Bioaccumulation:
A Case Study of British Columbia's Killer Whales

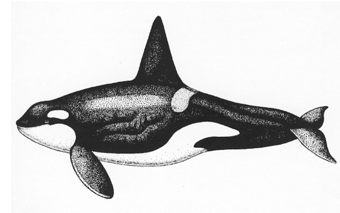


Image: Gloria Snively

Resource available on-line here.

Grade 7
Prescribed Learning Outcomes and Curriculum Organizers

Grade 7 Science
Life Science
- Analyse the roles of organisms as part of interconnected food webs, populations, communities, and ecosystems
- Assess survival needs and interactions between organisms and the environment
- Assess the requirements of sustaining healthy local ecosystems
- Evaluate human impacts on local ecosystems

Grade 7 Math
Patterns and Relations (Variables and Equations)
- analyse relations graphically to discover how changes in one quantity may affect others
- graph relations, analyse results, and draw conclusions

Grade 7 Social Studies
Applications of Social Studies
- design, implement, and assess detailed courses of action to address global problems or issues

English Language Arts 7
Comprehend and Respond *(Engagement and Personal Response)*
- develop personal responses and offer reasons for and examples of their judgments, feelings, or opinions

Communicate Ideas and Information *(Composing and Creating)*
- summarize what they know about specific topics or issues and identify and address gaps in the information available

Personal Planning 7
Personal Development *(*Healthy Living)
- give examples of how personal health relates to the environment, the economy, and society

Grade 10 Science
Prescribed Learning Outcomes and Goals

GOAL 1: Science, technology, society and the environment (STSE) – Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.
GOAL 4: Attitudes – Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.
Life Science: Sustainability of Ecosystems
- B2 assess the potential impacts of bioaccumulation

Overview of Activity

Students learn about the natural history of British Columbia's killer whale populations and the threats they face. The emphasis in the lesson plan is on the threat of the build up of toxins in food chains (bioaccumulation), connectedness through marine ecosystems and the reduction of threats through the Species at Risk Act (SARA). A further strong focus is on individual empowerment to enact positive change.

Estimate of time required

Number of lessons	5
Time required for each lesson	1.5 to 2 hours/lesson except lesson 3 = 1 hour
Can be done	Anytime

Natural area required Indoor activity. Do need an outdoor field or large indoor play area for two activities.

Overview of materials and resources required
5 lessons
2 activities requiring a large play area
PowerPoint slides included but not essential
See activities in lesson two for game materials

Suggested assessment activities
Included in lesson descriptions
Sample final test provided, click here and scroll to "student assessment"

Recommended additional resources and optional enrichment activities

- Two very worthy video compliments to the lessons are:
  - **Realm of the Killer Whales** (60 minutes) Ocean Wilds - PBS Home Video – excellent resource for natural history of British Columbia's killer whales, herring and salmon. Astounding footage of northern resident killer whales rubbing on the beaches of the Michael Bigg Robson Bight Ecological Reserve.
  - **Killer in Peril – Decline of the Orca – from ferocious predator to Species at Risk** (46 minutes) Canadian Geographic.
- Ford JKB, Ellis GM, Balcomb KC; Killer Whales – The Natural History and Genealogy of *Orcinus orca* in British Columbia and Washington; Second Edition. UBC Press, Vancouver 2000.
- www.econauts.org - conservation based webpage maintained by Jackie Hildering. See "Helping the Whales" for information on toxins and "Marine Mammal Science" for abundant links to BC killer whale natural history.
- Interactive game, Secrets at Sea http://www.secretsatsea.org/main.html. Teacher's Guide at http://www.secretsatsea.org/tg/. Addresses killer whales, food webs and bioaccumulation. Learning outcomes provided.
- Live web cameras from Johnstone Strait from July to October presented by the Orca Lab (pending continued funding).
- "Chemical trespass – Toxic chemicals in our everyday lives. Knowing how they affect us and how we can make changes". Learning resource guide and workshops. Contains curriculum connections and content on toxins in BCs Killer Whales. Labour Environmental Alliance Society (LEAS); 604-669-1921; info@leas.ca; www.leas.ca
- Further resources listed under individual lessons.

Previous knowledge needed:
Students should be familiar with the following definitions:
Organism = a living thing
Habitat = where an organism lives
Animals are either:

- Vertebrates = have a backbone
- Invertebrates = do not have a backbone

Plankton = small plants and animals that drift in the water; most are microscopic

- Phytoplankton = plant plankton
- Zooplankton = animal plankton. Most invertebrates start off as zooplankton often looking nothing like the adult form.

See Biomedia website to have students view animated images of zooplankton and the adult form of the marine invertebrate they develop into.

Note: For PowerPoint slides to accompany the lessons click here

Activity Description

Lesson 1- Natural History of British Columbia's Killer Whales

Teacher background Information

- British Columbia Wild Killer Whale Adoption programme – natural history of killer whales and identification photos of individuals using saddle patch and dorsal fin. Excellent summary at http://www.killerwhale.org/fieldnotes/field_body.html. Request brochures with information about the programme and the natural history of killer whales via adoption@vanaqua.org.
- British Columbia Cetacean Sightings network - natural history of killer whales. Click "BCs cetaceans" and then "killer whale"
- Natural history and threats to killer whales in detail – recovery strategy for resident killer whales and recovery strategy for transient killer whales
- Information about the Michael Bigg Ecological Reserve at Robson Bight
- Killer whale vocals http://www.killerwhale.org/fieldnotes/chat.html and http://www.zoology.ubc.ca/~ford/
- Maps of range for:
    - Northern residents
    - Southern residents
    - Transients
    - Offshores

Student Information Lesson 1

The Different Populations of Killer Whales in British Columbia

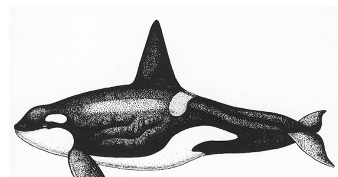


Image: Gloria Snively

Killer whales (or Orca) are the biggest members of the dolphin family. They are toothed cetaceans and are extremely intelligent and social animals.

They were named killer whales as they were all thought to be killers of other whales. Their scientific name *Orcinus orca* also reflects misunderstanding as it loosely translates into "hell creature."

