Pollution – Chapters 21 and 22

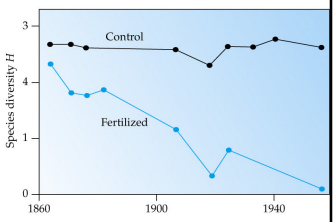
- Substance causing alteration of a natural chemical process in an ecosystem.
- **Anthropogenic** vs. N**atural**
  - **Point source**
  - **Non Point Source**

Pollution

- **Biodegradable**
  - Natural chemicals that break down or are used by species (eg. nutrients)
  - Ecosystems can often recover if source is contained
- **Non biodegradable**
  - Don't break down, often acumulate in tissue (eg DDT, PCBs)

Effects of Pollutants

- **Aesthetic**
  - "trashed" ecosystems not pretty
  - Over fertilized system – lost biodiversity, algal blooms
- **Health**
  - Air, drinking water
- **Altered ecosystem function**
  - Act as disturbance
  - Increase/decrease productivity
  - Change in biodiversity



Why pollute?

- Pollution has negative impacts on ecosystems.
- Pollution is created in the act of increase industrial or economic output
- Need to balance the two.
- Cost/benefit question
- **Mitigation**

Why pollute?

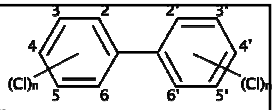
Aristotle "that which is common to the greatest number has the least care bestowed upon it."

- **Tragedy of the commons**
  - Conflict between the public good and availability of a shared resource.
  - Example – Pasture used by multiple sheep herders. Herders want to maximize profits, add sheep. Each sheep added benefits one owner, while degrading the pasture for the rest.
  - Actions of self interested parties do not serve the public good.
  - Other examples:
    - Fisheries
    - Pollution

Pollution regulation

- Solution is for the government to represent the public good, regulate use of common resources.
- Government Regulations
  - Clean Air Acts (1963, 1967, 1970, 1977, 1990)
    - Fuel efficiency, smog emissions, power plant emissions
  - Clean Water Acts (1972, 1977)
    - Mandated that public waters had to meet criteria to make them suitable for public use (swimming, fishing, drinking)

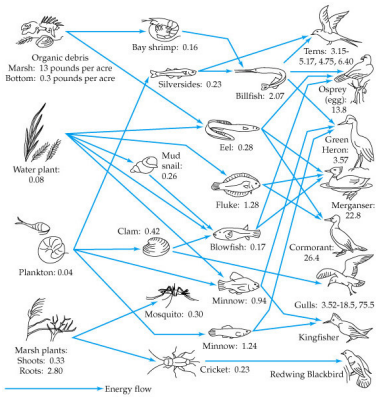
Example Non biodegradable toxin



- **Polychlorinated biphenyl (PCB)**
  - Class of chemicals that includes dioxin
  - Marketed by Monsanto under the trade name Aroclor from 1930-1977
  - Found to be highly toxic – rashes, liver, thyroid and stomach cancer, immune deficiency, reduced reproductive capacity
  - Hormone mimic- blamed in part for decline in male sperm counts
  - Banned in all open applications (adhesives, paints, fabrics)
  - Only allowed in contained applications (capacitors)
  - General Electric discharged 1.3 million pounds into the Hudson River in the 1970's, fish are still not edible.
  - Removal is difficult…

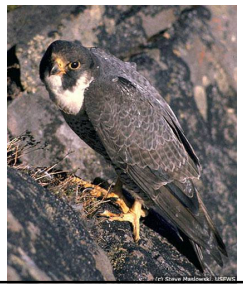
Non biodegradable pollutants

- Pollutants that organisms can't deal with physiologically, accumulate in tissues
- **Bioamplify** – larger concentrations accumulate in upper trophic levels
- Regulating ambient levels of toxins based on toxicity levels not adequate.



