Small-population paradigm

NRES 470/670

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The final extinction of a population usually is probabilistic. That is, once the population gets small enough, *demographic stochasticity*, *genetic drift*, and *inbreeding depression* can together deal the final death knell to a population. In conservation biology the study of processes that disproportionately influence small populations is called the *small-population paradigm.*

That is: the small-population paradigm refers to the tendency in **conservation biology** to study those largely *stochastic* factors that can result in the extinction or degradation of small populations.

Demographic stochasticity

We have already been through this concept, which is central to the small population paradigm!

The simple fact is: *it's much more likely for all 10 individuals in a population to be* ***unlucky*** *in a given year than for all 1000 individuals in a population to be* ***unlucky*** *in a given year!!* – just as it is very unlikely for all coin flips out of 1000 to come up heads…

This illustrates the very important concept, that small populations can go extinct due to demographic stochasticity alone, whereas this possibility is vanishingly small for large populations.

The moral of the story for demographic stochasticity was: weird and dramatic things (e.g., extinction) can happen in small populations!

Weird and dramatic things like random extinction just would **never happen** in large populations just due to random chance (in a stable, favorable environment)!

Same goes for *genetic drift*! Genetic drift is a *small-population phenomenon*!

Genetic drift

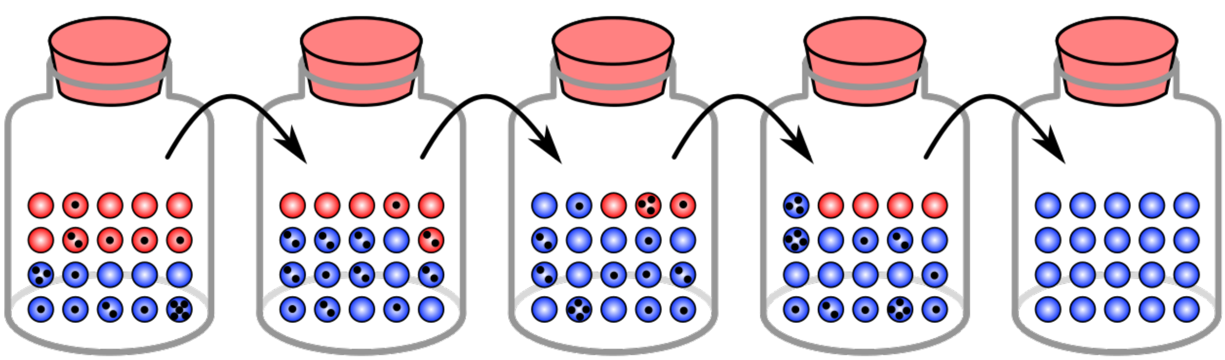

Figure 1:

For example: in large populations, you could never randomly get **fixation** of a particular gene (this could happen via natural selection, but not through random reproductive processes).

Let's imagine that the balls in the jars in the above figure are individuals. The black dots indicate how many offspring that individual will have (thereby passing on its genes). The different colored balls represent different genetic variants. Each jar, left to right, represents a different (non-overlappling) generation.

Does this sound familiar? Just by random chance, some individuals will breed and some will not. Just by random chance, some individuals will have more of their offspring survive. Genetic drift is simply a consequence of **demographic stochasticity**.

Finally, let's imagine that the red balls represent individuals that are more likely to survive a rare drought (but have no selective advantage or disadvantage under normal circumstances).

Under normal conditions, the number of births is completely random. And if this was a sexually reproducing diploid population, mating would be completely random too.

Just by random chance, the blue individuals happen to reproduce more than the red individuals- and the red individuals go extinct.

And now, by random chance, this population is now more susceptible to drought!

