Case Study: Puget Sound Orcas

I. Killer Whales: Orcas
   a. *Orcinus orca*
   b. Largest member of the dolphin family (*Delphinidae*)
   c. Identifying traits
      i. Tall dorsal fin
      ii. Saddle patch behind dorsal fin
      iii. White patches on sides, belly and behind eyes

II. Orca Biology
   a. Birth Weight: 395 lbs
   b. Adult Weight: 2.6-9 tons
   c. Males are larger than females
      i. Adult males also have a very tall, straight dorsal fin
   d. Lifespan
      i. Males live to around 40 years
      ii. Females live to over 60 years

III. Orca Natural History
   a. Distribution
      i. Orcas are found in all seas, including the Arctic and the tropics
   b. Orcas travel in pods of 3 to >150 individuals
   c. Orca food
      i. Fish
      ii. Squid
      iii. Marine Mammals
   d. Transient vs. Resident Orcas
      i. There are two major subspecies of orca, transients and residents
      ii. Transients live offshore, while residents live nearshore
      iii. Transients feed mostly on marine mammals, while residents feed mostly on fish
      iv. Transients live in pods of 3-5 individuals, while residents live in pods of >20 individuals
      v. Transients tend to be very quiet, while residents make a lot of vocalizations
   e. Resident Orcas
      i. Resident orcas live in extended familial units called pods
         1. Pods are matriarchal in structure with the oldest female as the grandmother of the other orcas
      ii. Northeast Pacific resident orcas are found in coastal waters from Puget Sound to Alaska
         1. Puget Sound resident orcas are the southern resident orcas
            a. Three pods: J,K and L
            b. Summer around the San Juan Islands feeding on salmon
            c. Winter on the outer coast, though no one knows exactly where

IV. State of the Southern Resident Orcas
a. Almost 20% of Southern resident orca community died between 1995 and 
2000.
b. Many females who should be in their reproductive years have not 
produced viable young for ten years.
c. Young males are dying rapidly and there are only four adult males in the 
entire community.

V. Southern Resident Orcas and PCBs
a. Southern resident orcas have, on average, the highest measured levels of 
PCBs of any marine mammal in the world, almost 150 ppm.
   i. <10ppm PCB is known to cause immune problems in seals.
b. PCBs build up over the years and are passed from mother to calf via her 
milk.
   i. A mother can pass on as much as 90% of PCBs to her offspring.
c. A female transient orca was found dead on Dungeness Spit in May 2002 
had 1000ppm PCB

VI. What are PCBs
a. Polychlorinated biphenyls (PCBs): A class of persistent organic pollutant 
(POP); Oily fluids that are very stable and resist degredation. They have 
been used in transformers, pesticides, carbonless copy paper and small 
electrical parts.
   i. Manufactured in the U.S. from 1929 to 1977, peak production of 
PCBs in the United States occurred during the 1950’s and 1960’s.
   ii. Roughly one third of the world’s total PCB production has escaped 
into the environment.
   iii. Products with PCBs leak then into the soil and water where the 
molecules rise into the atmosphere and are carried by the wind and 
redeposited all over the earth.
   iv. PCBs are fat soluble, thus entering the food chain and residing in 
fatty tissues of all the organisms in the food chain.
      1. In rodent assays, PCBs cause liver cancer, pituitry tumors, 
leukemia, lymphoma and intestinal cancer.
      2. PCBs are classified as a ‘probable human carcinogen’.
   v. Production has been banned in the U.S. since 1977.

VII. Ecosystem Review
a. Ecosystem: an array of organisms and the physical environment 
interacting through a one way flow of energy and cycling of material.
   i. Energy flows through ecosystems, but matter is cycled.
   ii. Energy flows through the ecosystem via the food chain
      1. Food Chain- A succession of organisms in an ecological 
community that constitutes a continuation of food energy 
from one organism to another as each consumes a lower 
member and in turn is preyed upon by a higher member.
         1. Begins with primary producers, which are consumed 
(eaten) by primary consumers (secondary producers),
which are consumed by secondary consumers, and so on.
a. Marine Example: Kelp (primary producer) is eaten by sea urchins (primary consumer) that are eaten by sea otters (secondary consumer).

b. Ecological Pyramid- The flow of energy through an ecosystem can be visualized as pyramid, with each level representing a different trophic level and the size of that level is proportional to the biomass in that trophic level.
   i. Because not all of the biomass of the preceding trophic level is used in the next trophic level, the higher trophic levels have less biomass.
      1. Ecological efficiency- percentage of energy taken in as food by one trophic level and then passed on as food to the next trophic level
      2. Ecological efficiency for most communities is about 10%.
         a. Ex: 100 grams of kelp will sustain 10 grams of sea urchin, which will sustain 1 gram of sea otter.

VIII. Idealized Puget Sound Ecological Pyramid
a. The resident orcas of Southern Puget Sound are the top predators of the Puget Sound food chain.
   i. Their preferred food is salmon, whose numbers have been seriously declining over the last decade.
   ii. The salmon feed mostly on zooplankton, in particular euphausiid krill, which in turn feed on phytoplankton, the primary producers of the marine ecosystem.

IX. Pollutants in Ecosystems
   c. Pollutant: Any agent that adversely affects the health, survival, or activities of living organisms or that alters the environment in undesirable ways.
      i. Persistent Organic Pollutants (POPs) are synthetic organic compounds used in various products (from electronics to automobiles) that resist environmental degradation and have been found to adversely affect the environment.
         1. Include PCBs and DDT

d. How do pollutants enter the environment?
   i. Point Sources- Specific locations of highly concentrated pollutant discharge, such as factories, power plants and sewage treatment plants.
      1. Example: For decades, GE dumped thousands of tons of PCBs into the Hudson River.
   ii. Nonpoint Sources- Scattered, diffuse sources of pollutants, such as runoff from farm fields and construction sites
      1. Example: Golf courses utilize large amounts of fertilizer, which can pollute the surrounding water.

e. Factors influencing the movement of a pollutant through an ecosystem
   i. Solubility of the Pollutant determines how, where and when a pollutant will move through the environment.
1. Water soluble pollutants move rapidly and widely through the environment because water is ubiquitous.

2. Fat Soluble pollutants generally need a carrier to move through the environment and into and within the body.
   a. Once inside the body, fat-soluble pollutants penetrate readily into tissues and cells where they accumulate and are stored as lipid deposits that are protected from metabolic breakdown.
   b. Fat-soluble pollutants may persist for many years.

ii. The persistence of a pollutant is how long it takes to breakdown and be removed from the ecosystem.
   1. Some chemical compounds are very unstable and degrade rapidly so that their concentrations decline quickly over time.
   2. Other chemicals, such as plastics and chlorinated hydrocarbons, are used for their resistance to degradation.
      a. Resistance to degradation can cause the chemical to have severe environmental effects long after it has been introduced to the ecosystem.
         i. POPs are, by their nature, quite persistent and therefore resistant to degradation.

f. Pollutants in the Food Chain
   i. Bioaccumulation: process by which cells selectively absorb and store a great variety of molecules, thus allowing the cell to accumulate nutrients and essential minerals, but they also absorb and store harmful pollutants.
      1. Bioaccumulation increases the concentration of a pollutant from the environment to the first organism in a food chain.
   ii. Biomagnification: process by which the effects of pollutants are magnified in the environment through food chains.
      1. Because some pollutants are very stable and resist metabolic degradation, they can remain for a long time inside organisms.
      2. When an organism is consumed by a member of a higher trophic level, the consumer is only able to assimilate roughly 10% of the biomass of the prey. However, because its solubility and stability, much of the pollutant is passed on from prey to consumer.
      3. Therefore, as the pollutant moves up the food chain the concentration of the pollutant in the body tissue increases dramatically.
         a. Ex: DDT Residues in an Estuary on Long Island (from Woodwell, Wurster and Isaccson, 1967)

<table>
<thead>
<tr>
<th>Trophic level</th>
<th>Organism</th>
<th>DDT in wet weight of whole organism</th>
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</thead>
<tbody>
<tr>
<td>Primary Producer</td>
<td>Green alga</td>
<td>0.08 ppm</td>
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<tr>
<td>Primary Consumer</td>
<td>Mud Snail</td>
<td>0.26 ppm</td>
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<tr>
<td>Secondary Consumer</td>
<td>Summer Flounder</td>
<td>1.28 ppm</td>
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<tr>
<td>Tertiary Consumer</td>
<td>Ring-billed Gull</td>
<td>75.5 ppm</td>
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<td></td>
<td></td>
<td>(Roughly 1000x initial concentrations!)</td>
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</tbody>
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X. The Puget Sound Orcas ‘Double Whammy’
   i. When stored in blubber, PCBs are not nearly as harmful as when they are in the blood stream.
   ii. However, because salmon runs have been so low, the orcas have to metabolize their blubber in order survive to the next meal.
   iii. When the blubber is rendered by the whales for energy, the PCBs are released into the blood, where they take the place of hormones and interfere with normal immune function, thus making the orcas more susceptible to diseases and pathogens already present in the environment.