# The River Mile
## Water Quality

### Lesson # 8

## Water Quality: Bioaccumulation & Biomagnification

Developed by the Lake Roosevelt Forum to support "The River Mile" National Park Service Program

**Suggested duration**:
90 minutes to optional multi day

**Inquiry Question:**
How do contaminants in water impact the food web?

**Inquiry Process:**
Draw conclusions based on data

**Standards:**
LS2, LS3

**Assessment:**
- Collaboration and team participation

**Materials:**
Computer, projector
Bioaccumulation ppt
Simulation Game

**Handouts**:
"You Ate What?"
Bioaccumulation

**Credits/Citations:**
Lake Roosevelt Forum
Remedial Investigation and Feasibility Study "A Public guide"
MEEC Simulation
You Tube Videos
Game Variations
* BioM and PCB's
* BioM - Hg & Algebra
*Up the Food Chain
* Population Dynamics

LESSON # 8

# Water Quality: Bioaccumulation & Biomagnification

INTRODUCTION:
Sediment contaminants can accumulate in the tissues of worms, clams, insect larvae and other organisms (called the benthic community) that inhabit the lake bottom.

Organic contaminants (like PCBs and mercury can biomagnify (increase) in the tissues of species as they move higher in the food chain, e.g., - a single fish will eat many stoneflies, an eagle will eat many fish, etc.

For fish species that accumulate contaminants in their tissue and organs, these toxins can move up the food chain to human, birds, and other species consuming fish. (source LRF Remedial Investigation and Feasibility Study)

STUDENT WORK AND ASSESSMENT
Students compete to survive in a life and death contaminated food web mystery. "Who Will Survive?"

QUESTIONS TO EXPLORE/INSTRUCTIONS/PROCEDURE

1. Show You Tube Videos on Bioaccumulation and Biomagnification
2. Group activity: You Ate What? *Appendix Lesson 8 handouts*
   a. Trace the contaminant path from mining in Canada 100 years ago to that big mouth bass I just ate. LRF Public Guide Bioaccumulation pages
3. Contaminated Food Web: Who will survive?
4. Understand the role of benthic organisms and aquatic plant life in determining which other organisms survive.
   a. In the field students can collect benthic organisms. Determine which feeding groups are more likely to contain contaminates (filter feeders, Shredders, etc.
5. An example activity for junior high/high school kids can be seen at:

http://www.uwsp.edu/cnr/wcee/envsci/Framework/pdf/LivingResources/BioaccumulationinWisconsinFisheries.doc
http://www.bigelow.org/edhab/tracing_toxins.html

OPTIONAL ACTIVITIES:
Research health effects of toxic metals and persistent organic pollutants

HOMEWORK: Continue Unit End Research Project and consider incorporating ideas from this lesson.

# WATER QUALITY: BIOACCUMULATION PATHWAYS
# "YOU ATE WHAT!!!"

Name: _____Date: _____

**Essential Question**:

How is water quality affected by wave interactions with beach sediments from soil erosion, and contaminant deposition?

**Inquiry Questions**:

How do contaminants in water impact the food web?

**Objectives:**

You will:

- Investigate the food web pathway for one day of all the food you ate.
- Trace the contaminant path from mining in Canada 100 years ago to that, "big mouth bass you just caught."
- Understand the role of benthic organisms and aquatic plant life in determining which other organisms survive

## Making Connections:

Use the table provided below:

- ☐ In column #1 - list every food you ate in one day
- ☐ In column #2 - identify the food web sources required for the growth, or production of each food item on your list.
- ☐ Name any possible contaminants

| Foods Eaten | Food Web Sources | Possible Contaminants |
|---|---|---|
| Example: milk | Cows, grass, hay, corn based commercial feed | Antibiotics, growth hormones, pesticides, herbicides, (air born hg particles on grass) |
| | | |
| | | |

| Foods Eaten | Food Web Sources | Possible Contaminants |
|---|---|---|
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## Think Time:

**Draw a diagram, story board or sketch that shows one possible way that mercury from a mining company in Canada could be found in the large mouth bass you just caught near Grand Coulee Dam.**

## View, Listen and Evaluate:

1. **Select one or more of the "You Tube" Videos or the MEEC Simulation.**
    a. **Michigan Environmental Education Curriculum - Bioaccumulation Simulation:** http://techalive.mtu.edu/meec/module02/BioconcentrationandBioaccumulation.htm

    b. **Biomagnification!** http://www.youtube.com/watch?v=E5P-UoKLxlA&NR=1/

    c. **Mercury Pollution--An Invisible Foe that Knows No Boundaries**: http://www.youtube.com/watch?v=xRqAS4Eow-c

    d. **Bioaccumulation of Pollution in Waterways: Animation (April 2010):** http://www.youtube.com/watch?v=MXSv0ifvDjc&feature=player_embedded/

    e. **PacMan Explains Bioaccumulation vs Biomagnification** http://www.youtube.com/watch?v=qgDqho7QqHg&feature=related/

    f. Six legged Spies – Bugs, Bombs & Bioaccumulation http://www.youtube.com/watch?v=p3lED8KvKyw

    g. **TOXIC SEAFOOD WARNING** http://www.youtube.com/watch?v=p0F8x4i5GYE&feature=related

2. **Record 3-5 factual details and your thoughts or ideas about the presentations.**
3. **Write a one sentence summary to explain the process of bioaccumulation.**

**Key points, ideas, and thoughts about the bioaccumulation videos/simulations**

**One Sentence Summary of bioaccumulation:**

## Contaminant Sources

View Power point slides 5-19
In small groups discuss the following questions.
Write your own responses and ideas prior to engaging in group discussion.

