What is Pollution?

**Pollution:** the introduction of contaminants into the environment (air, water, or soil)

- A contaminant is not always a toxic chemical or poison – it can be something naturally occurring (such as Nitrogen or Phosphorus) that disrupts ecological processes when introduced into a certain area.

Pollution

- Major forms of pollution:
  - Light (cars, boats, buildings, street lights, etc.)
  - Noise (cars, factories, human voices, music, sonar, aircraft)
  - Solid Waste (e.g. plastics, other garbage)
  - Chemicals (fuel burning byproducts, pesticides, fertilizer, etc.)
Light Pollution

Light at night from artificial sources (and its effects)

Some types of light pollution:
• Sky glow
• Overillumination
• Light trespass

Light Pollution: effects on wildlife

• Navigation, orientation
  - Disorientation in sea turtles, migrating birds
• Reproductive behavior
  - Decreased mating under night lighting
• Development
  - Delayed metamorphosis in frogs
• Foraging behavior
  - Altered timing and duration of foraging
• Communication
  - Impacts on coyote howling

Case Study: Light Pollution and Sea Turtle Hatchlings

- Increased mortality
- Disorientation at the end of the beach
- Negative impacts on survival
Light Pollution: migrating birds

- Over 450 bird species migrate at night across N. America (incl. threatened or endangered species - cerulean warbler and Henslow's sparrow)
- Use the moon and stars for navigation

Light Pollution: migrating birds

- Disoriented by artificial lights
- Fly into windows, collide with each other
- Reluctant to leave a light source once it has been entered
- Fly around until they are exhausted
- Drop to the ground – vulnerable to predation/injury
- Estimated 100 million to 1 billion birds killed by collisions with glass/buildings in US per year.

Light Pollution: mitigation

- Selectively turning off lights – building in Chicago turned off lights in half the building and reduced bird strikes by over 80% (field museum in Chicago)
- Different types of lights (eliminate stray light)
- Different color lights
  - Nocturnally migrating birds less disoriented by blue and green light
  - Poot et al. (2008) Ecology and Society

PBS documentary on light pollution
http://www.youtube.com/watch?v=ZGyFsiMCsQNE

FAU Astronomical Observatory
Noise Pollution

Unwanted noise that may interfere with natural processes, adversely affect wildlife or humans, or cause damage (e.g. to structures)

Noise Pollution: effects on wildlife

Communication: Altered bird singing activity
- Male nightingales (Luscinia megarhynchos) sing songs
- Songs are used to mark territory and to attract mates

- Birds sang louder in areas with more urban noise (e.g. traffic)
- Birds sang louder on weekday mornings than on weekends
- Birds did not differ significantly in size between noisier or quieter areas

What costs may be associated with singing louder songs?

Noise Pollution: effects on wildlife

Communication
- Female grey tree frogs (Hyla chrysoscelis) take longer to locate and find calling males when exposed to the sounds of passing traffic
- Several species of marine mammal stop vocalizing or experience difficulty in locating mates (air guns, sonar, boat noise)
Noise Pollution – effects on wildlife

- Navigation and Foraging Behavior
  - Altered foraging behavior to avoid noise (bats, marine mammals)
  - Disorientation
  - More vigilant foraging behavior

- Direct Injury
  - Hemorrhaging of tissues
  - Hearing loss (marine mammals)

Noise Pollution

Case study: the greater mouse-eared bat, *Myotis myotis*

- Hunt at night
- Rely on listening for prey rustling sounds to find food (gleaning bat)
- Prey on ground-running arthropods (beetles, crickets, etc.)

A “choice experiment”:
Bats were given the choice of foraging in a compartment where sounds were being played from a speaker or one without sounds being played.
Noise Pollution Case study: Foraging bats avoid noise

Fig. 4. Influence of noise treatments on foraging behaviour of the mouse eared bats.
Results from repeated-measures ANOVAs for the factors noise treatment and stimulus compartment position are given in the text. As the latter did not have a significant effect on any of the behavioural measures, we combined the behavioural data from both compartments for this graphic representation (averaged within each individual; error bars give the standard error, N=7 bats). Asterisks show significant differences revealed in post hoc paired t-tests for these combined data sets (sequential Bonferroni correction to account for multiple testing). ***P<0.001, **P<0.01, *P<0.05.

(A) Percentage of the flight time in the stimulus compartment.

