Issue 4:

Marine Pollution

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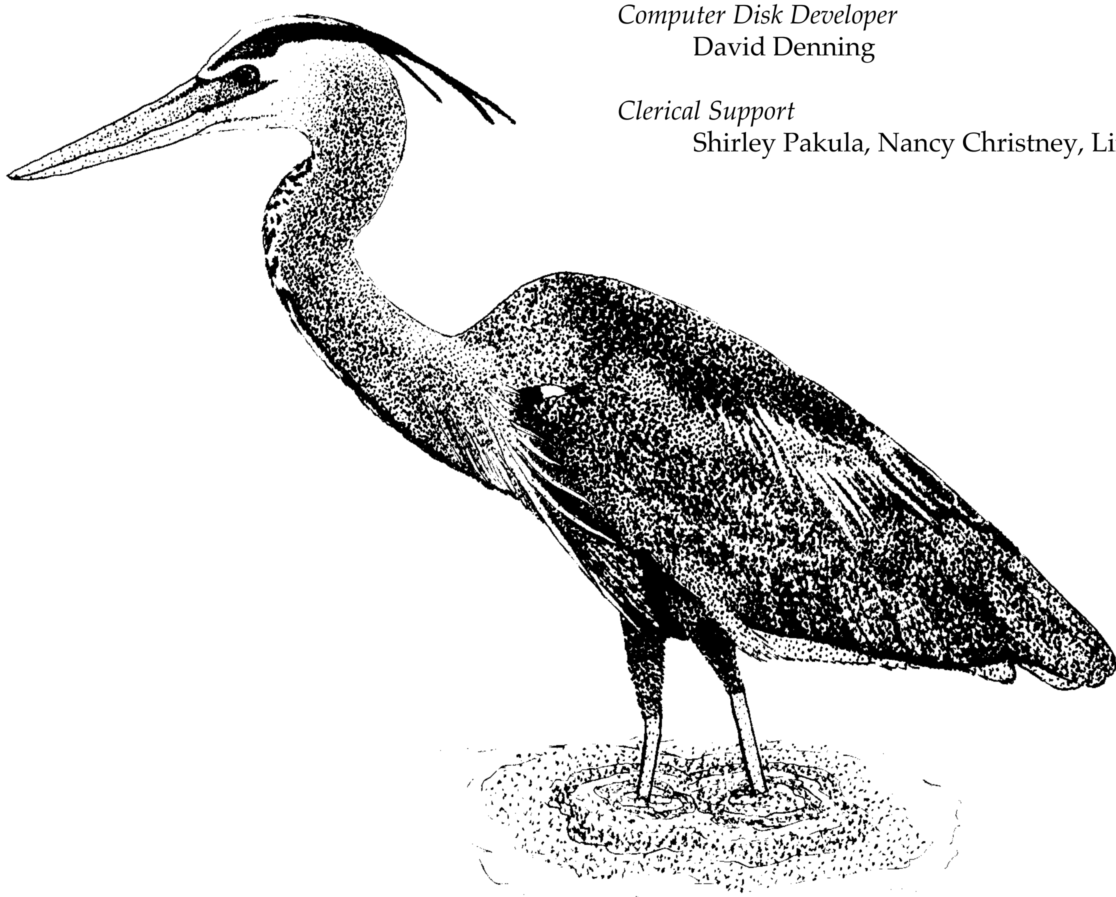

Other Sources For Activities Linking To Marine Pollution

Many excellent resources are available to promote the teaching of science and environmental education in B.C., Canada, and the Pacific Northwest. Of these, a number provide activities to involve students in thinking, problem solving and action, leading to a better understanding of pollution in general and marine pollution specifically. The following summary describes activities useful for teaching marine pollution and related topics.

Bamfield Marine Station. Ocean News. Other activities in this Teacher's Guide provide for study of issues directly or indirectly related to marine pollution. Some examples:

“How Whales Were Once Used” - Issue 2, p .77
“Oil and Feathers Don’t Mix” - Issue 3, p. 95
“Introducing Decisions” - Issue 3, p. 103
“Save That Habitat” - Issue 3, p. 107
“Endangered Water Birds” - Issue 3, p. 114
“Needless Noosing” - Issue 3, p. 117

Aspen Global Change Institute. 1994. Ground Truth Studies Teacher Handbook: British Columbia. Victoria: B. C. Environment. (For more information on this book and program contact: Environmental Education Coordinator, Ministry of Environment, Public Affairs Branch, 810 Blanshard St., Victoria, B.C. V8V 1X4)

This excellent handbook provides 22 activities on ground truth studies, satellite image sensing, watershed study, and other topics that can be linked to marine science and marine pollution studies. The following activities are suggested:

1) "Where Are You From: A Bird's Eye View?" (p. 45). Students interpret aerial photographs of their town, neighbourhood, school.

2) "Zooming In" (p. 53-56). Students explore aerial and satellite images provided in the handbook, including a composite image of B.C. and an excellent image of the Georgia Basin.

3) "Investigating the Invisible" (p. 73). Students discuss and research invisible phenomena.

4) "Back to the Future" (p. 91). Students investigate changes in their regional environment, and use ground truth investigations to determine what happened.

5) "Map Your Watershed" (p. 93); "A Changing Watershed" (p. 99); "Your Watershed's Story" (p. 103); "Make a Watershed Model" (p. 107); and "River Walk" (p. 111) are all thought-provoking activities which build students' understandings of the geography and natural history in their own watersheds, and the human interactions with those watersheds over time. These activities link well with state-of-the environment-reporting, biodiversity studies, water stewardship and the approach to marine environment protection taken in this teacher's guide.

Other Activity Sources *(continued)*

Binder, D., S. Guy and B. Penn. 1994. Backyard Biodiversity and Beyond. Ministry of Environment, Lands and Parks, Ministry of Forests and Department of Canadian Heritage.

This guide is targetted at upper elementary but it can be easily adapted for grades 8-10. Although the activities do not directly examine the marine environment or marine organisms, its focus on biodiversity of organisms in the natural habitat can be easily modified. This is a top-notch resource, of great value to teachers in biology and the environmental sciences. An example of one activity that is related to this issue is:

"Global Trees, Global Uses" - p. 5-9. Students make connections between products we use and biodiversity issues in other parts of the world.

Bunnell, Pille. 1994. Teacher's Guide to the State of the Environment Report for B.C. Environment Canada / ESSA Technologies Ltd.

a) Activity 3: "Developing Indicators – a peek at the environment", pp. 18- 20. This activity gets students to determine, discuss, select, and present a series of environmental indicators for a specific issue. It's excellent practice for looking at any issue, including marine pollution. Level: grade 10-12, adaptable for lower grades.

b) Activity 7: "Food to you! – Calculating an ecological footprint", pp. 45-51. In this activity students monitor their own food intake for a week and use the data they collect to calculate the area of land required to produce all of the items in their diet. Using a class total spreadsheet, the entire class determines an ecological footprint for selected food ingredients. This data is used to estimate the total ecological footprint for the class. Level: Grade 10-12.

Canadian Wildlife Federation. 1990. Project Wild (and Project Aquatic Wild). 1992. Canadian Wildlife Federation, 1673 Carling Ave, Ottawa, Ont., K2A 3Z1.

Project Wild is a thoroughly-tested activity-based program that is passed along to teachers through workshops. Contact the Ministry of Environment at 356-7111 for information on workshop schedules.

a) "Plastic Jellyfish" (p. 368) Students describe the potential effects of plastic waste on aquatic wildlife and identify specific actions they can take to help remedy the problem.

b) "Watershed" (p. 376) Students investigate watersheds, their importance to human and wildlife habitat, and how they can be conserved and protected.

c) "Dragonfly Pond" (p. 354) Students evaluate the effects of different kinds of land use on wetland habitats and discuss and evaluate lifestyle changes to minimize damaging effects on wetlands.

d) "Deadly Waters" (p. 322) Students will be able to name and describe different kinds of pollution that can affect water as well as animals and plants that live in water.

e) "The Glass Menagerie" (p. 283) Students learn about the characteristics of oligotrophic and eutrophic aquatic habitats, emphasizing the effects of nutrient loading.

f) "No Water Off a Duck's Back" (p. 230) Students identify the way oil spills can adversely affect birds and describe possible negative consequences to wildlife, people and the environment from human-caused pollutants.

g) "Wetland Metaphors" (p. 168) Students describe the characteristics of wetlands and demonstrate their understanding of the importance of wetlands to wildlife and humans.

h) "Environmental Barometer" (p. 98) Students observe and count wildlife in an area, discuss why the wildlife is, or is not, present and consider ways in which the presence of wildlife can be seen as an indicator of environmental quality.

ESSA. 1994. Eco Education Program: Household Hazardous Products. BC Environment. Available from; Ministry of Environment , Lands and Parks, Municipal Waste Reduction Branch, 3-777 Broughton Street, Victoria, British Columbia, V8V 1X4.

This resource is aimed at students up to grade 7. Some of the activities can be adapted to older groups. For example, Activity 10: "Advertising, what is the message?" (p. 54) engages students in a message analysis of ads from magazines, television, and other sources pertaining to products that may be toxic or harmful. In this guide, a similar activity is found on page 4 – 29.

Other Activity Sources *(continued)*

Kistritz, R. 1992. Discover Your Estuary. Environment Canada, Conservation and Protection. Available from: Environment Canada, Pacific and Yukon Region, 224 West Esplanade, North Vancouver, B.C. V7M 3H7, (604) 666-5900.

This beautifully-illustrated resource is aimed at the grade 5-7 level, but it is a good source of information and ideas for higher grade levels as well. The focus is on the Fraser River estuary system, the major watershed in B.C. and the home of most people in the province. Activities in the book use field experience as a starting point, and a number of activities and suggested field trip sites can be easily adapted to biology/ geography/environmental science at higher levels. Studies of micro-habitats (p. 61), plankton (p. 68), and changing estuaries (p. 87) all lead to valuable ecological knowledge. A chapter on aquatic pollution (Chapter 4, pp. 91-95) is basic, and is a good starting point for more detailed study.

Mason, Adrienne. 1991. The Green Classroom. Pembroke Publishers Ltd., Markham, Ontario.

