The Moose on Isle Royale

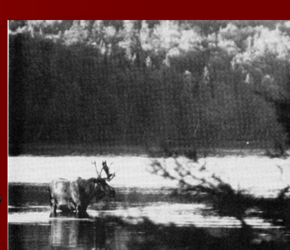
Another case study of the environment and environmentalists

An island in Lake Superior

- Isle Royale is a large forested island, in Lake Superior, named by French explorers 200 years ago.
- It lies about 25 km offshore from the Minnesota-Ontario border.

Original migration

- Around 1900 in the middle of a severe winter, a small number of moose left the shore of Lake Superior near the Minnesota-Ontario border and crossed to Isle Royale.



Isle Royale

- Isle Royale covers 210 square miles – 10 times the size of Bermuda and 9 times the size of Manhattan.

Moose paradise

- The moose had migrated from an area influenced by human civilization to an undisturbed wilderness – a primeval forest.
- Though people had visited, they never stayed.

Lack of predators

- The chief predator of the moose is the North American timber wolf.
- At the time of the arrival of the moose, there were no timber wolves on the island.

Moose change the environment

- In less than 10 years, the moose began to change the environment greatly.
- The water lilies, a favorite food, began to disappear
- So did the yew shrub, which had been the dominant ground cover.
- Both were threatened with extinction because of the moose.

Starvation

- By the mid-1930s the moose had increased vastly in numbers, but had also devastated their food supply.
- A major die-off occurred.
- The number of moose on the island dropped from about 3000 to less than 500.

Nature restores the balance

- A forest fire burned more than 1/3 of the island soon after.
  - The growth that regenerated contained many low, young stems of white birch, which the moose favoured.
- The moose population began to increase again.

A National Park

- In the mid-1940s, the island became a National Park.
- The rising moose population again became a problem.
- Concerned park personnel wished to avoid another catastrophic die-off.

What's natural?

- A National Park was supposed to be a "natural" environment.
- Was it natural for moose to die off in great numbers?
- Was the presence of the moose on the island natural at all?

What is natural in a National Park?

- To let nature "run its course" would mean letting the crisis point be reached when the population would collapse and die in huge numbers.
  - Moose were one of the park's main attractions to visitors.
- The natural environment preserved by a national park can only be natural up to a point.

The Moose were not "natural"

- Since the moose had migrated to an environment that lacked their major predator, the park authorities decided that their presence was "unnatural."

Making nature "natural"

- A population in the wild is kept in check by the presence of its predators.
  - But the timber wolf was missing from the island.
  - The National Park Service decided to introduce the timber wolf into Isle Royale.

Enter the wolves

- The Park Service obtained six wolves from zoos and released them on the island in 1946.
  - But these wolves were not wild creatures. They were accustomed to being cared for by people.
  - Instead of hunting moose, they hung around the Park Service looking for handouts.

Nature to the rescue

- Several years later, during another severe winter, a pack of wild wolves crossed the ice from the mainland.
  - They began living on the moose.
- The wolf pack went from about 12 in the 1940s to about 20 in the 1960s.

Balance of nature?

- The moose population stabilized at about 1000 adults.
- The wolf population also stabilized.
- Plants that moose fed on remained in adequate supply.

Environmentalists begin to study Isle Royale

- Isle Royale became the site of a study of the balance of nature through species interaction, based on the moose.
- Was it the wolf that kept the moose population at 1000? Was this in balance?

Does balance mean steady-state?

- During the study (over several years), the moose and wolf population varied considerably:
  - First the moose population rose.
  - Then the wolf population doubled.
  - Then the moose population declined.

Complex interactions

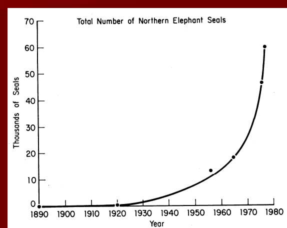
- The study concluded that sodium levels in plants was the most likely limiting factor on the moose population.
- This acted as an upper bound.
- How does the interaction actually work?

Threats to the balance of nature

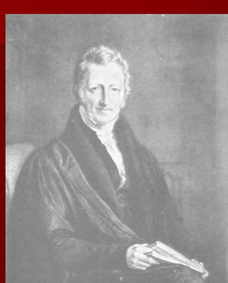
- For nature to remain in balance it must compensate for and fight off both disruptive forces, external and internal:
  - External: Assaults on the environment from without:
    - Wind, storms, rain, fire, chemical leaching of waters – all changing the basic environment.
  - Internal: The power of population growth.
    - The exponential curve that describes normal population increase under ideal conditions.