(B) Percentage of flights into the stimulus compartment.

Solid waste

Solid Waste: impacts to wildlife

- Ingestion – creates false sense of being full, intestinal blockage
- Entanglement - in plastics, fishing line, etc.
- Invasive species – "hitchhikers"
- Chemical pollution – degraded plastic
Chemical pollution

- Air
- Water/Soil

Global wind patterns for a typical month of January
Adapted from “Visit to an Ocean Planet” educational CD-ROM, Caltech and NASA/Jet Propulsion Laboratory

Chemical pollution: air

Most air pollution is caused by
- burning of fossil fuels (e.g. coal)
- exhaust from cars

Sources of common pollutants Sulfur dioxide and Nitrogen oxides:

<table>
<thead>
<tr>
<th>National Sulfur Dioxide Emissions by Source Sector</th>
<th>National Nitrogen Oxides Emissions by Source Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Combustion</td>
<td>Total Emissions</td>
</tr>
<tr>
<td>Industrial Processes</td>
<td>1,203,950</td>
</tr>
<tr>
<td>Mixed Sources</td>
<td>250,293</td>
</tr>
<tr>
<td>Food Processing</td>
<td>215,560</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>1,670,703</td>
<td></td>
</tr>
</tbody>
</table>

Photo: Peter Essick
Chemical pollution: air (acid rain)

- Sulfur dioxide and nitrogen oxides released into the atmosphere combine with other chemicals and water to produce acid rain
- Gases and dust particles can also become acidic
- Both wet and dry acid depositions can affect wildlife
  - Lowers pH levels of lakes and streams
  - Seeps into the ground, affecting health of forests, etc.

Chemical pollution: soil / water

- Oil spills
- Sewage
- Pesticides, herbicides, fertilizer
  - Contain nitrogen, phosphorus
  - Excess nitrogen and phosphorus runoff into aquatic ecosystems contributes to:

  **Eutrophication** - transformation of an ecosystem from low nutrient levels to a high nutrient system
  - Often results in a spike in plant and microbial growth (e.g. algal blooms)
  - Can deplete oxygen in a system, leading to "dead zones"

  Eutrophication can affect species dynamics in the entire ecosystem!

Chemical pollution: amphibians

Amphibians are "bioindicators" of environmental health

- Permeable skin, shell-less eggs
- Ectotherms
- Use aquatic and terrestrial habitats
- Do not move far from place of hatching
  - can be used to monitor local conditions
Case study: amphibian limb deformities

- Increase in prevalence of amphibian limb deformities (1990s)
  - More than 60 different species affected throughout the world
  - Higher percentage of populations affected - 15%-90%
    (under typical circumstances <5% deformed)

WHY??

Two of the main hypotheses:
- Parasitic infection
- Chemical contamination


Case study: amphibian limb deformities

Trematode (parasitic flatworm) infection increases amphibian limb deformities

1. Trematode reproduces in birds
2. Birds release eggs in to water
3. Eggs hatch into “miracidia”
4. Snails eat the miracidia and produce trematode larvae
5. Larvae burrow into developing amphibians, create improper limb formation

http://www.bbc.co.uk/nature/life/Frog#p00zbqrc (1:49)

So, what about chemical contamination?

- Laboratory experiments exposing amphibians to chemical contaminants did not show a significant effect
- Deformities seem to be more common in areas near agricultural runoff.

Why?
Case study: amphibian limb deformities

Kiesecker (2002) Proceedings of the National Academy of Sciences:

1. Compared frog deformities in ponds with trematodes vs. ponds without results: no deformities in ponds without trematodes

2. Exposed wood frogs to three common agricultural contaminants, then trematodes results: increased deformities in frogs exposed to contaminants.

Why?

Case study: amphibian limb deformities (2)

So, what else about chemical contamination?


- Elevated levels of nutrients (e.g. phosphorus) in ponds due to agricultural runoff (eutrophication)
- Increases in phosphorus related to density of large snail populations
- Large snails - intermediate host of trematodes
- More trematodes -> increased limb deformities in amphibians

Photo: Pieter Johnson

Case study: amphibian limb deformities (2)


Figures 2 A Relationship between peak phosphorus (mg/L) and peak trematode frequency (squares) among 27 Michigan ponds (R² = .982, P < .0001), 2 B Relationship between phosphorus and trematode frequency among 24 ponds (R² = .926, P < .0001), 2 C Relationship between phosphorus and trematode frequency among 6 ponds (R² = .860, P < .0001). Amphiobian species include L. analis, L. americanus, L. gracilis, L. pipiens, D. rubra, L. catesbeiana, L. terrestris, L. sylvatica, L. s. varicolor, and R. pipiens.
Case study: chemical pollution of amphibians

Effects of chemical pollution aren’t always the result of direct toxicity...

