The world is changing fast. In terms of biodiversity, there are two main reasons for this: (***1***) human population growth, and (***2***) the resource demands of humans relative to other species.

- THE INCREASE IN HUMAN POPULATION SIZE. The world had fewer than 3.5 billion people in it in 1962 when I was born. It reached 6 billion people in 1999, and we are adding another 95 million every year. Now ~6.6 billion.

  This class started at 12:00 and will be done at 12:50. There will be 11,000 more people on the planet by then. Every time you take a breath, the world's human population grows by 20 people.

  Human per-capita population growth rate is now about 1.7% per year. ($r = 0.017$)

  (***Demographic transition***: growth has regional variation tied to wealth. 1.9% in undeveloped nations, 0.3-0.4% in developed nations. Because most people in are undeveloped countries, the overall mean is close to the mean for poor countries.)

  $r = b - d$, where

  b = births/person/year,

  d = deaths/person/year

  If human population growth is exponential, how long will it take for world population to double? Equation for exponential growth is:

  $N_t = N_0 e^{rt}$

  Where N = population size

  t = time (here measured in years)

  r = per capita

  Set $N_t = 2N_0$ and solve.

  $2N_0 = N_0 e^{rt}$

  $2 = e^{rt}$

  $\ln(2) = rt$

  $t = \ln(2)/r = 0.69/0.017 = 40.8$ years.

This is a fairly good match to the observed doubling time (43 years).

Consider the ***implications of population doubling for resources consumed*** by a population (of any species, not just humans). For now, assume that resources consumed per individual is constant, and assume that generations don't overlap.

Time	Population Size
1	1
2	2
3	4
4	8
5	16
6	32
7	64

(1+2+4+8+16+32) = 63 < 64

At each doubling, there are more individuals present than were present in the entire prior history of the population. Returning to my first example, the impact on resources of the generation born today will be as great as the impacts of all generations in history, up to and including mine. That would be true even if individuals were not increasing their use of resources.

Technology and the race between N & K.

Despite the massive increase in numbers of people, human growth shows little sign of slowing down and leveling out at some 'carrying capacity'.

How can this be? Because humans have the ability to ***alter their own carrying capacity***. Unlike most species, carrying capacity of humans is not simply a product of the environment; it is also strongly affected by economic and cultural processes (see *resource demands*, below). This has important implications for when & how human growth will be slowed or reversed by resource limitation.

Population growth is offset by technological advances that increase carrying capacity. A race between N and K. As the first President Bush said "Every human being represents hands to work, and not just another mouth to feed" (see article by Geddes). As Cohen notes, this true but the work accomplished will depend in part on the resources available to that person.

Malthus' Equation, resource limitation or logistic growth:

$$\frac{dN(t)}{dt} = rN(t)[K(t) - N(t)]$$

(all variables as before, plus K = carrying capacity that varies through time)

Malthus assumed that growth would always immediately match increases in technology.

Condorcet's Equation, race between N & K:

$$\frac{dK(t)}{dt} = c\frac{dN(t)}{d(t)}$$

K = f(N)

- When c > 1, K grows faster than N, see faster than exponential growth
- When c = 1, K grows as fast as N, exponential growth
- When c < 1, K grows slower than N, logistic growth
- When c < 0, K decreases as N increases

Condorcet – Mill Equation, allows c to vary with N

$$c(t) = \frac{L}{N(t)}$$

(variables as before and L reflects resource limitation on the rate at which K can increase as N increases)

[Ohead: Cohen Figs 1,3,4]

Estimates of human N show faster (c>1)than exponential growth 1400-1970.

Note that scatter in estimates of global carrying capacity has INCREASED through time, "the opposite of the progressive convergence that would ideally occur when a constant of nature is measured" (Cohen 1995, p.342). There is a lot of ***uncertainty*** in this.

But note that UN population projections for 2050 = median of 65 estimates of human carrying capacity

- THE RESOURCE DEMANDS OF HUMANS. Our numbers alone would ensure a great impact, but we also use a disproportionate amount of the planet's resources on a per capita basis. One human ≠ one chimp, our phylogenetically closest relative. Chimps don't drive hummers, leave the lights on, flush toilets, etc.

1860 – 1991: global population quadrupled, inanimate energy consumption (MW-hours/year) increased 93-fold. 93/4 = 23.25-fold increase in inanimate energy consumption per person.

[Ohead: Cohen Fig 2.]

What about biological effects?

All energy in biological systems is originally trapped by photosynthesis.

In 1986, Peter Vitousek, Pam Matson, and Paul Ehrlich (*BioScience* 36:368-373) estimated that human beings capture and consume over 40% of global net primary productivity, meaning that we are responsible for consuming nearly half of the annual energy input into the world's living systems. A more recent study (Rojstaczer et al. 2001 *Science*, 294:2549-2552, emphasizes the uncertainty involved in estimating our total consumption, but concludes that humans use 10% - 55% of terrestrial net photosynthetic production (TNPP). Current best estimate is that humans consume about 32% of TNPP.