Killer whales can be found in all marine waters of the world but more often in colder seas. All over the world, populations of killer whales have developed different lifestyles depending on the geography and food availability of their area.

We know what we do about killer whales because of the work of Dr. Michael Bigg. Back in the 1970s, it was believed that there were thousands of killer whales in British Columbia and that they should be shot because they were eating too much salmon. Killer whales were also being captured for aquariums. Dr. Bigg found a way to tell killer whales apart so that they could be counted accurately. He did this using the saddle patch and dorsal fin. He catalogued the animals and proved that people were often seeing the same killer whales again and again. There were only hundreds of them, not thousands. His work led to stopping the shooting and capture of killer whales.

"Cetacean" is the name for the group of mammals that are whales, dolphins and porpoises.

Remember that **mammals**:
- Are able to keep their internal temperatures constant (they are homeothermic / endothermic).
- Give birth to fully developed young
- Nurse their young
- Have lungs

Most mammals have hair that traps air for warmth. Cetaceans do not have hair but blubber for warmth. Hair would not work to keep them warm since hair cannot trap air in the water. The hair would actually slow them down!

Once he could study killer whales as individuals, Dr. Bigg also found out that there were different kinds. We now know that there are 3 different kinds (eco-types) of killer whales in the waters of British Columbia that do not mate with one another. They have different diets which leads to their having distinct behaviour and culture.

The three kinds of killer whales are offshores, transients and residents. There are two resident populations in British Columbia – northern residents and southern residents. None of these populations mate with one another even though their ranges overlap. Their different languages stop them from mating between populations. Since they do not mate with one another, on average, they look different. For example, transients have more pointed dorsal fins and offshores appear to be smaller animals.

Not much is known about the offshores yet as they are not often seen close to the coast of British Columbia.

Transients feed on marine mammals. They do not eat fish. They have to be very quiet because their marine mammal prey can hear them and recognize that the sounds of transients mean they are in danger. Transients therefore also dive longer and do not travel in big family groups.

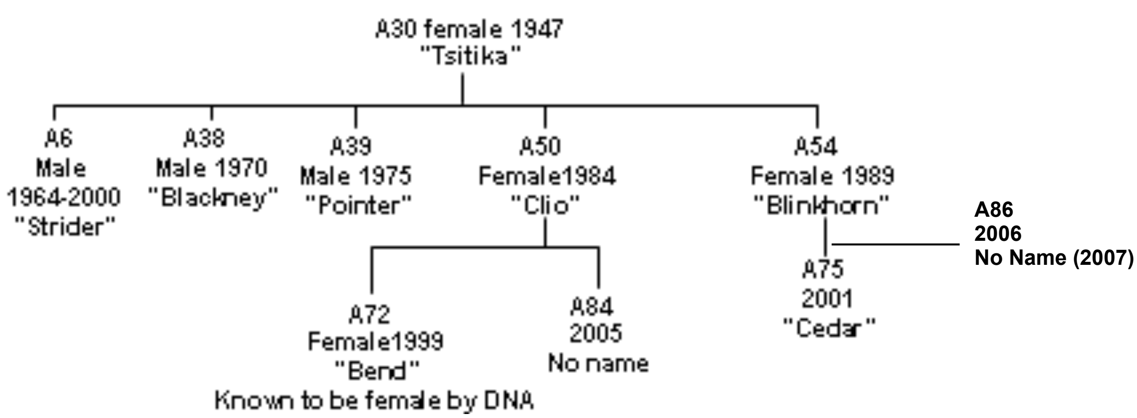
Resident killer whales feed on fish. In fact, about 98% of their diet is salmon. They do not eat marine mammals. They can afford to be very vocal since fish cannot hear them. They are very social and often travel in big groups. They have very structured family units called matrilines (mother, her offspring and her daughters' offspring). Neither males nor females leave the matriline. They do not mate within the family (they do not interbreed) since they can recognize who is and is not family because every matriline sounds different. If they sound exactly the same, they stay together but do not mate with one another. They mate with animals of the same population that sound different. But mated males and females do not stay together as a family. They stay in their matriline so that family sounds remain distinct and the system of recognizing otherness remains intact. The matriline is named for the eldest female.

Note that not all killer whales in the world are resident, transient or offshore types. They have lifestyles that suit the prey and geography of their area.

Sources: The work of Dr. Michael Bigg; Dr. John Ford; Graeme Ellis and Dr. Lance Barrett-Lennard

The A30 Matriline

Note: The names in quotations are assigned by the Wild Killer Whale Adoption Programme after the calves have been sighted for 2 years in a row. This is done because the death rate can be high in the first years of killer whale calves' lives.



<table>
<tr><td rowspan="2">Table 1</td><td colspan="4">British Columbian Killer Whale Population</td></tr>
<tr><td>Northern Residents</td><td>Southern Residents</td><td>Transients</td><td>Offshores</td></tr>
<tr><td>Diet</td><td colspan="2">Fish. Mostly salmon – with their favourite being Chinook. Some herring, squid, halibut, rockfish and flounder.</td><td>Marine mammals – mostly seals, harbour porpoise and Steller sea lions. Possibly some birds. They do not eat other killer whales!</td><td>Believed to be fish. Unlikely to eat salmon. Diet may include halibut and shark species</td></tr>
<tr><td>Population estimate (2006)</td><td>235</td><td>87</td><td>200</td><td>250+</td></tr>
<tr><td>Sound production (vocalizations and echolocation)</td><td>Very vocal and make great use of echolocation to find prey.
Three different dialects (acoustic clans) in the population.</td><td>Very vocal and make great use of echolocation to find prey.
Only one dialect in the population.</td><td>Very quiet; hunt using stealth</td><td>Very vocal</td></tr>
<tr><td>Range where most often sighted</td><td>Regularly found above the middle of Vancouver Island to southern Alaska
Sighted very regularly around Johnstone Strait</td><td>Regularly found around the Southern end of Vancouver Island but also sighted in Washington and Alaska</td><td>Southeast Alaska to California</td><td>Most often far off the coastline</td></tr>
<tr><td>Social structure</td><td colspan="2">Travel in matrilines where they stay with their mothers. They avoid inbreeding through each matriline sounding different. Northern and southern residents do not mate with one another as they sound too different.</td><td>Matrilines are not as stable. Combinations of matrilines traveling together can be very variable.</td><td>Travel in groups of 30+ Social structure unknown</td></tr>
<tr><td>Cultural behaviour</td><td>Rub themselves on black smooth stone beaches like those in the Michael Bigg Ecological Reserve at Robson Bight</td><td></td><td></td><td></td></tr>
<tr><td>Well studied?</td><td colspan="2">Yes – resident orca have somewhat predictable behaviours since they follow salmon and because they travel in matrilines</td><td>More difficult to study because:
They are very quiet
They dive longer
Absence from the matriline does not mean they are dead</td><td>More difficult to study since they are most often far off shore</td></tr>
</table>