- Synergistic effects - when two effects produce a greater effect than the sum of individual effects
  - Chemicals alone do not cause high incidence of deformity
  - Levels of amphibian trematode infection are elevated in cases of
    - Decreased immune function from exposure to chemicals
    - Increased host snail populations

Bioaccumulation

“a process by which chemicals are taken up by an organism either directly from exposure to a contaminated medium or by consumption of food containing the chemical, resulting in the biological sequestration of a substance at a higher concentration than that at which it occurs in the surrounding environment or medium.”

- U.S. Environmental Protection Agency, 2010

Bioaccumulation: how does it work?

- Organisms in lower trophic levels become contaminated
- Each successive trophic level sees a greater accumulation of the contaminant
- Toxins accumulate in top consumers
- Usually the contaminants are extremely difficult to eliminate from an animal’s body
Bioaccumulation: DDT

Dichloro-diphenyl-trichloroethane (DDT)

- Considered safe and effective insecticide (1940s-50s)
- Used worldwide as an agricultural insecticide
- Also used to prevent human diseases (e.g. malaria, typhus)
- Cheap to produce
- Persistent – takes a long time to break down
- No known significant adverse effects to either animal or human health, until...

Bioaccumulation: DDT

Osprey

1938-1965 – Reproductive failure in the Eastern USA

- S Connecticut: 200 pairs in 1938, dropped to 12 pairs in 1965
- Long Island, NY populations in steep decline

<table>
<thead>
<tr>
<th></th>
<th>Young Per Nest</th>
<th>DDT in Eggs (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>2.3</td>
<td>-</td>
</tr>
<tr>
<td>Maryland</td>
<td>1.1</td>
<td>3.0</td>
</tr>
<tr>
<td>Connecticut</td>
<td>0.5</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Bioaccumulation: DDT

Peregrine Falcon

1940s – 1970s

- Severe reproductive failure in N. America and Europe
- Broken eggs
- Extinction E of Rockies, became rare in Western US.
Bald Eagle

1940s-1970
Declining reproductive success and populations in the US

Bioaccumulation: DDT

- Egg breakage, unhatched eggs
- Problem with calcium metabolism

- Bioaccumulation of DDE (metabolite of DDT) inhibits reproductive enzymes in certain birds
- Enzymes control calcium content of eggshells
- Egg shells did not contain enough calcium

DDT banned June 1972 in the US
Following DDT Ban, Birds Recovered

**Peregrine Falcon**
The Peregrine Fund established 1970, Boise, Idaho
Nesting pairs lower 48:
1940s = 1,500
1970 = 39
2005 = 1,200

"the banning of DDT in 1972 was the single most important action taken to ensure the survival and recovery of the Peregrine Falcon in North America. Without it, we would not have celebrated the delisting of the American Peregrine in 1999"

The Peregrine Fund, Return of the Peregrine, 2003, p. 18

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**Bioaccumulation: DDT**

**Bald Eagle**

In Lower 48 States:
487 pairs in 1963
9,789 pairs in 2006
Removed from Endangered Species list, 1995

Many other species, including Osprey, Brown Pelican, Cooper’s Hawk, and Bermuda Petrel declined sharply until 1972, have recovered dramatically since 1972.

What do these birds have in common?