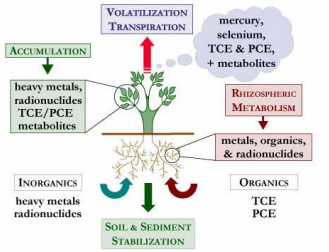
Bioamplification of Non biodegradable Pollutants

- Bald Eagle and Peregrine Falcon
  - Top predators
  - DDT accumulation resulted in thin egg shells
  - reduced to 500 pairs

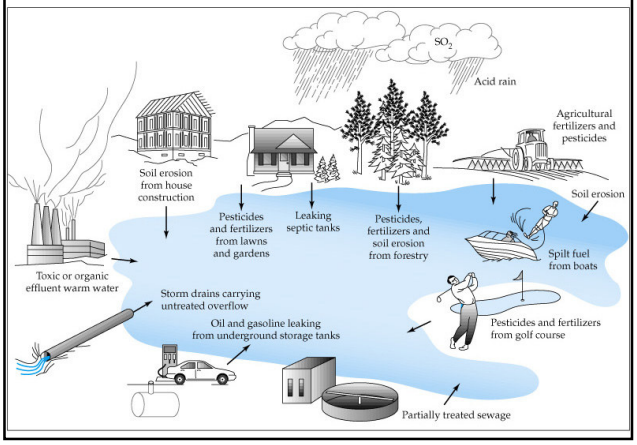


Phytoremediation

- Some non-biodegradable toxins accumulate in biological tissues
- **Phytoremediation** - Use plants to accumulate and remove or neutralize pollutants.

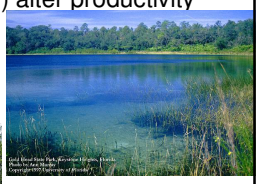


Most Pollutants End Up in Water

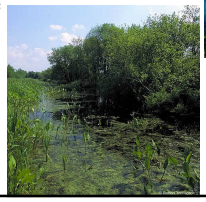


Pollution in aquatic ecosystems

- Aquatic ecosystem productivity
  - Non-biodegradable pollutants accumulate in sediments
  - Organic pollutants (nutrients) alter productivity
    - **Oligotrophic**

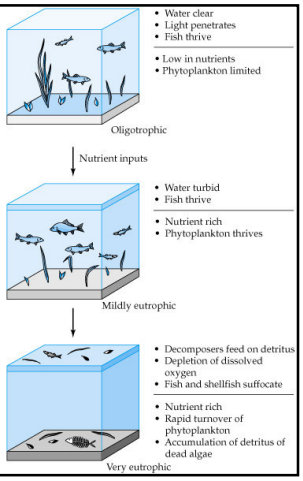


    - **Eutrophic**



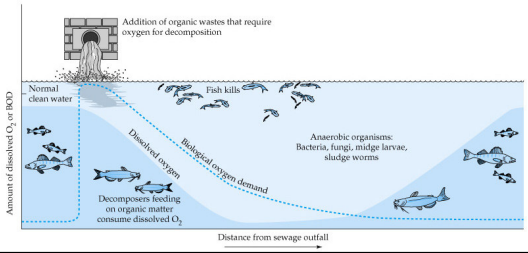
Eutrophication

- Adding nutrients to an aquatic system will lead to **eutrophication**.
- Lakes are closed systems, eutrophication faster.
- Flowing rivers typically slower to show effects.



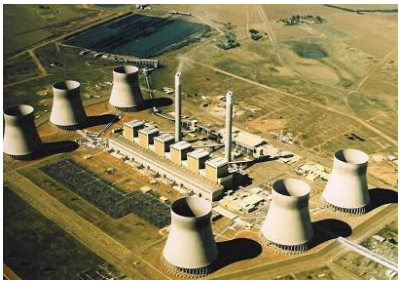
Mechanism for eutrophication damage

- **Biological Oxygen Demand (BOD)** – total ecosystem respiration rate.
- If BOD > oxygen available, system will go **anoxic**
- Organic input – needs to be decomposed
- Nutrient input – algae bloom (high night time BOD)