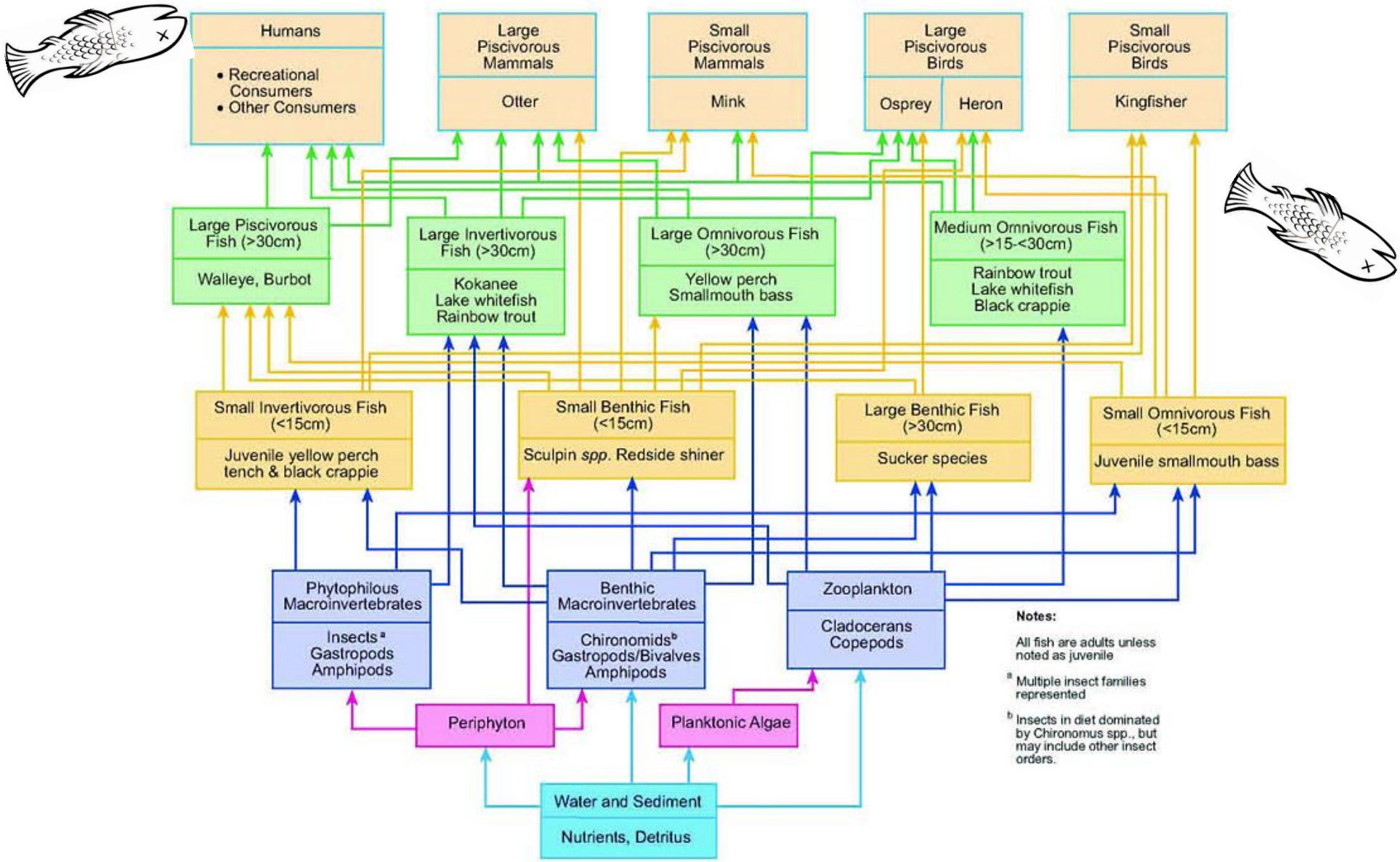
Identify some of the contaminant sources from which toxic metals and persistent organic pollutants have been deposited into the Upper Columbia River and Lake Roosevelt.

Name 3-5 ways that contaminated substances are transported throughout the Upper Columbia River and Lake Roosevelt.

Which species are most vulnerable to toxins? Why?

Which species carry the highest levels of toxins? Explain why using your understanding of bioaccumulation and the food web.

**You Ate What?!!** **Compare the Bio Accumulation Pathways chart below to your previous "Think Time" sketch. Trace one path of contaminated sediment through the food web and consumed by an osprey at Lake Roosevelt.**



## Optional Activities:

1. Bioaccumulation Simulation: Who Will Survive? Biomagnification and Mercury. *Directions for preparation and activity are provided in Lesson 8 appendix.*

2. Create a video, drawing or game to help younger students understand why some Lake Roosevelt fish are not safe to eat for species at the top of the food chain.

3. Research the health effects of a toxic metal or persistent organic compound being measured at North Port.

    a. Do the effects differ based on the species or the age of the organism?

    b. Is the substance toxic at any level or does the effect change with the level of concentration?

## Resources

WQ metals data for North Port http://www.ecy.wa.gov/programs/eap/fw_riv/rv_main.html

**Lesson 8 – Bioaccumulation and Biomagnification Reflections:**

How could bioaccumulation impact our River Mile site?

What evidence have we seen in previous visits? What evidence will we look for on our next site visit?

**WATER QUALITY: BIOACCUMULATION**

How is water quality affected by
wave interactions with beach sediments
from soil erosion, and contaminant deposition?

How do contaminants end up in that big mouth bass you just caught?

WQ Lesson 8 2

## BIOMAGNIFICATION

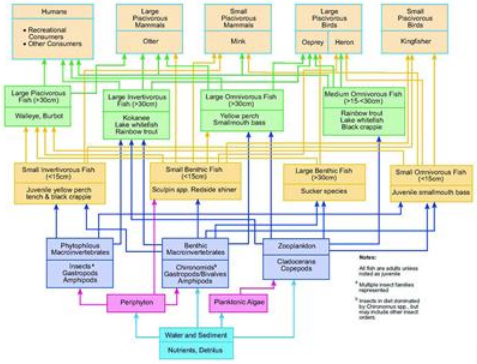
http://www.youtube.com/watch?v=E5P-UoKLxIA&NR=1

**MERCURY POLLUTION -**
**An Invisible Foe that Knows No Boundaries**
http://www.youtube.com/watch?v=xRqAS4Eow-c

Acadia National Park Maine

WQ Lesson 8 3

## BIOACCUMULATION PATHWAYS




WQ Lesson 8 4

## CONTAMINANT SOURCES

- Smelting operations in Trail, Canada are the primary source of metals contamination. Other contaminant sources include pulp and paper production in Canada, other mining operations, atmospheric deposition, the Spokane River, and unidentified sources.

WQ Lesson 8 5

## CONTAMINATION

- Contaminants from effluent (wastewater) and slag can move downstream and be trapped in sediment on the bottom, banks and beaches. They can also attach to fine particles that travel through the water column.

WQ Lesson 8 6

## BIOACCUMULATION

- Sediment contaminants can accumulate in the tissues of worms, clams, insect larvae and other organisms (called the benthic community) that inhabit the lake bottom

WQ Lesson 8 7

## BIOMAGNIFICATION AND FOOD CHAIN

- Organic contaminant concentrations (like PCBs) and mercury can biomagnify (increase) in the tissues of species as they move higher in the food chain, e.g.-- stone fly, to fish, to wildlife or humans

WQ Lesson 8 8

## FISH CONSUMPTION

- For fish species that accumulate contaminants in their tissue and organs, these toxins can move up the food chain to humans, birds, and other species consuming fish.

WQ Lesson 8 9

## REDUCED BIODIVERSITY

- Species that can not tolerate elevated levels of contaminants may die or suffer other adverse effects such as loss of reproductive functions. This can reduce the variety of species in the environment.

WQ Lesson 8 10

## DIRECT CONTACT

- Humans recreating and wildlife foraging on beaches may be directly exposed to contaminated sediments. Help protect your children from any contaminants by washing hands, face, feet and toys before eating and/or leaving the beach.

WQ Lesson 8 11

## AIR TRANSPORT

- Contaminated sediments can be exposed and placed in the atmosphere via windstorms. Human inhalation of dust during these conditions is a potential human risk pathway.

WQ Lesson 8 12

## SEDIMENT MOVEMENTS

- Sediment movement and accumulation is a natural, ongoing process. Flowing water, for instance, can erode, deposit and re-suspend sediments.
- Over time this can change the distribution pattern of contaminated sediments, re-exposing more biota (plant and animal life) to potential toxins. This process can also result in uncontaminated sediments (e.g.--from bank erosion) covering contaminated sediments in a way that reduces the exposure of potential toxins to biota.

WQ Lesson 8 13

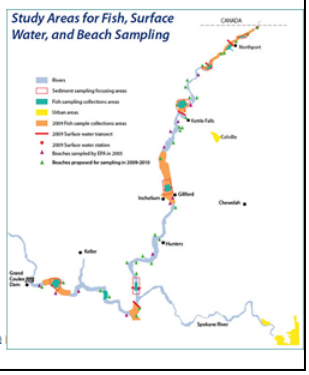
## MEASURING BIOACCUMULATION

- ✓ Beach Sediment Studies
- ✓ Zooplankton Tissue Studies
- ✓ Fish Tissue Studies
- ✓ Surface Water Studies

WQ Lesson 8 14

## BEACH SEDIMENT STUDIES

- Beach sediment data was collected at 15 beaches in 2005 and led to an initial finding that exposure was safely below human health-based risk standards.
- New sampling will be expanded to include 34 beaches from the Canadian border to Grand Coulee Dam.