This useful book, aimed at the elementary grades, includes a number of ideas to involve students in environmental issues. Some activities include:

"Benefiting from nature", p. 19. Students examine what we get from the environment and what we put back into it.

"Press Agent for a Day", p. 26. Students demonstrate that personal biases and judgements are often present when reporting information.

"Alternatives", p. 107. Students examine the things that we use to make our lives easier and consider some alternatives.

Roa, Michael L. 1993. Environmental Science Activities Kit: Ready-to-use lessons, labs and worksheets for grades 7-12. The Center for Applied Research in Education, Professional Publishing, West Nyack, New York 10995

Although directed mainly toward audiences in the United States, this book will also be found useful by Canadians. The 332–page guide contains 32 different activities with background notes, photocopy-permitted question sheets and activity pages, discussion notes, extensions and references. A wide variety of environmental topics are addressed in the activities – those most relevant to the marine pollution issue include: “Why Recycle” (p. 14); “Oil Spill!” (p. 89); “‘Water’ We Going To Do” (p. 107); “We ‘Auto’ Drive Less” (p. 270); “Toxics in the Home” (p. 281); and “Wants and Needs” (p. 290).

Save the Georgia Strait Alliance. 1993. The Straitkeeper’s Book: A Teacher’s Guide to Discovery of the Ecology of Georgia Strait. Save the Georgia Strait Alliance, Box 122, Gabriola, B.C. V0R 1X0

A variety of activities in this guide are designed to give the student background in marine biology and ecology that will be useful for marine pollution considerations. Most of these are appropriate for grades 5-7. The activity, “Quadrat Studies”, is particularly useful to broaden students ecological understandings and to generate baseline data for ongoing class ecological studies. This intertidal beach study could be adapted for wetlands or forest studies and can be easily used at higher grade levels.

Activities directly related to marine pollution are found on pages 70-79 including: “Toxic Research” and “The Toxic Hunt”.

Water Stewardship Development Team. 1995. Water Stewardship: A Guide For Teachers. Ministry of Environment, Lands and Parks. Available from: Ministry of Environment , Lands and Parks, Municipal Waste Reduction Branch, 3-777 Broughton Street, Victoria, British Columbia, V8V 1X4.

Because it deals with the ecosystem component common to every community, this excellent handbook is essentially a primer for environmental education at any location. Introduced with a seminal discussion of the rationale and purposes of environmental education by Dr. Milton McClaren, the handbook lays out twelve key concepts of water

Other Activity Sources *(continued)*

stewardship. Each concept then is elaborated with supporting activities, extensions, curriculum connections, and assessment ideas. All of these activities have some connection to the study of marine pollution, with the following sections being most directly related:

a) "Contaminants and toxins can move within water" (pp. 83-86) includes an activity designed to experimentally test run-off from the school parking lot for its effect on growing plants.

b) "There are a number of careers working with water and its management" (pp. 87- 91) includes activities that encourage students to look at agencies and people involved with water management.

c) "Different cultures have different values about water" (pp. 92-96) includes activities that encourage students to examine the influence of cultural factors in water use.

Another great component of this handbook is a chapter written by William Hammond entitled "Acting on action within schools: An agenda for environmental citizenship and leadership development" (pp. 124+). This chapter is an excellent rationale and guide to using action projects such as water stewardship, beach cleanup and wetland conservation.

Yates. S. 1991. Adopting A Stream: A Northwest Handbook. Seattle: Adopt-A-Stream-Foundation Publication distributed by University of Washington Press.

Although this well-illustrated, well-organized handbook is oriented primarily to Puget Sound region audiences, and it is not directly organized for teacher use, it is still a useful guide for anyone planning to teach about marine/water pollution through the avenue of water stewardship and watershed ecology studies.

Many activity ideas can be developed from this handbook, which includes sections on stream ecology, water quality monitoring, and basic hydrological survey techniques.

Other:

Beach or Stream Clean-ups/Surveys - Check with local environmental groups/agencies about coordinated beach or stream clean-ups.

Groups may also be interested in participating in the **Pan Pacific Survey of Marine Debris**, sponsored by the University of Alaska in Fairbanks. This project is more than just a beach clean-up. It is an attempt to measure and quantify amounts and types of debris throughout the Pacific Ocean.
General questions that the survey may answer include:
- How do the kinds and amounts of debris on my local beach compare with beaches in other countries?
- Is the amount of debris on my local beach increasing or decreasing over time?
- How long does plastic or other debris last on a beach?
- Where does marine debris come from?

For more information contact:

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University of Alaska Fairbanks
Fairbanks, AK
99775-1080 USA
907-474-7723
907-474-7204 (FAX)

For information on organizing **Salmon Enhancement Projects** contact:

Salmonid Enhancement Program
Department of Fisheries and Oceans
555 W. Hastings,
Vancouver, B.C. V6B 5G3

Fisheries Branch
780 Blanshard Street
Victoria, B.C. V8V 1X4

Glitches in the Chain

Ocean News Reference: *Poster, pages 6-7; "Powerful Plankton", page 10; "Meet a Scientist", page 3.*

Background:

Many metals and trace elements are required by plants and animals for normal biochemical processes (eg. copper, zinc, cobalt and manganese). Since these chemicals are usually found in very low concentrations, organisms have built-in capacities to accumulate and store them so that they are "on hand" when needed. Near sources of pollution involving high concentrations of these same chemicals, organisms continue to bioaccumulate the 'trace' elements, leading to excessive and even toxic levels of required trace elements building up over time.

Synthetic compounds, such as the wide variety of pesticides sprayed on crops, orchards, forests, gardens, and roadsides may also be concentrated over time. Often, these compounds are more soluble in fats than in water, thus the compounds are stored in fatty tissues inside the animal rather than excreted. Bioaccumulation of these toxins can lead to reproductive failure, health problems and death.

Biomagnification through the food chain is also a major factor in the concentration of toxins in living animals. Small levels of natural trace elements and synthetic toxins can be magnified to large levels of stored toxins as each level of predator in the food chain consumes large quantities of prey in order to meet its energy needs. Biomagnification of toxins is most readily seen at the top of the food chain, with animals such as marine mammals, seabirds, and sharks exhibiting highly magnified concentrations of toxins relative to animals low on the food chain per unit weight. Also, since these top-level predators are often long-lived, they suffer doubly under the combined burden of biomagnification and bioaccumulation, as the toxins magnified through the food chain continued to be stored in tissues over time.

Most people are familiar with the story of DDT, a toxic insecticide that does not break down readily, and has found its way into many different ecosystems through food chains. Rachel Carson's famous book Silent Spring eloquently pieced together the devastating effects of widespread persistent pesticide use following World War II on wildlife throughout the U.S. and other countries. Since the publication of Silent Spring in 1962, continuing research has documented the effects of these and newer toxins on animals. Rachel Carson's predictions did become realities.

In the case of predatory birds, such as herons, hawks and eagles, toxic pesticides and residues can either kill directly after the ingestion of contaminated prey or they can interfer with reproduction. Often, either no eggs are laid, or the yolk is so contaminated that chicks don't develop properly, or die soon after hatching. Although the use of DDT is banned in Canada, the chemical is still being used in other parts of the world. Traces of DDT are found in marine ecosystems everywhere.

In this activity, the food chain is used to demonstrate how toxins move from

Main Ideas:

Toxins in the environment accumulate in animal tissue and concentrations are magnified with each step up the food chain.

Objectives:

Students will:
- play an interactive game to learn about predators, prey and food chains
- learn how toxins become accumulated in animals and that the concentration gets magnified moving up the food chain

Vocabulary:

bioaccumulation: the process by which chemical substances are concentrated in an organism over time through ingestion of organisms or materials containing those chemicals and storing the substances within the body.
biomagnification: a cumulative increase in the concentration of a persistent substance in successively higher levels of the food chain.
metabolism: the sum of all the chemical processes within a cell or organism.

This activity has been adapted with permission from Project Wild. (See p. 4-2 for information on Project Wild).

one group of animals to another in the copepod - herring - killer whale food chain sequence. Copepods, the most abundant animals in the ocean, are tiny arthropods related to crabs and shrimp which drift with the plankton. Copepods are found in all oceans. They feed on phytoplankton, tiny single-celled plants which provide the primary food source for almost all food chains in the sea. Copepods also feed on other tiny animals in the plankton, and in turn are a major food source for small fish such as herring. Killer whales are top predators in their food chains since no other animals prey on them. Herring are a main food source for some populations of killer whales.

It is important to remind students that a particular food chain represents just one of many possible sequences of “eat and be eaten” relationships between animals (and plants) in an ecosystem. In other words, herring eat other prey besides copepods, and killer whales eat other prey besides herring. In general, the farther up a food chain an animal is, the more likely it is to be near the top of at least one food chain that is concentrating toxins in a polluted environment.

Materials:

- 30-50 paper or plastic squares or circles per student (4/5 white and 1/5 coloured)
- flagging tape (two or three colours) for arm bands
- plastic or paper bags, enough for about 2/3 of the class (one per “copepod”)
- blackboard or notebooks and pencils

Procedure:

The activity is best done outdoors if conditions permit, or in a large space like a gym.

1. After introducing the concept of food chains, using copepod - herring - whale as the example for this game, divide the class into three groups with approximately the following ratios:

tertiary consumers (killer whales) : secondary consumers (herring): primary consumers (copepods) = 1:3:9

For a class of about 26 students this would make 2 killer whales, 6 herring and 18 copepods. (With different group sizes, you should adjust the ratios toward the side of fewer killer whales and herring, rather than fewer copepods.)

Hand out three colours of flagging tape for arm bands to differentiate the three groups of animals. (If two colours are available, one group will have no arm bands). Give each 'copepod' a bag which represents its stomach.

2. While students have their eyes closed, distribute the white and coloured squares over the ground or floor. Explain that this is copepod food, but don’t say anything about the significance of the two colours. At a given signal, the copepods start to “eat” by picking up food pieces and putting them into the bags.

