Lab 4

Biomagnification Through a Food Chain

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Abstract

You will use M&M candies to model bioaccumulation and 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, as well as review how energy is transferred through a food chain.

Objectives

- Visualize the processes of bioaccumulation and biomagnification.
- Distinguish between the similar concepts of bioaccumulation and biomagnification using a mathematical model.
- Calculate the amount of energy gained/lost through the energy transfers of a typical food chain.
- Review trophic level names and energy characteristics.

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 it 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 to 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.

Materials and Equipment (per lab group)

100 M & M's

Paper towel to lay M & M's on

20 small cups labeled "zooplankton"

5 medium cups labeled "minnow"

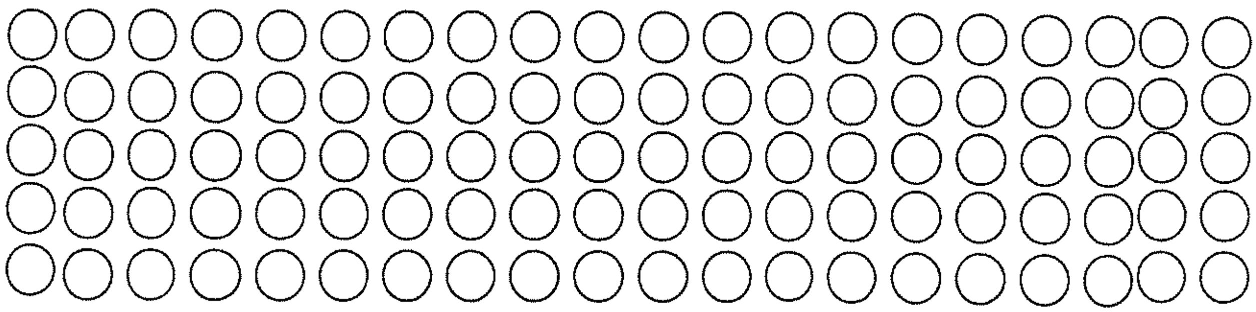
2 larger cups – one labeled "eel #1", other labeled "eel #2"

1 bowl labeled "osprey"