Other non-chemical pollutants

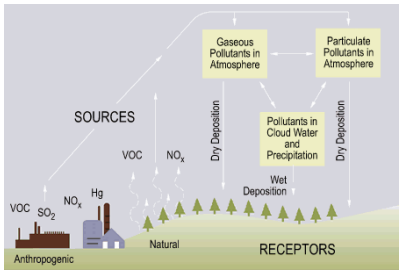
- Hot water from power plant cooling ponds (**thermal pollution**)
  - Raise productivity and BOD
  - Alter system temperature
  - Lower oxygen content of water



Atmospheric Pollution - Acid Rain

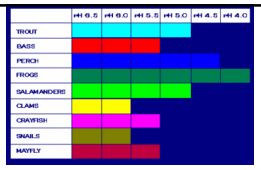
- Emissions combine with atmospheric water to form acidic precipitation.
- Result – low pH precipitation, lowering of pH in aquatic ecosystems

$SO_2\,(g) + H_2O \rightleftharpoons SO_2{\cdot}H_2O$
$SO_2{\cdot}H_2O \rightleftharpoons H^+ + HSO_3^-$
$HSO_3^- \rightleftharpoons H^+ + SO_3^{2-}$

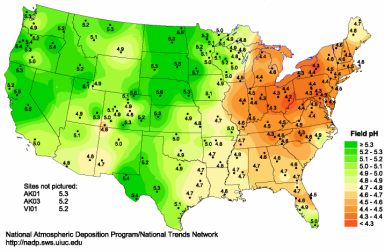


Lowering of Environmental pH

- Greatest effects in northeast, high industrial emissions
- Not all taxa equa impacted
- Successfully mitigated for the most part.

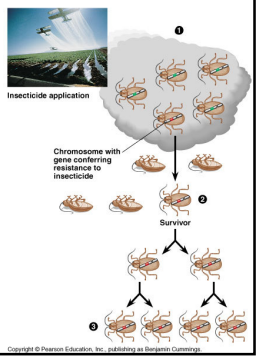


Hydrogen ion concentration as pH from measurements made at the field laboratories, 1999



Pesticides

- **Pest** – species that occurs in an area where it is not wanted
- Pesticides and crop yields – another cost/benefit question
  - Mechanisms
    - Neurotoxins
    - Sterilants
    - Contact poisons
    - Systemic poisons
  - Specificity – pesticides target desirable species.
- **LD_{50}** – lethal dose for 50% of population
- Evolved resistance



Rachel Carson

- Author of "Silent Spring"
  - Pesticides are non-specific
  - Chemicals bio-amplify in food webs
  - Farmers are not adequately educated
  - Contaminants were directly linked to bird and fish kills, showing up in groundwater
- Chemical companies tried to suppress publication

Bioengineering and Pesticides

- Roundup producing gene placed in some crops
- Danger of **horizontal gene transfer** ?

Judge Stops Sale of Monsanto's Genetically Engineered Alfalfa

By ANDREW POLLACK
Published: March 13, 2007

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A federal judge revoked the government's approval of Monsanto's genetically engineered alfalfa yesterday, ordering a halt to seed sales and banning any planting of the crop after March 30.

The decision, by Judge Charles R. Breyer of Federal District Court in San Francisco, came after a ruling he made a month ago that the Agriculture Department had violated the law by failing to prepare an environmental impact statement before approving the crop in June 2005.

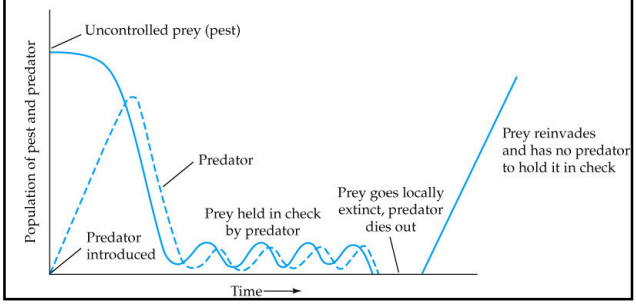
Yesterday's order, the first time that approval of a genetically engineered crop had been revoked by a court, was a preliminary injunction. The judge said he would consider whether to make the injunction permanent at a hearing in late April.