3. After 30 seconds, stop the copepods from feeding, and at this point introduce the concept of metabolism. Ask copepods to count the number of squares of each colour collected. Have the herring and whales record these on the blackboard or in a notebook. Each copepod, by name, will have an entry for colour and white squares. Explain how some of the food energy is used up by metabolism, and ask copepods to return 1 out of each 2 food pieces - white pieces only - to the floor to account for this metabolism. (Do not yet explain the function of the coloured squares)

4. Resume the game by having the copepods continue to collect more food, but also allowing the herring to start to prey on them. When a copepod is tagged by a herring it is “consumed”. The 'copepod' must then give her or his bag of food to the 'herring', and then stand in a designated area outside the play area. After about 30 more seconds (or when each herring has caught one or more copepods), stop the game again and have each 'live' copepod and herring 'metabolize' 1 out of each 2 of their white 'food pieces', returning the white tokens to the ground or floor. Record the data on copepod food remaining in the stomachs (both coloured and white) and then resume the play. At this time the killer whales are allowed to enter the ecosystem and begin to 'feed' on herring. When a herring is tagged by a whale, it gives up its food bags to the whale and joins the “dead” copepods on the sidelines. Stop the game about every 30 seconds to have each live player 'metabolize'(by discarding back onto the floor, 1/2 of their white 'food pieces'). Each time, record the white/coloured food data for the remaining live copepods. Each time the game is resumed, allow

copepods a slight head start on the herring, and the herring a slight head start on the killer whales. Continue the game for a few minutes, with 30 second interval 'metabolism stops', but stop before all the herring are gone!

5. Gather in a circle, and ask all animals still alive to add up the contents of their "stomachs". Record numbers of white and coloured food pieces each animal has. Now explain that a pesticide, represented by coloured paper pieces, entered the food chain when agricultural run-off containing pesticides from heavy rains washed out to the ocean.

6. Discuss with students how the pesticide was bioaccumulated by the normal metabolic functions of the copepods, so that the proportion of contaminated food pieces increased over time. Discuss how this process occurs at each level of the food chain. Then discuss how the toxin concentration is increased, especially in the top-level predators, through biomagnification.

7. Repeat the activity several times, with the following possible variations: a) have students change roles; b) change the metabolism ratio to 4 out of every 5 pieces of white food discarded; c) change the metabolism interval to 1/2 as long or twice as long. Record results each time and compare between games. Discuss the effects of bioaccumulation and biomagnification in each case, and the causes of the variation. Discuss the validity of this model in simulating natural ecosystem. (If the topics of recycling or reproduction come up at this time, you might wish to try the variation of the game outlined in the "extensions" section).

Discussion:

1. Toxic compounds such as dioxins have been found in the breast milk of Inuit women living in the Arctic. These people live far from the sources of such pollution, yet their tissues contain on average more dioxins than people living in the industrialized south. A large part of the Inuits' diet consists of marine mammals. How has the dioxin found its way into Inuit mothers' milk? (Have students look at a map of Canada to determine the rivers that flow to the Arctic)

Due to prevailing weather patterns, winds carry airborne pollutants from regions in central North America up to the Canadian Arctic, where they become incorporated in aquatic food chains as pollutants settle via precipitation into the Arctic Ocean. Also, toxins that enter north-flowing watersheds will eventually end up in Arctic ecosystems. Through the process of biomagnification, the Inuit people, who feed at the top of the Arctic food chain, ingest proportionately high amounts of toxin which are then incorporated into breast milk. One possible food chain for this is: phytoplankton - copepods - herring - seal - people.

2. Have students draw a picture or make a poster showing the difference between bioaccumulation and biomagnification in a food chain which involves seafood and humans.

3. Brainstorm ideas about how each of us can make decisions in everyday life that will make a difference to other living organisms. The less we contaminate our environment, the fewer are the repercussions in the web of life around us.

Examples: don't use pesticides on our lawns or garden; save water, soap and shampoo by showering less frequently; use only biodegradable laundry and dish soaps; use vinegar and baking soda as cleaning agents; buy organically grown food; buy food that is grown locally rather than transported long distances; walk or take public transit whenever possible; use both sides of every piece of paper; etc. Every such action, no matter how small, makes a difference, and the real consequence of thinking about these approaches will be to focus us on more healthy, ecologically appropriate lifestyles.

Extensions:

Two other aspects of ecosystems and food webs can be introduced into the game in order to further discuss this simulation as a model of real-world systems. These aspects are <u>reproduction</u> and <u>nutrient recycling</u>. You might try allowing 'sidelined' copepods and herring to 'reproduce' or become 'recycled' after fixed lengths of time on the sideline, say for example, 2 metabolism cycles for copepods and 4 metabolism cycles for herring. This simulation will allow you to discuss the concepts of population dynamics and/or the constant recycling of materials in the living world. This approach will also get students almost continuously active in the simulation rather than watching from the sidelines.

Where Has It Gone?

Ocean News Reference: *"Let's Be Straight about the Strait", page 2; poster, pages 4-9.*

Main Ideas:
Habitats change over time due to natural and human-influenced causes. Loss of estuarine and other wetland areas can mean significant losses of wildlife habitat, and decrease in productivity with repercussions up the food chains.

Objectives:
Students will:
- discover areas in their community where habitat has been lost due to industrial, agricultural, residential or other developments
- interview long-term residents of the area and do library or archival research to learn how these areas have changed over the years

Vocabulary:
estuary - semi-enclosed body of water with free connection to open sea, where seawater is measurably diluted with freshwater from land drainage
habitat - an organism's place or "home" in the environment, required for the success of important functions such as feeding or rearing of juveniles
detritus - dead organic matter from plants and/or animals

Background:

Most organisms are adapted to specific habitats where the essential functions of feeding, reproduction and hiding from predators can be successfully carried out. If the local habitat for an organism disappears through natural or human-caused events, and the population cannot relocate successfully elsewhere, that population will become locally extirpated. If all its habitat is destroyed, an organism will become extinct.

Estuaries are among the most biologically productive habitats on earth. Within the estuary, rich sediments brought down by the river system provide valuable nutrients to fuel a complex food web. Estuaries are essential habitats for many different organisms.

Brackish and freshwater marshes, salt marshes, tideflats and sloughs found in estuaries are home to productive stands of grasses, rushes, eelgrass and other plants eaten by populations of migratory waterfowl. As these marsh plants lose their leaves and die back each year they produce a steady supply of detritus which is food for microscopic organisms. Bacteria, along with the tiny single-celled plants which drift in the plankton of the estuary's waters, are food for small invertebrates (worms, copepods, amphipods, snails, etc.) which, in turn, are eaten by fish, crabs, shrimp and vast flocks of migrating shorebirds. Besides the host of animals that make permanent homes in estuaries and wetlands, these habitats provide critical "refuelling" stops for migratory birds. Many animals such as crabs, herring, salmon and flounder depend on estuaries for part of their life cycle - for example: feeding as juveniles, laying eggs, or seeking refuge from predators.

People have harvested the abundant wildlife and food plants of estuaries and other wetlands for thousands of years. In modern times, estuaries have served as safe harbours, fishing grounds, mariculture locations, sites for industry, and they have been drained for agricultural and residential land. All of these uses have led to changes - often drastic - in the natural habitats occupied by the rich variety of plants and animals characteristic of estuaries or wetlands.

Materials:

- tape recorder (or notebook and pen)
- video camcorder, if available
- library, archive materials, government publications, etc. which refer to changes over the years in wetland or estuarine areas in the community

Procedure:

1. Initiate a class discussion on the importance of estuaries, wetlands, rivers or other sensitive aquatic habitat in your area. Choose a well-known area that students and other local residents are likely to know. Brainstorm the following questions along with other related

questions? How has the size of this area changed over the years? How do students think it looked 20, 50, 100 years ago? How might animal or plant life be different between then and now? How have human uses of this area changed over time? Record students' ideas for later comparison.

2. Over a weekend or longer period, have students find out more about the area of concern by talking to neighbours, relatives or friends who are long-time residents in the community. Have students ask whether their sources would be willing to give a taped or videotaped interview on their memories of how the chosen habitat has looked and changed over the years.

3. Working in pairs, ask students to research in the library, archives and local government offices for information on the habitat in question. Look for records about activities such as diking, draining, landfilling, wharf construction, etc. What were aboriginal uses, if any, of the area? How have people used the area since the time of European contact?

4. Having done this, brainstorm in class a list of appropriate questions to ask during the interviews, so that all interviewees are asked similar questions. Encourage students to ask more questions on their own if so inclined. An alternative for interviewees who do not wish to be recorded, or when recording equipment is not available, is to simply take notes. Have students work singly or in pairs for these interviews.

Some examples of questions to ask include:

- What line of work was your family involved in when you were growing up? What type of work did you do during your working career?

- When and what is your earliest memory of this wetland?

- What kinds of plants and animals do you remember seeing there?

- How big was the wetland? Has it changed in size?

- How have people in the community used this wetland in the past? Have the uses changed over the years?

- When was the area diked, dredged or otherwise altered?

- Do people interviewed think this area has value outside of its value for humans – that is, do the interviewees think that the area has its own intrinsic value? In their views, have the changes brought about by people in this area been worth the sacrifice of the habitat for use by other creatures? (This question may lead to an interesting discussion of the ideas of 'intrinsic value'.)

- How has the wetland and any changes in it over time personally affected the interviewee? (Is the person a birdwatcher or angler, or is their house or farmland on land that has been 'developed' through the use of dikes?)

5. Students conduct the interviews, transcribe and summarize the answers.

Discussion:

Were the answers to questions as students expected?

In comparing what was reported in the various interviews, did the interviewees have different memories of how the habitat looked in the past? Did these memories differ greatly from the recorded history as discovered from library research?

Did people's opinion of the value of the wetland bear any relation to their livelihood? Did farmers, fishermen, tug boat operators have a different outlook from biologists, birdwatchers, etc?

From what students learned collectively, map the changes in the wetland over time. How many hectares of wetland habitat have been lost? Make a list of wildlife no longer seen in the area.

Extension:

Help students discover ways that they can get involved in helping to restore lost wetland habitat. Contact a local conservation officer or other appropriate resource person to visit the class and discuss the habitat in question. Better yet, ask the person to accompany the class on a field trip to the site.