WQ

## ZOOPLANKTON TISSUE STUDIES

Water Flea Photo: http://www.buffalo.edu/

- Zooplankton is at the base of the aquatic food chain. They include a range of organisms that can drift in the water and individually are undetectable to the naked eye. Lake Roosevelt zooplankton such as water fleas are a critical dietary source for fish in Lake Roosevelt.

WQ Lesson 8 16

## ZOOPLANKTON TISSUE STUDIES

- Do chemicals of interest pose an unacceptable risk to the health of zooplankton?
- Do concentrations of chemicals of interest in zooplankton create a health risk for fish that prey on zooplankton?

**"People use water fleas as aquatic 'coal-mine canaries,'" said Taylor. "They are good indicators of environmental change."**

http://www.buffalo.edu/news/fast-execute.cgi/article-page.html?article=76670009

WQ Lesson 8 17

## FISH TISSUE STUDIES

- What are the tissue concentrations of chemicals of interest in fish species that are eaten by birds, mammals, and other fish? Can these concentrations affect the health of these species or other species that may prey on them?
- Game fish expected to be sampled include walleye, rainbow trout, lake whitefish, large scale sucker, burbot, smallmouth bass, and kokanee. Small body fish (e.g., yellow perch) are also being collected to evaluate ecological concerns. Fish will be collected in different locations throughout Lake Roosevelt.

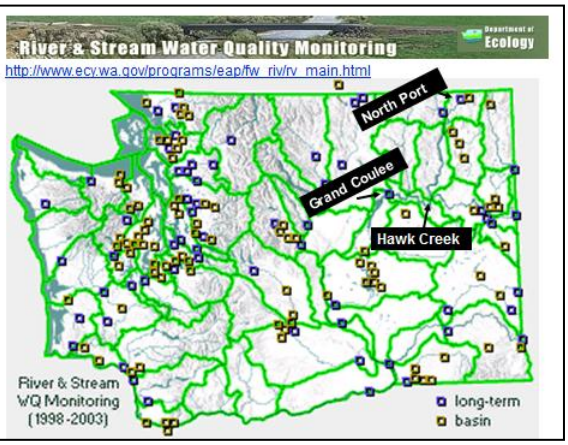
WQ Lesson 8 18

## SURFACE WATER STUDIES

- Chemicals of interest may be present in Lake Roosevelt's water. The surface water study will take place at multiple locations from the Canadian border to Grand Coulee Dam, and during different times of the year. This study will address the following types of questions:

- At any location tested, are chemicals of interest (e.g., Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, PBDE, PCB, Dioxin, Furans… ) below or above protective criteria and guidelines for ecological and human health?
- Are chemicals of interest more concentrated in certain areas or water depths?
- Do chemicals of interest pose unacceptable risks to aquatic life, wildlife or humans by migrating up the food chain?

WQ Lesson 8 19




## 61A070 – COLUMBIA RIVER @ NORTHPORT

http://www.ecy.wa.gov/apps/watersheds/riv/station.asp?sta=61A070


LOCATED AT THE BRIDGE CROSSING THE COLUMBIA RIVER ON STATE HIGHWAY 25, IMMEDIATELY NORTHEAST OF NORTHPORT

Overall water quality at this station is of moderate concern. (72/100 based on water-year 2008 summary)

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## NORTH PORT- METALS MEASURED

- Ag Silver
- As Arsenic
- Cd Cadmium
- Cr Chromium
- Cu Copper
- Hg Mercury
- Nl Nickel
- Pb Lead
- Zn Zinc

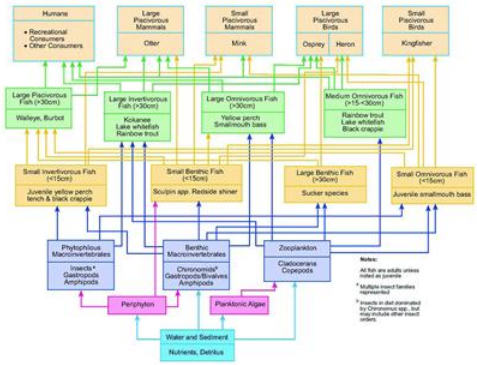
**Optional:**

**Do Your Own Research:**

- In what ways could each metal affect the health of organisms shown in the bioaccumulation pathways chart?
- How much is too much? Analyze the North Port data. Which, if any, metals exceed safe limits?

WQ Lesson 8 22

## BIOACCUMULATION PATHWAYS

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# Water Quality: Toxic Metals and Persistent Organic Pollutants

Pure water, $H_2O$, is hard to find outside of the laboratory. As precipitation moves over and through the earth chemicals are dissolved in the water. Wastes are placed on and in the land and discharged to lakes and streams can contaminate the water. Pollutants are materials added to water which can cause bad effects if present in high enough concentrations. Communities work together to reduce contaminant levels and make sure that we have good water quality.

Mercury... dioxin... phosphorus... coliform bacteria... we often hear of these pollutants and their impacts on our lives. Typically present in the environment only at trace levels, these substances can have serious effects on human and ecosystem health. Some pollutants come from near our homes and others from far away, but they are present across the United States of America and the world.

## Toxic Metals

- **Arsenic**
- **Cadmium**
- **Lead**
- **Mercury**

## Persistent Organic Pollutants

- **PCBs/PBDEs**
- **DDT**
- **Aldrin/Dieldrin**
- **Dioxins/Furans**

Toxic substances can act as a poison, producing either immediate (acute) illness following short-term exposure to high concentrations or delayed (chronic) effects after long term exposure at lower levels. Many of these materials cause birth defects, gene mutation and/or cancer. Two classes are typically recognized: toxic metals and persistent organic pollutants. The word persistent, which could well be applied to both classes of toxic substances, is important because it means that the chemical hangs around long enough to enter the food chain and cause harmful effects.

One of the problems with many of the toxic substances is that they build up in the bodies of aquatic organisms to levels which can harm humans that consume them. Uptake of a chemical from the water and from eating other contaminated organisms is called bioaccumulation.

This animation illustrates the process (http://techalive.mtu.edu/meec/module02/BioconcentrationandBioaccumulation.htm ). A toxic substance is emitted from a land-based source and is deposited in a lake. Phytoplankton (free-floating algae) absorb the chemical and are grazed upon by zooplankton (free-floating animals), concentrating the toxicant. The zooplankton are then consumed by small fish which are, in turn preyed upon by larger fish. As the toxicant is transferred up the food chain, its concentration can be magnified by bioaccumulation as much as a million times. Here, bioaccumulation is reflected deepness of the red color and the height of the bar as the chemical moves up the food chain.


## Toxic Metals: Arsenic

Arsenic is a semi-metallic material, often grouped with the toxic metals. Compounds containing arsenic were used as long ago as Roman times and the Middle Ages as a poison in murders and suicides. Prior to the development of synthetic organic chemicals, arsenic was used as a pesticide and it still serves this purpose in parts of the world.

Arsenic can be released during the mining and smelting of metals (gold, lead, copper, and nickel), in the production of iron and steel, and in coal combustion. Hazardous waste dumps also may serve as a site for arsenic exposure. Arsenic also occurs naturally in some soil, rocks and water (see EXPLORE). Chronic exposure to arsenic can cause skin disease and cancer, while acute exposure can cause lung distress and death.


