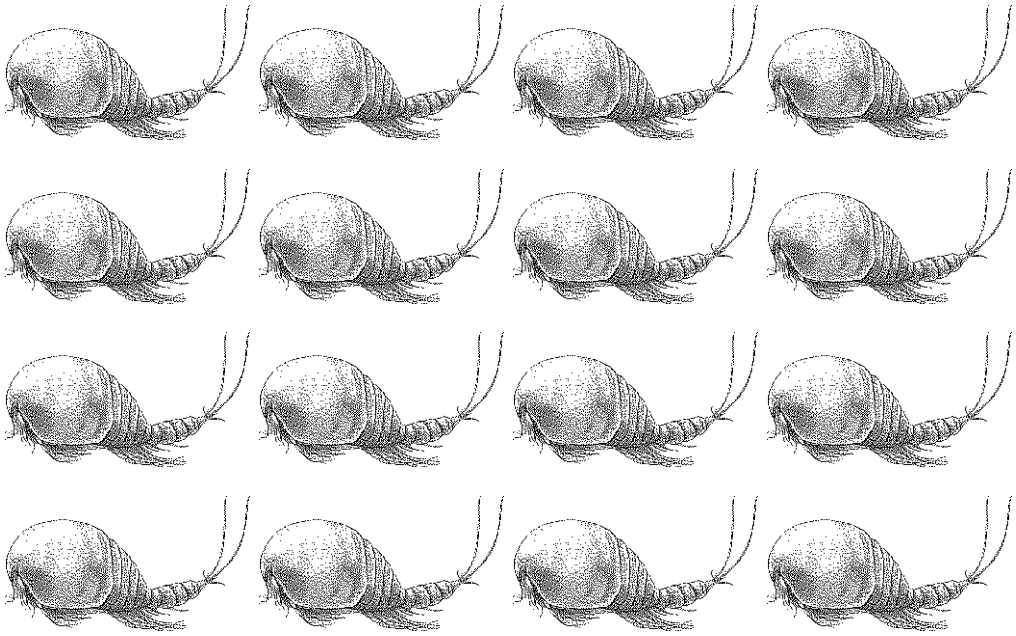
c. Research one of the other "Dirty Dozen" pollutants, preferably one that has a history in your area. Find out what the chemical was/is used for, a typical food chain that it impacts, what the toxic effects on that food chain are and how its use is being controlled (i.e. is it banned outright or are there certain uses it is still allowed for?).

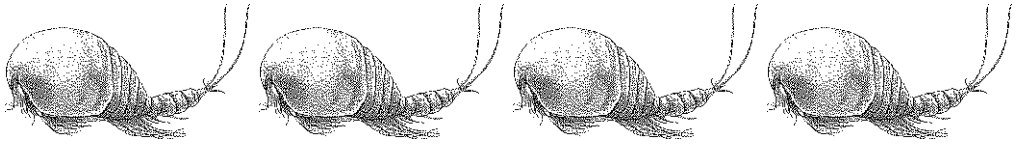
d. The other main substances that tend to biomagnify are heavy metals. Research a heavy metal that has a history of bioaccumulation in humans. Find out what the metal was/is used for, how humans typically ingest the heavy metal, what the toxic effects are and how, or if, its use is being controlled.

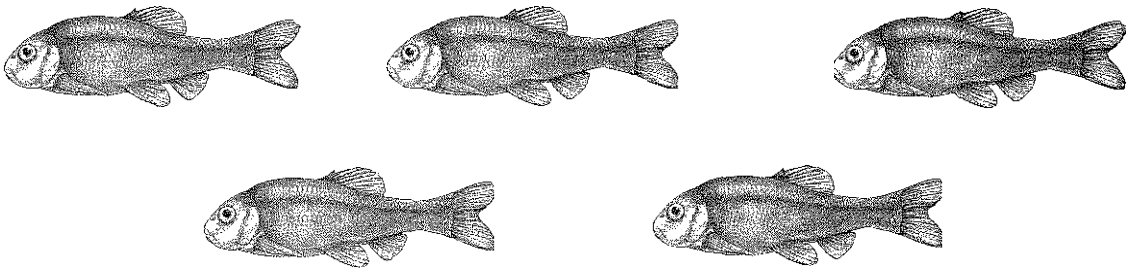
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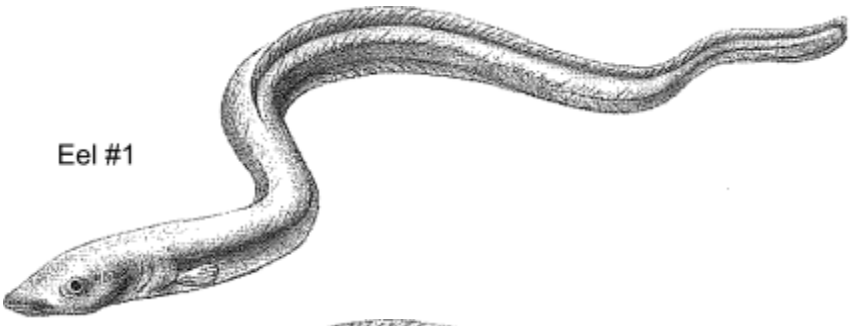
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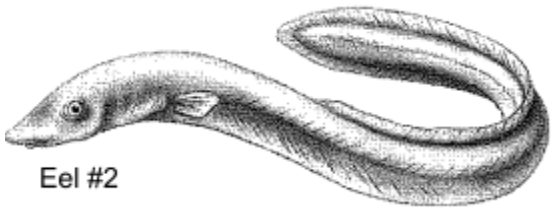