Bioregional Mapping

Ocean News Reference: *"Water Stewardship", page 12.*

Main Ideas:

Bioregional mapping allows individuals to examine their role in the ecology of their local region and to think about their connections to marine pollution.

Objectives:

Students will:
– make a map of their personal bioregion which includes watershed issues such as "where does the water I use come from and go?"

Background:

This activity invites students to think about their personal living situation – whether a city apartment, rural home, suburban setting – in the context of a bioregion. A bioregion is a "place of life" in the biosphere. It is often thought of as a watershed or collection of local ecosystems that directly influence us. A bioregion has a continuity of natural characteristics – climate, watershed, native plants and animals, human occupation. Unlike the 'biogeoclimatic zone' used to classify ecological regions of forests in British Columbia, the bioregion may include a collection of ecosystems that work together to make the whole. Thus, high mountains in a local region may collect the rain that feeds a watershed, that empties into a major river, that dumps into an estuary, that then feeds an ocean basin. The bioregion is a group of localized ecosystems that together determine the nature of the communities of plants, wildlife and the humans living there. The bioregion is a unified, natural whole.

There is a growing recognition of the usefulness of this bioregional approach. Perhaps the most pronounced shortcoming of the study of ecosystems is that we tend to isolate humans as distinct from, or outside, the ecosystem. The bioregion concept overcomes this shortcoming by locating humans and their activities in relation to the landscape and surrounding biotic community.

Bioregionalism is an extension of the bioregional concept into more frequent or everyday thinking. Thus, bioregionalism involves knowing more about the inter-relationships between the various parts of the community surrounding us – the geological and climatic factors at work, the organisms that affect us and are affected by us, and the political and social inter-relationships that govern how we live together in the community and landscape.

Materials:

- large piece of paper for each student,
- felt pens,
- journal.

Procedure:

A. (Approximately 1 hour) Ask students to do the following on their own large piece of paper: (Write these on the board or overhead as you say them.)

1. Put an X in the center of the paper to indicate where your house is.
2. Draw the nearest body of freshwater and the nearest body of saltwater on the map.
3. Show your source of drinking water and how it gets to your home.
4. Show where your household wastes drain to. If it is a sewage system show the location of any treatment facilities and show the outflow.
5. Add any large land forms such as mountains or valleys.
6. Add native plants.
7. Add native animals in the water, air and on land.
8. Show where north is.

9. Show where storms come from.

10. Show the worst thing humans are doing in your region.

11. Show the best thing humans are doing in your region.

Now have students report to the rest of the class:

a. where the region is.

b. the answers to # 6, 7, 10, 11.

B. (Approximately 1 hour) Form groups according to region, neighbourhood, or other geographical breakdown (3 or 4 only in each group). Have students either cut and paste their individual maps together to make a big picture of the region, or prepare a new map of the region graphically showing the answers to the following questions:

1. What happens to the waste when you flush the toilet?

2. Where does your food come from?

3. Where does your water come from?

4. Where does your garbage go?

5. Show the worst thing humans are doing.

6. Show the best thing humans are doing.

Have students present these new maps to the class. In journals have students summarize what they know about their region. Discuss the importance of studying larger 'bioregions' like these, as well as political territories.

C. (Approximately 1 hour) In journals, using felt pens, coloured pencils, or paint, have students prepare a bioregional map of their property or neighbourhood, a walk they do often, a special place, etc. Use 'artistic license' to exaggerate the special features on these maps. (This could be planned in the journal and then transferred to large, special paper, with a border and a legend, and displayed in the school afterwards.)

Discussion:

A rich discussion can come out of these activity involving students' perceptions of their local environment and their interconnections to the rest of their bioregion. For example, food is often thought of as 'coming from the supermarket', and human wastes 'go down the toilet'. Yet, in reality, food is living organisms that come from certain ecosystems and sewage is organic material and bacteria that ends up in (usually) other ecosystems. Discussing the ecosystem dynamics of these items will help students to expand their understandings of their bioregion.

Extension:

1) Bioregional mapping will make an ideal lead-in to groundtruth studies using satellite images. A number of activities described in Ground Truth Studies Teacher Handbook: British Columbia (see the resources section of this guide for information on ordering this book) can be used to get students involved in this work and to expand their understandings of their own watersheds and bioregions. Questions related to marine pollution can be addressed directly and indirectly through satellite image work.

The Transportation Connection

Main Ideas

Transportation of food and all of the other goods we consume is a large factor in creating marine pollution.

Objectives:

Students will:
- prepare a list of the different types of food consumed in their households.
- research the point-of-origin of foods they consume, and determine the average distance foods travel before consumption.
- discuss alternatives to consumption which promotes long-distance transportation of goods.

Ocean News Reference: *"Shadow Across the Ocean", p. 1; "Pollution Solutions", p. 9.*

Background:

It has been calculated that, on average, an item purchased in North America travels about 2100 kilometres from its place of growth or manufacture to point-of-purchase.

The connection between marine pollution and the extensive transportation of consumer goods or food may seem, at first, to be remote, but in reality much of the marine debris, oil pollution, and toxic wastes arrive in the ocean directly from ships used to transport consumer goods and food, or as run-off from land-based vehicles. Reducing our consumption of foods that require extensive transportation is one way we can lessen the impact of our ecological shadows upon the ocean.

Materials

- table for data collecting
- calculator, atlas, maps, globe for calculating distances

Procedure

1) As homework, have students make a list of all of the different food items eaten by their family in an 'average' week (not quantity, only a list of the items). One way to do this would be for students to go shopping with parents and make a list of all of the items purchased. For each item, where possible, students should read the label and note down the place of growth, processing, or manufacture. Also note the major ingredients, especially if these seem likely to come from a different location than the point of manufacture. (For example, bananas may be one of the main ingredients in a food 'canned' in Toronto. Obviously, bananas are not grown in Toronto).

2) (In class). Working in pairs, have students compare their two lists and come up with a 'shopping list' (again only the items, not the specific quantities) for a 'hypothetical family' somewhat similar to their families. They can be encouraged to add 'preferred' foods to the list, as well. Have the pair prepare a table with four columns - the first column for the list of foods; the second for major components in the food item, if required; third for the place of growing or packaging/processing as indicated on labels, boxes in the produce department, etc.; and fourth, for the distance the item travelled to reach their home. (See page 4-14) **(It is important not to place value on any items or selections indicated by anyone in the class, and it is important to recognize cultural differences in food choices as normal and healthy).**

3) Send students to the food store to complete the location of origin portion of the table. Back in the classroom, using maps and the atlas, calculate the average distance travelled by each food item.

Some creative estimations will probably be necessary. Keep in mind that point-of-packaging or processing to store may not reflect the actual distance travelled by the food item. For example, potato chips may be made from potatoes grown in a local region, but if they are cooked in coconut oil, which must come from a tropical region, the potato chip product involves distant travel. In another example, tuna may be canned in Thailand, but it was actually caught in the South Pacific Ocean. So, to be accurate, the 'transportation factor' of these foods will have to reflect transportation distances more than 'point -of-processing' to 'store'.

4. (Class Discussion) In class, discuss the point that food may travel long distances to get to our local stores. Examine some of the food items commonly found on the students' lists, and discuss the distance travelled by these items. Discuss the type of transportation probably used to bring the food item from point-of-manufacture to point-of-purchase. How might this transportation cause marine pollution?

Make a table of the average distance travelled by the food of different pairs in the class. If any pairs of students had low average distances for the food in their 'shopping lists', find out how this was accomplished.

Discuss ways in which food transportation can be minimized or lowered through purchasing choices. Keep the discussion centred on what can be done to improve a situation where society as a whole is relying on too much long distance transportation. Blame for this 'problem' does not rest on any particular group, but anyone can be part of the solution.

Extension:

If your school has a cafeteria, get permission for a group of your students to carry out an audit of food items used at the cafeteria and their point-of-manufacture/growing. Include an extra column for purchase price for each food item. Back in class, have students determine the distance travelled by each item.

Using this data, have another group of students research alternatives that are grown locally and have them compare the price differences for the local and distant items.

This research may lead to a proposal to make the cafeteria more ecologically sustainable.

These activities can lead to a discussion and further work with the concept of 'full cost accounting'. In full cost accounting, the price of goods is structured to include environmental costs incurred when those goods are produced. A productive class discussion can be centred around the questions: what factors should be incorporated into full cost accounting, and how can these be 'collected'?

Food Item Travel Survey

Food Item:	*Major Components*	*Point of Manufacture/Growing*	*Distance to Point of Use (km)*

Biodiversity Quiz

Ocean News Reference: *"Protecting the Ocean's Biodiversity", p. 1; "Water Stewardship", p. 12.*

Main Ideas:

Knowledge of local natural history is important to preserving biodiversity values in the local bioregions where we live, and to valuing biodiversity in other ecosystems.

Objectives:

Students will:
- demonstrate their knowledge of local natural history,
- research local natural history to improve their knowledge of biodiversity-related information.

Background:

For students to appreciate and be committed to action on the issue of marine pollution, they need to understand and value the need for humans to preserve the wide diversity of living organisms and the habitats that support them. Biodiversity is an important concept that is beginning to guide management policies and practical living. The new field of conservation biology is built on the fundamental ideas of biodiversity, which involve three aspects: 1) species biodiversity - the diversity of species in a habitat; 2) genetic biodiversity - the question of population size and diversity in the gene pool of any one species; and, 3) ecological or habitat biodiversity - the question of whether sufficiently large natural habitat is available to each species.

Materials

- copies of the 'Biodiversity Quiz' from page 4-17.
- resource books such as natural history guides to the local area, and/or resource naturalists.
- binoculars, and other field trip equipment

Procedure:

1. Read 'Ocean Biodiversity' from Page 1 of Ocean News 4. As a class, discuss the three aspects of biodiversity - species, genetic, and ecosystem biodiversity. Begin to find out what students know about local biodiversity. Have students studied ecosystems or specific habitats in previous classes? What do they know about the concept of populations? If possible, carry out a field trip to a local natural area where you can examine biodiversity.

2. Pass out the 'biodiversity quiz' and go over it, to be certain students understand each question. Depending on your location and the natural history skills and background of the students, either start with a completion of the quiz sheet or begin directly with a discussion on how to find the information required by the quiz. You might also discuss why it is important to know about local biodiversity. Give students time to complete the quiz sheet and direct them to resources that will help them find answers to the quiz.