Table 2:

	Male killer whales	Female killer whales
Maximum size	9 m; 5,568 kg	7.7 m; 4,000 kg
How long they live - years (Life expectancy)	Average = 30 Maximum = +/- 60	Average = 50 Maximum = +/- 80
Average age of puberty	13.5 Only then do the males grow much bigger dorsal fins; up to 1.8 m	14
Reproduction	Possible from puberty to death. Note that older males appear to be more often chosen by the females.	From puberty to around age 40
Note: Only 1 calf born at a time. On average, a female has a calf every 5 years. Gestation is 17 months.		

Student Activities

1. What is the relationship between A30 and A75 in the matriline above? A30 is A75's grandmother
2. Even though A6's body has never been found, why is it known that he is dead? Since residents always travel with their families in matrilines, if an animal is not in the area with his family, he is dead. Scientifically, they are said to be "missing" for a year and then presumed dead. [*There are some extreme exceptions like the young whales A73 (Springer) and L98 (Luna).]*
3. Why isn't it known whether A75 is male or female?
   - A75 is too young to see if it does or does not grow the large identifiable dorsal fin of males. Males do not begin to "sprout" until the age of puberty. [If A75 is female, she is also to young to have a calf which would conclude that she is female].
   - DNA testing has not been done
   - The pelvic area (underside of the animal) of the individually identified animal has not been seen. The white pigmentation in this area is different in males and females.
4. Why can resident killer whales afford to travel in large groups and be very vocal?
   - Large groups: Their food supply is usually in large numbers and is predictable (the salmon spawn).
   - Vocal: Fish cannot hear the killer whales' calls.
5. Why can't transient killer whales be highly vocal animals that travel in large groups?
   - They can't make a lot of sound because their marine mammal prey can hear the calls and will try to get away.
   - If they are in large groups, they would be more easily detected.
6. How are residents able to recognize how closely related they are to other killer whales? This is how they avoid inbreeding and why they must stay in matrilines.
   - They can judge degree of relatedness by sound. If they sound exactly they stay in matrilines but do not mate.
   - If they sound different (but are member of the same population) they may mate but must stay with their matriline. There is no pair bonding – mothers and fathers do not stay together since the system of distinct sounds would then fall apart.
7. In 2006, why hadn't the Wild Killer Whale Adoption Programme given A84 a name and included the animal in their symbolic adoption programme?
   - Many calves die in their first two years. If the young calf were in the adoption programme and would die, this would lead to complications.

Extension Activities/ Resources Lesson 1

Click here

Lesson 2- Killer Whale Food Chains and Food Webs

Teacher background Information

- Ecological & Environmental Learning Services' detailed information on Food Chains and Webs

Student Information Lesson 2

The Roles of Killer Whales in the Ecosystem

An ecosystem is all the organisms interacting with one another and the non-living factors (light, soil, temperature, water) in their environment.

Predators are animals that eat other animals.
Prey are the animals that get eaten by predators.

Producers are organisms that can make their own food. Plants are the main producers. They trap energy from the sun and store the energy in the form of sugar. This process is called photosynthesis. The light energy gets trapped in the bonds of the sugar molecules.

Consumers – are organisms that get energy from eating other organisms.
Types of consumers:
a) Herbivores - eat only producers (eat plants)
b) Carnivores – eat other consumers. Carnivores are predators (e.g. transient killer whales) that eat prey (e.g. seals)
c) Omnivores – eat producers and consumers
d) Decomposers are consumers that feed on dead organisms. Bacteria and fungi are decomposers. They "clean up" turning dead organisms back into nutrients in the ecosystem. They are different from scavengers like eagles and hermit crabs because decomposers grow in or on the dead or waste matter taking the nutrients directly into their cells. This is how they recycle nutrients into the environment.

A food chain is a model that shows how energy stored in food passes from organism to organism. The arrows show the flow of energy; they point from what is eaten to what eats it.

Example:

Phytoplankton → zooplankton → herring → salmon → seals → transient killer whales

In the example, the food chain shows that zooplankton get energy by eating phytoplankton; herring get energy by eating zooplankton; seals get energy by eating salmon; salmon get energy by eating herring and transient killer whales get energy by eating seals.

At the beginning of a food chain, there are always the producers since they are the only ones that can make their own food from the sun's energy. Remember, phytoplankton are plants so they are producers!

Usually, food chains are drawn with the producer at the bottom or beginning of the chain. Remember, the direction of the arrows is really important as they show the transfer of energy; they show which way the food goes.

The consumers that eat the producers are the first order consumers (or primary consumers). The consumers that eat these consumers are the second order (or secondary) consumers and so on.

<u>Student Activities 1:</u>

1. Draw a food chain for resident killer whales:

2. In the food chain for resident killer whales:
    a. Circle the producer(s)
    b. Put a check mark above the consumers
    c. Put a square around the prey of salmon
    d. Put a star over zooplankton's predator

Food Webs

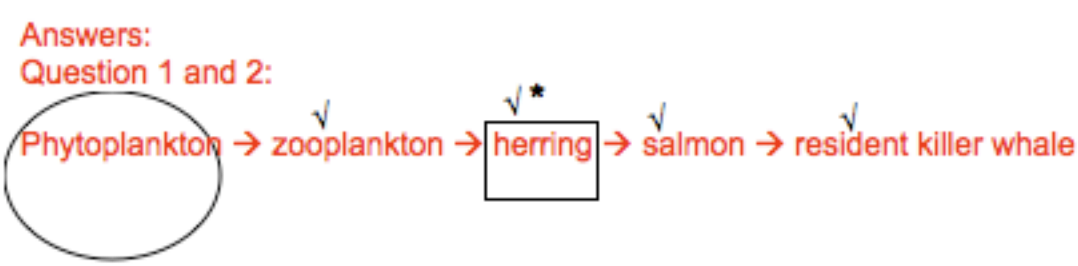
A food web shows the interactions between the food chains. It is a combination of many different food chains, showing the interrelationships between many different producers and consumers in an ecosystem. It is made of many food chains!