Inbreeding depression

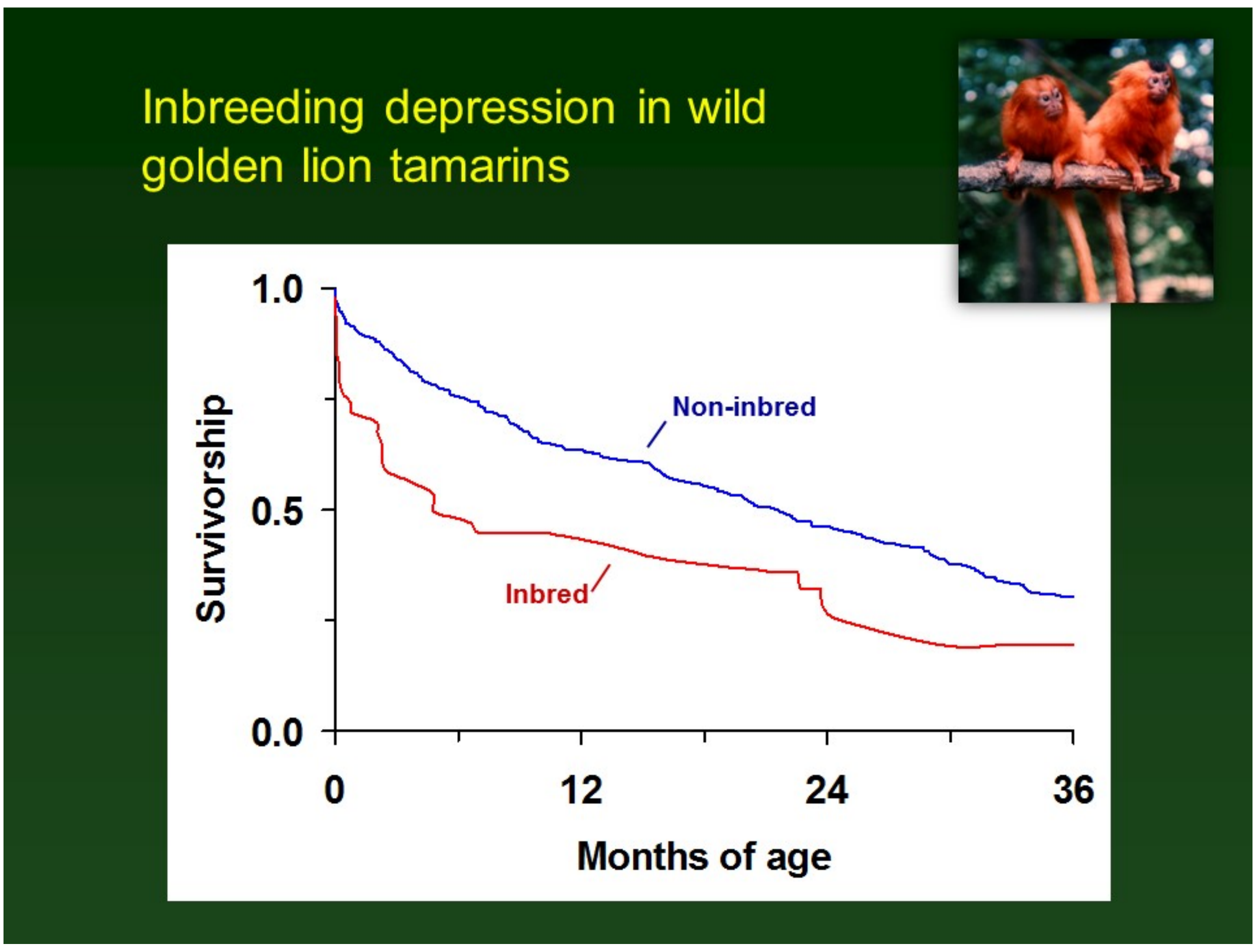

Figure 2:

Inbreeding depression is very similar to genetic drift, but more specific! Again, inbreeding problems only occur in small populations.

Most diploid populations have some “bad genes” floating around. These are often called **deleterious alleles**. These deleterious alleles usually don’t cause problems becuase in general they are **recessive -** that is, the bad effect is only apparent if an individual has *two copies of that allele*!

Figure 3:

Q: Why is it more likely to get two copies of the same allele if your two parents are close relatives?

Q: Why is it more likely for your two parents to be close relatives if you are living in a small population?

Extinction vortex

One of the central ideas arising from the small population paradigm is the concept of the **extinction vortex**. This concept is illustrated in the above figure.

Once a population gets small enough, it becomes subject to catastrophic declines due to demographic stochasticity, leading to inbreeding and random loss of useful genes, leading to reduced vital rates, leading to smaller population sizes, leading to further genetic degradation, leading to more possibility of catastrophic declines due to demographic stochasticity, leading to . . . EXTINCTION!!

Minimum Viable Populations (MVP)

We have seen this concept already, in the context of the Allee Effect. However, there is a more general definition, related to the extinction vortex.