Example of unfettered population growth

- The Northern Elephant seal population on the Channel Islands off the coasts of southern California and Mexico.
  - The seals were nearly hunted to extinction in the 19th century. There were only 12 left in 1890.
  - Then, left alone, they rebounded at a rate of about 9% per year. By the mid-1970s had reached over 60,000.



Malthusian Growth



- In 1798, Rev. Thomas Malthus published his analysis of the problem of increasing human populations versus increasing food supplies.
  - Malthus' basic point was that populations tend to increase at an exponential rate (cf. the seal population), while food supplies can only increase at a rate limited by arable land.

The limitation of resources

- Exponential Growth of Population
  - Malthus argued that the unfettered rate of growth of the human population was an exponential rate that doubled every 25 years, given unlimited resources.
- Linear growth of resources
  - But, he argued, the food supply necessary to feed people could not be increased at a rate close to a linear function.

The Malthus Crisis Point

- Crisis inevitable
  - There must at some point be a competition over the resources.
- Malthus estimated that this crisis would occur sometime in the 19th century.

Malthus' estimate was wrong

- Human population growth has been greater than exponential.
  - Because of modern medicine, better hygiene and better nutrition, the human population has been increasing at a rate greater than exponential.
- But also greater than linear growth of resources.
  - Farming techniques improved enormously, getting far greater output from existing land due to fertilizers, irrigation, harvesting techniques and transportation to markets – and the Green Revolution with new crops.
- The crisis is yet to come.

Refining Malthus: Feedback

- Malthus' simple model pointed to the inevitability of the crisis to come but could not predict the timing of it.
  - It failed to account for interactions before the crisis hits.
- Interactions take the form of feedback loops.
  - More sophisticated models incorporate feedback information.

Positive Feedback

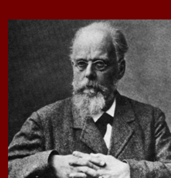
- Mechanism as a philosophy
  - Examples:
    - Population – More births mean more people. More people mean more births.
    - Compound interest – More interest means greater bank balance. Greater bank balance means more interest.
- These lead to exponential functions that runaway on the upside.

Negative Feedback

- An increase in one quantity leads to a decrease in another, causing a counter effect on the first quantity.
  - Examples:
    - Predator-Prey interactions – More predators → fewer prey → fewer predators → more prey → more predators.
    - Governors on automatic machines – More output → less input → less output → more input → more output
- These have the effect of stabilizing a quantity over time.

Ecology

- Ecology is the study of the relationship between living things and the environment.
  - Term first coined by Ernst Haeckel in 1866
    - Based upon Darwin's *Origin of Species*
    - Developed in the underlying framework of mechanistic explanation in science.



The Assumed Foundations of Ecology

- The science developed from three elements:
  1. Naturalists' evidence
  2. Beliefs about order in nature
  3. The mechanist model of science

Naturalists' evidence

- The data of natural history, reported by naturalist observers
  - Interpreted in terms of Darwin's theory of evolution, especially the concept of natural selection and the survival of the fittest.

Beliefs about order in nature

- The assumption of inherent stability.
  - The belief that nature is planned – a great design, beyond our understanding, but orderly in some way we can't fully understand.

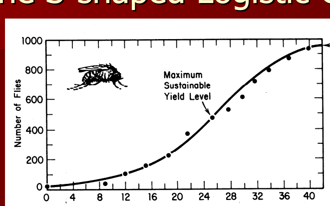
The mechanist model of science

- Reductionism
  - Almost the opposite of the argument that nature has an inherent design.
  - Reductionism is the doctrine that everything in nature is reducible to the laws of chemistry and physics, and therefore is mindless and inexorable.
- Ideal of the mathematical model
  - The accepted language of reductionism is the formalism of the mathematical model.

Mathematical Models in Ecology

- Theoretical models used in ecology taking into account the Malthusian population growth principle as well as the Darwinian struggle for existence – and incorporate notions of feedback loops.
- Two basic models:
  - The S-shaped logistic curve, leading to the concept of carrying capacity.
  - The Lotka-Volterra equations for predator-prey interactions.

