EEB 2208 LECTURE TOPIC 15

CONSERVATION GENETICS

Reading for this lecture

Primack: Chapter 12.
Discussion reading: Traill et al. 2007. Minimum viable population size: A meta-analysis of 30 years of published estimates. Biological Conservation 139: 159-166. Available on-line at: http://courses.forestry.ubc.ca/Portals/37/docs/READINGS/MVP%20MetaAnalysis.pdf

Optional reading: O'Grady et al. 2006. Realistic levels of inbreeding depression strongly affect extinction risk in wild populations. Biological Conservation 133: 42-51. Available on-line at: http://si-pddr.si.edu/dspace/bitstream/10088/8469/1/D97EB81A-F200-46A4-854F-CD9E459504D3.pdf

1. Introduction

A) GENETIC PROBLEMS ARE MORE LIKELY IN SMALL POPULATIONS

i) As previously mentioned, small populations are inherently vulnerable for a lot of reasons.
ii) **Point endemics** (species found in only one place) are especially vulnerable. For instance the Tiburon mariposa lily is found only on one mountain in northern California. The current population is quite large (10,000s), but it is very vulnerable to a single catastrophic event that affects the one small site where it occurs.
iii) Genetic problems also primarily affect small populations – both in the wild and in captivity – and so they exacerbate the effects of demographic and environmental conditions.

B) TWO KEY QUESTIONS

i) What kind of genetic changes occur in small populations?
ii) Why are they a threat?

2. Genetic variation is lost in small populations, due to drift

A) GENETIC DRIFT

i) **Genetic drift** is a random (neutral) process that leads to changes in the genetic makeup of a population.
ii) It is different from natural selection, because it results from random variation in birth and death rates. For instance, some individuals may happen to produce a lot of young in one year – the genes carried by these individuals will be passed on to the next generation at a high frequency. Other individuals may happen to produce few or no young – their genes will be rare or absent in the next generation. By this process, gene frequencies can change.
iii) Drift happens in all populations, but in moderately large populations the effects of drift are negligible (more on this below). In small populations, however, drift can have large effects on genetic variation.

B) THE MATH

i) The genetic variation (**heterozygosity**) of a population refers to the number and abundance of alleles/genotypes in the population.
ii) The change in heterozygosity between generations can be determined using this formula: $H_{t+1} = [1 – (1/2N_e)]*H_t$. H_t is the heterozygosity in the current (t) generation and H_{t+1} is the heterozygosity in the next (t+1) generation. N_e is a measure of how big the population size is (referred to as the **effective population size**; more on what that means below).
iii) If you plug some numbers into this equation you can see how heterozygosity changes with different population sizes. Try doing the math with a small population size (e.g., $N_e = 5$). Then do it again for a larger population size (e.g., $N_e = 50$), and compare the results.
iv) Note that the part of the equation $(1 - 1/2N_e)$ must always be less than one (because N_e is always positive). This means that heterozygosity will always decline as a result of drift.

v) If you don't really understand this, go back and work through it again (really doing the calculations will help). If you still don't get it, ask for help.

vi) The rate at which genetic variation is lost from a population will vary depending on the effective population size and on the length of time over which it is measured. See Figure 11.3 in Primack.

C) DOES GENETIC VARIATION ALWAYS DECLINE?

i) NO!!! The results described above mean that if drift is the only process affecting genetic variation then there will always be a decline. But, other processes also occur.

ii) Counteracting the loss of variation due to drift is mutation, which increases variation. But, the mutation rate is relatively low and does not change with population size. In large populations, where the loss of variation due to drift is very, very small, the mutation rate can counterbalance the losses. But, in very small populations, the rate of loss (through drift) goes up and the rate of gain (through mutation) stays the same, leading to a net loss.

iii) If you are considering an endangered population, rather than an entire species, variation can also be increased through immigration. Even relatively low rates of immigration (1 or 2 individuals per generation) can be enough to counter the effects of drift. How would this information influence the way you manage a captive population?

3. Effective population size

A) DEFINITIONS

i) In the equation given above we used a value called N_e, the **effective population size**. This value is different from the actual population size (sometimes called the **census population size**, because it is the number you would come up with if you did a census and counted every individual in the population). The difference between these two measures is very important.

ii) The effective population size is a theoretical measure of how many individuals are contributing their genes to the next generation.