3. After the quiz has been completed, go over it in class. Generate a list of questions raised during students' work on the quiz. Also, make the connection between knowledge (or lack of knowledge) of local biodiversity, and the effects human have on the local environment. Then extend this discussion to other environments, particularly the marine environment. What do students know about marine biodiversity? Is their knowledge sufficient to serve as a basis for action on marine pollution? If not, what can be done to improve this knowledge?

Discussion:

Edible plants:

In the appropriate season, it is relatively easy to find 5 different edible plants in most parts of Canada - even cities will have a number of edible weeds such as dandelion, oyster flower, blackberries, sour dock, peppermint, pigweed, etc.

The 'biodiversity quiz' was adapted from a 'bioregional quiz' developed by Leonard Charles, Jim Dodge, Lynn Milliman, and Victoria Stockley, first published in the Co-Evolution Quarterly, Winter 1981.

Resident and migratory birds:

Those students who need help with this question might be encouraged to go directly outside with binoculars and bird guide in hand. Are there students who can expand this list to 20 or 30 birds?

Natural fire:

Natural fires are often difficult to determine, but usually the base of trees in a local forest, or the soil of an undisturbed patch of ground will provide a record of fire occurrence in recent times. Also, old records from newspapers or archives or long-time residents of your area may be of some help. If possible, take a field trip to a relatively undisturbed area near your school and dig one or more soil pits. Distinctive burned layers in the soil horizons indicate historical or prehistoric fires.

Spring wildflowers:

Is the first spring flower in your area a native or introduced species? The term 'wildflower' usually refers to native species. Members of the lily family are often among the early spring wildflowers in many areas.

Local natural forest:

If possible, carry out a field trip to a natural forest. Carefully examine canopy trees, shrubs, and herbs. Late spring is probably the best time for easy identification of the herbs and shrubs, but any time is appropriate for a first look at the forest biodiversity even when there is considerable snow. What distinguishes a natural, from a disturbed, forest?

Deer rut and birthing:

The rut takes place in the fall. Depending on the species and latitude, deer are usually born in May and June. Contact a local wildlife biologist for details on deer in your region

Local reptile:

Except in the far north, there are snakes or turtles in most areas, and lizards in some.

Local amphibians:

Frogs, salamanders, and toads are found in most areas. Check guidebooks for the local species.

Extinct or extirpated species:

Most wildlife has been extirpated from our city areas but the actual extinction or regional extirpation of species in your area may require some research. A number of species such as passenger pigeon, great auk, buffalo, black-footed ferret, and blue-eyed walleye are species which have been extirpated or driven to complete extinction in recent history. Since 1500, at least 19 species have disappeared from Canada and only 10 of those survive elsewhere. It is possible that many other species have also suffered extinction as a consequence of human activities such as logging, dams, wetland development, or urban growth - we simply do not know.

Nearest salmon/steelhead stream:

Anadromous fishes - those that live most of their lives in the sea, but return to their freshwater place of birth to spawn - include steelhead trout, coho, spring, humpback (dog), sockeye, and pink salmon.

Local native fishes:

Fish are one group of animals in B.C. suffering from an already-definable 'biodiversity crisis'. Thus, these animals might also serve as good indicators of successful efforts to preserve biodiversity or maintain water quality by limiting water pollution. There many species of pricklebacks, sculpins, dace, shiners, minnows, etc. found in B.C. waters and some are endemic to relatively small regions.

Nearest undisturbed old growth forest:

Undisturbed, old-growth forest is exceedingly rare near most of our population centres. A patch of this type of forest of any size is an important biodiversity asset to the community. How do you know this forest area is 'undisturbed old growth'? Is it possible to compare this forest with a 'disturbed' site in order to examine how biodiversity varies with these two forest types.

Name an introduced species in your area that is causing trouble with native species.

Included in this list are many plants such as scotch broom, gorse, purple loostrife, blackberry, Eurasian millfoil, Russian knap weed, star thistle, etc. or animals such as opossums, starlings, rats, and others.

Extension:

1) Have students research and develop a biodiversity quiz appropriate to the school ground.

2) Have students send a biodiversity quiz to local politicians and then discuss with them the implications of knowing this type of information. Presentations in a school meeting or local community town-council meeting may influence others to consider biodiversity as an important factor in monitoring the health of the community.

3) Read Chapter 21; 'Threats to Biodiversity in the Strait of Georgia', in <u>Biodiversity in British Columbia: Our Changing Environment</u> (see resources listing).

Biodiversity Quiz

Many people, in many parts of the world, live in close contact with the natural surroundings. Questions such as the ones in this quiz are part of their basic knowledge. Challenge yourself by completing this quiz. A perfect score means you are a biodiversity expert. If you don't know the answers, how long will it take you to find them? Try it!

Name five edible plants in your region and their season(s) of availability.

	Name of Plant	*Edibile season*
1.		
2.		
3.		
4.		
5.		

Name five resident and five migratory birds in your area.

	Resident Bird Species		*Migratory Bird Species*
1.		1.	
2.		2.	
3.		3.	
4.		4.	
5.		5.	

When was the last time a natural fire burned in your area?

What spring wildflower is consistently the first to bloom where you live?

Name three dominant species in each of the following sections of a nearby natural forest:

	Canopy Layer	*Shrub Layer*	*Herb Layer*
1.			
2.			
3.			

Where do the deer rut in your region and when are the young born?

Name one reptile that lives in your area.

Name three amphibian species living near you.

1. ______ 2. ______ 3. ______

What species have become extinct or extirpated in your area?

Where is the nearest creek, stream or river where you would find a species of fish that swims up from the sea to spawn? What species is it?

Name three species of fish that are native to your region.

What is the size and type of the nearest undisturbed old growth forest?

Checks And Balances

Main Idea:

Wildlife managers must make difficult decisions affecting the future of animal populations. Complex variables come into play, and chance events make decisions even more difficult.

Objectives:

Students will:
- use role play to learn about the difficulties that wildlife managers face while trying to regulate a population of intertidal crabs

This activity has been adapted with permission from Project Wild.

(See Appendices for inform-ation on Project Wild).

Background:

Wildlife managers face a difficult task in attempting to 'regulate' populations of animals or plants in the face of many complex variables. While some factors are 'controllable', many others are not. Some of the factors affecting wildlife populations are: loss of habitat from human activities or natural causes; weather conditions; pollution of food, water or habitat; pressure from industry for resource development; poaching, and recreation.

It is important that students understand that actions and decisions we make in our daily lives can have far-reaching impacts on animals around us. Discuss this concept with students before and after doing this activity and see how their perspectives change.

Materials:

- copies of game cards photocopied on heavy paper stock (3 different colours)
- dice
- paper and pencil or game chips
- calculator

Procedure:

This game can be played individually or in small groups. There are 36 game cards in 3 sets: 18 condition cards, 9 reproduction cards and 9 management cards, shuffled and piled separately. If playing individually, each student needs a die. The teacher holds the 3 sets of cards and reads them out to class as game proceeds. If playing in groups, each group needs a die and a set of 36 game cards.

1. Each player is a wildlife manager responsible for a population of 100 intertidal crabs (or other animal of your choice). Changes in population numbers as the game proceeds can be noted on paper or by using game tokens.

2. Each player's turn represents a cycle of one year on the beach, and a turn is played by drawing four cards in order and following instructions on each to determine the fate of the original population of 100 crabs.

3. Cards are drawn from decks in this order: condition card, reproduction card, condition card, management card. After each card is drawn, player rolls a die and uses that number to follow instructions on the card, arriving at a new population size after each draw. **N = the number rolled on the die**.

4. The game proceeds for 9 rounds, representing 9 years. Starting with initial population size of 100, the object is to end up after 9 years with a viable population. For the purposes of this game, viable means maintaining between 10 and 200 crabs at all times during the play. If his/her crab numbers fall outside these limits, a player is out of the game because the crab population has grown too large or too small to be viable.

Discussion:

1. For players whose populations survived 9 cycles, how did numbers fluctuate over time? What seemed to be the main factors influencing increases and decreases?

2. Ask students to evaluate management decisions made during the game. Did these decisions seem to have a positive effect on crab numbers? What decisions would students have made differently if given a second chance?

3. Discuss which aspects of the game seemed most realistic to students. Did rolling a die seem like a fair way to determine impact of management decisions?

- Although rolling of dice oversimplifies real life situations, for the purposes of this game, it points out to students that chance can often have significant effects on wildlife management - for example, hurricanes, wildfires, and earthquakes may not be predicted or prevented.

4. What other intertidal organisms might be affected by management decisions aimed at protecting crabs? The concept of food webs and interrelatedness of all organisms in an ecosystem comes into play here.

5. Some wildlife managers say that their job involves management of people more than of wildlife. Discuss the meaning of this comment with class.

Extension:

Ask students to modify the game by making additional cards, or changing some of the ones in this set. Design the game for an animal or plant that lives in a different habitat. Introduce another aspect to the activity by designing the game for an animal that is valued by game hunters or fishermen. How does this complicate the wildlife manager's job?

Checks and Balances Game Cards - Management Cards

MANAGEMENT

HABITAT RESTORATION: Nearby log booms are moved elsewhere.

Increase population by 5N %

MANAGEMENT

LAW ENFORCEMENT: Federal regulations on toxins in industrial effluent are monitored and enforced.

Increase population by 2N

MANAGEMENT

HABITAT RESTORATION: Home previously dumping sewage onto beach is required to install septic system.

Increase population by 3N %

MANAGEMENT

EDUCATION: Visit to beach with naturalist instils new respect for crabs.

Longterm effect is positive, so increase population by 2N %

MANAGEMENT

HABITAT RESTORATION: Rocks previously removed from intertidal for firepit are returned to original locations.

Increase population by 5N

MANAGEMENT

HABITAT ACQUISITION: Intertidal area protected by National Park.

Increase population by 5N

MANAGEMENT

HABITAT ALTERATION: Area is dredged to allow building of dock.

Decrease population by 3N %

MANAGEMENT

COLLECTION REQUEST: A request is made to collect crabs for research study. Do you allow this?

