

EEB 2208: LECTURE TOPIC 5

GLOBAL CHANGE

Reading for this lecture

- **Primack:** pp. 205-212, Chapter 22
- **Root et al. 2003.** Fingerprints of global warming on animals and plants. *Nature* **421**:57-60. Available at: <http://www.nature.com/nature/journal/v421/n6918/pdf/nature01333.pdf> I've used this paper for discussions in the past (though not this year) – it was one of the first papers to show how widespread the biological effects of climate change are. You should read it, and think about it, in the same level of detail as if we were going to discuss it in class.

Useful optional reading:

- McCarty, J.P. 2001. Ecological consequences of recent climate change. *Conservation Biology* **15**:320-331. Available at: <http://www.blackwell-synergy.com/doi/pdf/10.1046/j.1523-1739.2001.015002320.x> This paper gives a review of the evidence for biological effects, but is now a little outdated – there's lots more evidence today.

Supplemental:

- For lots of information on climate change, go to the web site for the Intergovernmental Panel on Climate Change (IPCC) at <http://www.ipcc.ch/>.
- To investigate the climate effects of different policy scenarios, there is a neat on-line model that you can play around with at <http://chooseclimate.org/>.
- For graphics illustrating the “ecological footprints” of human society around the world, go to <http://news.bbc.co.uk/2/hi/science/nature/6080074.stm>.

1. Human population growth

A) RATE OF GROWTH

- i) Current estimates suggest that the human population is well over 6,750,000,000, with a 15% increase just between 1990 and 2000.
- ii) The population continues to increase and is not expected to slow until it gets up to 9 or 10 billion.

B) CONSEQUENCES OF CONTINUED GROWTH

The potential effects of this continued growth are numerous, but a few things to think about include:

- Increased food needs – increased production can play a partial role (perhaps through genetically modified crops?), but production gains alone are not likely to be enough. Therefore, more land will probably be converted to agriculture, especially in the tropics.
- Increased water needs – Many of the world's people already have an inadequate water supply. And in many areas, water is increasingly scarce. Wetlands in particular are likely to suffer as a result.
- Increased energy needs – the combination of an increasing population plus increasing standards of living means that more and more energy is needed. Fossil fuels almost certainly contribute to climate change, and eventually will become scarce. But, many of the alternative sources of energy also have (often uncertain) effects on biological diversity.

C) GLOBAL CHANGE HAS MANY OTHER FORMS

- i) In class I don't have time to talk about all the ways in which human populations are affecting global changes. In fact, it would be quite easy to teach an entire course on the subject.
- ii) One other example is simply the increase in human mobility – the rate and extent to which we move ourselves and our things around the world. One unintended consequence of all this movement is the increasing spread of disease and other species. This is a topic we'll revisit later in the semester when we talk about invasive species.

D) ECOLOGICAL FOOTPRINT

- i) The “ecological footprint” is an estimate of humanity’s impact on the Earth, relative to the resources available. The details of how to calculate such a footprint are complex and debated, and I do not plan to go into them in detail. But, if you’re interested in conservation and the environment I would suggest you do some research of your own on the topic.
- ii) Not surprisingly, the total ecological impact of humanity is estimated to be increasing.
- iii) Globally, it has been estimated (by the Worldwide Fund for Nature; reported by the BBC, see web link above) that each person needs 2.2 hectares to support their use of environmental resources. In contrast, the Earth is estimated to be able to sustain about 1.8 hectares per person. The discrepancy in consumption among countries is large, with the U.S. currently using about 5 times the average global capacity that has been estimated.
- iv) One interpretation of this result (though not one that everyone will agree with) is that, to be fair to everyone else on the planet, each of us should reduce our consumption of materials by four-fifths!
- v) In much of the world (the US, Europe, North Africa, the Middle East, much of Asia), the footprint is estimated to be more than 50% greater than the biological capacity in the region. To see a map of “eco-debtors” (those who use more than they have) vs. “eco-creditors” (those who use less) follow the ecological footprint link above.

2. Example: Climate change

Although global change takes many forms, one of the most profound and widespread changes facing us right now is climate change. Hence, I will focus on this example for the rest of the lecture.