The lawsuit had been filed by some alfalfa seed companies and environmental and farm advocacy groups against the department.

Monsanto intervened in the case after Judge Breyer's ruling last month in an effort to keep the crop on the market. It was joined by several alfalfa growers and by Forage Genetics International, an alfalfa breeder that worked with Monsanto and now handles the sale of the seeds to farmers.

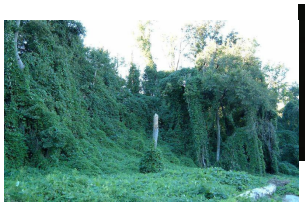
Biotic Control

- Assume **top-down** control – novel predator will be able to control pest population
  - Predation on non-pests?
  - Replacing native predators?



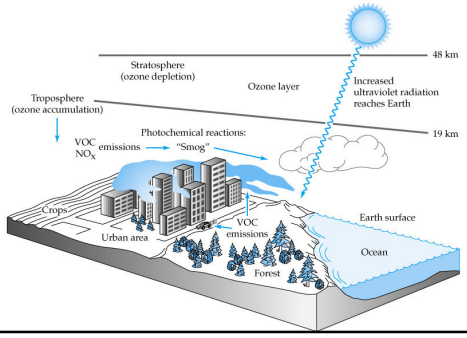
Biotic Control and Introduced Species

- Non-native or exotic species
- Replace native species, alter ecosystem function
- Advocated by R. Carson
- Arguably one of the biggest environmental problems we have today. Good invaders often outcompete native species.



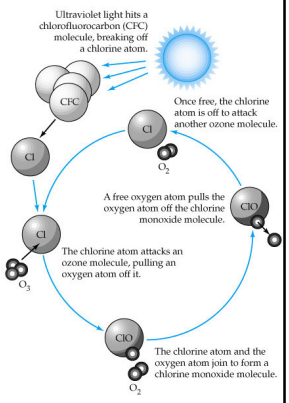
Air Pollution - ozone

- Ozone in the upper atmosphere = good
- Ozone on the surface = bad



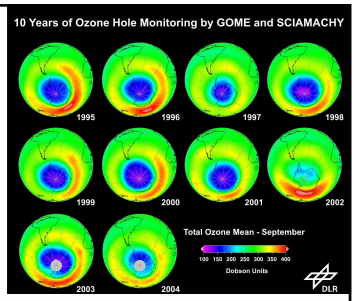
"Hole" in the ozone layer

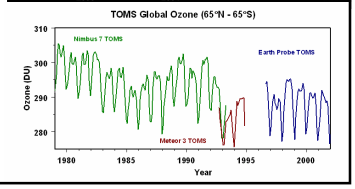
- Observation: Steady decline in ozone concentration above Antarctica, roughly 4% per decade since the late 1970s. Not really a "hole".
- Cause: **photodissociation** of chlorofluorocarbon (**CFC**, "**freons**") compounds
- Free Cl $O_3 \rightarrow O_2$



"Hole" in the ozone layer

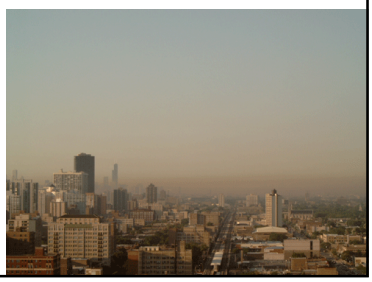
- Mitigation: **Montreal Protocol** (1983) signed by 43 countries, phased out use of all CFC. Eg. Freon use ended in 1995.
- Result: CFC concentrations significantly reduced, rate of ozone loss declined, projected full recovery by 2050
- No relation to climate change