If yes, decrease population by 5N.

If no, no change in population size.

MANAGEMENT

RESEARCH: Research on how removal of dog whelks affects other populations has resulted in a **decrease in crab population of 2N.**

Checks and Balances Game Cards - Condition Cards

CONDITION:

WEATHER: Hot weather and low tides stress crabs.

Decrease population by 5N %

CONDITION

HABITAT DESTRUCTION: Pulp mill containment pond for BOD control is built in intertidal

Decrease population by 5N

CONDITION

WEATHER: Freezing weather and low tides stress crabs.

Decrease population by 5N %

CONDITION

HABITAT DESTRUCTION: Log boom pushes all rocks into subtidal area and destroys intertidal cover.

Decrease population by 5N

CONDITION

WEATHER: Ideal weather results in huge plankton bloom which benefits all animals up the food chain.

Increase population by 5N %

CONDITION

HABITAT DESTRUCTION: Dredged material stored on land is washed into intertidal by heavy rains, covering everything with sand.

Decrease population by 5N

CONDITION

WEATHER: Cool summer allows intertidal life to flourish.

Increase population by 5N %

CONDITION

HABITAT DESTRUCTION: Lost fish net washes ashore, entangling all crabs.

Decrease population by 5N

CONDITION

HABITAT DESTRUCTION: Beach visitors move most intertidal rocks to make a firepit.

Decrease population by 5N

CONDITION

HABITAT DEGRADATION: Industrial effluent adds dioxins to environment.

Decrease population by 3N

CONDITION

HABITAT DESTRUCTION: Oil spill covers intertidal with oil.

Decrease population by 5N

CONDITION

HABITAT DEGRADATION: Nearby marina illegally uses tin based bottom paint on all boats.

Decrease population by 3N

CONDITION

HABITAT DESTRUCTION: New home owner removes all “unsightly” rocks from intertidal.

Decrease population by 5N

CONDITION

HABITAT DEGRADATION: Agricultural runoff results in eutrophication and choking of crabs.

Decrease population by 3N

CONDITION

HABITAT DEGRADATION: Increased number of visitors increases intertidal trampling.

Decrease population by 3N

CONDITION

PREDATOR: A black bear eats N% of crabs.

Decrease population by N%

CONDITION

DISEASE: PCB ingestion has weakened immune system so that disease **decreases population by N%**

CONDITION

COLLECTION: Uninformed beach visitors collect crabs to keep as pets.

Decrease population by 2N

Checks and Balances Game Cards - Reproduction Cards

REPRODUCTION: Average year

If population is greater than 50, increase by (100/current population size) X 3N

If population 10 - 50, increase population by 3N

REPRODUCTION: Average year

If population is greater than 50 increase by (100/current population size) X 3N

If population 10 - 50, increase population by 3N

REPRODUCTION: Average year

If population is greater than 50 increase by (100/current population size) X 3N

If population 10 - 50, increase population by 3N

REPRODUCTION: Excellent year

If population is greater than 50 increase by (100/current population size) X 5N

If population 10 - 50, increase population by 5N

REPRODUCTION: Average year

If population is greater than 50 increase by (100/current population size) X 3N

If population 10 - 50, increase population by 3N

REPRODUCTION: Excellent year

If population is greater than 50 increase by (100/current population size) X 5N

If population 10 - 50, increase population by 5N

REPRODUCTION: Average year

If population is greater than 50, increase by (100/current population size) X 3N

If population 10 - 50, increase population by 3N

REPRODUCTION: Excellent year

If population is greater than 50 increase by (100/current population size) X 5N

If population 10 - 50, increase population by 5N

REPRODUCTION: Average year

If population is greater than 50, increase by (100/current population size) X 3N

If population 10 - 50, increase population by 3N

Heavy Metal Band

Main Idea:

Many heavy metals introduced into the ocean through natural processes, including selenium, chromium, copper and zinc, are essential elements required in a variety of enzyme functions. However, many heavy metals and chemicals such as PCBs, furans and chlorine, introduced through human activities, can create serious pollution problems in the ocean.

Objectives:

Students will:
- learn about the sources of heavy metals, PCBs, dioxins, furans and chlorine in the marine environment
- learn about some of the potential hazards of large concentrations of heavy metals, PCBs, dioxins, furans and chlorine
- create a presentation (play, rock video, rap song, poem, etc.) about heavy metals, their sources and impacts on wildlife, people and the environment

Vocabulary:

toxicity – the capacity of a substance to cause adverse effects in a living organism.

Background:

Heavy Metals

Traces metals such as lead, mercury, cadmium, arsenic and copper occur naturally in water, sediment and some plants and/or animals. Natural weathering of rocks, leaching from soils and vegetation, volcanic activity and forest fires all can introduce trace metals into the environment. Humans contribute further to the concentration of heavy metals in the environment through: offshore oil and gas development; ocean dumping; mining and smelting processes; burning coal and oil; and processing and disposing of municipal and industrial wastes.

Many of these metals play an important role in plant and animal health. Essential trace metals include selenium, chromium, copper and zinc. Other metals, including lead, cadmium, mercury and aluminum, are nonessential metals and have no known biological function. The toxicity of these elements depends on the chemical state of the element, the concentration and location in the organism. Many elements that are in fact essential, can become toxic when they are in concentrations higher than is biologically useful. They can also become toxic in combination with other substances.

There are currently few Canadian guidelines for acceptable levels of heavy metals in fish and shellfish. Currently, only mercury has a minimum limit established, at 0.5 mg/kg wet weight. Prior to strict guidelines being imposed on the discharge of mercury, levels as high as 13.4 mg/kg were found near a mercury-cell chlor-alkali plant in Howe Sound north of Vancouver.

PCBs

PCBs are synthetic chlorinated hydrocarbons that have been used in such products as plastics, inks, paints and pesticides, hydraulic and lubricating fluids. Characteristics that make them a desirable industrial material also make them a hazard to the environment. PCBs are very stable and are not easily metabolized (broken down). This allow PCBs to be accumulated into all levels of the food chain. Toxic effects from PCBs have been observed in birds, humans and other mammals, marine vertebrates and invertebrates. A level of 2 mg/kg wet weight has been established by Health and Welfare Canada as an acceptable level for fish and shellfish intended for human consumption.

PCBs have not been manufactured in North America since 1977 however, they are still in use. One of the major uses for PCBs is in electrical equipment. Sediment sampling indicates that PCBs are found at locations associated with industrial, urban and port activities. PCBs in sediments near pulp mills are likely there as a result of leaks from PCB-containing electrical equipment. Contamination of sediments in harbours is probably a result of sewage discharges, stormwater run-off and unreported spills from electrical and hydraulic equipment. In the past, many marine paints also contained PCBs.

Dioxins

Dioxins, or dibenzo-*p*- dioxins, are extremely toxic to animals and their discovery in the marine environment raised concerns over the effects these chemicals would present to humans and the environment. Dioxins enter the environment through a variety of avenues including: municipal and industrial incineration; chlorophenols in wood preservatives and pesticides; landfills with liquid organic wastes; wood burning; fires involving electrical equipment containing chlorinated organics; cigarette smoke and car exhaust; pharmaceuticals and household products including some disinfectants.

Discharge from pulp and paper mills and associated industries were a major source of dioxins up until very recently. Recent regulations required that dioxins and furans be undetectable in effluents from pulp mills using the chlorine bleaching process.

Materials:

- pollutant biography cards (one copy of each card for each group of students)
- prop/costume materials as required by students
- periodic table

Procedure:

1. Using the background material, provide a short introduction to heavy metals and other pollutants. Point out some of the heavy metals on the periodic table.

2. Divide the class into group. Give each group a set of pollutant biography cards. Each student "becomes" one of the pollutants and develops a "character" using the information provided. For example - "I'm mercury. Hanging out too much with me can be a killer. I'll affect your nerves, your brain, and your red blood cells."

3. Give the students an hour to develop a presentation in a style of their choosing. Some ideas: become a heavy metal rock band; produce a rap song; develop a short play; perform a poem, etc. Students should, through the course of their presentation, let their audience know the sources of these heavy metals and other pollutants, along with some of the potential problems associated with them. If possible, they may suggest some creative solutions to high concentrations of heavy metals and other toxins in the environment.

Discussion:

1. As a class, brainstorm to create a list of potential sources of heavy metal and organic toxins such as PCBs in your community. What controls are placed on the disposal or discharge of these chemicals?

Extension:

1. Have students investigate actual cases of heavy metal poisoning. Some examples:

Mad Hatter's Disease - Beaver pelts from the fur trade in Canada were taken to manufactures in London, England to be sheared, tanned and moulded into fashionable hats for the gentry. This process used mercury. Hat makers (hatters) became chronically ill after exposure to this toxic metal.

Grassy Narrows, Ontario - Mercury effluent dumped into the river from a pulp and paper mill passed through the food chain and concentrated in pike, a popular sport fish. These pike formed the main diet of the band members from a nearby Indian Reserve. The people suffered directly from mercury poisoning, and indirectly from the closure of the fishery.

Sunshine Coast well water -Arsenic has been found in high concentrations in Sechelt/Pender Harbour area wills drilled into bedrock. Arsenic has been leaching naturally from the igneous bedrock.

Minimata Disease - World attention focused on an unusual disease or poisoning in Japan in the 1950s. Starting in the 1930s a chemical plant near the coastal fishing community of Minimata, Japan, released effluent containing mercury compounds directly into Minimata Bay. Methyl-mercury chloride became concentrated in the bay, and this toxin accumulated in fish and shellfish, which in turn were eaten by local people. Severe neurological disorders began to show up. The pathological characteristics of this poisoning became known as 'Minimata Disease'. The causative agent was not determined until 6 years after the first outbreak of the disease in 1953. A close relationship between the level of mercury in the victims hair, and the onset of the disease was finally recognized. The poisoning is now known as methyl-mercury poisoning. It took until 1970s before Japan halted the discharge of mercury, and before other nations blacklisted mercury dumping.

INTRODUCING LEAD

Sources: leaches from lead pipe and lead-based solder pipe joints; airborne lead from gasoline combustion; found in many consumer products including paints and gasoline,

Health effects: central and peripheral nervous system damage; kidney problems. Highly toxic to infants and pregnant women and can irreversibly affect mental and physical development. Can cause impaired mental performance in children.

INTRODUCING PCBs (polychlorinated biphenyls)

Sources: (no natural sources) industrial chemicals found in paints, inks, carbonless copy paper, plastics, electrical transformers, agricultural pesticides, sewer outfalls, wastewater from pulp and paper mills, electrical and hydraulic equipment. In B.C. the forest industry is the largest user of PCB-containing electrical equipment followed by B.C. Hydro.

Health effects: effects on humans not fully known, but evidence shows that PCBs cause cancer, reproductive failure, birth defects and reduced resistance to disease in other animals. Animals at the top of the food chain are especially at risk due to biomagnification. In fish, the liver retains the highest levels of PCB, followed by the gills, heart, brain and muscle.

Other: tend to concentrate in sediments; very stable; accumulate in food chain

INTRODUCING CADMIUM

Sources: weathering of rocks, burning of fossil fuels, mining and smelting, fertilizer application, sewage sludge, eating contaminated molluscs whose livers concentrate cadmium; rust-proofing materials; batteries; plastics.

Health effects: insufficiently eliminated by human body and accumulates in bones, causes renal (kidney) dysfunction, hypertension (high blood pressure), anemia, altered liver function

INTRODUCING DIOXINS AND FURANS

(chlorinated organic compounds)

Sources: (no natural sources) by-products of industrial incinerators, chemical processes such as bleach kraft pulp mills and chemically treated lumber

Health effects: long term exposure in various mammals has led to immune system damage, impaired reproduction, birth defects and cancer; in humans, the only health effect so far directly linked to dioxin exposure has been chloracne, a temporary skin condition

INTRODUCING MERCURY

Sources: weathering of rocks, volcanic eruptions, burning of fossil fuels, used as a catalyst in chemical processes such as chlorine fabrication, agricultural fungicide, dental fillings, anti-fouling paints, electrical systems and fluorescent tubes.

Health effects: central nervous system and kidney disorders. In Japan in the 1950's, mercury contamination from industrial sources led to poisoning of fish and subsequently many human deaths, and was labelled Minimata disease. Symptoms include numbness of lips and limbs, drunken gait and impaired mobility, disturbed senses (touch, hearing), impaired speech, and concentric narrowing of vision.

Household Hazard Search

Ocean News Reference: *"Pollution Sources", page 4; "Pollution Solutions", page 9.*

Main Idea:

Although industry is often blamed for the toxins in the environment, many individuals also contribute to this problem. Many store-bought household cleaning agents and solvents can be replaced by easily purchased or produced substitutes which lower the toxic threat to aquatic and marine life.

Objectives:

Students will:

- use a system for identifying and labelling hazardous/toxic materials to survey and identify household products in their homes
- research the effects of hazardous/toxic chemicals on marine and aquatic life
- systematically explore the use of alternative cleaning agents and their effectiveness


Poisonous


Explosive


Flammable


Corrosive

Background:

Every day organisms in the ocean are exposed to toxic chemicals that have been improperly disposed down toilets, sinks or via storm drains. We would not foul our own bathwater with these substances, yet they are often thoughtlessly flushed down the drain — out of sight and into the (constantly-occupied) "bathwater" of local aquatic life.

The extent that these chemicals damage marine ecosystems and kill marine organisms is a complicated issue related to concentration of toxins, ocean currents, freshwater/seawater mixing, solubility, temperature, tolerance of the organisms, half-life or degradability of the chemicals, and many other factors. In any case, it is clear that the smaller the amount of potentially harmful chemicals we introduce into the ocean, and any body of water, the better the health of the marine life occupying our coastal waters.

In reality, it is possible for the flow of toxic/hazardous chemicals from households to be stopped or reduced to a bare minimum. Working towards this reality involves awareness, behavioural change, finding alternatives, and critical thinking about advertising messages.

Materials:

- an assortment of labelled (but empty) containers for potentially hazardous household products (collected by the teacher)

- data sheets for student household survey

Procedure

Part A:

1. (1/2 hour) Review the labelling system for hazardous products. Ensure that the students understand the difference between: toxic or poisonous; flammable; reactive or explosive and corrosive materials, and the symbol shapes for danger, warning and caution.

2. (1 hour) As a homework assignment, have students survey the following rooms in their home:

- garage/basement
- kitchen
- bathroom
- laundry room

Students should complete the attached worksheet, filling in all products that have one or more of the hazardous product symbols or other warning messages on the label. Items to consider include: **deodorants, hair spray, shaving cream, air fresheners, oven cleaners, toilet bowl cleaners, drain cleaners, aerosols, window cleaners, laundry detergents, bleach, ammonia-based cleaners, abrasive cleaners, furniture polish, nail polish, spot removers, rug cleaners, motor oil, antifreeze, old batteries, paint, wood preservatives, insecticides, fertilizers, herbicides**, etc.

3. Have students choose one of the hazardous products from their list and investigate:

- the proper method for disposal

- possible alternatives to this product

(Some "proper" methods for disposal include:

- for some products, such as paint, they should be used up entirely. Share them with a friend if necessary.

- some garages will accept used car batteries and motor oil

- hazardous waste collection sites (in some communities)

- call the B.C. Ministry of Environment for more information

- prevention is the best remedy of course, avoid buying them in the first place

Part B:

1. Have students set up tests that will compare potentially hazardous household cleaners with "environmentally-friendly" home-made alternatives. Students should develop a hypothesis such as: "Home-made window cleaner cleans just as effectively as Brand X" and create a valid experiment. They should develop well laid out procedures that can be duplicated for each product tested. All variables, except the product tested, should be constant. For example, the same type of cleaning cloth should be used on the same type of dirt or surface.

Some sample recipes include:

Warning: Do not mix household ammonia with bleach, toxic fumes are produced.

Light window cleaner: white vinegar mixed half and half with water

Heavy duty all-purpose cleaner: Mix 50 ml household ammonia, 50 ml vinegar, 125 ml baking soda and 2 l warm water

Scouring solution: Mix 125 ml baking soda and 125 ml water.

Carpet cleaner: sprinkle cornstarch on the rug. Wait 1/2 hour. Then vacuum.

Air freshener. Boil cinnamon and cloves in water or keep the house well-dried. Place 30-60 ml of baking soda in small bowls around the house and in the fridge.

Silver polish: line the bottom and sides of a frying pan with non-stick coating with aluminum foil. Fill the pan with boiling water and add 15 ml each of baking soda and salt. Add silver and soak for 10 minutes.

Discussion:

Why do people use hazardous products in their home?

Do we really need all of these products?

If no, why do we use so many of them?

Does advertising "tell us" that we need some of these products?

What did people use for household cleaners 40 years ago?

Extensions:

1) Develop a brochure or pamphlet giving the results of the class experiments and listing some alternative household cleaners.

2) Research the potential hazardous chemicals that are used in your school.

3) Contact B.C. Poison Control Centre 1-800-567-8911 for information on poisons and treatment.

References for recipes for alternative cleansers:

ESSA Technologies. 1994. Eco Education Program: Household Hazardous Products.

Pollution Probe. 1991. The Canadian Green Consumer Guide. McClelland and Stewart. Toronto.

Household Hazard Search and Survey

Name:

Room surveyed:

Item	*(check where applicable)*				*Other warning messages (for example "Keep out of reach of children")*	*Alternative?*
						

What's In (and Not In) A Message

Ocean News Reference: *"Shadow Across the Ocean", page 1; "Pollution Solutions", page 9.*

Main Idea:

Advertising for household, workshop, and personal care products requires careful analysis for consumers to make environmentally informed and appropriate decisions.

Objectives:

Students will:
1) Develop criteria for analyzing media messages about household products
2) Analyze both magazine ads and TV commercials for household products in detail for the real messages they are providing, and for the validity and full implications of their claims.

Background:

Some marine pollution is a direct result of people discarding toxic materials through sewage systems or down storm drains. One way to do something about this problem is to avoid purchasing products which might cause harm - this avoids the need to discard them. But a powerful force is at work to encourage the consumption of products we may not even need - advertising.

In this activity, students will 'deconstruct' magazine ads and TV commercials in small groups. The activity promotes problem solving and critical thinking about: 1) how consumers are manipulated by advertisements, 2) the 'ecological shadow' of various products, and 3) the lifestyle and environmental implications of using various products or their alternatives.

Many product advertisements hide or do not clearly indicate their potential hazard, nor is the hazard of the product always known. Even products that claim to be environmentally safe must have some type of environmental costs. These costs may be less than for other products, but the validity of this can only be known through some critical thinking about the product and the messages used to advertise it.

Materials:

- magazine ads for household products with potential hazardous effects collected by every student in the class

- one blank, or re-recordable videotape for each group of 4 students

- videotapes of ads taped off of television (by students and/or teacher)

- magazine ads for household products prepared as slides or colour overhead transparencies

- copies of Ad Analysis Sheet

Procedure

Ahead of time, prepare one or more copies of ads for household cleaners or other potentially hazardous products as colour slides or colour overhead transparencies for display/discussion. Colour slides can be made by photographing the ads (outside in sunlight) with a 35mm camera using colour slide film. Colour transparencies of ads can be made at a copy centre on a colour copy machine. Ads for products such as window cleaners, oven cleaners, laundry detergents, polishes, rust removers, paints, etc. will make appropriate material for this activity.

Part A:

1) Start with a reading of Ocean News 4: Marine Pollution, page 1 and pages 4-9. In a class session, brainstorm a list of characteristics that might distinguish products that are environmentally appropriate from those that are not environmentally appropriate. Criteria such as 'contains no toxic heavy metals' or, 'does not contain phosphates' will be on this list.

2) Now look at and discuss the ad examples you have prepared. During the discussion, generate a list of criteria that could be used to analyse an ad in order to understand its complete message. What are the explicit messages? What are the implicit messages? What questions can be asked to allow viewers of the ad to 'dig out' these messages? Generate a second list of questions about the product(s) advertised that should be asked in order to learn more about the product's impact on the environment.

Divide the class into working groups of 4, with each group having at least one person with possible access to a home VCR. As a homework assignment (perhaps over a weekend or several day period) to be used in Part B, have each student collect a magazine ad or videotaped TV commercial for household/workshop/automotive products that might potentially end up going 'down the drain'. Assign each group to collect appropriate numbers of magazine ads or videotaped TV commercials depending on the number of viewing stations you can arrange in your class for this activity. When Part B takes place in the classroom, you may wish to set up two or more video viewing stations.

Part B:

1) Back in class, have the groups analyse their magazine ads and TV commercials using the attached Ad Analysis Sheet, or a similar one you have developed as a class.

Groups should prepare a group report with a spokesperson to report out in the final class discussion. Students should be encouraged to report out the common features of the ads and commercials they analysed. What aspects of the ads/commercials, in their opinions, are most effective for convincing the audience to buy the advertised products? How are audiences manipulated (if they are)? Why do advertisers need to convince people of the merits of their product? When is an ad informative, and when is it coercive?

Discussion:

Discussion is extremely important to this activity. When students report out from their group analysis sessions, look for the common themes that come up. How do advertisers convince people in the audience of their ads to buy their product? Do any of these manufacturers try to educate the public about the dangers of dumping hazardous materials down the drain? Do any suggest cutting back on your use and disposal of cleaning agents? Do any advertisers make claims that a product is environmentally better than an competitors product? How can one check these claims?

Extension:

1) Have students carry out research into the full life-cycle of one of the products featured in one of the ads they examined. The first task would be to get a list of all of the ingredients in the product. Where is the product made, and where are the ingredients made, mined, or extracted? What kinds of processes are involved in the preparation of each ingredient of the product. How are these ingredients moved to the manufacturing site of the product? Are there any hazards associated with any of the manufacturing steps in manufacture?

One of the difficult parts of this activity will be to trace down how chemicals present in many household products are made. Information may be obtained from various chemistry handbooks, from a quality encyclopedia, from other library sources, or directly from the manufacturer. Some manufactures distribute information on all aspects of their manufacturing process, although most guard their ingredients and processes. For a list of addresses and other information of manufacturers, check The Ethical Shoppers Guide to Canadian Supermarket Products (1992) by Joan Helson, et. al. (Peterborough, Ontario: Broadview Press)

Ad Analysis Sheet

Names: ____

Product advertised: ____

Type of ad: ______ Magazine ad ____ Newspaper ad ____TV Commercial _____Other

Print Ad: Mag. Name:______________________________ **Size:** __full-page __ 3/4 page __ 1/2 page __1/3 page or less

TV Commercial: Length in minutes ____

1) What is the main message of this ad?

2) How are people portrayed in the ad? Are they happy? Does their happiness appear to be related to the product being sold? Are people in the ad portrayed in realistic, respectful ways?

3) Does the ad claim or imply that people who use the product will get special status or benefits?

4) What do you know about the raw materials for the product? Are there any potentially harmful ecological effects from collecting the raw materials?

5) Are there potentially harmful effects from manufacture of the product?

6) Are there potentially harmful effects from the disposal of this product?

7) Where is the product manufactured? Is transportation of this product to your local store appropriate?

8) Does the product make claims about environmental friendliness? What is the basis of these claims?

9) Is the product really needed? If the product addresses a real need, are there more environmentally friendly/ appropriate alternatives for the job?

10) other:

Is Dilution a Solution?

Main Ideas:

Dilution in the ocean does not make chemicals go away. Dilution of even small quantities of toxins in the oceans still results in traces of those toxins being present in local waters. Local oceanographic properties and many other factors influence the extent of dilution in the oceans.

Objectives:

Students will:
1) calculate the dilution factor involved when a quantity of 'marked' water is dispersed thoroughly throughout the entire volume of the world's oceans
2) discuss some of the reasons why dilution in the ocean is limited, and where concentrations of toxins are likely to reside

Reference: Mehrle, P.M., et al. 1988. Toxicity and Bioconcentration of 4,3,7,8-TCDD and 2,3,7,8-TCDF in Rainbow Trout. Env. Tox. Chem., 7: 47-62.

Background:

One group of toxins of great concern in relation to marine pollution in western Canada is the large group of substances known as organochlorines, of which the dioxins and furans are the best known. The dioxins and furans are a group of more than 210 related chemicals, with varying levels of toxicity, including some which are extremely toxic to mammals. One dioxin in particular, 2,3,7,8-TCDD is considered to be one of the most toxic substances known – concentrations in the parts per quadrillion range are known to significantly increase deaths in rainbow trout[1].

This activity uses the **mole concept** to calculate a hypothetical dilution factor over the entire volume of oceans throughout the world. An experiment is imagined where a glass of water is removed from the ocean and all water molecules in the glass are magically marked. The water is returned to the ocean and after total mixing, a second glass of water is removed. Students are likely to be quite surprised at the number of marked molecules in this second glass.

The activity then looks at dilution factors that will lead to parts per trillion and parts per quadrillion.

Materials:

- calculator or computer with calculator (both optional)

Procedure:

1) Provide students with Problem 1. After reading the problem, but before they begin the calculation, you might have students **estimate** how many molecules will be in the second glass of water. Most students estimate a very small number. Now have students do the calculation. Students with little experience in mole calculations will need extra prompting, hints and help.

Problem 1

You take 1 liter of water from the ocean and somehow you mark each individual water molecule in the glass. You then dump the water back into the ocean and wait long enough for the marked molecules to spread out evenly throughout the entire ocean (volume 1.68 x 10^{16} cubic metres). Now you take a second 1 liter sample of water from the ocean. How many of the original marked molecules are in your the second sample?

Problem 2

A hypothetical spill of 100 kg of a particularly hazardous dioxin (molecular weight = 248) happens in the Strait of Georgia. Assuming this spill dissolves and mixes evenly in the **top ten metres of the Strait**, what will be the final concentration of the dioxin in a) moles/l and b) parts per trillion? The approximate dimensions of the Strait of Georgia are about 222 km by 28 km.

Calculation for problem 1:

a) Calculate the number of molecules in a liter of water (this is the number of molecules that will be marked):

1 litre of water = about 1000g of water

Molecular weight of H_2O = 18g/mole

1000g of water = 1000g/18 grams/mole
= 55.6 moles of H_2O

55.6 moles x 6.02×10^{23} molecules/ mole

= 3.35×10^{25} molecules marked

b) Use the number of litres in a cubic metre = 10^3 l/m^3 to calculate the number of litres in the ocean:

1.68×10^{16} m^3 x (10^3 l/m^3) = 1.68×10^{19} litres

c) Divide the number of marked molecules by the total number of litres in the ocean to find the number of marked molecules in the second sample.

Number of molecules in 1 litre after thorough mixing:

3.35×10^{25}molecules/1.68×10^{19} litres

= 2.0×10^6 molecules

= 2,000,000 molecules

= 2 million molecules

Discussion:

1) How much of a highly-soluble toxic substance, if dispersed throughout the world's oceans in a similar manner to the water in Problem 1, would yield a concentration of 2,000,000 toxin molecules per litre?

About fifty-five moles of any soluble substance would yield this concentration. To calculate the required mass of a particular toxin such as a 2,3,7,8-tetrachlorodibenzo-p-dioxane (one of 75 different chemicals in the family of dioxins)($C_{12}H_4Cl_4O_2$, molecular weight = 322) multiply the molecular weight by 55 moles. (For this dioxin 55 moles x 322 grams/mole =17710 grams = 17.7 kg)

2) Name some of the reasons why toxic chemicals may not mix thoroughly throughout the entire oceans:

- mixing throughout the oceans is slow and the oceans are vast

- the deep ocean, which is >90% of the ocean's volume, mixes very little with the surface waters. Reasons for this include haloclines (boundaries of water separated by density differences as a result of salt concentration), and thermoclines (boundaries of water separated by density differences as a result of temperature differences).

- chemicals may have low solubility. They may coagulate or become attached to oils or lipids.

- chemicals are usually concentrated in coastal waters where they originate. Dispersal from these coastal waters into the vast ocean realm is slow.

- chemicals may be taken up by organisms in the environment, especially because these chemicals often have a great affinity for cell membranes.

Calculation for Problem 2:

Moles of the dioxin spilled:

100 kg x 10^3 g/kg/ 248 g/mole = 400 moles

Volume of affected region of Georgia Strait:

222 km x10^3 m/km x 28 km x10^3 m/km x 10 m =

6.2 x10^{10} m^3 x 10^3 litres/m^3 = 6.20 x10^{13} litres

Concentration (moles per litre):

400 moles / 6.20 x10^{13} litres = 6.45 x10^{-12} m/l

Concentration (parts per ...)

100 kg toxin/6.20 x10^{13} kg H_2O = 1.61 x10^{-11}

= 16.1 x10^{-12}x10^{12} (trillion) = 16.1 parts/trillion

3) It has been reported that for the most toxic of all the dioxin group, 2,3,7,8-TCDD, concentrations in the parts per quadrillion range are toxic to rainbow trout. a) What is a part per quadrillion and how does the concentration found in Problem 2 compare to a part per quadrillion. b) How much 2,3,7,8-TCDD dissolved into the volume of Georgia Strait in problem 2 would yield parts per quadrillion.

a) In steps of one thousand, a quadrillion is the next level beyond a trillion. (The sequence is:

10^{-3} - parts/thousand; 10^{-6} - parts/million; 10^{-9} - parts/billion; 10^{-12} - parts/trillion; 10^{-15} - parts/quadrillion)

The concentration of dioxin in Problem 2 (16.1 parts per trillion) is 10,000 times more concentrated than 1.6 parts per quadrillion.

b) 1 part per quadrillion = one out of 10^{15} = a ratio of 10^{-15}

x/6.20 x10^{13} kg (water in Georgia St.) = 10^{-15}

x = 6.20 x10^{-2} kg = .062 kg = 62 g

Only 62 grams of 2,3,7,8-TCDD will yield a concentration of one part per quadrillion in the top 10 metres of Georgia Strait. Although no evidence on this matter has been collected, extrapolation of the studies with trout suggests that this small amount of the dioxin may be enough to cause toxic effects in many of the fish of the Strait.