## Toxic Metals: Cadmium

Cadmium is a metal found in natural ore deposits and is used in the manufacture of machinery, transportation, and electronic equipment. It is also found in some batteries and paint pigments. This heavy metal reaches the environment through the leaching of ore deposits, from industrial releases and landfills and corrosion of water pipes. Metal processing (smelters) are also major sources.

Exposure to cadmium in water can cause a variety of acute and chronic effects including vomiting, muscle cramps and damage to the liver and kidneys.

**EXPLORE:**

Learn about the successful clean-up of a cadmium pollution problem. Cadmium cookies???


## Toxic Metals: Mercury

Mercury in its elemental form is a shiny liquid nicknamed quicksilver. Toxicity effects include damage to nerve and muscle systems and can cause death (see EXPLORE). Chronic exposure can lead to emotional problems. Hat makers in the 1800s used mercury to prepare furs and this exposure often led to strange behaviors. This is where the Mad Hatter in *Alice in Wonderland* got his name.

Today, one of the most common mercury products is the amalgam used in dental fillings. Amalgam accounts for more than half of the total mercury used commercially. Although there is no evidence that dental fillings pose health risks, the use of mercury amalgam is being phased out to reduce discharges of mercury to nature.

Mercury enters the environment when coal is burned to make electric power. The mercury falls back to the earth and into lakes where microbes change it into a special form (methylmercury) which can build up in fish. It is especially important to protect unborn babies (who get the mercury through their mothers) and children from mercury pollution. The government tells us what kinds and how much fish is safe to eat.

## Persistent Organic Pollutants: PCBs

Polychlorinated biphenyls are synthetic organic (carbon-based) compounds which were used in electrical fixtures, machinery, plastics and inks. Over 1.5 billion pounds of PCBs were manufactured between their invention in 1929 and implementation of a government ban in 1977. They cause cancer and other adverse health effects in lab animals and are thought to result in similar problems in humans.

Today, the major sources of PCBs are environmental reservoirs remaining from periods of significant use. PCBs move easily from air to soil and water and thus have been distributed around the globe. PCBs pose environmental problems because they are persistent and because they accumulate in the bodies of aquatic organisms such as fish. Government advisories recommend that we avoid eating certain fish from specific bodies of water (see EXPLORE), e.g. carp and catfish from the Saginaw River in Michigan.

Another group of industrial chemicals of environmental concern is PBDEs (Polybrominated Diphenyl Ethers). Their structure is similar to PCBs with bromine replacing the chlorine atoms. PBDEs are used as flame retardants in furniture and electronics. These chemicals, presently banned in Europe, have many of the same properties and potential health effects of PCBs and are present in the air, water and biota of the Great Lakes.

## Persistent Organic Pollutants: Aldrin/Dieldrin

Pesticides are among the most common persistent organic pollutants, making up all but one of the 'Dirty Dozen' toxic chemicals represented by the United Nations (see EXPLORE). DDT is the most famous of these and was the focus of Rachel Carson's 1962 book 'Silent Spring' which helped make the public aware of the environmental effects of pesticides.

Aldrin and dieldrin are two closely-related pesticides (aldrin breaks down to form dieldrin in organisms). These chemicals are now banned in most countries, but were once used to control soil pests which damaged crops such as corn, potatoes and fruit. Dieldrin was also used to control insects, such as the tsetse fly, which spread tropical diseases. Aldrin and dieldrin persist in the environment and can travel through the air to contaminate environments far from their original site of application. Aldrin and dieldrin bioaccumulate in aquatic organisms, resulting in reproductive problems. Acute exposure in humans can cause seizures and death, while chronic exposure leads to headache, dizziness, vomiting and psychological/nerve disorders.

## Persistent Organic Pollutants: Dioxins and Furans

The first two persistent organic pollutants that we considered, PCBs/PBDEs and Aldrin/Dieldrin, were intentionally manufactured to meet specific consumer needs. This is not the case with dioxins and furans. Among the most toxic chemicals known, these compounds are not intentionally produced, but rather are byproducts of chemical and combustion processes. The primary path by which dioxins/furans enter the environment is through the air, where forest fires and incineration of hazardous, medical and municipal wastes are major sources. Dioxins/furans are discharged to water by pulp and paper mills that use chlorine to make the paper whiter.


Like many other toxic substances, dioxins and furans, are persistent and have a tendency to bioaccumulate, making them of particular environmental significance. Studies of health impacts on humans are limited. Dioxins/furans are known to cause cancer and to disrupt reproduction and development in animals. One of the major dioxin issues in the State of Michigan relates to contamination in the flood plain of the Tittabawassee River downstream of Dow Chemical Company. The Michigan Department of Environmental Quality and Dow have recently reached an agreement which will lead to cleanup of dioxin contamination in Midland, along the Tittabawassee River, the Saginaw River, and Saginaw Bay.

# Regulation of Toxic Substances in the Environment

The environmental awakening, ignited by Rachel Carson's 1962 book 'Silent Spring' and leading to the first Earth Day in 1970, prompted Congress to pass several laws to protect humans and wildlife from exposure to toxic substances. These laws give the U.S. Environmental Protection Agency the authority to regulate the manufacture and disposal of toxic materials and to clean up existing hazardous waste disposal sites. The Toxic Substances Control Act (1976) calls for the government to track industrial chemicals, screening them for environmental or human health hazards. If a chemical poses an unreasonable risk, its import or manufacture can be banned.

The Resource Conservation and Recovery Act (1976) provides for management of hazardous waste from 'cradle to grave', i.e. generation, transportation, treatment, storage, and disposal. A document follows the waste from 'birth' (generation) to 'death' (disposal) so that chemicals can be tracked until they are safely disposed.

The Comprehensive Environmental Response, Compensation, and Liability Act (1980), also called Superfund, supports the cleanup of abandoned or uncontrolled hazardous waste sites. Taxes placed on the chemical and petroleum industries under Superfund and its successor SARA (Superfund Amendments and Reauthorization Act, 1986) have provided a fund of $8.5 billion to pay for cleanup projects.

# Regulation of Toxic Substances in Drinking Water and Wastewater

Other legislation protects us by limiting concentrations of toxic substances in the water we drink and in the treated wastewater that we discharge to the environment. The Safe Drinking Water Act (1974) sets levels of toxic metals and organic chemical permitted in water delivered to the public. These limits are called maximum contaminant levels or MCLs. For example, the MCLs for cadmium and PCBs are 5 and 0.5 parts per billion, respectively.

The Clean Water Act (1977) seeks to make all of our nation's waters 'fishable and swimmable'. Under this legislation, 127 priority pollutants (metals and organic chemicals) are identified and limits set for their concentrations in wastewater treatment plant effluent and in the lakes and rivers which receive those discharges. All wastewater treatment facilities are required to get a permit which specifies the quality of the treated wastewater that they discharge to the environment.

# Toxicity Testing

Sometimes it is not the concentrations of individual chemicals which cause problems, but rather interactions among them and with the receiving water. These effects are determined through toxicity testing. U.S. EPA has identified 10 common freshwater and marine organisms for use in the test. Among the most common 'lab rats' for toxicity tests are the water flea (Daphnia pulex) and the fathead minnow (Pimephales promelas).

**Fathead Minnow**

**Water Flea**


# Toxicity Testing Activity

Test organisms are placed in glass or plastic bottles containing the water to be tested and left there for 2-4 days. Bottles are set up for pure effluent, several dilutions of that effluent and a control water (where no more than 10% of the organisms should die). The percentage of organisms surviving exposure in each bottle is determined and the toxicity of the effluent is expressed as the effluent dilution which is lethal to 50% (LC50) of the population. An acute toxicity unit is defined as 100/LC50. The State of Michigan limits discharges to 1 acute toxic unit. If the effluent contains more than that, the treatment plant must add new processes to reduce the toxicity of their discharge.

