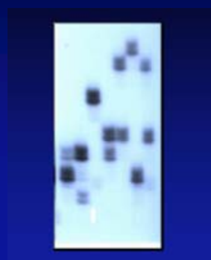
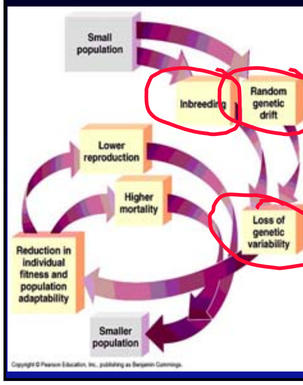
Conservation genetics of Island species

Mauritius ISLA, November 2007



The Extinction Vortex



Demographic factors

Genetic factors

Genetic diversity in Island Species

Richard Frankham (1997) *Heredity* 78:311-327.

Low levels of genetic diversity

~29% less than mainland species

Birds, 21% less
Mammals, 35% less

Even less genetic diversity in island endemics

Endemic birds, 63% less diversity than mainland species
Endemic mammals, 80% less diversity than mainland species

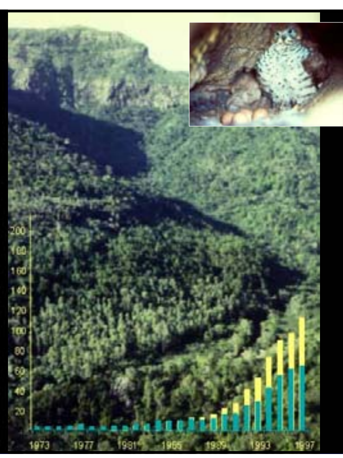
Genetic diversity in Island Species

1. Longer history of small (restricted) population size in island endemics

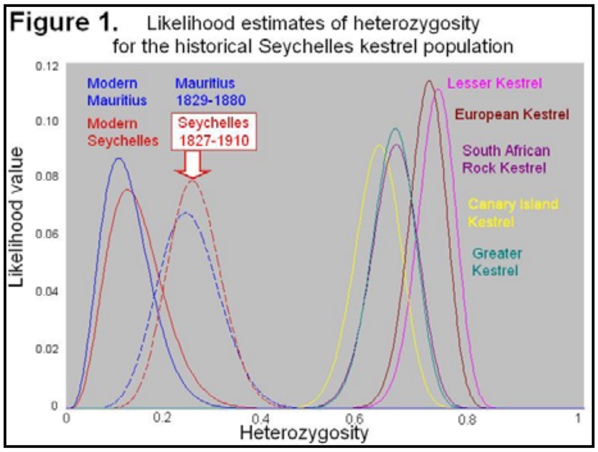
2. Low genetic diversity is partly responsible for high extinction risk of island species

Divergence of Indian Ocean kestrels

Mauritius kestrel

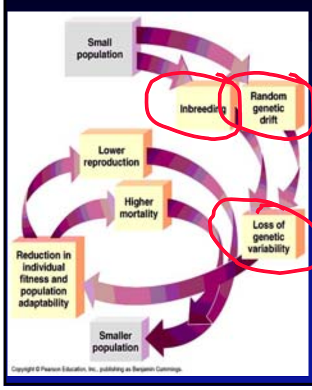


Seychelles kestrel



So, island species tend to be genetically impoverished (relative to mainland species) because they have evolved on islands

The Extinction Vortex



Demographic factors

Genetic factors

Evolution in LARGE populations

All populations need to evolve to survive.

Evolution in LARGE populations

All populations need to evolve to survive.

Populations (species) need genetic diversity to adapt to changing environments.

Evolution in LARGE populations

All populations need to evolve to survive.

Populations (species) need genetic diversity to adapt to changing environments.

Large populations contain high levels of genetic diversity (mutation, Balancing selection).

Evolution in LARGE populations

All populations need to evolve to survive.

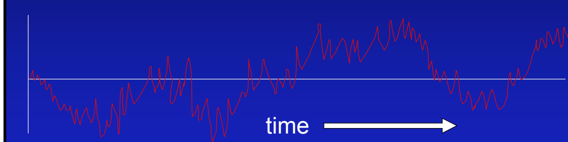
Populations (species) need genetic diversity to adapt to changing environments.

Large populations contain high levels of genetic diversity (mutation, Balancing selection).

Evolutionary processes such as natural selection ensure that genetic diversity is RETAINED in LARGE populations.

On Monday we considered…
What determines an islands biota?

Eg. Climatic changes…
On an evolutionary timescale, populations experience different oscillations



Akialoa

Clermontia peleana

Where does genetic diversity in a population come from?

Immigration
(uncommon in island populations?)

MUTATION!
(a very slow process)

When populations become small (rare), they loose genetic diversity.