Bad Ozone

- Combustion emissions: $NO_2 \rightarrow NO + O$
- $3\ O \rightarrow O_3$
- O_3 is highly reactive
- $NO_x + H_2O \rightarrow H_2NO_3 \rightarrow H+ + HNO_3^-$
  - Acidic fog/precipitation
  - Highly reactive free O_3
- Worst cities have
  - dense population
  - high traffic
  - Warm
  - Dry
  - low wind



Endangered Species Act (ESA)

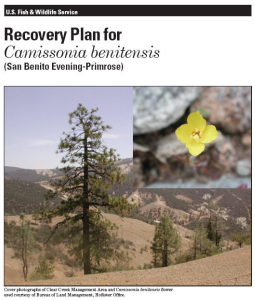
- Passed by Congress in 1973
- Forbids government agency, corporation, or citizen from taking, harming, harassing, or killing individuals of any listed species.
- Once listed as threatened or endangered, the ESA requires "**critical habitat**" be designated for that species.
- Federal agencies may not authorize, funding, or carrying out action which "destroys or adversely modifies" critical habitat.
- Only applies to vertebrates, plants and invertebrates
- Does not apply to fungi (considered plants in 1973) or bacteria

How are Species Listed?

- Federal Government can list a species
  - Fish and Wildlife Service (FWS)
  - National Oceanic and Atmospheric Administration (NOAA)
- Individuals can petition FWS or NOAA to force them to review and consider a species for listing

What happens after listing?

- **Recovery plan** - protocols for protecting and enhancing rare and endangered species populations.
  - Reason for Decline
  - Population Estimate
  - Population Demographics
  - Basic Ecology
  - Niche Parameters
  - Critical Habitat



U.S. Fish & Wildlife Service

Recovery Plan for
Camissonia benitensis
(San Benito Evening-Primrose)

Cover photograph of Clear Creek Management Area and *Camissonia benitensis* flower used courtesy of Bureau of Land Management, Hollister Office.

Recovery Plan

Actions Needed:

1. Protect known occurrences and suitable habitat for *Camissonia benitensis* throughout its range in the CCMA.
2. Reduce or eliminate soil erosion and stream sedimentation above natural baseline levels in watersheds that support habitat for *Camissonia benitensis* and other special status species in the CCMA.
3. Develop and implement a species management plan, including monitoring, for *Camissonia benitensis* to ensure that we have sufficient information on its life history and ecology in the CCMA.
4. Establish an *ex situ* (off-site) seed collection as a hedge against extinction and as a source of seed for introduction efforts.
5. Develop and implement a public awareness program to conserve *Camissonia benitensis* and its habitat.

Time to Recovery: Recovery of the species requires implementation of recovery actions and fulfillment of all recovery criteria. Research is needed on the potential for restoration of eroded serpentine terrace habitat. If such restoration proves to be feasible, monitoring of restored plant habitat and plant population levels should be continued over at least 20 years to meet recovery criteria. Given current knowledge about the extent of soil structure alteration (e.g., destruction of some natural surface crusts that form on the soil surface and function to reduce surface erosion rates), as well as altered erosion regimes, the amount of time we believe necessary to achieve restoration and enable delisting may be 50 years. The recovery criteria should also be reassessed pending results of research on seed bank dynamics and population modeling.

Enforcement of the ESA

- Has to be demonstrated that one knowingly broken the law…

ENDANGERED SPECIES ACT PENALTY SCHEDULE
16 U.S.C. §1561 *et seq.*

VIOLATION	VIOLATION HISTORY - PENALTY AMOUNT		
	FIRST	SECOND	THIRD
A. Taking			
Kill	$3,500 - Statutory Maximum	$7,500 - Statutory Maximum	$13,000 - Statutory Maximum
Wound/Injure/Hunt/Capture	$2,000 - Statutory Maximum	$4,500 - Statutory Maximum	$10,000 - Statutory Maximum
Taking via Significant Habitat Modification or Degradation	Penalties to fit the facts and circumstances of a particular case up to the statutory maximum.	Penalties to fit the facts and circumstances of a particular case up to the statutory maximum.	Penalties to fit the facts and circumstances of a particular case up to the statutory maximum
Harass	$1,000 - $10,500	$2,000 - Statutory Maximum	$7,500 - Statutory Maximum
Collect parts	$500 - $2,000	$1,000 - $5,500	$2,000 - $10,500
B. Transportation and Transactions			
Import/Export	$500 - $4,000	$2,000 - $15,000	$7,500 - Statutory Maximum