**You Tube Videos** Search key words: Bioaccumulation & Biomagnification

| Biomagnification! | |
|---|---|
| URL | http://www.youtube.com/watch?v=E5P-UoKLxlA&NR=1 |
| Producer | **GarnetVengeance** |
| Posted Description | **A video I did for science class that helps explain Biomagnification. The text rolls by a little fast, but other than that, I really like it.<br>Uses the song 'Tank!' from Cowboy Bebop.** |
| Length | 2:03 |
| # Views | 14,223 |
| Selection Comments | |

| Mercury Pollution--An Invisible Foe that Knows No Boundaries | |
|---|---|
| URL | http://www.youtube.com/watch?v=xRqAS4Eow-c |
| Producer | NPS SERC Institute August 12, 2010 SERC Institute is the nonprofit partner of the Schoodic Education and Research Center of Acadia National Park. Its mission is to guide people to greater understanding of nature by providing research and learning opportunities. |
| Description | mercury deposition , Acadia National Park, biomagnification |
| Length | 4:22 |
| # Views | 41 |
| Selection Comments | |

| Bioaccumulation of Pollution in Waterways: Animation (April 2010) | |
|---|---|
| URL | http://www.youtube.com/watch?v=MXSv0ifvDjc&feature=player_embedded |
| Producer | New York State |
| Posted Description | Science & Technology |
| Length | 1:09 |
| # Views | 1,997 |
| Selection Comments | **New York State routinely produces health advisories for fish caught in local waters. These advisories are based on the potential for harmful substances- that is, pollutants- to be present in the flesh of the fish, which can be transferred to humans through consumption. The advisories vary depending upon the species of fish and the location where its caught, but generally, the higher up the food chain a fish is, it has potentially higher contamination levels. But how does pollution get into a fish in the first place? And why do larger, predatory fish have more of it? The answer to the first question is, from the environment. As for the second, bioaccumulation is the term referring to the accumulation of substances in an organism. Check out the animation to see how pollution gets from the environment into fish and concentrates in larger fish.** |

| PacMan Explains Bioaccumulation vs Biomagnification |
|---|

| | |
|---|---|
| URL | http://www.youtube.com/watch?v=qgDqho7QqHg&feature=related |
| Producer | **ClinicalVideoStudios** \| September 10, 2009 PacMan (c) to Namco |
| Posted Description | What's the difference between Bioaccumulation and Biomagnification? Let's learn with PacMan! |
| Length | 1:45 |
| # Views | **1,409** |
| Selection Comments | Used for Educational Purposes Only |

| **Biomagnification of Pollution in the Environment** | |
|---|---|
| URL | http://www.youtube.com/watch?v=ezw-CJkPCEc |
| Producer | **jfrey0725** \| September 10, 2010 Student Project |
| Posted Description | How pollutants bioaccumulate in the environment, and how it affects humans |
| Length | 3:43 |
| # Views | 210 |
| Selection Comments | Education Music by **Prince Negaafellaga** - Introduction (Feat.Starcrimes,A-Million) |

| Six legged Spies – Bugs, Bombs & Bioaccumulation | |
|---|---|
| URL | http://www.youtube.com/watch?v=p3lED8KvKyw |
| Producers | **vculifesciences** \| June 25, 2008<br>**Virginia Commonwealth University** |
| Description | Insects are everywhere, on everything, in everything — which makes them a terrific first line of detection for biological weapons attack. Bugs sample the environment thoroughly — if it's out there, it's on the insects. Spectrometry, PCR and genetic analysis turn them into weapons against bioterrorrism. |
| Length | 5:21 |
| # Views | **1,313** |
| Selection Comments | **All 50 Secrets of the Sequence videos have an accompanying classroom-tested lesson that encourages students to further explore the video topics. Each lesson includes background information, state and national science standards, discussion questions and answers, teacher notes and an activity that will ensure a hands-on, "minds-on" experience. To see lessons for this series, visit http://www.pubinfo.vcu.edu/secretsoft...** |

| TOXIC SEAFOOD WARNING | |
|---|---|
| URL | http://www.youtube.com/watch?v=p0F8x4i5GYE&feature=related |
| Producer | ABC News .com **Orbit26200** \| November 08, 2007 |
| Description | Beware of imported seafoods many cannot pass minimum food standards |
| Length | 3:38 |
| # Views | **1,836,443** |
| Selection Comments | |

| BP Is Ignoring Health Concerns | |
|---|---|
| URL | http://www.youtube.com/watch?v=I1HJwEH8eNg&feature=channel |
| Producer | **Congressman Nadler** \| June 09, 2010 |
| Description | Congressman Nadler's opening statement during a House Transportation and Infrastructure Committee hearing on the Deepwater Horizon BP Oil Spill. During the hearing Congressman Nadler outlined the need to enforce all response and recovery workers responding to the Deepwater Horizon BP Oil Spill be provided proper protective equipment, including respirators, and that all federal laws governing worker safety and respiratory protection be enforced.<br><br>According to news reports, numerous workers have fallen ill after exposure to the oil, the dispersants, or some combination of the two. |
| Length | 2:36 |
| # Views | 822 |
| Selection Comments | |

# Biomagnification

**By: Kirstin Bittel, Rachel Hughes, and Sally Rusk**

| | |
|---|---|
| **Time:** | 1-2 class periods |
| **Preparation Time:** | 5 minutes copying overhead |
| **Materials:** | Biomagnification Overhead<br>DDT Half Life Overhead |


## Abstract

A lesson integrating the creation of algebraic equations with biomagnification.

Purpose – To algebra to explain how the build up of small levels of contaminates can quickly become detrimental to species higher in the food chain


## Objectives

Students will be able to: Use data to create an algebraic equation.

## Math Standards: *Algebra*

Represent and analyze mathematical situations and structures using algebraic symbols.
Use mathematical models to represent and understand quantitative relationships.

## Teacher Background

Biomagnification is the increase in a contaminant from one member of the food chain to another.

## Resource Websites

http://www.on.ec.gc.ca/community/classroom/millennium/m3-science-assign2-e.html
http://www.marietta.edu/~biol/102/2bioma95.html
http://www.epa.gov/pesticides/about/index.htm

## Activity

### *Engage*

Ask student, “Did you know that the chemical DDT, which was banned in the United States in the 1960s is still around and can affect us today? How do you think that is possible?” Allow a few minutes for students to share ideas.

### *Explore*

Put up the Biomagnification Overhead
Ask students the following questions

1. Let's look at our food chain to see how biomagnification works. Let's say for example that each piece of plant material has one microscopic drop of methyl mercury. One insect eats 25 pieces of plant material that would mean that each insect would have _____ microscopic drops of methyl mercury in its body. (25)

2. If one small fish needs 10 insects to live, then one fish would have _____ microscopic drops of methyl mercury. (250)

3. One big fish eats 5 small fish to live. So, one big fish would collect a total of _____ microscopic drops of methyl mercury in its body. (1250)

4. What about you and me? Lets say we eat 1 big fish a day for 3 days. We would collect a total of _____ drops of methyl mercury in our body over the 3 days. This is how biomagnification works! (3750)

***Explain:*** So what does this have to do with us?

5. Now let's say that methyl mercury makes living things sick. The more methyl mercury in the living organism, the more sick it would get. From our example above, which organism will be most affected by the toxin methyl mercury? _____

Using the information from your paper and the overhead. Create an algebraic equation that will calculate how much metal mercury is in our bodies based upon how much food our food ate. Keep in mind the number of plants and insect eats is variable.

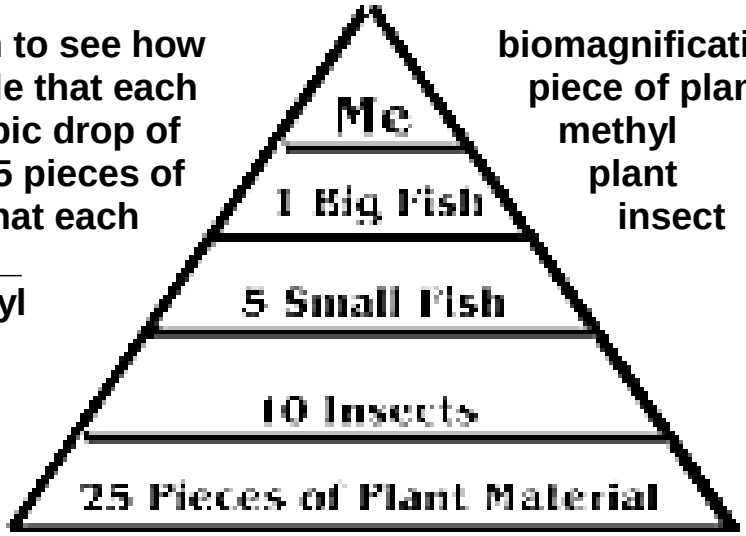
***Expand***
How do they feel now about GMF's? Tell students to be prepared to defend their view using evidence from their piece. Students write this information down on easel paper shared between their group to then share with the class.

***Evaluate***
Did the students correctly calculate the levels of methyl mercury in the example?
Were the students able to write a correct algebraic equation with multiple variables?
Where the students able to take the metal mercury model and expand it to DDT?
*Theoretical calculations are ok. It gives the students an idea of how quickly contaminants add up, but give extra credit to students whose data accurately reflects eating habits of species on the pyramids.

**Homework**
Complete Expand piece to share in class tomorrow.

# Biomagnifications

1. **Let's look at our food chain to see how biomagnification works. Let's say for example that each piece of plant material has one microscopic drop of methyl mercury. One insect eats 25 pieces of plant material that would mean that each insect would have _____ microscopic drops of methyl mercury in its body.**

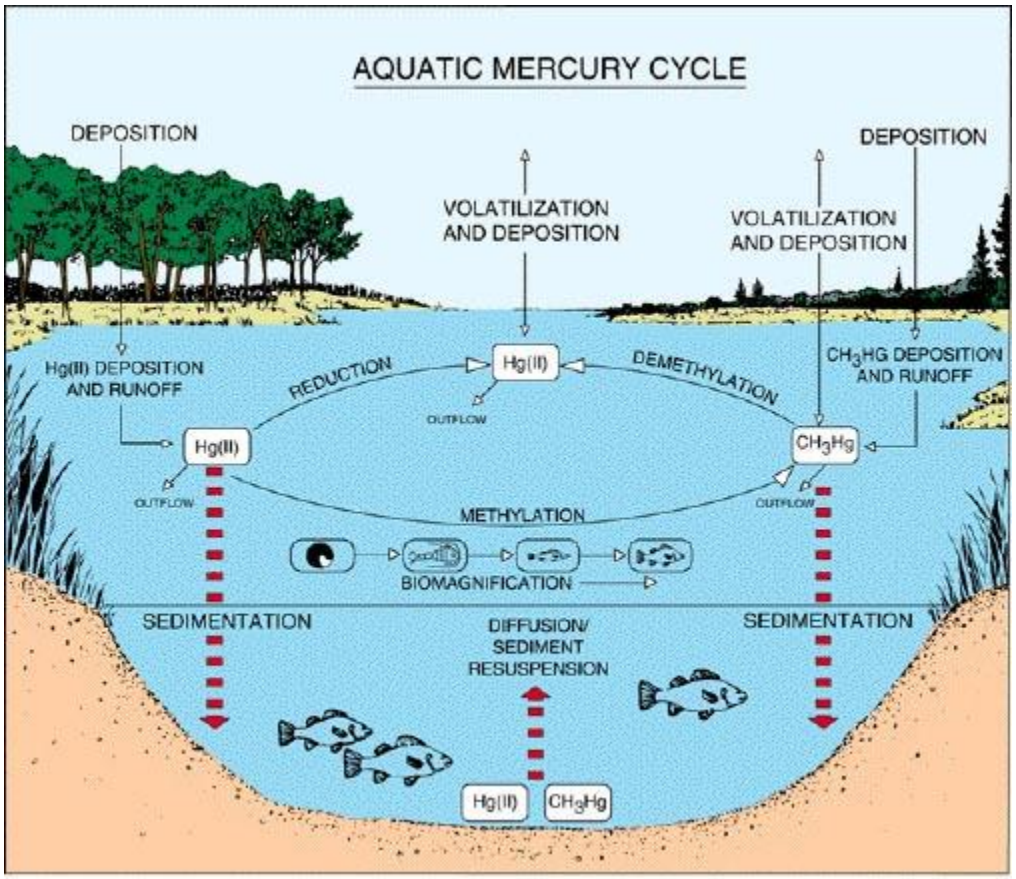



2. If one small fish needs 10 insects to live, then one fish would have _____ microscopic drops of methyl mercury.

3. **One big fish eats 5 small fish to live. So, one big fish would collect a total of _____ microscopic drops of methyl mercury in its body.**

4. **What about you and me? Let's say we eat 1 big fish a day for 3 days. We would collect a total of _____ drops of methyl mercury in our body over the 3 days. This is how biomagnification works!**

5. Now let's say that methyl mercury makes living things sick. The more methyl mercury in the living organism, the more sick it would get. From our example above, which organism will be most affected by the toxin methyl mercury?
   _____


AQUATIC MERCURY CYCLE
DEPOSITION
VOLATILIZATION AND DEPOSITION
VOLATILIZATION AND DEPOSITION
DEPOSITION
Hg(II) DEPOSITION AND RUNOFF
REDUCTION
Hg(II)
OUTFLOW
DEMETHYLATION
CH3HG DEPOSITION AND RUNOFF
Hg(II)
CH3Hg
OUTFLOW
OUTFLOW
METHYLATION
BIOMAGNIFICATION
SEDIMENTATION
DIFFUSION/ SEDIMENT RESUSPENSION
SEDIMENTATION
Hg(II)
CH3Hg

# DDT Half Life Data

**DDT stands for *d*ichloro, *d*iphenyl *t*richloroethane. It is a** chlorinated hydrocarbon**, a class of chemicals, which often fit the characteristics necessary for biomagnification.**

**DDT has a half-life of 15 years, which means if you use 100 kg of DDT, it will break down as follows:**

| Year | Amount Remaining |
|---|---|
| 0 | 100 kg |
| 15 | 50 kg |
| 30 | 25 kg |
| 45 | 12.5 kg |
| 60 | 6.25 kg |
| 75 | 3.13 kg |
| 90 | 1.56 kg |
| 105 | 0.78 kg |
| 120 | 0.39 kg |

**This means that after 100 years, there will still be**

**almost 1 kg of DDT left in the environment.**

**Grade Level:** 10+
**Subject:** Science
**Duration:** 1 class

*Population and Bioamplification Game*

**Scope and Sequence:**
This game simulates population dynamics and bioamplification of a toxin in a food chain.

**Materials Needed:**
2 dice, 25 small cups, 5 large cups, 250 game pieces, 8 to 12 players.

The game pieces could be bread bag tags or bingo type plastic markers (multi-colors but only about 25 blue and 25 yellow—or whatever colour you have least).

**Class Management:**
Assign roles to the players. One player is Mother Nature. The next player to the left is the *predator* (a prairie falcon) and all of the rest of the players around the table are the *prey* (field sparrows). Ten small cups are distributed among the sparrows; each containing two game pieces. Each game piece represents one unit of energy that has been converted into *biomass*. Groups of 8-12 works best, if there are less numbers, give out 2 cups.

**Activity Procedure:**
Rules for Play:

1. Each player who represents prey (field sparrows) rolls a die and collects as many energy units (random colours picked by Mother Nature) as indicated on the die. The roll of the die affects all of the sparrows represented by that player if there is more than one.
2. The player representing the predators then rolls the die – one roll for each falcon. The number on the die indicates the number of sparrows in total that fall prey to the falcon. The falcon chooses which sparrows will be eliminated. All of the sparrow's biomass energy goes to the falcon. The remaining indigestible material (the cup) is recycled through the *nutrient cycles* back to the Earth (Mother Nature).
3. Sparrows that have an abundance of energy (7 units) are capable of breeding. They can ask Mother Nature for a new cup and transfer about half of their energy to their offspring. If all cups are in use, half of that sparrow's energy units are forfeited to Mother Nature – the offspring have emigrated away from this ecosystem. The *carrying capacity* of the ecosystem is 25 sparrows (cups).
4. Falcons require 70 units of energy to breed.
5. Sparrows die immediately if they give up all their biomass.
6. If a falcon cannot catch the required amount of prey as shown on the dice, the falcon will die. The last five sparrows in play can never be caught by the falcons – their population is so small that falcons have a hard time identifying their presence.

7. Each player has a graph on which to record the population changes as the game progresses. At the end of each round, the remaining sparrows are distributed among the players who represent the prey.

Normal Game: Play begins with the first sparrow to the left of the predator rolling the dice and accumulating the correct number of energy units. When the play passes to Mother Nature, a Life and Death card is drawn. All players must follow the directions on the card. Play continues clockwise to the falcons and then to the sparrows. The game ends when the time limit (set by the teacher) is reached or after ten generations.

Poison Food Game: The yellow game pieces represent energy that has been obtained from food that is poisoned with an *organic pesticide* (like DDT). These game pieces cannot be forfeited to Mother Nature as payment to stay alive, but they can pass from prey to predator. If any sparrow accumulates 2 yellow game pieces, this sparrow is incapable of breeding. If 3 game pieces are accumulated, the sparrow dies. If a falcon accumulates 4 game pieces, it cannot breed. Falcons have a higher *tolerance* for the poison, but they will die if they accumulate 5 game pieces.

Rule Summary:

| | Sparrows | Falcons |
|---|---|---|
| Energy units needed to stay alive | 1 | # of sparrows caught on each roll |
| Energy units needed to breed | 7 | 70 |
| Yellow energy units to prevent breeding | 2 | 3 |
| Yellow energy units to cause death | 4 | 5 |

# Analysis

1. Draw a population graph that shows number on the y-axis and generation time on the x-axis. Record populations of **sparrows and falcons** on the same graph. Use differently coloured lines for the normal version of the game and the poisoned food version.
2. Define the *italicized* words that you've read so far.
3. At any time in the game were the population levels stable? That is, was the ecosystem supporting the populations so that their numbers remained relatively constant? Explain.
4. What effect do the nutrient cycles have on the ecosystem shown in this game?
5. How is the concept of *bioaccumulation* demonstrated in the simulation game?
6. How is the concept of *biomagnification* demonstrated in the simulation game?
7. What effect does biomagnification have on the stability of the species in this ecosystem? Your graph should help you answer this question.
8. List all of the environmental factors that affect populations that you can think of that are described in the Life and Death cards.

9. Are the factors that you listed in the last question dependant upon the "crowdedness" of the population (density dependent) or not (density independent)? **This question will require some discussion and insight!**

**Modifications/Adaptations:**
Vary the number of students representing prey to involve the whole class. This might require varying the number of game pieces.

The ratio of red game pieces to the rest is also variable. This will determine the amount of time before one species becomes extinct.

Variation to introduce Darwinian evolution: Instead of the rule which does not allow the last five sparrows to be caught, consider a different colour of game piece to represent a special gene. It could represent a gene for protective colouration or some other survival advantage. Sparrows with this gene can never be chosen as prey by the predator.

Relations to Curriculum:

**Grade 10: Sustainability of Ecosystems learning objectives SE2, SE3, SE5**
**Biology 20: Ecological Organization learning objectives 2.6, 4.1, 4.2, 5.1-5.4**
**Biology 30: Evolution learning objective 1.2**

Additional Resources:

**http://en.wikipedia.org/wiki/Population_growth**

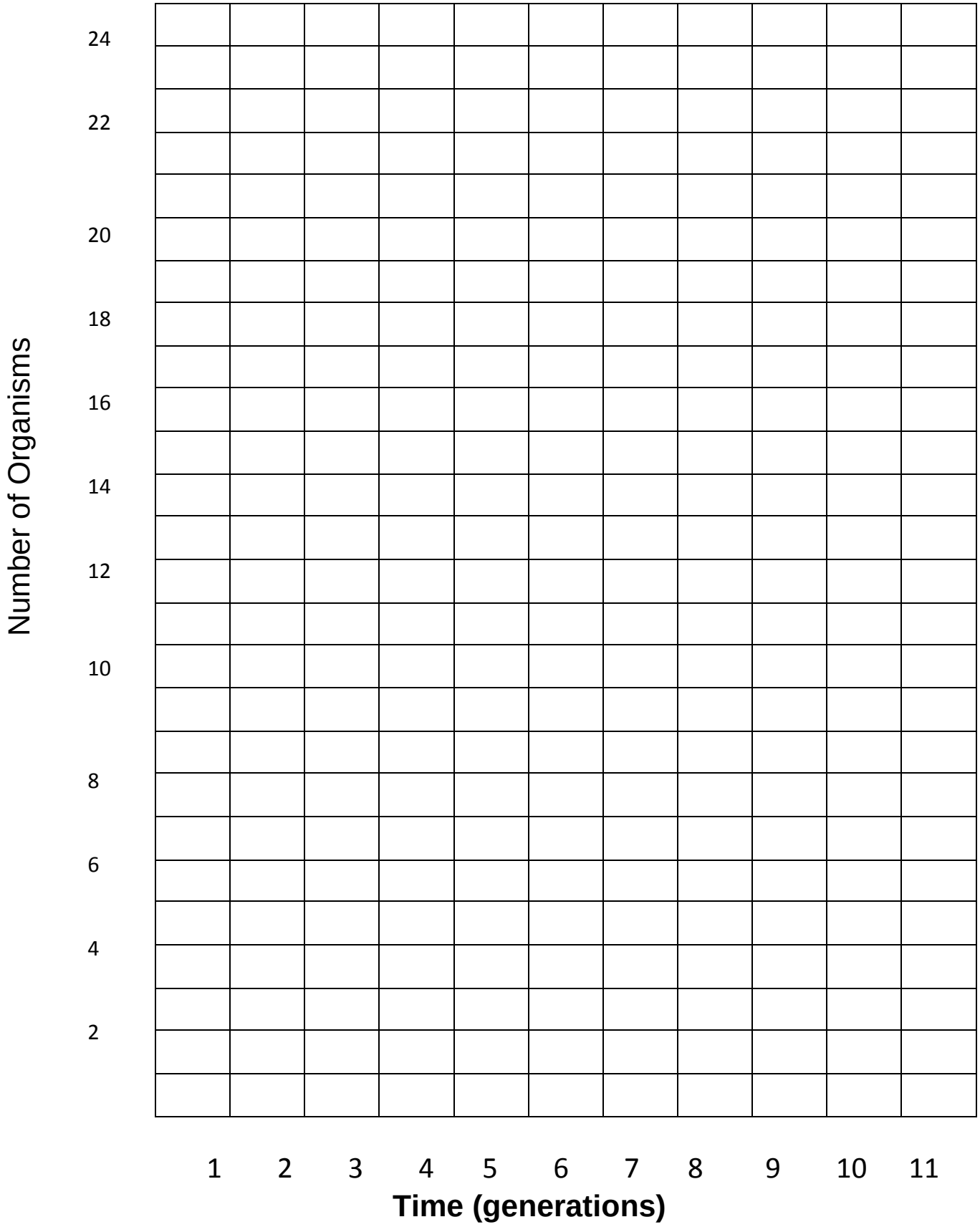
**http://www.geography.ndo.co.uk/analysingpop.htm**

**http://www.geography.learnontheinternet.co.uk/topics/popn1.html**

**http://www.globaleye.org.uk/secondary_summer2002/focuson/index.html**

References:

**David Hall, Swift Current Comprehensive High School**


Number of Organisms
24
22
20
18
16
14
12
10
8
6
4
2
1 2 3 4 5 6 7 8 9 10 11
Time (generations)

# Life or Death

A spring flood has washed away topsoil in the ecosystem and destroyed some grasses. One out of every four sparrows dies. Count and graph your populations.

# Life or Death

An early fall frost has forced a late harvest. Many crops remain in the field. Each sparrow gets 3 energy units. Count and graph your populations.

# Life or Death

A new species has moved into the ecosystem to provide an additional prey for falcons. Each falcon gets 5 energy units. Count and graph your populations.

# Life or Death

Ornithologists have come to study the sparrow population. Their presence has caused one out of every four sparrows to emigrate. Count and graph your populations.

**Life or**

More nesting spaces are available for the sparrows because of a shelterbelt growing in the ecosystem. Four more sparrows (2 units each) are hatched. Count and graph your populations.

**Death**

**Life or**

The black capped chickadee population decreased due to predation, so there is more food for sparrows. Each sparrow receives 1 energy unit. Count and graph your populations.

**Death**

**Life or**

Environmental conditions have activated a lethal gene in the sparrow population. Any sparrow with a blue energy unit dies. Count and graph your populations.

**Death**

**Life or**

A late spring storm has set back the maturation of wild grasses. Every sparrow forfeits one energy unit. Count and graph your populations.

**Death**

**Life or**

A drought has occurred. All sparrows forfeit one energy unit and all falcons forfeit two energy units. Count and graph your populations.

**Death**

**Life or**

Warm weather and lots of rain have increased productivity. Every sparrow gets one extra energy unit and every falcon gets four. Count and graph your populations.

**Death**

**Life or**

A new type of bird flu has infested your sparrow population. Every third sparrow dies. Count and graph your populations.

**Death**

**Life or**

A red tailed hawk has moved into the ecosystem and is competing with the falcons for food. Each falcon must forfeit 3 energy units. Count and graph your populations.

**Death**

# Who Will Survive?

# Biomagnification and Mercury

Grades 6-12

## Learning outcomes

Students simulate the flow of mercury up through the food web as it contaminates the soil, water and air; is integrated into plant material; consumed and through a process called biomagnification becomes highly concentrated. Simple and easy to prepare paper cutouts are used to represent plant & animal matter containing mercury consumed by zooplankton, macroInvertebrates, small, medium & large fish, birds, mammals and humans. Students record and analyze the amount of mercury taken in by each species as the game rounds move from producers to herbivore, carnivore and omnivore consumers.

## Teacher planning Written by University of North Carolina Chapel hill

**TIME REQUIRED FOR LESSON -** 1 hour

**MATERIALS TO PREPARE AHEAD**

- Bioaccumulation Pathways chart ( L8 Student handout page 6)
- 10 strips of red colored paper to represent aquatic plants Planktonic Algae & Periphyton (Each Student = ES)
- 5 strips of blue colored paper to represent Zoo plankton, Benthic Macroinvertebrates and Phytophilous Macroinvertebrates (ES)
- 3 strips of yellow colored paper to represent small omniverous fish, large & small benthic fish, and small Invertiverous fish (ES)
- 10 strips of green colored paper to represent medium and large omniverous, intertiverous and piscivorous fish (Whole group=WG)
- 3–5 strips of brown colored paper to represent small & large piscivorous birds and mammals and humans (WG)
- masking tape
- markers or crayons for each student

## Activities

1. Post a key at the front of the room identifying what each color strip represents:.
2. Give each student four or five of the strips of paper representing aquatic plants. Using markers or crayons have the student place two colored dots on one strip, three dots on the next strip, four dots on the next strip and five dots on another strip. The optional fifth strip may be left plain or have one dot put on it. Explain that these dots represent the metal mercury that have been taken into the plants from pollution in the water.
3. Collect all of the strips then scatter them about the room.
4. Tell the students that they are going to be zooplankton, and macroinvertebrates eating the plants. Give them about fifteen to twenty seconds to go out and collect as much food as they can.
5. When students have returned to their seats, have them count the number of dots their zooplankton/macroinvertebrates “ate” and put the total number of dots onto a blue colored strip to represent their zooplankton/macroinvertebrate (this paper was given to the students in the beginning). Have them also make another blue colored strip with the same number of dots as the first. Set this second set off to the side for use in step seven.
6. Draw a number line on the bottom of the board and label numbers covering the range of dots taken in. Each student can then tape one of his/her fish above the appropriate number, making an effective pictograph or line plot of the results. Discuss what information can be obtained from the graph and determine the mean, mode, median, and range of the graphed data. Discuss what each of these terms means and how it might be important.
7. Take up the second zooplankton/macroinvertebrate from each student and scatter them about the room as was done with the “plants.”
8. Give the students fifteen to twenty seconds to collect as many zooplankton/macroinvertebrate as they can.
9. Repeat step six using the brown colored strips to represent eagles.
10. Compare the amount of chemicals taken in by the fish with the amount of chemicals taken in by the eagles.

Assessment

Take up all of the “fish” strips and all of the “eagle” strips. Divide the students into two or three smaller groups. Next, randomly distribute the fish strips then the eagle strips to the groups. Have students make their own pictographs from the data collected, then write their own definition of biomagnification.

Instructions to Students:

- Draw the pictograph using a key that shows a fish and eagle standing for a particular amount (i.e., one fish is equal to two dots).

- Correctly show the numbers of dots the fish and the eagles had.
- Give a brief definition, in your own words, of what biomagnification is (A sample student definition might be: when toxic metals like mercury get into rivers and other bodies of water and build up into plants that animals eat. Those chemicals build up in the animals as they move through the food chain).

## COMMENTS

Extension Activities:

1. A further math extension would be to figure the contaminate level of fish and of eagles as percent of weight. Students may research average bald eagle weights and average weight of fish caught, or you may use ten pounds as the average eagle weight and $1^1/_2$ pounds for each fish weight.
2. Use the graphs to discuss the meaning of a mean and how sensitive the mean is to extremes in the data.

THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

**ADAPTED FROM BIOMAGNIFICATION AND EAGLES**

**BY ELIZABETH CAVENY, JANET CARSON, HEATHER SUBLESKI, AND JEANNIE GALLUZZO**