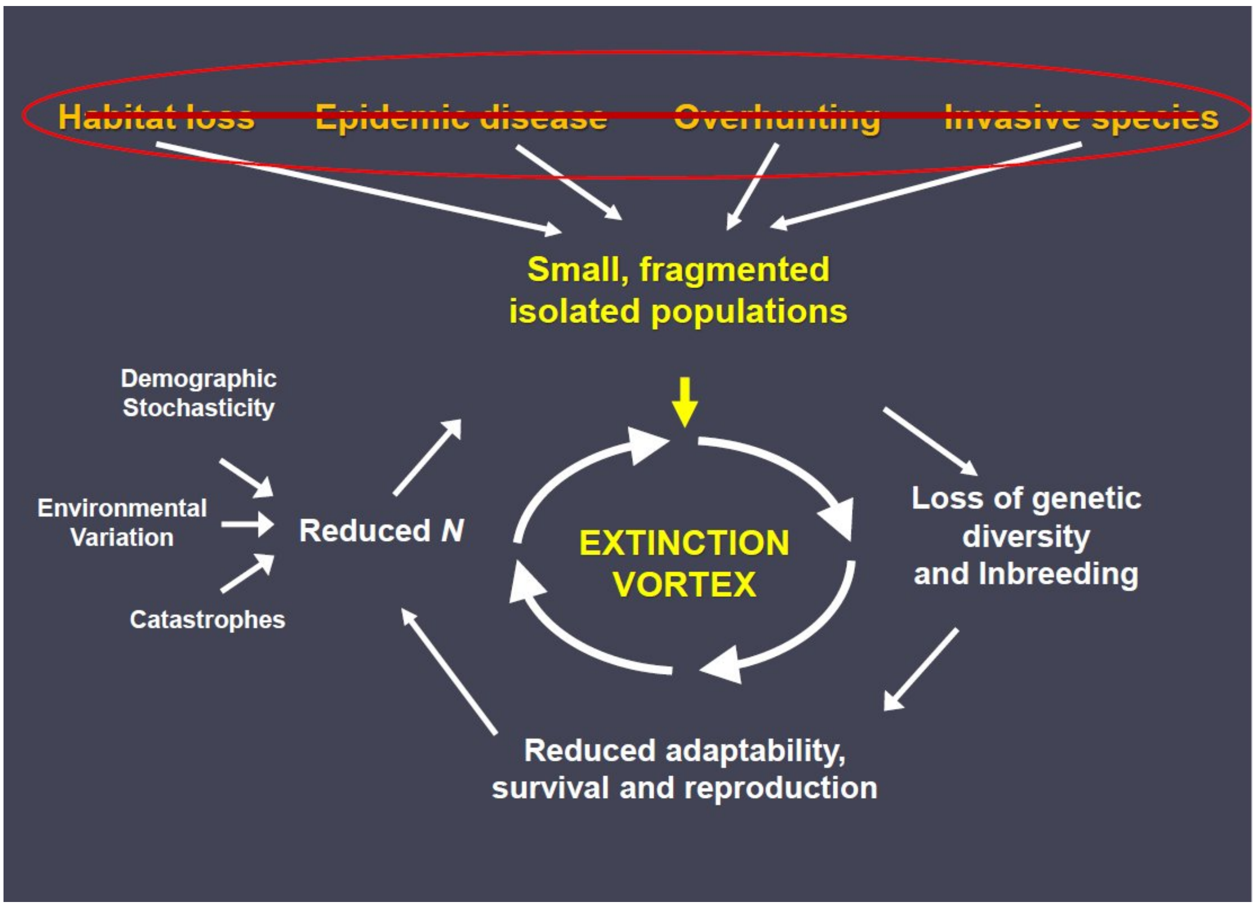
~~Habitat loss~~
~~Epidemic disease~~
~~Overhunting~~
~~Invasive species~~
Small, fragmented
isolated populations
Demographic
Stochasticity
Environmental
Variation
Catastrophes
Reduced *N*
EXTINCTION
VORTEX
Loss of genetic
diversity
and Inbreeding
Reduced adaptability,
survival and reproduction

Figure 4:

Minimum Viable Population is defined as that *population size above which the extinction vortex can be safely averted*!

Population Viability Analysis (PVA)

Population Viability Analysis (PVA) is often used to model the processes in the extinction vortex, including genetic drift. In this class, we won't get into modeling genetics (that's for a different course!)

The most widely-used PVA software, Vortex, gets its name from the extinction vortex concept. Vortex does allow explicit modeling of inbreeding and loss of genetic diversity in small populations.

Example: Aruba island rattlesnake

The aruba island rattlesnake, or Cascabel (*Crotalus durissus unicolor*), is the top predator on the island of Aruba, and primarily consumes rodents.

The Aruba island rattlenake, as you might expect, occurs only on the island of Aruba.

