EEB 2208: TOPIC 12

GLOBAL CHANGE

Reading for this topic

Primack: pp. 205-214

Other supplemental stuff that might be of interest:

- 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/.

1. Human population growth

A) RATE OF GROWTH

i) Current estimates suggest that the human population is well over 7 billion.

ii) The population continues to increase, with a projected ~9 billion by 2050. By then, however, the growth rate is expected to have slowed.

iii) Projected growth rates tend to be highest in areas with the greatest biological diversity.

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 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 FORMS

i) In class I don't have time to talk about all the ways in which human populations are creating global changes. In fact, it would be easy to teach an entire course on the subject.

ii) One less obvious 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 (see lecture notes on Invasive Species and Disease).

iii) Another example you may not think of is ocean acidification. Increased CO_2 in the atmosphere results in more CO_2 dissolving in ocean water. This in turn causes the ocean to become more acidic, which in turn interferes with the development of the many marine organisms that build shells etc., from calcium carbonate.

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 in this class … but I encourage you to look into it.

ii) Not surprisingly, however, the total ecological impact of humanity is estimated to be large and increasing.

iii) Globally, it has been estimated (by the Worldwide Fund for Nature) 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. Obviously as population size and consumption rates increase, the discrepancy grows. The discrepancy in consumption among countries also is large, with the US 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 plant, 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.

2. 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 mid-1800s, we know that there has been an average increase of about 0.5ºC over the last 100 years. We also know that the 1990s was the hottest decade of the last century, that the 2000s were hotter, and that 2016, 2015, 2014, 2010, and 2013 were the five hottest years on record (every year so far this decade is in the top 15).

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 isolated mountain peaks show that temperatures have increased by more than 1ºC 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 temperatures have gone up and down considerably in the past, which is correct.

iii) But, 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 warming. He made this prediction in 1896!

iv) Over the last 50 years, CO_2 has increased from about 316 parts per million by volume to >400 ppmv.

v) Like temperature, CO_2 levels have fluctuated in the past. Evidence from ice cores, however, show that they have not been as high as is currently the case for 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 fossil fuel burning.

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 CO_2 is currently expected to contribute by far the most to global warming.

C) WHAT ARE THE CONSEQUENCES?

i) Obviously, weather change is a major one. Average temperatures are expected to increase even more, 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. Predicting exactly how precipitation will change, especially at regional levels, is much harder than predicting temperature changes because it is affected much more by local conditions such as topography.

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 to rise. The amount of ice melting is exacerbated by the fact that warming is greatest in polar regions. Sea-level rise is partly due to melting, but only ice that is on land contributes to rising waters (i.e., melting Arctic sea-ice plays little role). Much of sea-level rise is due to thermal expansion (as water warms up it expands). These changes are already happening.

iv) Note that past IPCC predictions for sea-level rise have <u>underestimated</u> what has since been observed. The most recent 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 effects will be. This uncertainty does not mean that things are not changing though.

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 (NPP). 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 growing seasons have consistently lengthened (by almost 2 weeks in Europe). Global models also predict that crop yields will increase ... in some, but not all, areas (this is potentially a good thing about warming … but only if 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 initially 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. More recently, similar patterns have been seen in many other types of organism, both on land and in marine systems.

iv) Yet other studies have shown that changes in the life-history characteristics of many species can be attributed to climate change. For example, many biological events happen earlier in the year – these include things like the start of egg-laying in birds, flowering times in plants, emergence of insects in the spring, etc. These shifts in **phenology** could have benefits (e.g., by increasing the length of the breeding season and allowing opportunities to produce more young), or they 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.

E) MODELLING CONSEQUENCES OF CHANGE

i) Because climate change plays out over a long time it is often hard to tell exactly what the consequences will be. As a result, ecologists increasingly use complex mathematical models to predict how species distributions will change and whether populations are likely to increase or decrease.

ii) One of the simplest approaches is to look at the climate conditions in places where a species occurs today, use climate projections to determine where those conditions will be in the future, and assume that the species will be able to move with the changing conditions.

iii) This approach probably works as a good first approximation, but it has drawbacks – for example if there is a barrier of inhospitable habitat a species might not be able to move across it. Similarly, if change happens rapidly and the species is poor at dispersing, it might not be able to keep up with the changing conditions. Finally, species that live in places like mountain tops, or near the poles, may simply run out of places to go as the climate conditions they use disappear from the planet.

iv) Recognizing the importance of models in conservation biology (and science in general) is very important. But, it is also crucial to recognize that models are only as good as the biological understanding that underpins them, and that we need to use basic ecology both to design models and to interpret them appropriately.