(Keep this number in mind when we review the relative abundance of species in different taxonomic groups, in a few days… all the mammals put together are a tiny portion of current species.)

[oheads: Rojstaczer Figs 1-3 and Table 1]

- This is only the impact we have on net primary production. Other impacts are inevitable, for a species that consumes 1/3 of TNPP
    - ***Modification of landscapes***: Consider flying over the US and looking out the window from 5 miles up – the impacts of only one species can be seen, but they are obvious.
    - .10-15% of the earth's land surface is occupied by row-crop agriculture or by urban-industrial areas, and another 6-8% has been converted to pastureland. Total affected by urbanization and agricultural conversion = between 15 and 25%. Altogether, 40-50% of land surface has been transformed or altered by human activities.
    - ***Direct exploitation***: 22% of marine fisheries are overexploited or depleted, another 44% are at their limit of exploitation.
    - ***Impacts on water and chemical cycling***: Humans use about 50% of accessible fresh run-off water. Human activities add at least as much fixed nitrogen to terrestrial ecosystems as all other sources combined.

In the United States, there have been three broad classes of response to these problems, or three 'philosophies' about conservation.

- Transcendentalist

  In the mid 1800's, Ralph Waldo Emerson, Henry David Thoreau, and John Muir wrote about nature in almost religious tones. Their writings convinced many of the values of wild places, regardless of whether those places provide any direct economic benefit. One of the first conservation organizations that was not born of hunting and fishing, the Sierra Club, grew out of Muir's efforts to protect Yosemite and other parts of the Sierra Nevada.

- Utilitarian

  In the late nineteenth century Gifford Pinchot, Theodore Roosevelt, and others recognized that it was in our own best interest to protect at least some portions of the natural world. Their motivation for doing so, however, was that we derived important resources (food) and services (water cycles, photosynthesis) from the earth. Unlike the transcendentalists, who hoped to protect natural areas for their own sake, Pinchot and the utilitarians hoped to protect natural areas b/c of the things they can do for us. Many issue-related conservation groups, like Ducks Unlimited and the Rocky Mountain Elk Foundation derive mainly from this movement.

- Land Ethic

  As presented in Aldo Leopold's *A Sand County Almanac*: a synthesis of the preceding two. It avoids the purple passion of Thoreau and Muir, and the strictly utilitarian approach of Pinchot. Fundamentally, the land ethic recognizes that we derive benefits from nature, but the complexity and interdependence of ecological systems makes it difficult or impossible to identify only some components as useful.

  "The first rule of an intelligent tinkerer is to keep all of the pieces." Aldo Leopold.

The first and third of these ethics are widely accepted *within* conservation circles, but only the second has been persuasive to those not committed to conservation for its own sake. ("Conservation is fine as a personal choice, but it has no place in a national energy policy" Dick Cheney, Vice President of the US)

Conservation efforts up to about 1960 were predominantly either concerned with:

- Land conservation – setting aside parcels of land for protection and public enjoyment, e.g., the NATURE CONSERVANCY, mainly following the transcendentalists and the land ethic.

- Wildlife conservation – management of fish and game populations to provide opportunities for hunting, fishing, and observation, e.g., the AUDUBON SOCIETY and the NATIONAL WILDLIFE FEDERATION, mainly following the utilitarians and the land ethic.

In early 1980s, ecologists and evolutionary biologists traditional biology departments, (and to a lesser degree, departments of FWLM) began to take the basic principles of ecology, evolutionary biology, and systematics and apply them to the problem of saving endangered species. 1981, Soulé and Wilcox edited a book, Conservation Biology, that many regard as a founding document for the field. Over the last 25 years, programs in basic ecology and evolution have shown increasing interest in questions related to conservation, and their interests have grown to overlap heavily with programs in applied ecology and wildlife management. A SOCIETY FOR CONSERVATION BIOLOGY was founded in the mid 1980's, programs in conservation biology have sprouted, and several journals have appeared (*Conservation Biology, Animal Conservation, Biological Conservation*, and others). The focus of the field has also broadened.

Three currently major areas of conservation biology:

- Conserving endangered species — Demographic and genetic consequences of small population size, population viability analysis, biology of small populations, manipulative techniques that enhance survival probability and design of nature reserves for particular species.
- Conserving functional and structural aspects of important ecosystems – Diversity and stability of ecological communities, habitat fragmentation, landscape ecology, island biogeography, and restoration ecology
- Conservation evolutionary potential – Adds the concern that small populations do not necessarily maintain enough diversity to provide for evolutionarily responses through geological time.