The S-shaped Logistic Curve

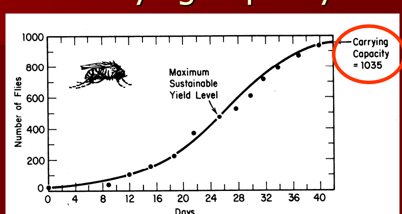


- A concept describing population growth.
  - First proposed in 1849.
- Takes the form of an S-shaped logistic growth curve.
  - Above graph is of the growth of a fruit-fly population.

The Logistic curve in practice

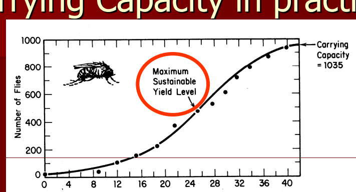
- Verified in the case of organisms grown in laboratories, e.g. bacteria or insects.
  - Provided that they are maintained under constant environmental conditions and provided with a constant supply of food.

Carrying Capacity



- Population is stable at the carrying capacity.
  - It will rise until it reaches it.
  - If increased above, it will fall back to the same number.

Carrying Capacity in practice



- The mathematical model that generates this graph shows that the maximum growth rate is achieved at a population that is ½ of the carrying capacity.
  - This equation was used to determine the maximum allowable harvest of a population that could be sustained indefinitely.

Maximum Sustainable Yield Population

- Problems of applying this concept outside of the laboratory:
  - Population must have an exact, single carrying capacity.
  - Growth must follow the logistic curve.
  - Need to know precisely the carrying capacity and the present population size.

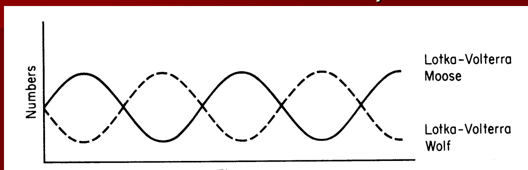
Unrealistic simplifying assumptions

- All harvesters must cooperate completely so that the exact number is harvested each year.
- Implicit here is the assumption that other forces of nature involved will tend to a stabilizing balance that supports the model.

The Lotka-Volterra equations for predator-prey interactions

- A model incorporating negative feedback.
  - Forces that work against each other.
- Lotka and Volterra were two of the scientists to investigate predator-prey interactions and describe them with a negative feedback model.

A Lotka-Volterra graph of Moose vs. Wolfe on Isle Royale



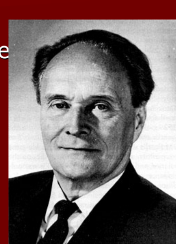
- The prediction of this model is that the moose and wolf populations will oscillate forever around stable ranges.

Does Nature behave as the models predict?

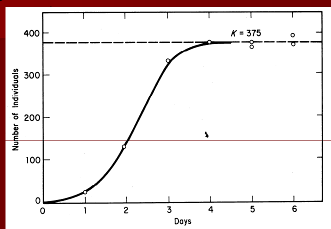
- The mathematical models of ecology have an implicit assumption that nature has an inherent stability that will assert itself.
  - The only question is how.
- Is this assumption borne out by the facts or is it merely a tidy theory?
- Can these models be tested empirically?

The "Struggle for Existence" studied in the laboratory

- In 1934, G. F. Gause published a study in which he tried to demonstrate the logistic S-curve leading to a carrying capacity and the Lotka-Volterra equations of interactions in microbes cultured in laboratory flasks.



Logistic Curve Demonstrated



- Growth of a population of *Paramecium caudatum* as reported by G. F. Gause in his *Struggle for Existence*, 1934.

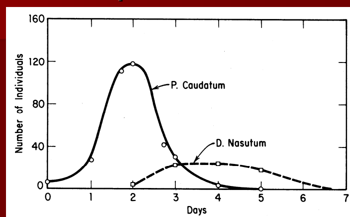
Gause's method

- Gause grew paramecia alone in flasks with a constant food supply, and obtained a growth pattern matching the theoretical logistic S-curve.
  - A result similar to the fruit fly study cited earlier.

Predator-Prey Curve not found

- When he attempted to produce the predator-prey oscillating interactions, he found it impossible.
  - After only a few cycles the interactions went wildly out of control and both species starved.

Uncooperative nature



- Interaction between *Paramecium* prey and *Didinium* predators. The predators quickly reached numbers where they wiped out the prey, and then starved.

Is Nature Stable?

- The mathematical models that predict stability have not been verified in controlled experiments.
  - Do we have any right to assume that there is any long-term stability in nature?
  - Will nature, if left alone to produce its own interactions, produce stability, or will it destroy itself?