A) EVIDENCE FOR CLIMATE CHANGE

- i) Based on data collected since the 1870s, we know that there has been an average increase of about 0.5°C over the last 100 years. We also know that the 1990s was the hottest decade of the last century.
- ii) Another indication of rising temperatures is the increasing rate of glacial and permafrost melting in many arctic and alpine areas. Increased melting does not exist everywhere, but it is sufficiently widespread to be a clear sign of warming in many areas.
- iii) Data from several isolated mountain peaks show that temperatures have increased by more than 1°C during the past century. Similarly in several tropical mountain ranges, the mean elevation at which freezing occurs has shifted upslope by several meters.

B) WHAT IS THE CAUSE?

- i) Although there is very strong evidence that average temperatures have increased, there remains controversy over the cause of the increase (although the degree of controversy is declining rapidly).
- ii) Some argue that increases are nothing more than natural fluctuations, and are not caused by human activities – and temperatures have certainly gone up and down considerably in the past.
- iii) On the other hand, there is very good evidence that humans have greatly altered the composition of the atmosphere in ways that are expected to cause warming. In fact, the famous Swedish chemist, Svante Arrhenius, predicted that carbon dioxide releases would result in climate change. He made this prediction in 1896!
- iv) Over the last 50 years, CO₂ has increased from about 316 parts per million by volume to 370 ppmv.
- v) CO₂ levels have also fluctuated in the past, but evidence from ice cores show that they have not been as high as is currently the case for many millennia. Ice core evidence also shows that, in more recent times, concentrations were stable for 1700 years prior to the industrial revolution and then rapidly increased following the large increase in the burning of fossil fuels.

- vi) Release of other “greenhouse gases” (i.e., those expected to cause warming of the Earth) have increased. These include methane, chlorofluorocarbons, and nitrous oxide. But CO₂ is currently expected to contribute by far the most to global warming.

C) WHAT ARE THE ENVIRONMENTAL CONSEQUENCES?

- i) Obviously weather will change. Average temperatures are expected to increase, but there will be a lot of variation – some areas will cool, others will stay about the same. Precipitation patterns will also change, with both an overall increase and much greater variability. Variability is predicted to increase both in terms of the spatial and temporal distribution of rainfall.
- ii) Among the consequences of increased variation in precipitation are (a) more flooding and soil erosion in areas where rainfall is more concentrated, and (b) the need for more irrigation in areas where rainfall declines.
- iii) Ice-caps are expected to continue to melt and sea-levels consequently rise. Both of these things are already happening – to the extent that the human populations of some small atolls in the Pacific are being forced to leave their homes. Another consequence of ice-cap melting is that it might (though this is uncertain) change the flow of major ocean currents, which could have direct and dramatic effects on climate.
- iv) Note that past IPCC predictions for sea-level rise have underestimated what has since been observed. The latest predictions suggest 0.5 – 1.4 m of sea level rise by 2100 (maybe more).
- v) Many more things that I don’t have time to discuss could also happen but there is also a lot of uncertainty about what the exact effect will be.

D) WHAT ARE THE BIOLOGICAL CONSEQUENCES?

- i) At an ecosystem level, recent studies have suggested that there have been widespread changes in patterns of net primary production during the period 1982-1999. As with climate, these changes are not evenly distributed across the Earth. For example, much of the global increase in NPP occurred in Amazonian forests. Reasons for the changes included less cloud cover and increased solar radiation.
- ii) Another change has been in the amount of crop production. For example in Europe, between 1959-93, the growing season lengthened by about 11 days. In many (but not all) areas, global models predict that crop yields will increase (this is potentially a good thing about warming ... as long as you live in one of those areas!).
- iii) Various studies have shown that the geographic ranges of many species have shifted in concert with increasing temperatures. These studies have largely focused on birds and butterflies – being very mobile these species are perhaps able to respond more quickly than other species. Speckled wood butterflies, for example, have spread north and greatly increased their range in Britain over the last century.
- iv) Yet other studies have shown changes in the life-history characteristics of many species that can be attributed to climate change. For example, many birds in temperate areas have begun to breed earlier than in the recent past. This shift could have benefits (e.g., by increasing the length of the breeding season and allowing opportunities to produce more young), or it could cause problems (e.g., by creating a mismatch in the timing of breeding and peak food production if the phenology of prey species does not shift in accordance). Different studies show different things – in some cases species seem capable of adjusting ... but the same species in other places fail to adjust. Think about why this might be.