EEB 2208: LECTURE TOPIC 4

BIODIVERSITY PATTERNS

Reading for this lecture

Primack: Chapter 3
Discussion reading (for today, Monday 30th Jan): Hahs, A., et al. 2009. A global synthesis of plant extinction rates in urban areas. Ecology Letters 12: 1165-1173.
On-line at: http://www3.interscience.wiley.com/journal/122581716/abstract
An optional reading: Mora et al. 2011. How many species are there on earth and in the ocean? PLoS 9. On-line at: http://www.plosbiology.org/article/info:doi/10.1371/journal.pbio.1001127

1. What does biodiversity mean in practice?

i) Although biodiversity encompasses many different things, the reality is that species diversity continues to receive most attention from conservation biologists and practitioners.
ii) When people talk about variation in biodiversity, they are frequently (perhaps usually) referring to variation in species richness. In part, this is because it is relatively easy to quantify species-level diversity compared to other forms of biological diversity (though even this task is not simple).
iii) The remainder of this lecture will focus on species level diversity. But, do not forget that biodiversity as a whole has many other components.

2. How many species are there?

A) ESTIMATES

i) Currently, about 1.2-1.5 million species have been described. But, we know that there are also lots of species that have not yet been described.
ii) Estimates of the number of undescribed species vary considerably. But, there is general agreement that we have described only a small proportion of all species. Most estimates of global species richness put the number somewhere between about 5 and 10 million, but some range up to 30 million species. As our understanding of very small organisms improves we may find that the true number is even larger.
iii) One of the most recent attempts to answer this question predicts that there are a total of 8.7 million species, about 2.2 million of which are in the oceans. This study, by Mora et al. 2011 (see above for full reference) suggests that 86% of all species, and >90% of marine species, are yet to be discovered.

B) UNDESCRIBED SPECIES

i) Perhaps surprisingly, newly described species include some large organisms from well-known groups. For example, several new birds are described annually, mostly from the tropics, but occasionally from well studied areas (e.g., Gunnison Sage-Grouse in Colorado). Many “new” mammals are in fact things that we’ve known about for some time, but have not previously been classified as distinct species (e.g., “forest” elephants), but others are completely new discoveries (e.g., saola – discovered in Vietnam in 1990s, and considered to be in a totally new genus).
ii) But, the vast majority of the species that remain to be described are invertebrates, and estimating how many of these remain is difficult.
iii) The main problem is that to make an estimate of the number of undescribed species several other numbers have to be estimated first. These numbers are then combined, which inevitably results in compounded errors. See canopy fogging example in text book (pp. 63-64).
iv) Limited taxonomic work, and biases in the way that taxonomy is studied, contribute to the problems. For example, nematodes did not get studied in detail by taxonomists until it was realized that they have important agricultural impacts (see text book for details). Similarly,

our current (lack of) understanding of microbial diversity might mean that we are missing a lot of diversity that we do not know exists.

v) IMPORTANT: It is critical to recognize that although these discoveries are often described as "new species", they are really only newly discovered. The species have been there all along; humans just had not found them and put names on them. So, these new species are not the result of recent speciation and do not counterbalance losses in biodiversity due to recent extinction.

3. Diversity patterns

A) PROBLEMS DESCRIBING PATTERNS

i) Because most species have not been described it is hard to really know how species richness varies spatially.

ii) Consequently, we have to assume that patterns seen in well known groups of species are representative of all species. This may or may not be a reasonable assumption.

B) SPECIES RICHNESS PATTERNS CORRELATE WITH MANY THINGS

i) Richness increases with habitat diversity (e.g., number of bird species increases with plant diversity and with structural diversity of the vegetation).

ii) Richness increases with habitat patch size – many species are increasingly more likely to occur in patches that are larger than some threshold size (this is sometimes referred to as "**area-sensitivity**" and will be important later when we discuss habitat fragmentation).

iii) Richness decreases with increasing elevation. Similarly, in oceans and lakes, richness decreases with increasing depth).

iv) Richness decreases with increasing latitude and tends to peak near the equator.