3. Draw a food web for the following organisms in the space below: Herring; salmon; zooplankton; phytoplankton; transient killer whale; humans; resident killer whale; harbour seal

Hints: Seals eat herring and salmon *and* so do we. Very few of us eat seals so do not include this link. Transients do not eat humans!

<u>Draw food web here:</u>

4. How many food chains are there in this food web?
5. Describe where the decomposers would be in this food web.



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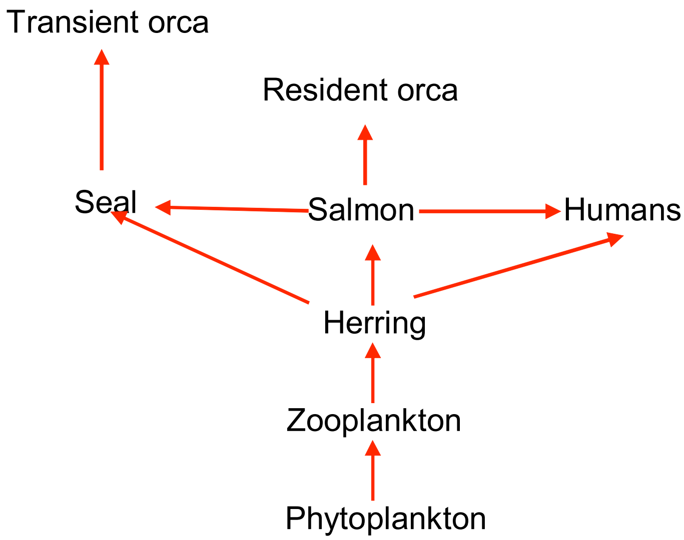


Question 3: See diagram to left.
Question 4: There are 5 food chains are in this food web.
Question 5: The decomposers would get energy from every other organism in the food web when they died. There would be an arrow going to them from every organism in the food web.

Student Activities 2:

Food Chain Game
Adaptation of the Ohio Sea Grant Education Program's activity "How do toxins move through the food chain" and Project Wild's activity "Deadly Links".

Materials needed:
For a class of 30 students, about 200 pieces of small objects like poker chips or milk bottle caps. These objects represent plankton (both phytoplankton and zooplankton). 1/3 of the markers should be a different colour or have a distinct marking. Why this is done will become apparent when the game is played in Lesson 4.

- 1 plastic bag (recycled) for each student that is a herring. The bags represent stomachs.
- Armbands, pinnies or face-paint to mark what organism the student is.

Round I – Resident killer whale food chain:
Assign the following roles to students. Numbers in brackets show number of students. There should be about 3 times as many salmon as killer whales and about 3 times as many herring as salmon:

- Herring (21)
- Salmon (7 students)
- Resident killer whales (2 students)

Students should be marked so that it can be recognized who the herring, salmon and resident killer whales are.

The plankton markers are spread out through the playing area. The playing area is defined and it is explained to students that the bags represent stomachs. Explain that the game is going to mimic the resident killer whale food chain. Herring are only allowed to feed on plankton by gathering the markers. Salmon are only allowed to feed on (tag) herring and resident killer whales are only allowed to feed on (tag) salmon. When you get tagged, you hand over your bag(s) to your successful predator and go to the sidelines.

The herring are sent into the playing field to collect plankton into their stomachs. When about 1/3 of the plankton are still left, send in the salmon. The salmon should attempt to tag the herring. The herring are still trying to collect plankton markers.

Once the herring have had some time to feed, send in the resident killer whales. The resident killer whales attempt to tag the salmon. The salmon are still trying to tag the herring and the herring are still trying to collect plankton markers!

Stop the game when there are still some surviving salmon.

Have students collect in a circle. Count and record how many of each kind of surviving organism there are and the amount of food that each surviving organism has. Total the amount of food for each level in the food chain. Discuss with students what they learned from the game.

Organism	**Number Surviving**	**Amount of food energy per animal (number of plankton markers)**	**Total amount of food energy for the species**
Resident killer whales	2		
Salmon		Salmon #1 Salmon #2 Etc.	
Herring		Herring #1 Herring #2 Herring #3 Etc.	

Discussion points:

- Are the results what you would expect in nature?
- Why are there usually less organisms at every level of the food chain?

Round 2 – Transient killer whale food chain

Play starting with the same number of pieces representing plankton. You will need another colour pinny or armband.
Play as above but assign the following roles to students:

- Herring (21 students)
- Salmon (6 students)
- Seals (2 students)
- Transient killer whale (1 student)

Seals may only eat salmon and the transient killer whale may only eat seals.

Stop the game when there is still at least one surviving seal.

Count and record how many of each kind of surviving organism there are and the amount of food that each surviving organism has. Total the amount of food for each level in the food chain.

Organism	**Number Surviving**	**Amount of food energy per animal (number of plankton markers)**	**Total amount of food energy for the species**
Transient killer whale	1		
Seals		Seal #1 Etc.	
Salmon		Salmon #1 Salmon #2 Etc.	
Herring		Herring #1 Herring #2 Herring #3 Etc.	

Discussion points:
Are the results what you would expect in nature? How is the situation different for the transient killer whale than it was for the resident killer whale? The transient is feeding further up the food chain so there is less energy available than there was to support the resident killer whales. The seals are at the same level as the resident killer whales so have the same amount of energy available to them.

Extension Activities/ Resources Lesson 2.
Click here

Lesson 3 – SARA and Threats to Killer Whales

Teach background Information

- See backgrounder on the Species at Risk Act (SARA).
- Threats to killer whales in detail – recovery strategy for resident killer whales (see from page 15 on) and the recovery strategy for transient killer whales (page 10 to 17)

Threats:
The current threats to BC's killer whales are broadly defined as being:

- Environmental contamination,
- Reductions in the availability or quality of prey,
- Disturbance - both physical and acoustic disturbance.

Historic threats that impacted killer whale populations include culling and being taken for captivity.

It is important that students gain an understanding that not just one threat is having an impact. Rather, **multiple threats interact** to create stresses on the populations. Current research (Dr. John Ford and Graeme Ellis) indicates that both southern and northern resident population declines coincided with a decline in Chinook salmon stocks. The effect was more pronounced in the southern resident population. With less food, toxins are more likely to metabolize and stresses such as noise and boat traffic are likely to have a greater impact as they reduce the chance of catching the limited prey.

Student Information Lesson 3

Killer Whales in Trouble

In 2001, the Committee on the Status of Endangered Wildlife in Canada determined:

- Southern resident killer whale are 'endangered'
- Northern resident killer whales are 'threatened'
- Transient killer whales are 'threatened'
- Offshore killer whales are of 'special concern'

The transient population and both resident populations are listed in Schedule 1 of the Species at Risk Act (SARA).

Note: Southern residents travel in both Canadian and American waters. In November 2005, America also listed this population as 'endangered' by their laws.

Student Activities

Have students brainstorm the following:

1. Brainstorm and list all possible threats to British Columbian killer whale populations:

- Loss of habitat
- Disease (biological pollution)
- Climate change
- Entanglement
- Ship strike (boat collision)
- Noise (Acoustic disturbance = boats, seismic activity, low - mid frequency sonar, drilling, dredging, etc.)
- Over-fishing / changes in prey availability
- Human interaction / physical disturbance
- Historical capture for aquariums

- Culling (that they used to be shot at)
- Contaminants (toxins, oil spills)
  Note that both resident populations declined when there was a crash in Chinook stocks in the late 1990s. The effect was more pronounced in the southern resident population. Again, it is important that students recognize that these stresses interact to threaten killer whale populations.

2. Why transients might be more affected by noise as a disturbance.
- Transients need to detect their marine mammal prey by hearing them.
- Noise could mask the sound of their prey so that the transients can't find their food.

3. Why southern resident killer whales might be in more trouble than other BC killer whale populations.
   With their often being in an area with more people, there may be:
   - less food
   - more contaminants (chemicals)
   - more noise
   - more physical disturbance from boats

   There were more southern residents taken into captivity, more may have been shot [and they may be eating food that is more contaminated, possibly from sources far away.]

Extension Activities/ Resources Lesson 3

Click here

Lesson 4 - Bioaccumulation and Killer Whales

Teacher background Information

- Dr. Peter Ross' (Institute of Ocean's Sciences) scientific paper on bioaccumulation in killer whales. Data source for this lesson.
- See summary of Canada's PCB reality, killer whale natural history and a summary of Dr. Ross' research by DFO Education Coordinator Jackie Hildering for background on bioaccumulation in Killer Whales.
- "Chemical trespass – Toxic chemicals in our everyday lives. Knowing how they affect us and how we can make changes". Learning resource guide and workshops. Includes toxin lists and alternatives. Contains curriculum connections and content on toxins in BCs Killer Whales. Labour Environmental Alliance Society (LEAS); 604-669-1921; info@leas.ca; www.leas.ca
- Detail about contaminants – see the recovery strategy for resident killer whales (see Table 1 on page 19 for a listing of persistent organic pollutants and their associated risks to killer whales) and the recovery strategy for transient killer whales .
- Information about the brominated fire retardants, the new persistent organic pollutants
    - See "toxin" links under point 1 "Helping the Whales"
    - See the Labour Environmental Alliance Society's fact sheet

Student Information Lesson 4

Bioaccumulation and Killer Whales

What is bioaccumulation?

Many chemicals we use in our daily lives are toxic. Toxic chemicals include pesticides, engine products and many household cleaners. Most toxins are made by humans; they do not occur naturally.

Some of these toxins are **persistent.** This means that they do not break down and as a result they build up in the food chain.

They usually build up in the fat of organisms. The mother's milk of mammals has lots of fat in it.

The build up of toxins in organisms is called **bioaccumulation.**

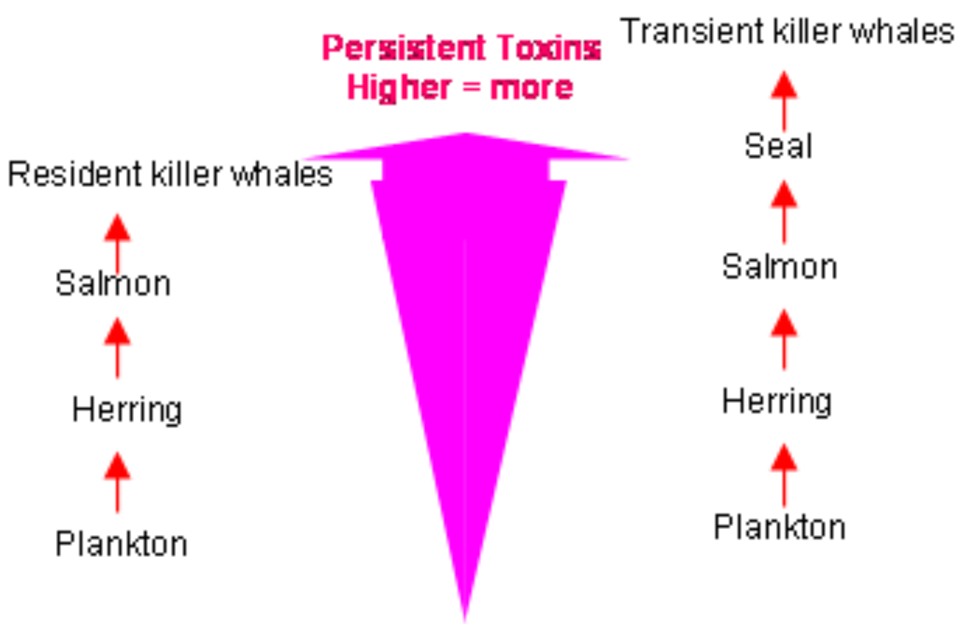
Persistent toxins are also known as Persistent Organic Pollutants (POPs).

These toxins can cause the following problems:
- Reproductive failure
- Birth defects
- Immune system disorders (cancers and weakness to disease)
- Behaviour and learning disorders
- Death

The more toxins an organism has, the greater the problems.

We may use toxins on land, but they go through the soil to the groundwater and into the ocean. All persistent toxins eventually end up in ocean food chains.

The diagram below shows what bioaccumulation means for killer whales. Transient killer whales would have more persistent toxins because they are higher in the food chain than resident killer whales. Since resident killer whales and seals are both 4th order consumers, if they had the same range, it would be expected that they would have the similar levels of persistent toxins.



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It is not only local sources of toxins that are affecting the killer whales. Persistent toxins accumulate in cold countries like Canada by evaporating and condensing again and again. (This is known as global distillation). It has been proven that it **only takes 5 to 10 days** for toxins to come from as far away as Japan into British Columbia's waters.

Source: Dr. Peter Ross' research

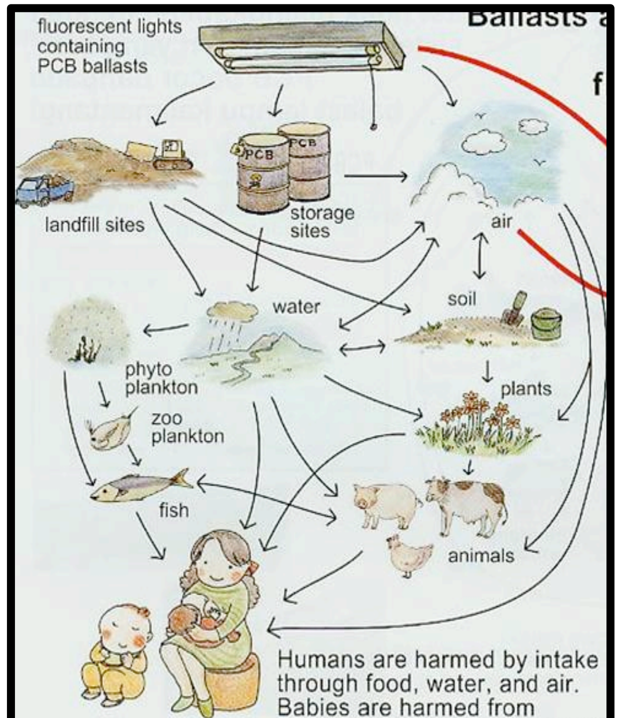


Diagram: Japan Offspring Fund; Stop PCB – end the sources of PCB pollution worldwide. jof@niffy.ne.jp

<u>How can it be that we allow these chemicals to go into the environment and build up in the food chain?</u>

We made mistakes in the past with chemicals like the pesticide DDT and PCBs. People thought these were "super chemicals", great inventions that solved problems. They were not tested for their long-term effects before they were put to use.

DDT kills mosquitoes that could carry disease. PCBs can conduct electricity, they insulate, they don't burn and they don't corrode. They were used in everything from electrical lights to paint and printing ink. Look at the diagram to see how chemicals like PCBs move into and through the food chain.

The table below shows more of these persistent toxins. These are known as the "Dirty Dozen".
Notice that 9 of these 12 are pesticides!

Persistent organic pollutant (POP) name	**Pesticide**	**Industrial Chemical**	**By-product**
1. Aldrin	√		
1. Chlordane	√		
1. DDT	√		
1. Dieldrin	√		
1. Endrin	√		
1. Heptachlor	√		
1. Mirex	√		
1. Toxaphene	√		
1. Hexachlorobenzene	√	√	√
1. PCBs		√	√
1. Dioxins			√
1. Furans			√

After years of using these chemicals, animals in the food chain started having problems. For example, with DDT, the shells of large birds were too weak so that they would be crushed by the weight of the adults. **Then** the chemicals were tested and it was discovered that they bioaccumulate.

<u>So we learned our lesson right?</u>

No. We have definitely not learned our lesson.

- Many countries still use the chemicals that have been proven to bioaccumulate.
- The chemicals are stored all over the world and are often not properly disposed of.

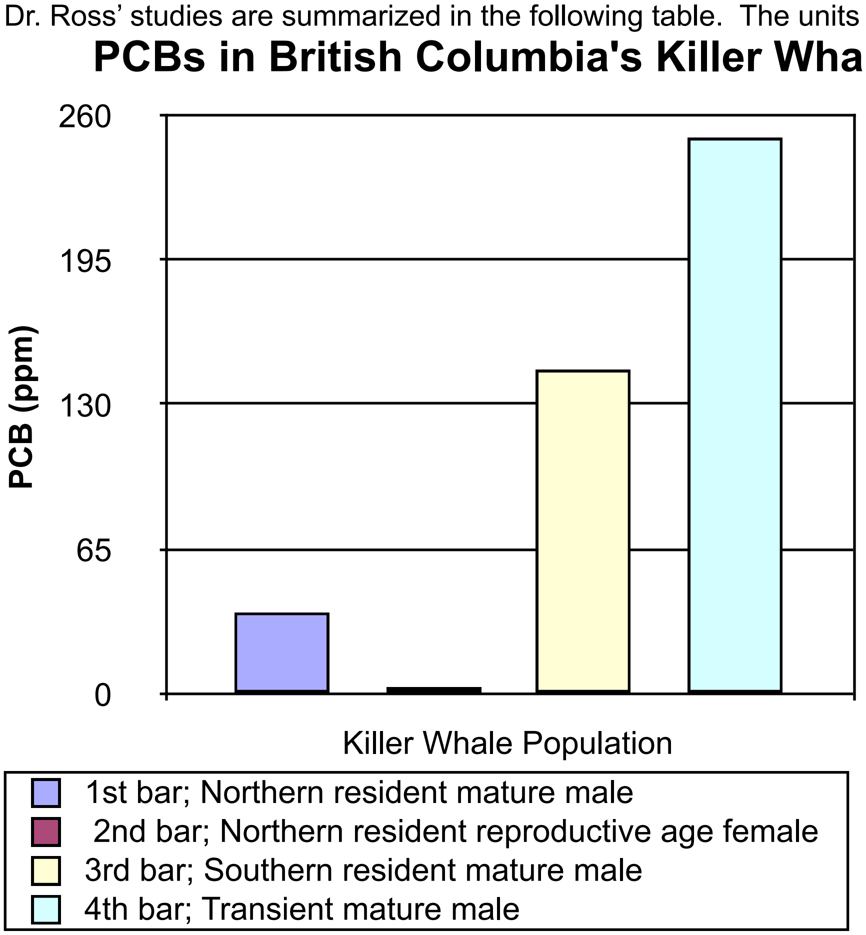
- Canada and America do not have adequate laws that insist on the testing of new chemicals that are not used in food. (Source: Chemical Trespass).
- Of 300,000+ chemicals used in N. America, about 400 are "emerging chemical contaminants" (ECC) and can bioaccumulate. 75% have not been studied. (Source: Derek Muir, Environment Canada, Feb 2008).
- There is a new group of chemicals that are being produced in North America that has already proven to bioaccumulate. These are the PBDEs, a group of chemicals that are of use to humans because they don't burn. They also are fire retardants just like PCBs were. There are at least 15 alternatives to their use that do not bioaccumulate. Europe has banned most PBDEs. North America has not.

The "PBDEs" are a group of chemicals that contain the chemical bromine and stop fires. They have been proven to be persistent organic pollutants and are found in furniture, televisions and computers.
PBDE = polybrominated diphenyl ethers

<u>Persistent Toxins and British Columbia's Killer Whales</u>

Dr. Peter Ross studied the amount of toxins in the blubber of British Columbia's resident and transient killer whales. The blubber samples were used for both DNA and toxin research. The samples were collected by using a retractable dart system that removed a sample the size of a pencil eraser.

Dr. Ross' studies are summarized in the following table. The units are parts per million (ppm).



Student Activity 1:

1. Use the graph “PCBs in British Columbia’s Killer Whales” to fill in the following table:

	1. Northern resident mature male	2. Northern resident female of reproductive age	3. Southern resident male	4. Transient mature male
Estimate of amount of PCBs in blubber (ppm)		3		

2. Researchers found that beluga whales in the St. Lawrence had PCB loads of about 79 ppm. These animals had malformed skeletons and cancers and their population was severely endangered (Source: Muir et al). In ringed seals, a level of 77 ppm causes reproductive problems (Source: Oceana). Which killer whale populations are above these levels?
3. A level of 16.5 ppm causes immune system problems in harbour seals (Source: Oceana). Which killer whale populations are above this level?
4. A level above 50 ppm, is considered toxic waste by Canadian guidelines (Source: Oceana). Which killer whale populations are above this level?
5. In Canada, the action level for PCBs is 2 ppm. This is the amount that is too high for humans to eat food with this level of PCBs. Which killer whale populations are above this level?
6. Approximately how many times greater is the level of PCBs in Northern resident males than Northern resident females of reproductive age? Why do you think the males might have so many more toxins like PCBs?
7. Knowing what you do now about toxins in killer whales, explain why males might live so much shorter lives.
8. Approximately how many times greater is the level of PCBs in Southern resident males than Northern resident males? Why do you think the southern residents might have so many more toxins like PCBs?
9. Summary: In each column, mark the one that is most likely to have more toxins

Type of Killer whale		Gender		Birth Order		Range
1. Resident		1. Male		1. Firstborn calf		1. Near big cities
2. Transient		2. Female		2. Not firstborn calf		2. Further away from cities

	1. Northern resident mature male	2. Northern resident female of reproductive age	3. Southern resident male	4. Transient mature male
Estimate of amount of PCBs in blubber (ppm)	35	3	145	250

Answers:

1. Southern resident male and transient male
2. Northern resident male, southern resident male and transient male
3. Southern resident male and transient male
4. All
5. Approximately 12 times greater (37 / 3). Females of reproductive age download toxins to their calves through the fatty mother’s milk and through the placenta. Males have no way of getting rid of the toxins
6. M ales may live shorter lives because they have far more toxins. [Where reproductive age females download the chemicals to their offspring via milk and the placenta].
7. Approximately 4 times greater. They are more often in areas with more people meaning more pollution. Puget Sound specifically has high local toxin loads but toxins do come from around the world too.

Type of Killer whale		Gender		Birth Order		Range
1. Resident		1. Male √		1. Firstborn calf √		1. Near big cities √
2. Transient √		2. Female		2. Not firstborn calf		2. Further away from cities

Student Activity 2:

<u>Food Chain Game with Toxins</u>

Play the game as in Lesson 2 but this time the 1/3 of the markers of a different colour (or with the distinct marking) represent plankton containing persistent toxins. **Students should not be told this until both rounds of the game have been completed.**

At the end of the resident killer whale round, record the number of each surviving organism and the amount of food energy each surviving organism has. Ask the surviving organisms how many pieces of their food had the distinct marking without telling them what it means. The final column of the results table will be filled in at the end of the game.

Organism	Number Surviving	Amount of food energy	Total number of marked food pieces	Survived (S), Died (D) or reproduction and immune system problems (RI)
Resident killer whale	1			
Salmon		Salmon #1 Salmon #2 Etc.		
Herring		Herring #1 Herring #2 Herring #3 Herring #4 Etc.		

Repeat the game for the transient killer whale food chain. Collect the data as for the resident killer whales.

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Organism	Number Surviving	Amount of food energy	Total number of marked food pieces	Survived (S), Died (D) or reproduction and immune system problems (RI)
Transient killer whale	1			
Seals		Seal #1 Etc.		
Salmon		Salmon #1 Salmon #2 Etc.		
Herring		Herring #1 Herring #2 Herring #3 Etc.		

Now tell the students that the markings meant that the food had a persistent toxin. Remember that persistent toxins build up in the food chain because they do not break down.

Use the table below to determine how many of each organism died because of the persistent toxin, how many survived and how many survived but will have reproduction and immune system problems.

Organism	**Number of toxic plankton markers**	**What this means**
Herring	○ Less than 3 ○ 3 to 4 ○ More than 4	○ Survives ○ Survives but will have reproduction & immune system problems ○ Dies
Salmon	○ Less then 4 ○ 4 to 6 ○ More than 6	○ Survives ○ Survives but will have reproduction & immune system problems ○ Dies
Seals or resident killer whales	○ Less than 5 ○ 5 to 8 ○ More than 8	○ Survives ○ Survives but will have reproduction & immune system problems ○ Dies
Transient killer whales	○ Less than 8 ○ 8 to 12 ○ More than 12	○ Survives ○ Survives but will have reproduction & immune system problems ○ Dies

Analyse the results and discuss. Possible discussion points:

- How many of the herring that survived being eaten by salmon (in both food chains) died because they accumulated too much toxin? How many of them will likely get reproduction and immune system problems.
- How many salmon that survived being eaten by resident killer whales or seals died because they accumulated too much toxin? How many of them will likely get reproduction and immune system problems.

- How many of the seals that survived being eaten by the transient killer whales died because they accumulated too much toxin?
- What will likely happen to the resident killer whale because of the toxins?
- What will likely happen to the transient killer whale because of the toxins?
- Discuss whether the game results are what you would expect in nature.

Discussion questions:

1. In nature, the amount of persistent toxins gets higher and higher as you go up the food chain. Why? The toxins do not break down and the amount of food eaten from one food chain level to the next goes up so the amount of toxin goes up. For example, 12 herring are eaten by 4 salmon which are eaten by 1 resident killer whale.
2. Why do transient orca have so many more toxins than resident orca? They are higher up the food chain.
3. How would the game need to be played differently for southern resident orca? You would have to start with a greater percentage of markers representing plankton with toxins.
4. Explain why the second born killer whale may have 4 or more times less toxins than the first born? The mother has far more toxins when she has her first calf. She has all the toxins that she has built up in her lifetime – around 10 to 20 years. When the second calf is born, it only gets some of the toxins from that the mother has built up in some 2 to 5 years.
5. Do you expect that firstborn transient calves or firstborn resident calves will have more toxins? Firstborn transient orca will likely have more toxins since the transient killer whale mothers feed higher up the food chain than the resident killer whale mothers.

Extension Activities/ Resources Lesson 4

Click here

Lesson 5 – Ready, Set, Action!
Solutions for Killer Whales

Teacher notes and background Information

- Great action ideas available through the Wild BC resource "Leap into Action" resource.
- Ten top ways lifestyle changes can be made to improve the state of the environment (David Suzuki Foundation)
- Seeds Foundation's Green Schools Campaign
- The EPA's "Make a Difference Campaign for Middle Schools" http://www.epa.gov/epaoswer/education/mad.htm - lots of helpful information on smart shopping, interesting environmental science projects, reducing waste and the life-cycles of everyday objects.
- Listing of resources to help whales "Helping the Whales".

Solutions to reducing the chemical load in the environment

- The intent is to emphasize individual empowerment and celebrate human intelligence. All living things do need to use the Earth's resources but every little positive change helps.
- Note please that environmental problems must only be relayed with solutions, student empowerment and action, otherwise despair, paralysis, and eco-phobia may result.
- Chose from the activities below.

Student Activities

1. "What I have learned from killer whales" - Guided discussion on what the bioaccumulation of toxins in killer whales is teaching us and what can be do to improve the situation. Click here for a summary.

2. "I can make a difference! My contract with mother Earth" Students reflect on their own lives and think of ten specific ways that they can make changes to reduce chemicals in the food chain. Output can be in the form of a poem, drawing, poster, essay or journal entry. The table below will help as well information at www.econauts.org under "Helping the Whales."

3. Students write a letter or sign a petition to voice their concern about PBDE's.
   - Letters can be directed to the member of parliament and/or Ministers of Environment, Health, or Industry
   - Sign the Labour Environmental Alliance Society's petition.

4. Undertake further **action** to help the whales. Suggestions below. It is vitally important that students be able to apply what they have learned in order to enforce that their actions *can* make a difference. See teacher background information for helpful links.
   - Students report back on their successes and difficulties in acting on their ten points in activity 2.
   - Undertake a class campaign to adopt a killer whale www.killerwhale.org (Pacific northeast transients and northern residents) or http://www.whale-museum.org/ (southern residents)
   - Initiate an improved recycling programme for the school
   - Identify an environmental problem at the school and solve it e.g. reduce the use of disposable items by having people bring their own plates etc. to events; design and produce a school cup, school shopping bag, etc; reduce the amount of paper that is used; start using recycled paper; recycle batteries; have a campaign to reduce school electricity use; etc.
   - Set up a school environmental club (see The Young Naturalist Club of Canada's school programme).

5. Reflect and comment on the following quotes:
    a. "Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it's the only thing that ever has." *Margaret Mead*
    b. "There may be some grand, sacrificial, heroic answer, but the best answers I know are almost trivial. Environmental problems are caused by billions of small, unthinking actions. They'll be cured by billions of small, sensible actions, simple substitutions of environmentally conscious habits for thoughtless and wasteful ones." *Anonymous*
    c. "So long as we are more motivated to have than to be, we shall continue down the tunnel of consumerism. We shall do so despite knowing full well that the light at the end is not the sun. It's the train." *Erich Fromm (written 50 years ago)*

Action	Ways to reduce persistent organic pollutants	Additional ways to reduce other chemicals in the environment	Explanation
Be chemical aware!	• Know if the chemicals you use are harmful to the environment and if you have to use them dispose of them properly • Use environmentally safe alternatives • Avoid using pesticides		
Care!	• Live knowing that you are connected to the Earth's other creatures • Insist on finding out if things are dangerous **before** we start using them		
Make your voice count	• Share what you know with others. Use your vote and stand up for your right to be toxin free!		
Buy smart	• Buy less things you don't really need • Buy from companies with good environmental practices	• When you have a choice, buy things you need from close to home	E.g. IKEA and Toshiba,Apple, Dell and Hewlett Packard do not use PBDE's in their products. Buying from close to home means less pollution from fossil fuels
Eat smart	• Eat less animal fat	• Eat less food with additives	By eating less animal fat, there is less chance that you are taking in persistent organic pollutants.
Make less garbage	• Through buying less • Don't use disposable items e.g. non-rechargeable batteries; Styrofoam cups; plastic bags! Reuse things. • Share things you no longer need instead of throwing them out e.g. donate to second hand store • Fix things rather than throwing them out • Recycle more	• Buy things with less packaging • Compost more • Create less food waste	The more we reduce, reuse, repair and recycle, the fewer chemicals go into environment. In electronics and foam products, these chemicals can include PBDEs
Save energy	• Use less electronic devices	• Walk, bike, skate-board, etc more as a form of transportation • Carpool and use public transportation more • Use alternatives to fossil fuels • Use energy efficient vehicles, appliances, light bulbs, etc. • Unplug more and enjoy nature! Unplug appliances you are not using, use less TV, game boys, computer, etc.)	Less electronics means less chance of having a product with PBDEs Using less gas and oil means less fossil fuel pollution Most electrical generators operate on fossil fuels
Save water		• Use less water so that it does not need to be treated as often	Also saves energy that goes into treating sewage and purifying water