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**Bioaccumulation: Killer Whales (Orcinus orca)**
**Bioaccumulation: Killer Whales (Orcinus orca)**

**Orcas**
- **Life expectancy:** males 50-60 yrs, females 80-90 yrs
- **Females 1 calf every 3-5 years, gestation 15-18 months**
- **Reach sexual maturity in their teens**
- **Stop reproducing around 40 years old**

Length: males 10 m, females 8.5 m
Weight: males 9,000 kg, females 5,500 kg

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**Bioaccumulation: Killer Whales (Orcinus orca)**

**Orcas**
- "**Resident**" populations (N. and S.)
  - Eat fish (salmon)
- "**Transient**" populations
  - Eat marine mammals (harbour seals, sea lions, etc.)
- **Offshore populations**

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**Bioaccumulation: Killer Whales (Orcinus orca)**

**Persistent Organic Pollutants (POPs)**

Bioaccumulation in resident Orca whales

[Image: www.beamreach.org]
Bioaccumulation: Killer Whales (Orcinus orca)

Persistent organic pollutant (POP):

Polychlorinated biphenyls (PCBs)
- Introduced in the early 1900s
- Used in adhesives, sealants, paints, hydraulic fluids, coolants, etc.
- Banned in Canada and the US in the 1970s but persist in the environment.
- Still produced and used in some parts of the world.

Bioaccumulation: Killer Whales (Orcinus orca)

Persistent organic pollutant (POP):

Polychlorinated biphenyls (PCBs)
- Stored in fat (blubber)
- Can disrupt endocrine function
  - Impair reproduction
  - Impair development
- Immunotoxic – leads to increased susceptibility to diseases
- Difficult to metabolize and eliminate

Bioaccumulation: Killer Whales (Orcinus orca)


- Took samples (biopsies) of blubber from resident and transient orcas
- Analyzed for concentration of PCBs

NOAA
**Bioaccumulation: Killer Whales (Orcinus orca)**


- Females show less accumulation of PCBs
- Transients show greater accumulation of PCBs

**WHY?**

**Bioaccumulation: Asian vultures**

- Long-billed/Indian Vulture (Gyps indicus)
- White-rumped/Asian White-backed vulture (Gyps bengalensis)
- Slender-billed Vulture (Gyps tenuirostris)

Once abundant, now all three critically endangered

Gyps tenuirostris range (IUCN)
Bioaccumulation: Asian vultures

Ecological Role of Vultures

Nature's "clean up crew":

- Consume carcasses
- Digestive processes able to kill many viruses and bacteria
- Vulture droppings, pellets, and urates are disease-free

Bioaccumulation: Asian vultures

Are vultures dirty?

Vulture adaptations:

- Expose wings to UV
- Bald head
- Uric acid in their waste kills bacteria on their feet

Bioaccumulation: Asian vultures

Asian vulture crisis – Population declines

In India, populations of white-rumped vultures dropped by 99.7% from 1990-2008.

Researchers from the Asian Vulture Crisis Project documented in Pakistan: from more than 2,500 pairs in 2000, none bred there in 2007.

The Peregrine Fund
Bioaccumulation: Asian vultures

Asian vulture crisis

• By 2000, so many dead and dying vultures were being found in Nepal and India it was thought that they were suffering from an epidemic.
• Many of the dead vultures had experienced “visceral gout” (kidney failure leading to a build up of urate deposits)
• Testing eventually revealed: kidney failure caused by the consumption of cattle that had previously been treated with the drug diclofenac

Diclofenac: a (until recently) widely used non-steroidal anti-inflammatory drug (NSAID) used to treat inflammation, pain, and fever in livestock.

Bioaccumulation: Asian vultures

Asian vulture crisis

Diclofenac: a (until recently) widely used non-steroidal anti-inflammatory drug (NSAID) used to treat inflammation, pain, and fever in livestock.

• Vultures cannot metabolize diclofenac and/or excrete it
• Less than 1% of carcasses containing diclofenac would be enough to account for the 99% of decline
• Asian vulture population declines are happening faster than even the decline of the Dodo bird

Bioaccumulation: Asian vultures

• Asian vulture crisis – effects on humans

• Rotting carcasses remain untouched, posing a health hazard
• Increased feral dog populations which carry rabies
• Increased rats
• Human corpse disposal debates (Parsis)
Bioaccumulation: Asian vultures

Asian vulture crisis – actions taken
- Vulture restaurants

White-rumped and long-billed vultures on carcass

Bioaccumulation: Asian vultures

Asian vulture crisis – actions taken
- Diclofenac banned in India 2005
- Meloxicam is a safer alternative
  - More expensive

Slender-billed vulture

Bioaccumulation: Asian vultures

Asian vulture crisis – actions taken
- Establishment of captive breeding centers

Indian vulture (Gyps indicus) chicks fledged in captivity
Bioaccumulation: Asian vultures

Asian vulture crisis – will have to wait and see
- Only one offspring each year
- Wild populations still declining