The Aruba rattlesnake is listed as *Critically Endangered* by IUCN, and has several attributes that make it particularly susceptible to falling into the extinction vortex:

- Range is limited to the small island of Aruba **Q**: why does this matter?
- Total abundance is estimated as 250 individuals
- Population has been declining due to:
  - loss and degradation of habitat (overgrazing, human encroachment, forest clearing)
  - human persecution

–go to next lecture–

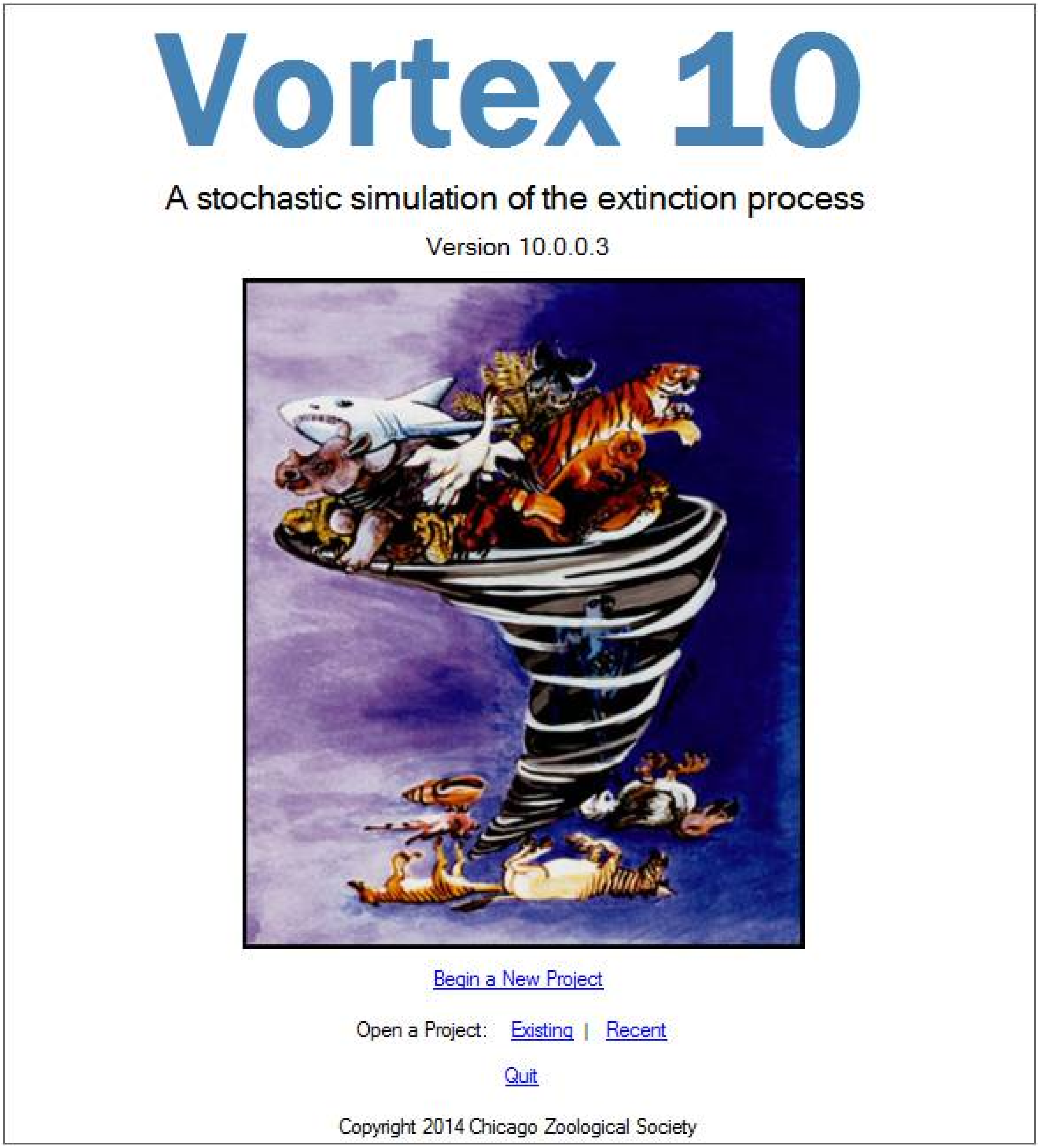
Vortex 10
A stochastic simulation of the extinction process
Version 10.0.0.3
Begin a New Project
Open a Project: Existing | Recent
Quit
Copyright 2014 Chicago Zoological Society

Figure 5:

Figure 6:

Figure 7: