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

A series of five classroom lessons introducing students to the natural history of killer whales, the threats they face, and personal actions that can be taken to help protect them.

Prescribed Learning Outcome(s) met and Curriculum Organizer(s)
It is expected that students will:

Science 7

Life Science: Ecosystems

- 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

Math 7

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

Social Studies 7

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

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Overview of Activity:
Through these five related lessons, students learn about the natural history of British Columbia's killer whale populations and the threats they face. Emphasis 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 create positive change. The lessons are:

- Natural History of British Columbia's Killer Whales
- Killer Whale Food Chains and Food Webs
- SARA and Threats to Killer Whales

- Bioaccumulation and Killer Whales
- Ready, Set, Action! Solutions for Killer Whales

[If internet access is available, online slides are available to support the lesson, and extension activities are available to download.]

Estimate of time required:
Number of lessons: 4-6 lessons
Each lesson requires: 1-2 hours
Can be done: Anytime ☒ Fall ☒ Winter ☒ Spring ☒ Summer
Notes: La durée de chaque leçon varie entre 1½ et 2 heures, sauf celle de la leçon 3, qui n'est que d'une (1) heure.

Natural Area Required: None - Indoor Activity ☐Ocean OR ☐Stream OR ☐Estuary
Notes: Vous aurez besoin d'une cour extérieure ou d'une vaste aire de jeu intérieure pour mener deux de ces activités.

Overview of Materials and Resources Required:
Material Available for downloading:

☒Activity Description(s)
☒Student Handout(s)
☒Background Information
☐Discussion Questions
- [Included in student handouts]

☒Evaluation /Assessment Tool(s)
Material indicated is included in each lesson plan.

Other Required Material:

- PowerPoint slides designed to accompany the lessons [optional]
- Lesson 1: Summary tables contrasting BC's killer whale populations [optional]
- Lesson 2: Food Chain Game [optional]
- Lesson 4: Food Chain Game with Toxins [optional]
- Extension activities for Lessons 1-4 [optional]
- Student Assessment sample final text (with answer key available) [optional]
All the above are available at: www3.telus.net/public/a6h4z2/SARA%20index.htm

Students should be familiar with the following definitions:

- Organism: a living thing
- Habitat: where an organism lives
- Vertebrates: animals that have a backbone
- Invertebrates: animals that 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 which look nothing like their adult form)

Suggested Assessment Activities:

- The student handouts' questions may be done in class or as homework. An answer key is provided.
- A student assessment test is available at www3.telus.net/public/a6h4z2/SARA%20index.htm

Recommended Additional Resources and Optional Enrichment Activities:
(E.g. Web-sites, Teaching Guides, Student Reading, Videos/Audio-tapes, Posters and Brochures, Field Trips):
Lesson 1:

- British Columbia Wild Killer Whale Adoption programme – natural history of killer whales and identification photos of individuals using saddle patch and dorsal fin. Brochures with information about the programme and the natural history of killer whales can be requested from the Vancouver Aquarium: adoption@vanaqua.org.
  www.killerwhale.org/fieldnotes/field_body.html.
- British Columbia Cetacean Sightings network - natural history of killer whales.
  www.wildwhales.org (Click "BCs cetaceans" and then click "killer whale")
- "Ocean Wilds: Realm of the Killer Whales" video (60 minutes) Public Broadcasting Service. This film is an excellent resource on the natural history of British Columbia's killer whales, herring and salmon. It contains astounding footage of northern resident killer whales rubbing on the beaches of the Michael Bigg Robson Bight Ecological Reserve.
  www.shoppbs.org
- "Killer Whales: The Natural History and Genealogy of Orcinus Orca in British Columbia and Washington State", Ford JKB, Ellis GM, and Balcomb KC (2000), UBC Press, Vancouver.
  ISBN: 0295979585
- Draft recovery strategy for resident killer whales, containing detailed natural history and threats to killer whales.
  www-comm.pac.dfo-mpo.gc.ca/pages/consultations/marinemammals/RKWrecoverystrategy_e.htm
- Michael Bigg Ecological Reserve at Robson Bight
  members.shaw.ca/robsonbight
- Live web cameras from Johnstone Strait, British Columbia (July to October).
  www.orca-live.net
- Killer whale vocals!
  www.killerwhale.org/fieldnotes/chat.html
  www.zoology.ubc.ca/~ford/
- Maps of ranges for different killer whale species:
  Northern residents www.speciesatrisk.gc.ca/search/speciesDetails_e.cfm?SpeciesID=698
  Southern residents www.speciesatrisk.gc.ca/search/speciesDetails_e.cfm?SpeciesID=699
  Transients www.speciesatrisk.gc.ca/search/speciesDetails_e.cfm?SpeciesID=606
  Offshores www.speciesatrisk.gc.ca/search/speciesDetails_e.cfm?SpeciesID=700

Lesson 2

- Ecological & Environmental Learning Services' detailed information on Food Chains and Food Webs
  www.eelsinc.org/id43.html
- Animated images of zooplankton and the adult form of the marine invertebrate they develop into.
  www.ebiomedia.com (click "Galleries", then click "Babes in the Sea")

Lesson 3

- Threats to British Columbia's resident killer whales and the national recovery plan for killer whales.
  www-comm.pac.dfo-mpo.gc.ca/pages/consultations/marinemammals/RKWrecoverystrategy_e.htm
- DFO's information page on the Species at Risk Act (SARA), SARA registry and Environment Canada's on-line resources.
  www.dfo-mpo.gc.ca/species-especes/species/species_searchSpecies_e.asp
  www.speciesatrisk.gc.ca/
- **"**Killer in Peril: Decline of the Orca – from Ferocious Predator to Species at Risk**"** video (46 minutes), Canadian Geographic. This film follows North America's top whale researchers on the Pacific coast as

they unravel the complexities of killer whale culture and probe the causes of the orca's decline.
www.shop.canadiangeographic.com

Lesson 4

- Dr. Peter Ross' (Institute of Ocean's Sciences) scientific paper on bioaccumulation in killer whales. (The data source for this lesson).
  actionstudio.org/home/orca/ross_pcbs_orcas.pdf
- Persistent organic pollutants and their associated risks to killer whales. (See Table 1).
  www-comm.pac.dfo-mpo.gc.ca/pages/consultations/marinemammals/RKWrecoverystrategy_e.htm
- "Secrets at Sea" interactive game that addresses killer whales, food webs and bioaccumulation. Learning outcomes and a Teachers' Guide are provided.
  www.secretsatsea.org
- Background on bioaccumulation in Killer Whales, summary of Canada's PCB reality, killer whale natural history and a summary of Dr. Ross' research (by DFO Education Coordinator Jackie Hildering).
  www3.telus.net/public/a6h4z2/bioaccumlation%20in%20kw.htm
- Information about the brominated fire retardants, the new persistent organic pollutants
  www.stubbs-island.com (Click "Helping the Whales", see links under point 1).
  leas.ca/Ban-should-include-all-PBDEs.htm

Lesson 5

- Great action ideas available through the Wild BC resource "Leap into Action" resource
  www.hctf.ca/wild/resources/leap/leap.htm
- Ten top lifestyle changes to improve the state of the environment (David Suzuki Foundation)
  www.davidsuzuki.org/files/WOL/GreenGuide.pdf
- The EPA's "Make a Difference Campaign for Middle Schools". Lots of helpful information on smart shopping, environmental science projects, reducing waste and the life-cycles of everyday objects.
  www.epa.gov/epaoswer/education/mad.htm
- Listing of resources to help whales (Stubbs Island Whale Watching)
  www.stubbs-island.com (Click "Helping the Whales", see links under point 3).
- Direct letters to the Ministers of Environment, Health and/or Industry. Links to these Ministers are In Northwest Environment Watch's background on PBDE's.
  www.northwestwatch.org/publications/CS_news_10_04_regionalPBDE.asp (BC and Canada section).
- Sign the Labour Environmental Alliance Society's petition.
  www.leas.ca/Ban-should-include-all-PBDEs.htm (Click on "Download our petition…")
- Adopt a killer whale
  http://www.killerwhale.org/ (Pacific northeast transients and northern residents)
  www.whale-museum.org (southern residents)
- "Chemical trespass – Toxic chemicals in our everyday lives. Knowing how they affect us and how we can make changes". Learning resource guide and workshops containing curriculum connections and content on toxins in BC's Killer Whales. Labour Environmental Alliance Society (LEAS); 604-669-1921; info@leas.ca; www.leas.ca

Support may be Available.

Contact your local Stream to Sea Education Coordinator or Community Advisor.
www-heb.pac.dfo-mpo.gc.ca/community/contacts/ec_e.htm
or phone (604) 666-6614 to find out if an Education Coordinator in your area assists with this activity.

Lesson plan written by: Jackie Hildering
Edited by: Elizabeth Leboe

Lesson 1: Activity Description
Natural History of British Columbia's Killer Whales

1. Review with students [with PowerPoint slides, if internet is available] the natural history of British Columbia's killer whales.
   - Three types of killer whale
   - How to tell killer whales apart (Dorsal fins and saddle patches are like human fingerprints: all different).
   - Resident killer whale diet and social structure
   - Concept of "matrilines" (like a family tree for humans)
   - Transient killer whale diet and social structure
2. Provide "Student Handout: Lesson 1" to each student.
3. Have students do questions 1-6 in class individually, and discuss answers as a class.

Lesson 1: Student Handout
Natural History of British Columbia's Killer Whales

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 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 whales' 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 of 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)
- 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!

The Different Populations of Killer Whales in British Columbia

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 and distinct behaviour and culture.

The three eco-types 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.

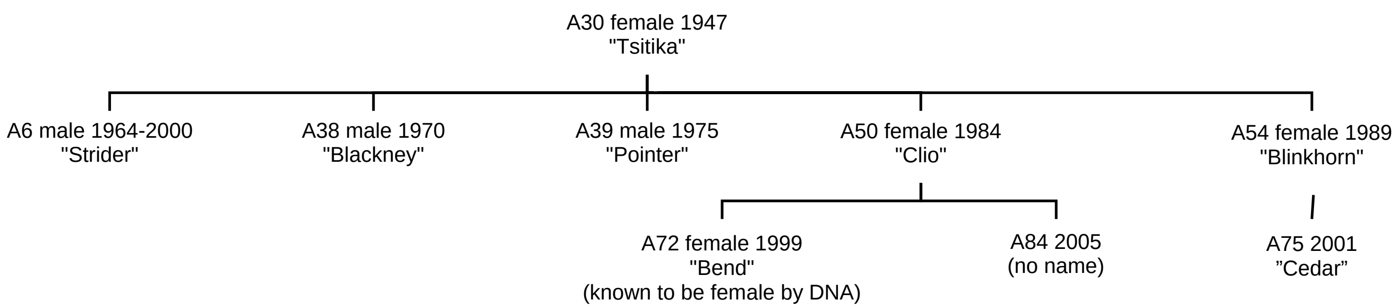
Resident killer whales feed on fish. In fact, about 98% of their diet is salmon. They do not eat marine mammals. They can afford to be very vocal since fish cannot hear them. They are very social and often travel in big groups. They have very structured family units called **matrilines** (mother, her 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. Mated males and females do not stay together as a family. They stay in their matrilines so that family sounds remain distinct and the system of recognizing otherness remains intact.

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

Whales are assigned names 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.



Questions

1. What is the relationship between A30 and A75 in the matriline example?

2. Even though A6's body has never been found, how is it known that he is dead?

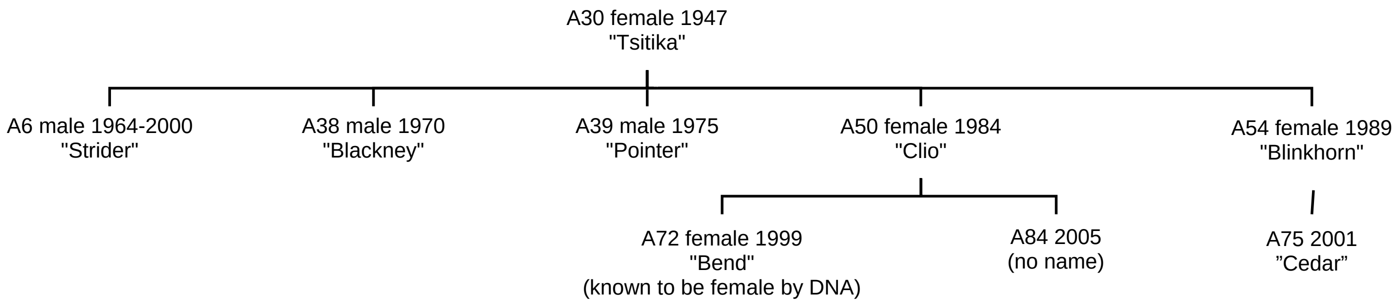
3. Why isn't it known whether A75 is male or female?

4. Why can resident killer whales afford to travel in large groups and be very vocal?

5. Why can't transient killer whales be highly vocal animals that travel in large groups?

6. How are residents able to recognize if they are closely related to other killer whales?

Lesson 1: Answer Key
Natural History of British Columbia's Killer Whales



1. What is the relationship between A30 and A75 in the matriline example?

   A30 (Tsitika) is the grandmother of A75 (Cedar). A75 is either the granddaughter or grandson of A30 (Cedar's gender is not specified)

2. Even though A6's body has never been found, how is it known that he is dead?

   Resident killer whales always travel with their families in matrilines; if Strider is not in the area with his family, he is dead. There are some extreme exceptions like the young whales A73 (Springer) and L98 (Luna) that separated from their matrilines and lived alone in proximity to coastal communities. Scientifically, these whales are said to be "missing" for a year and then presumed dead.

3. Why isn't it known whether A75 is male or female?

   The large identifiable dorsal fin of males does not begin to "sprout" until the age of puberty. Therefore, the gender of young whales like A75 is not known unless DNA testing is done or there is a chance to see the pelvic area of the animals (underside of the animal). 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?

   The fish that residents feed on are predictable (they spawn) and cannot hear the whales' calls.

5. Why can't transient killer whales be highly vocal animals that travel in large groups?

   The marine mammal prey of transients can hear the whales' calls and will try to get away. Transients must be very stealthy in order to be successful hunters of marine mammals.

6. How are residents able to recognize if they are closely related to other killer whales?

   They can judge degree of relatedness by sound. If they sound exactly the same they stay in matrilines together and do not mate. If they are of another acoustic clan (but the same population) they may mate but must stay with their matriline. There is no pair bonding – mothers and fathers do not stay together.

Lesson 2: Activity Description
Killer Whale Food Chains and Food Webs

1. Review with students [with PowerPoint slides, if internet is available] the concepts of food chains and food webs.
   - Food chains of resident and transient killer whales
   - Food webs
2. Provide "Student Handout: Lesson 2" to each student.
3. Have students do questions 1-5 in class, and discuss as a class.
4. Play the "Food Chain Game" [optional].
   www3.telus.net/public/a6h4z2/SARA%20index.htm (Click "SARA Lesson 2 Activity")

Lesson 2: Student Handout
Killer Whale Food Chains and Food Webs

An **ecosystem** is defined as a group of organisms interacting with one another and with the non-living factors (light, soil, temperature, water) in its 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 of light energy getting trapped in the bonds of the sugar molecules in called photosynthesis. **Consumers** are organisms that get energy from eating other organisms. Types of consumers:

a) **Herbivores** eat only producers (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” by 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 in the environment.

Food Chains

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. Here is an 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; salmon get energy by eating herring; seals get energy by eating salmon; and transient killer whales get energy by eating seals.

Producers are always at the beginning of a food chain since they are the only organisms 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 consumers** (or secondary consumers) and so on.

Food Webs

A food web is a model that shows the interactions between food chains. It is a combination of many different food chains that shows the inter-relationships between many producers and consumers in an ecosystem.

Questions

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

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!

4. How many food chains are there is this food web?

5. Describe where the decomposers would be in this food web.

Lesson 2: Answer Key
Killer Whale Food Chains and Food Webs

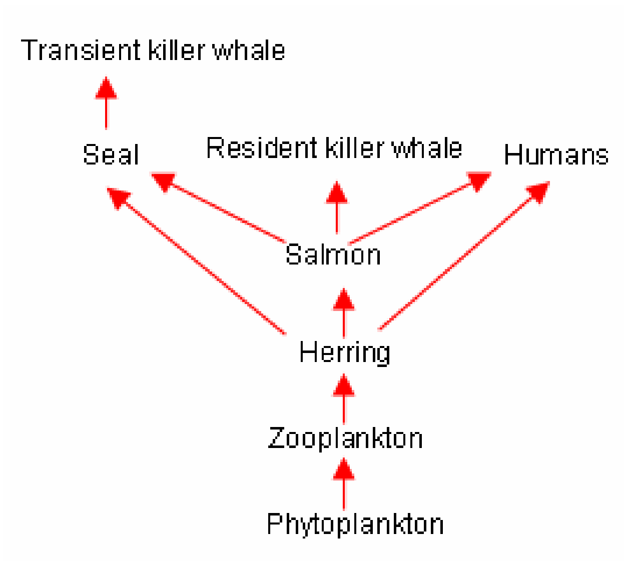
1 Draw a food chain for resident killer whales:

Phytoplankton → zooplankton → herring → salmon → resident killer whale

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

	√	√ ☼	√	√
Phytoplankton	*→ zooplankton*	*→ herring*	*→ salmon*	*→ resident killer whale*

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!



4. How many food chains are there is this food web?
   There 5 food chains are in this food web.

5. Describe where the decomposers would be in this food web.
   The decomposers would get energy from every organism in the food web once it dies. To add them to the food web, one would draw an arrow going to the decomposers from each and every organism in the food web.

Lesson 3: Activity Description
SARA and Threats to Killer Whales

1. Review with students the Species at Risk Act and threats to killer whales.
    - Species at Risk Act and its purpose
    - How killer whales are classed according to SARA
    - What threats (natural and human-caused) to killer whales exist
2. Provide "Student Handout: Lesson 3" to each student.
3. Have students do questions 1-3 in class, and discuss as a class.

Lesson 3: Student Handout
SARA and Threats to Killer Whales

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), Canada’s law to protect wildlife species from becoming extinct.

Southern resident killer whales travel in both Canadian and American waters. In November 2005, America also listed this population as ‘endangered’ according to their laws.

Questions

1. What are some possible threats to all British Columbia killer whale populations?

2. Why might transient killer whales be more disturbed by noise?

3. Why might southern resident killer whales be in more trouble that other BC killer whale populations?

Lesson 3: Background Information
SARA and Threats to Killer Whales

The Species at Risk Act: Working together to Protect Aquatic Species

The Species at Risk Act (SARA) was created to protect wildlife species from becoming extinct in two ways:

- By providing for the recovery of species at risk due to human activity; and
- By ensuring through sound management that species of special concern don't become endangered or threatened.

The Act became law in June 2003. It includes prohibitions against killing, harming, harassing, capturing or taking species at risk.

A Collaborative Effort

Three government departments are directly involved in protecting species at risk: Environment Canada, Parks Canada, and Fisheries and Oceans Canada. Fisheries and Oceans is responsible for all aquatic species, freshwater and saltwater alike.

From the beginning, it was recognized that no single government, industry or community could protect Canadian species at risk on its own. Governments and stakeholder groups across Canada must all work together. In fact, SARA was designed to encourage such cooperation.

The good news is that everyone can help in some way: by knowing the species at risk and understanding why they're threatened (for example), or by taking steps to care for their habitat.

How Does A Species Get on the List?

Species are designated "at risk" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), an independent body of experts that assesses wildlife according to a broad range of scientific data. The federal Cabinet then decides whether those species should get legal protection under the Act. These decisions are made after consultations with affected stakeholders and other groups.

Species Can Be Listed As:

- **Extinct**: no longer found anywhere on the planet.
- **Extirpated**: no longer in the wild in Canada, but existing in the wild elsewhere.
- **Endangered**: a wildlife species facing imminent extirpation or extinction.
- **Threatened**: likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction.
- **Special concern**: a wildlife species that may become a threatened or endangered species because of a combination of biological characteristics and identified threats.

More information about Species at Risk can be found at www.speciesatrisk.gc.ca

Threats to Killer Whales:

The current threats to resident 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 affected 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 on killer whale populations. 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 limited prey.

Lesson 3: Answer Key
SARA and Threats to Killer Whales

1. What are some possible threats to all British Columbia killer whale populations?

   Noise (boats, seismic activity, low and mid frequency sonar, drilling, dredging, etc.); human interaction; loss of habitat; contaminants (toxins, oil spills); being shot at (they were hunted to reduce populations thought to eat too much salmon); being put in captivity (for aquaria); disease; getting stuck in nets (entanglement); boat collision (ship strike); reduced availability of food (over-fishing).

   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 might transient killer whales be more disturbed by noise?

   Transient killer whales need to detect their prey by hearing them. They rarely use echolocation.

3. Why might southern resident killer whales be in more trouble that other BC killer whale populations?

   Because southern resident killer whales are often in an area with more people, there may be:

   - *less food*
   - *more pollution*
   - *more noise and stress from boats*

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

Lesson 4: Activity Description
Bioaccumulation and Killer Whales

1. Review with students concept of bioaccumulation.
    - What is bioaccumulation
    - What persistent organic pollutants can do to an organism
    - Where POPs come from
    - That PCBs in different whale populations were measured
    - How levels of toxins in organisms increase up the food chain
2. Provide "Student Handout: Lesson 4" to each student.
3. Have students do questions 1 to 7 in class. Questions 5 to 7 can be adapted to be class discussion questions.
4. Play the "Food Chain Game With Toxins" [optional] www3.telus.net/public/a6h4z2/SARA%20index.htm (Click "SARA Lesson 4 Activity")
5. Have students complete question 8.

Lesson 4: Student Handout
Bioaccumulation and Killer Whales

What is bioaccumulation?

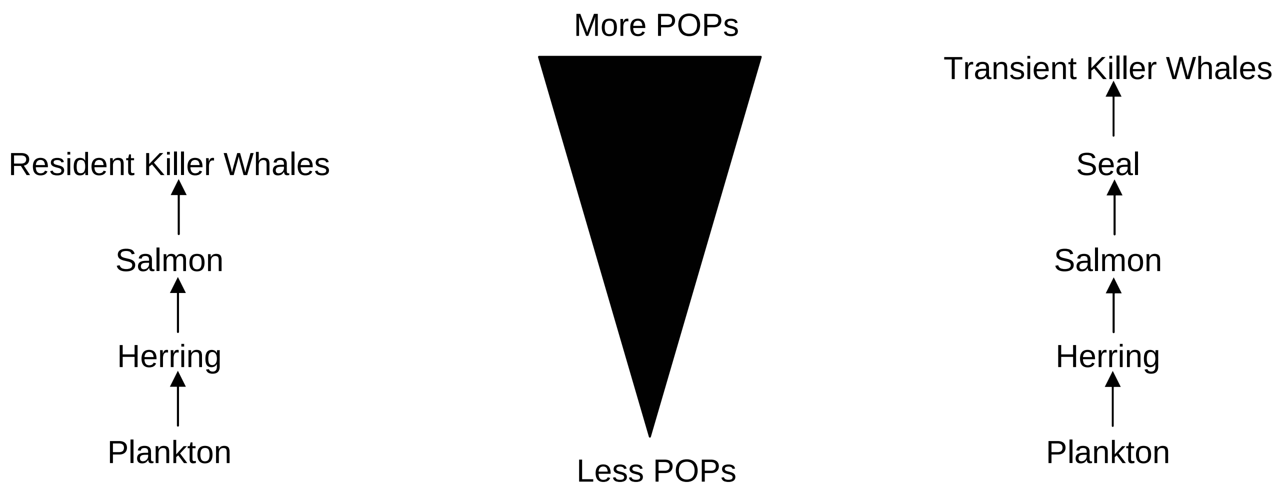
Many chemicals we use in our daily lives are toxic. Toxic chemicals include pesticides, engine products and many household cleaners. Most toxins are made by humans; they do not occur naturally.

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, usually in the fat of organisms. Mother's milk of mammals has lots of fat in it. Persistent toxins are also known as Persistent Organic Pollutants (**POP**s). The build up of persistent toxins in the food chain is known as **bioaccumulation**.

Persistent 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 its problems. The diagram below shows what bioaccumulation means for killer whales. Transient killer whales contain 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.



We (humans) may use toxins on land, but they can travel through the soil in groundwater into waterways and into the ocean. All persistent toxins eventually end up in ocean food chains. It is not only local sources of toxins that affect 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

Persistent Chemicals in the Food Chain

How can it be that we allow these chemicals to go into the environment and build up in the food chain? 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 (DDT kills mosquitoes; it was used to kill bugs that might be carrying disease. PCBs conduct electricity, insulate, don't burn and don't corrode; they were used in everything from electrical lights to paint and printing ink.) These "super chemicals" were not tested for their long-term effects before they were put to use.

Look at the diagram to see how chemicals like PCBs move into and through the food chain.

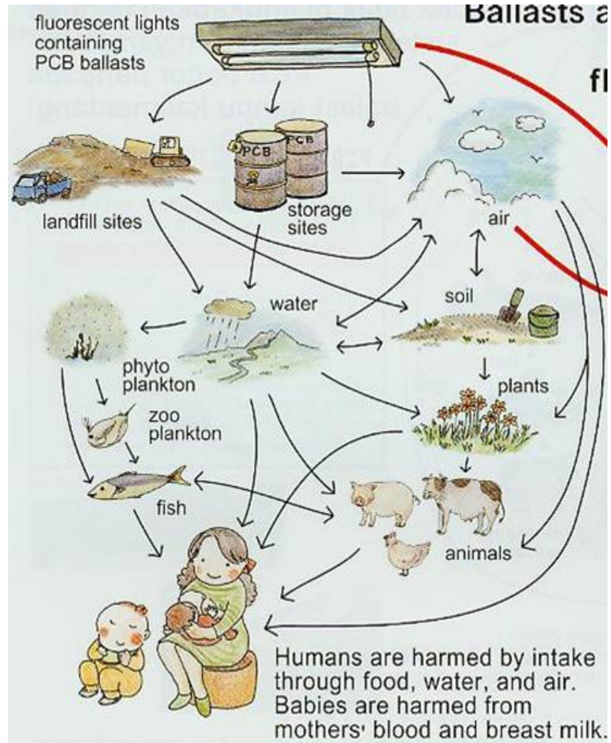


Diagram: Japan Offspring Fund
www.tabemono.info/english

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

Persistent Organic Pollutant (POP)	**Pesticide**	**Industrial Chemical**	**By-product**
Aldrin	√		
Chlordane	√		
DDT	√		
Dieldrin	√		
Endrin	√		
Heptachlor	√		
Mirex	√		
Toxaphene	√		
Hexachlorobenzene	√	√	√
PCBs		√	√
Dioxins			√
Furans			√

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

So we learned our lesson right?

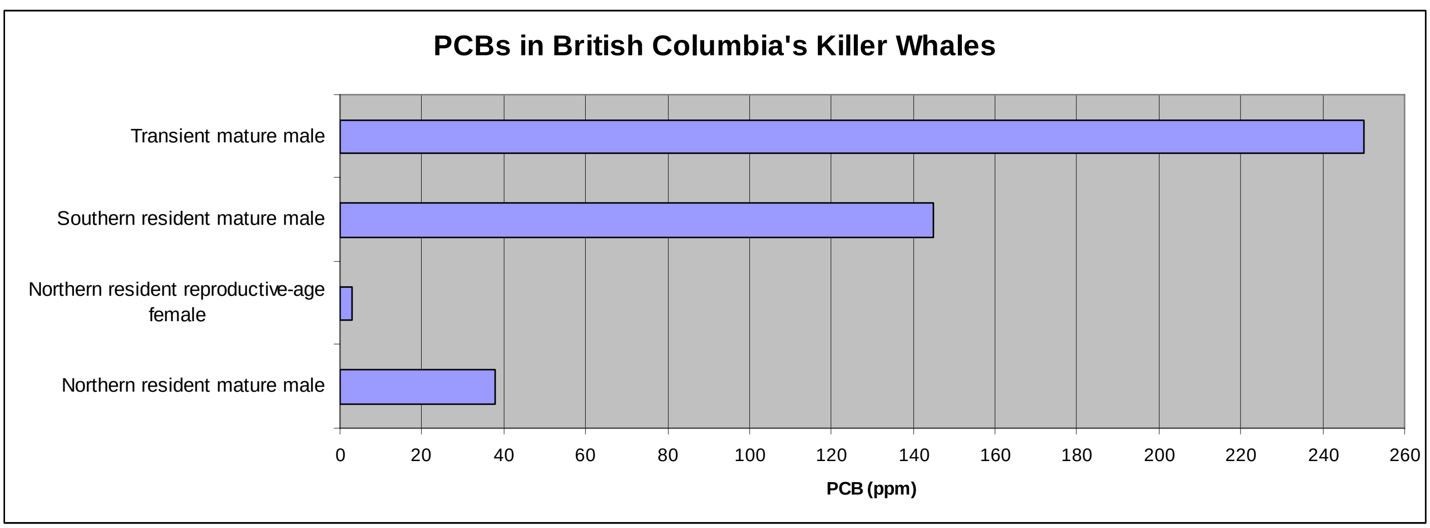
No. We have definitely not learned our lesson.

- Many countries still use the chemicals that have been proven to bioaccumulate.
- These chemicals are stored all over the world and are often not properly disposed of.
- Canada and America do not have laws that insist on the testing of new chemicals that are not used in food. In fact, of some 85,000 chemicals used in North America, only 10% have been tested for their environmental effects (Source: Chemical Trespass).
- There is a new group of chemicals that is 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 are fire retardants. There are alternative fire retardants that do not bioaccumulate. Europe has banned PBDEs. North America has not.

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

Persistent Toxins and British Columbia's Killer Whales

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 chart below; the units of measurement are parts per million (ppm).



Questions

Use the "PCBs in British Columbia's Killer Whales" graph to fill in the following table:

	Northern resident mature male	Northern resident female of reproductive age	Southern resident male	Transient mature male
Estimate of amount of PCBs in blubber (ppm)	e.g., **37**			

Use the graph and the table to answer the following questions.

1. Researchers found that beluga whales in the St. Lawrence River 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?

2. A level of 16.5 ppm causes immune system problems in harbour seals (*Source: Oceana*). Which killer whale populations are above this level?

3. A level above 50 ppm, is considered toxic waste by Canadian guidelines (*Source: Oceana*). Which killer whale populations are above this level?

4. 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?

5. 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?

6. Knowing what you do now about toxins in killer whales, explain why males might live much shorter lives.

7. 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?

8. Summary: For each topic, check the selection that is most likely to have more toxins

Type of Killer Whale:	☐ Resident	☐ Transient
Gender:	☐ Male	☐ Female
Birth Order:	☐ Firstborn calf	☐ Not firstborn calf
Range:	☐ Near big cities	☐ Further away from cities

Lesson 4: Answer Key
Bioaccumulation and Killer Whales

Use the graph to fill in the following table:

	Northern resident mature male	Northern resident female of reproductive age	Southern resident male	Transient mature male
Estimate of amount of PCBs in blubber (ppm)	*37*	*3*	*146*	*250*

1. Researchers found that beluga whales in the St. Lawrence River 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?

   Southern resident male and transient male

2. A level of 16.5 ppm causes immune system problems in harbour seals (*Source: Oceana*). Which killer whale populations are above this level?

   Northern resident male, southern resident male and transient male

3. A level above 50 ppm, is considered toxic waste by Canadian guidelines (*Source: Oceana*). Which killer whale populations are above this level?

   Southern resident male and transient male

4. 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?

   All

5. 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?

   Approximately 12 times greater. Females of reproductive age download toxins to their calves through the fatty mother's milk and through the placenta.

6. Knowing what you do now about toxins in killer whales, explain why males might live much shorter lives.

   Males may live shorter lives because they have far more toxins

7. 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?

   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.

8. Summary: For each topic, check the selection that is most likely to have more toxins

Type of Killer Whale:	☐ *Resident*	☒ *Transient*
Gender:	☒ *Male*	☐ *Female*
Birth Order:	☒ *Firstborn calf*	☐ *Not firstborn calf*
Range:	☒ *Near big cities*	☐ *Further away from cities*

Lesson 5: Activity Description
Ready, Set, Action! Solutions for Killer Whales

1 "What I have learned from killer whales". Guide a class discussion on what the bioaccumulation of toxins in killer whales is teaching us and what can be do to improve the situation.
www3.telus.net/public/a6h4z2/SARA%20index.htm (Click "SARA Lesson 4 Activity")

2. "I can make a difference!" Ask students to reflect on their own lives and think of ten 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.

3. Have students write a letter or sign a petition to voice their concern about PBDE's. Letters can be directed to the Ministers of Environment, Health and/or Industry.

4. Have students plan to undertake further action to help the whales, using some of the 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.

   - 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;
   - 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 to events; design and produce a school cup, shopping bag, etc.; reduce the amount of paper that is used; start using recycled paper;
   - Set up a school environmental club.

Lesson 5: Answer Key
Ready, Set, Action! Solutions for Killer Whales

Activity 2: "I can make a difference!"

The intent of this activity 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. Following are some ways to reduce the chemical load in the environment.

ACTIONS:

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!*

Action	*Ways to reduce POPs*	*Ways to reduce other chemicals*	*Explanation*
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.*	*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 POPs.*
Make less garbage	*Buy 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 stores. 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*	*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.*

		using, use less TV, game boys, computer, etc.).	
Save water		*Use less water so that it does not need to be treated as often*	*Saves energy that goes into treating sewage and purifying water*