B) WHAT INFLUENCES THE EFFECTIVE POPULATION SIZE?

i) N_e depends on several different things, including the sex ratio (the more skewed the sex ratio, the smaller N_e will be relative to N), variation among individuals in the number of young produced (a lot of variation reduces N_e), and fluctuations in population size.

ii) Estimating the difference between N_e and N can be complex (see Primack). But the key thing to know is that the effective population size is almost always smaller than N, and often much smaller.

iii) Since loss of genetic variation depends on N_e, the rate of loss can be much greater than one would suspect based simply on the number of individuals that you know are in the population. This is why it is really important to consider N_e rather than N when assessing the likely genetic effects for a particular population.

4. What are the consequences of losing genetic diversity?

A) SHORT TERM EFFECTS

i) The primary short-term problem is **inbreeding depression**. Inbreeding occurs when close relatives mate, and when populations get small it becomes inevitable that the remaining individuals will be closely related. Consequently, inbreeding is common in very small populations.

ii) Inbreeding depression arises when individuals are produced that are homozygous for deleterious recessive alleles. The result is reduced survival and reproductive output of the offspring, and these demographic changes can alter the dynamics of the population in a manner that increases the risk of extinction.

iii) In small populations, genetic diversity is also lost at random, which means that both good and bad alleles can be completely lost from the population. Hence, just through random processes, alleles that have benefits to a species (e.g., those that confer disease resistance) may be lost.

B) EXAMPLE: FLORIDA PANTHER

i) The Florida panther population has declined considerably and now numbers only a few dozen individuals, which are clearly isolated from the nearest mountain lion population in Texas (Florida panthers are a subspecies of mountain lion). In the late 1980s there were only 30-50 and the population had been small for some time. The population is listed as Endangered under the US Endangered Species Act.

ii) At this time, there were signs of inbreeding in the population. For instance, a high proportion of the sperm produced by males was abnormal. A lot of the cats in the population also had kinked tails, which in itself is not necessarily a problem, but is a sign of inbreeding.

iii) Because immigration was unlikely, conservation managers decided that they needed to do something to reduce the effects of inbreeding. In 1995, mountain lions from Texas were introduced to bring more genetic variation into the population. This move was controversial, because there was concern that mixing individuals from the two populations would be tantamount to destroying the distinct Florida subspecies.

iv) The offspring of the introduced females proved to have fully functional sperm and to lack kinked tails – a sign that the introductions worked (i.e., they reduced the effects of inbreeding). Populations have also increased a little since that time (though this could also be because of other conservation measures).

v) This situation does, however, raise questions about whether the current population is really still a population of Florida panthers. What do you think?

C) EXAMPLE: LAKESIDE DAISY

i) The Lakeside daisy is found around the Great Lakes and is listed as Threatened under the Endangered Species Act.

ii) A remnant population in Illinois was found to produce no seed, and was heading for extinction. The lack of seed-set was because the species is self-incompatible, which means that two individuals with the same genotype cannot produce viable seed, and all individuals in the population had the same genotype.

iii) The only way for this population to persist was to introduce plants with a different genotype.

D) GENERAL EFFECTS OF INBREEDING

i) A recent study (see above) used simulation models to investigate just how serious inbreeding effects could be for a range of species.

ii) The study looked at about 30 species, all mammals and birds (why do you think this was?).

iii) The authors created population models that simulate populations dynamics and allowed them to estimate the chance of extinction. They also included a component that simulated the effects of inbreeding that would be found in a typical population so that they could compare the model output with and without the genetic effects.

iv) The result was that the time to extinction was reduced by an average of 37% … in other words, species went extinct about a third faster when the inbreeding effects were included. If these simulations are accurate, they indicate that predictions that do not account for inbreeding will consistently underestimate the risk of extinction.

E) LONG TERM EFFECTS

i) Loss of genetic variation also has long term consequences for a population because it reduces the potential for that species to adapt to changing conditions. This is because natural selection requires variation in order to act (otherwise there is nothing to select between!).

ii) An ability to adapt to new conditions might be critical for species in light of fundamental changes in their habitats, e.g., as climate changes, or as chronic pollution arises.

5. Last thoughts

In this lecture we have considered examples in which the population has probably always been very small (e.g., the lily), and others where they have declined rapidly in recent times to a small population size (e.g., the panther and daisy). Which of these scenarios do you think would be the greatest cause for concern?