Listing Rates and Politics

Administration	Listed	Annual Rate Listed	Delisted	Annual rate Delisting
Nixon/Ford	46	15.3	0	0.0
Carter	151	37.8	1	0.3
Reagan	253	31.6	13	1.6
Bush I	234	58.5	3	0.8
Clinton	521	65.1	10	1.3
Bush II	42	8.0	11	2.2

Why is this political?

Recovered Species

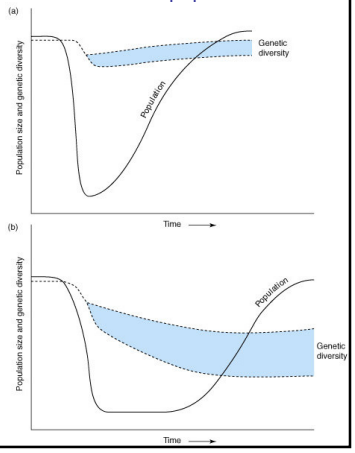
- Most species populations increase in size after listing, examples:
  - Bald Eagle (increased from 417 to 9,250 pairs between 1963 and 2006)
  - Whooping Crane (increased from 54 to 436 birds between 1967 and 2003)
  - Kirtland's Warbler (increased from 210 to 1,415 pairs between 1971 and 2005)
  - Peregrine Falcon (increased from 324 to 1,700 pairs between 1975 and 2000)
  - Gray Wolf (populations increased dramatically in the Northern Rockies, Southwest, and Great Lakes)
  - Gray Whale (increased from 13,095 to 26,635 whales between 1968 and 1998)
  - Grizzly bear (increased from about 271 to over 580 bears in the Yellowstone area between 1975 and 2005).
  - California's Southern Sea Otter (increased from 1,789 in 1976 to 2,735 in 2005)
  - San Clemente Indian Paintbrush (increased from 500 plants in 1979 to more than 3,500 in 1997)
  - Florida's Red Wolf (increased from 17 in 1980 to 257 in 2003)
  - Florida's Key Deer (increased from 200 in 1971 to 750 in 2001)
  - Big Bend Gambusia (increased from for a couple dozen to a population of over 50,000)
  - Hawaiian Goose (increased from 400 birds in 1980 to 1,275 in 2003)
  - Virginia Big-Eared Bat (increased from 3,500 in 1979 to 18,442 in 2004)
- Nine listed species are now extinct

Problems with the ESA

- Extinction is a natural process.
- Is conserving one species at a time the right approach?
- Advantages/disadvantages to conserving ecosystems.
- Human nature – we tend to be concerned with the cute and cuddly

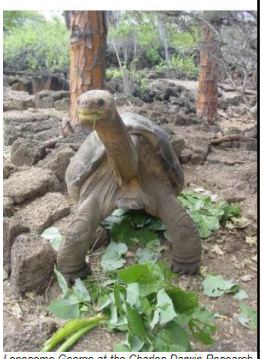
The living dead, genetic bottlenecks and viable population size

- Genetic Diversity
- Genetic Bottleneck
- Genetic Drift
- Inbreeding Depression
- Minimum Viable Population



Lonesome George

- Giant galapagose island tortoise (*Geochelone abingdoni*)
- One individual, George, remains



Lonesome George at the Charles Darwin Research Station. (Credit: Alison Llerena/CDRS)

International Law

- **Convention on International Trade in Endangered Species of Wild Fauna and Flora** (CITES)
- Most diversity in tropics – less developed countries
- Only targets trade (poaching) not habitat loss
- 800 species listed as facing immediate extinction