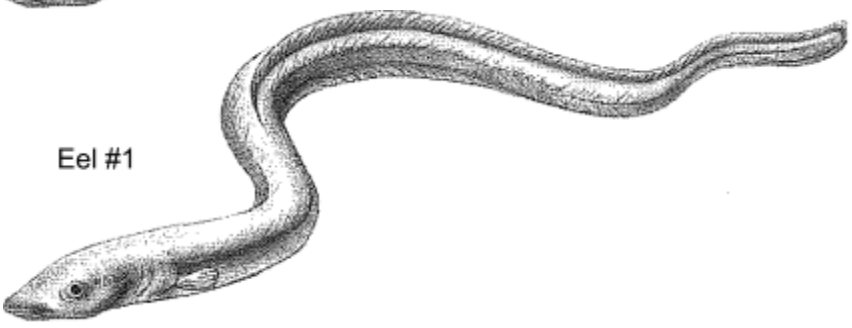


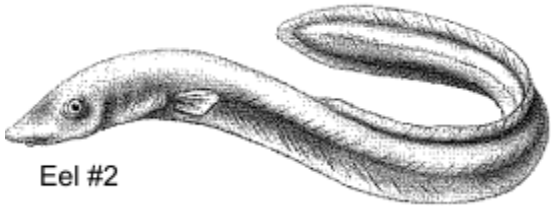


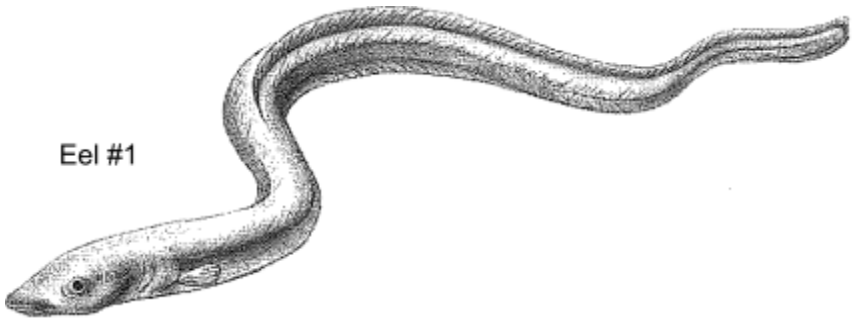


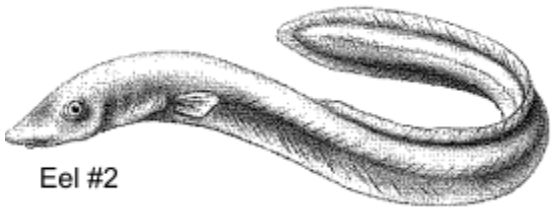

Eel #1

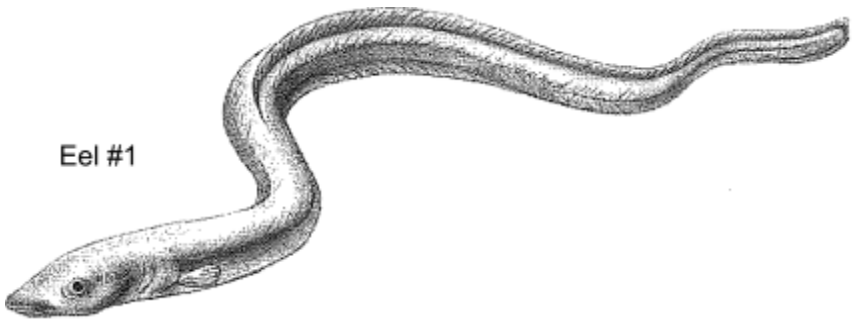

Eel #2

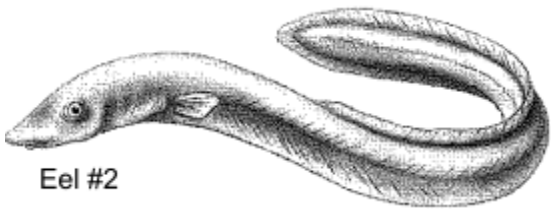

Eel #1


Eel #2


Eel #1


Eel #2


Eel #1


Eel #2

Phytoplankton w/ ingested DDT toxin.

Phytoplankton w/ ingested DDT toxin.

Phytoplankton w/ ingested DDT toxin.