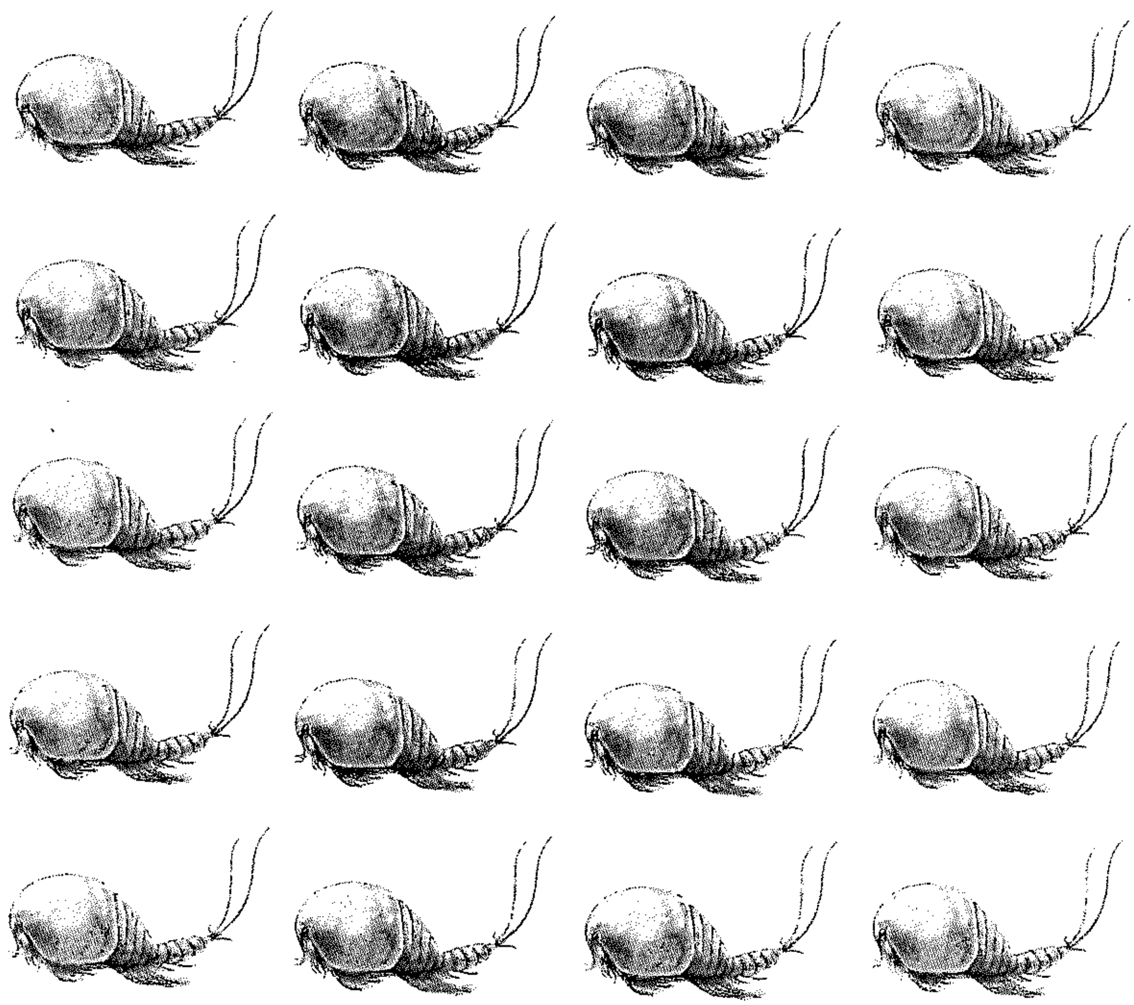
Procedure

1. The pile of M&M's represents the phytoplankton population in a lake. The printed "M" on the candy represents the amount of DDT (in ppm) the algae ingested from pesticide runoff from a nearby agricultural area. There are 100 M&M's in the pile. Each circle below represents one phytoplankton. Mark the amount of toxin each phytoplankton has ingested. If there is a full "M" stamped on the candy then that phytoplankton has ingested 1 ppm of DDT, so write a "1" in one of the circles below. If there is no "M" on the candy then that

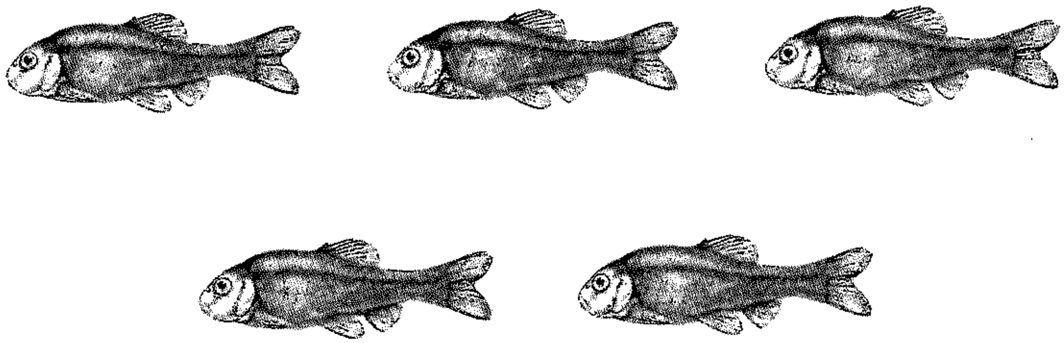
phytoplankton did not ingest any DDT so write a "Ø" in one of the circles below. If there is a partial "M" on the candy then estimate how much of the "M" there is. For example, if there is only one hump of the "M" then that would equal ½ a unit of DDT ingested by that phytoplankton so you would fill in one of the circles below with "½".



2. Zooplankton in the lake (population size 20) each eat 5 algae. Move 5 M & M's into each of the zooplankton cups. Record the amount of DDT each zooplankton has ingested using the instructions from step 1. Write these amounts onto the individual copepod pictures below.

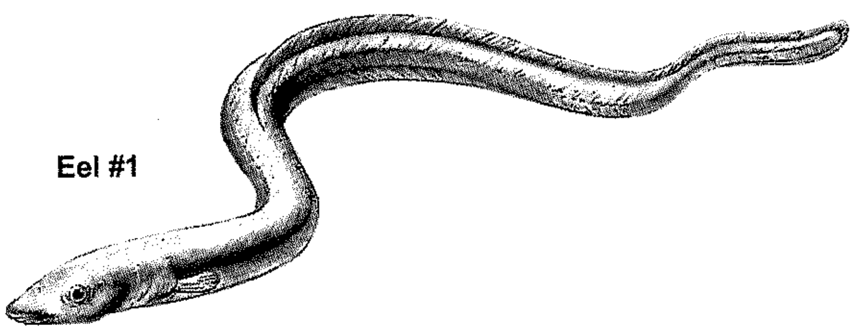


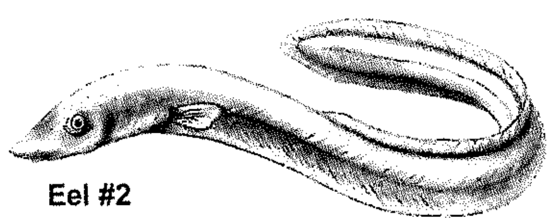
3. Minnows (population size of 5) in the lake each eat 4 zooplankton, ingesting energy and the toxin that is stored in the zooplankton as well. Move the correct number of M & M's from the zooplankton cups into the minnow cups. Record the amount of DDT ingested by each of the small fish onto the fish below using the instructions from step 1 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 correct number of M & M's from the minnow cups into the eel cups. Write the amount of DDT ingested by each eel onto the pictures below. Use the instructions from step 1 to calculate the total amount of DDT for each.

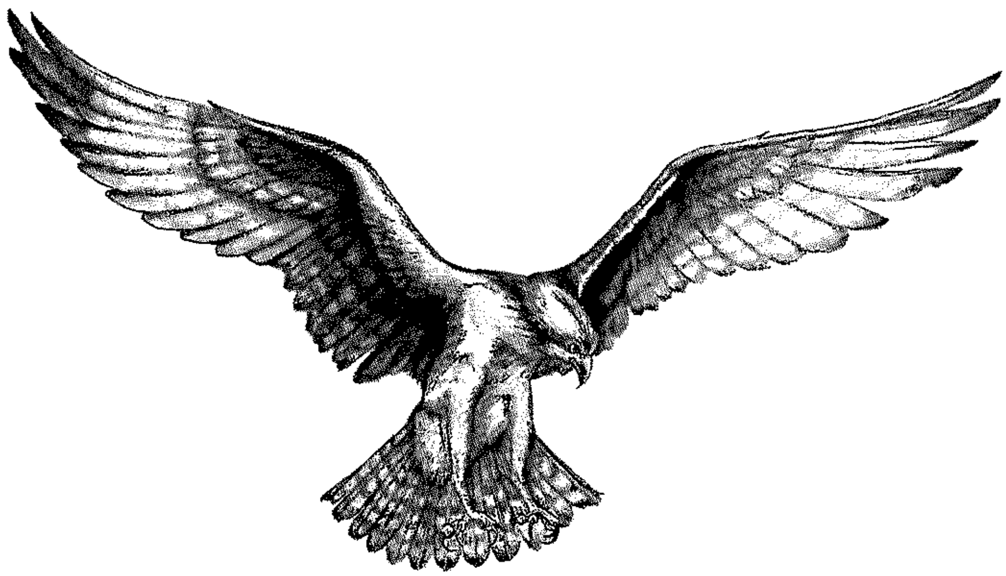
Eel #1





Eel #2

5. Finally, an osprey flies by and eats both eels. Move the correct number of M & M's 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. Using the numbers you have written onto the images above, calculate the average amount of DDT ingested at each trophic level. Show all your work below in the appropriate section of Data Analysis- Calculations. Write the final averages into column A.
   b. Given that each phytoplankton has 200 kcal of energy stored in its' tissues, calculate the energy acquired by each individual at each trophic level and write these numbers in column B. Show all your work below in the appropriate section of Data Analysis- Calculations.
   c. Using the numbers you calculated in column B, determine the total energy held at each trophic level and fill in column C. Show all your work below in the appropriate section of Data Analysis- Calculations.
   d. In column D, use the following terms to name each trophic level and feeding relationship: herbivore, primary consumer, carnivore, secondary consumer, primary producer, tertiary consumer, and top consumer. You will use some terms more than once.

	A DDT ingested (ppm)	B Energy acquired (kcal)	C Total energy at trophic level (kcal)	D Name of trophic level/feeding relationship
Phytoplankton				
Copepod				
Minnow				
Eel#1				
Eel #2				
Osprey				

Data Analysis

1. Show your calculations for each of the following columns:

   Column A calculations:

   Column B calculations:

   Column C calculations:

2. Graphs. Draw a pyramid of numbers, an energy pyramid, and a pyramid showing the relative concentrations of DDT at each trophic level 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. Write a paragraph where you compare and contrast what your pyramids tell you. Discuss similarities and differences between the pyramids, above and beyond the obvious (i.e. that the energy pyramid shows the amount of energy, etc.). 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?

Suggestions for Further Investigation

1. 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?).
2. 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.
3. 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.
4. 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.
5. You can choose to go a traditional experimental design route and choose an independent variable such as the amount of decabromodiphenyl ether and a dependent variable such as the blood concentration of rats (or other mammals that could be extrapolated to humans), or you can look at the problem from more of an epidemiological route, picking a population to take histories of exposure to PBDEs (IV) and then take, for example, blood samples from those individuals (DV). In either case, fill in the following Experimental Design Diagram to describe your experiment.