International Union for the Conservation of Nature and Natural Resources(IUCN)

- No legal authority
- www.iucn.org
- Maintain a "redlist" of threatened species
- www.iucnredlist.org

The IUCN Red List of Threatened Species™ — Summary Statistics

Table 1: Numbers of threatened species by major groups of organisms (1996–2004)

	Number of described species	Number of species evaluated in 2006	Number of threatened species in 1996/98	Number of threatened species in 2000	Number of threatened species in 2002	Number of threatened species in 2003	Number of threatened species in 2004	Number of threatened species in 2006	Number threatened in 2006, as % of species described	Number threatened in 2006, as % of species evaluated**
Vertebrates										
Mammals	5,416	4,856	1,096	1,130	1,137	1,130	1,101	1,093	20%	23%
Birds	9,934	9,934	1,107	1,183	1,192	1,194	1,213	1,206	12%	12%
Reptiles	8,240	664	253	296	293	293	304	341	4%	51%
Amphibians*	5,918	5,918	124	146	157	157	1,770	1,811	31%	31%
Fishes	29,300	2,914	734	752	742	750	800	1,173	4%	40%
Subtotal	**58,808**	**24,284**	**3,314**	**3,507**	**3,521**	**3,524**	**5,188**	**5,624**	**10%**	**23%**
Invertebrates										
Insects	950,000	1,192	537	555	557	553	559	623	0.07%	52%
Molluscs	70,000	2,163	920	938	939	967	974	975	1.39%	45%
Crustaceans	40,000	537	407	408	409	409	429	459	1.15%	85%
Others	130,200	86	27	27	27	30	30	44	0.03%	51%
Subtotal	**1,190,200**	**3,978**	**1,891**	**1,928**	**1,932**	**1,959**	**1,992**	**2,101**	**0.18%**	**53%**
Plants										
Mosses***	15,000	93	---	80	80	80	80	80	0.53%	86%
Ferns and allies***	13,025	212	---	---	---	111	140	139	1%	66%
Gymnosperms	980	908	142	141	142	304	305	306	31%	34%
Dicotyledons	199,350	9,538	4,929	5,099	5,202	5,768	7,025	7,086	4%	74%
Monocotyledons	59,300	1,150	257	291	290	511	771	779	1%	68%
Subtotal	**287,655**	**11,901**	**5,328**	**5,611**	**5,714**	**6,774**	**8,321**	**8,390**	**3%**	**70%**
Others										
Lichens	10,000	2	---	---	---	2	2	2	0.02%	100%
Mushrooms	16,000	1	---	---	---	---	---	1	0.01%	100%
Subtotal	**26,000**	**3**	---	---	---	**2**	**2**	**3**	**0.01%**	**100%**
TOTAL	**1,562,663**	**40,168**	**10,533**	**11,046**	**11,167**	**12,259**	**15,503**	**16,118**	**1%**	**40%**

Review

1 An introduction and understanding of the science of ecology
2 An introduction to factors shaping population and community dynamics
3 An understanding of some of the current issues impacting ecosystems

- May 29 Introduction to Ecology, Ch. 1
- 31 Natural selection, changes in the environment and evolution, Ch. 2
- June 5 Biodiversity, Ch. 3
- 7 Gradients and the physical environment, Ch. 4-5
- 12 Energetics of life, Ch. 6
- 14 Life history, Ch. 7
- 19 Exam 1
- 21 Life history, Ch. 7
- 26 Intraspecific interactions, Ch. 8
- 28 Interspecific interactions, Ch. 9
- July 3 Introduction to communities and ecosystems, Ch. 15
- 5 Community dynamics, Ch. 16
- 10 Community dynamics, Ch. 16
- 12 Exam 2
- 17 Applied Issues - Climate change, Ch. 17
- 19 Applied Issues - Fragmentation, Ch. 18
- 24 Applied Issues - Point and non-point source pollutants, Ch. 21
- 26 Applied Issues - Conservation and biodiversity, Ch. 19