C) RICHNESS IS (SOMEWHAT) PREDICTABLE

i) Tropics > temperate

ii) More structural complexity > less complexity (e.g., coral reefs > open ocean; forests > grasslands)

iii) High productivity > low productivity (e.g., productivity is often inversely correlated with elevation/depth)

iv) Mainland communities > island communities

v) Larger area > smaller area

vi) Ecotones (edges) > interiors

D) THERE ARE EXCEPTIONS TO MOST GENERAL PATTERNS

i) Example: In the southern US, tree diversity declines compared to more northern latitudes. This is because much of the southern US is desert, where trees mostly do not grow.

ii) Example: Parasitic insects are less common in the tropics than farther north. But, this might just be because of sampling bias (i.e., tropical insects have not been studied well enough).

iii) Example: Salt marshes are extremely productive habitats, yet species richness is low.

4. Hotspots

A) WHERE DOES SPECIES RICHNESS PEAK?

i) In the past two decades, conservation biologists have tried to identify areas where species richness is greatest.

ii) Neither this endeavor, nor the interest in patterns of biological diversity, is driven by a desire to maximize richness or to try to increase richness – these are not the goals of conservation biology. <u>Maintaining</u> richness is generally what is considered important.

iii) But, identifying areas of high species richness is seen as a way to streamline conservation actions – by finding places where the maximum number of species can be protected within the smallest area. These areas of high species richness are often referred to as "hotspots".

B) WHERE ARE THE RICHNESS HOTSPOTS?

i) In general terms, hotspots are where you would probably expect them to be – e.g., most are tropical, many are in areas of rainforest, etc.

ii) But, there are clear exceptions. E.g., some are in temperate "Mediterranean" climates (e.g., California and the Cape region of South Africa). Others are distinctly temperate. Why do you think New Zealand is a hotspot?

iii) Hotspots are not only found on land. Although early hotspot maps focused on terrestrial species, maps of marine diversity hotspots have also been created. The seas between Australia and SE Asia in particular have several hotspots.

C) DO RICHNESS HOTSPOTS MATCH UP?

i) Hotspots are usually defined based on some set of well-known species.

ii) But, it is not always clear that one well-known group will be representative of other types of organisms.

iii) A study done in Britain highlights this issue. Britain is a good place for such a study, because there is very good distributional information about a lot of different types of organisms, and because there have been a lot of taxonomists working there for a long time, so taxonomic biases are probably not as bad as they might be elsewhere. Prendergast et al. (1993; http://www.nature.com/nature/journal/v365/n6444/abs/365335a0.html) mapped out hotspots for several different groups of organisms to see how well the patterns matched. They found that some groups matched quite closely (e.g., butterflies and dragonflies), but others did not match at all well (e.g., liverworts have a completely different pattern compared to the other groups examined). The conclusion of this study (and others since) was that areas of high richness for different taxonomic groups often do not coincide.

D) WHAT ABOUT OTHER TYPES OF HOTSPOT?

i) Richness hotspots do not necessarily identify areas with high numbers of rare species. Even if they do, lots of rare species occur outside of hotspots. Can you think of some examples?

ii) Hotspots also do not always coincide with **zones of endemism** (areas where there are large numbers of species that are found nowhere else). These areas are considered important for conservation planning because there is no alternative to protecting these areas if extinctions are to be avoided. Examples of such areas that do coincide with richness hot spots include: the South African Cape (for higher plants); Madagascar (for mammals, reptiles and swallowtail butterflies); coastal Brazil (for amphibians).

iii) Orme et al. (2005; http://www.nature.com/nature/journal/v436/n7053/abs/nature03850.html), in a global analysis, found limited overlap between hotspots of species richness, rare species, and locally endemic species. So, just as with different taxonomic groups, the top priority areas depend on which aspect of biodiversity one aims to maximize.

iv) Additionally, just like richness hotspots, areas with many rare species or with high endemism differ among taxonomic groups.

E) OTHER LIMITATIONS OF THE HOTSPOT FOCUS

i) Although richness hotspots, rarity hotspots, and zones of endemism contain many species and can be considered high conservation priorities, there are also many species that do not occur in any of these areas. Can you think of any? Unless conservation protection is broad-based many of these species will not be protected.

ii) Finally, biodiversity is not just about numbers or rarity. There are many unique ecosystems that do not have high species richness, and who is to say that these are less important or less valuable than very diverse tropical rainforest. Examples: Salt marshes are among the most productive habitats on Earth. Arctic tundra and boreal forests support huge numbers of organisms (albeit of relatively few species), and play important roles in global geochemical processes. Saline lakes are biologically amazing and highly productive places yet support only a handful of species.