So, how does this happen?

and

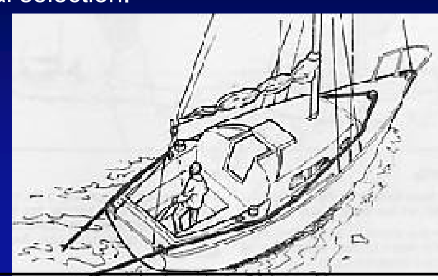
What's all the fuss about?!

Genetic Drift
in
small populations

How small are endangered populations ?

Genetic drift in small populations

Genetic drift is the random loss of genetic diversity in small populations, genetic drift dominates over natural selection.

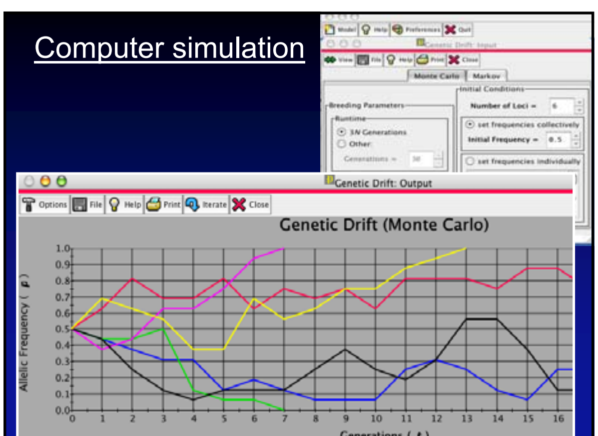


Evolution in small populations

The dominating evolutionary processes,
in small populations (in order of importance):

1. **Chance (genetic drift)**
2. Inbreeding
3. Mutation (accumulation of…)
4. Natural Selection

Computer simulation



Implications of Genetic Drift

(a) large random changes in the genetic make-up of the population

(b) Loss of genetic diversity

(c) Fragmented populations may end up with very different genes simply by chance

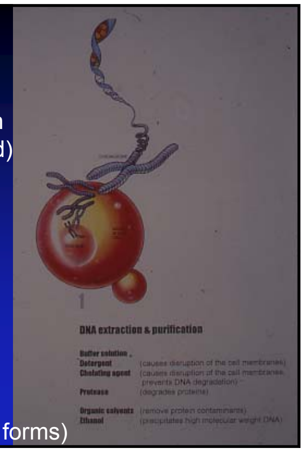
Genetic diversity is contained on chromosomes in cells

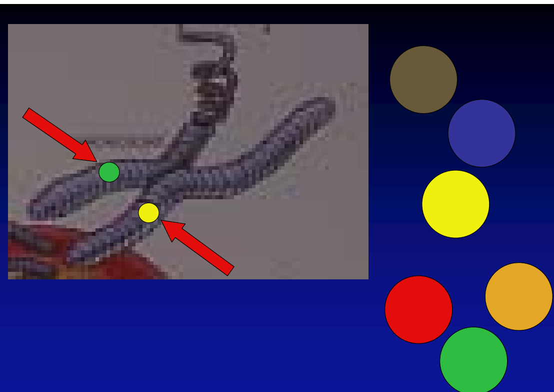
We have two copies of each chromosome (we are diploid)

Chromosomes contain genes

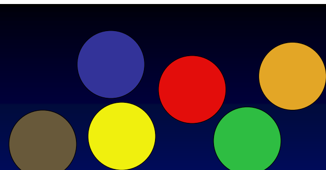
The same genes in two different individuals can be genetically different (variation)

Alleles (genetically different forms)





- What is your own genotype?
- How many of you are heterozygous?
- How many of you are homozygous?
- What are the frequencies of each of the alleles amongst all of you?



Frequency of each of the 6 alleles in your parents generation

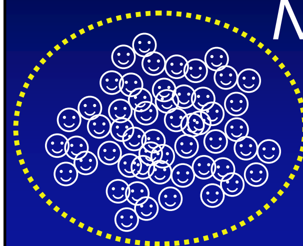
Time	0	1	2		
Blue	20%				
Yellow	4%				
Red	20%				
Orange	20%				
Green	16%				
Brown	20%				

So, genetic drift changes the frequency of different alleles in a population

(rare alleles are lost by not being transmitted into the next generation)

The impact of genetic drift is directly linked to POPULATION SIZE

N



What other ways can populations loose genetic diversity?

Inbreeding

How do we measure inbreeding ?

Unit of measurement = *F* (Inbreeding Coefficient)

F = probability that any 2 alleles at a particular locus in an individuals genome will be identical by shared descent

F = probability value between zero and 1

Alleles identical by descent

$A_1\ A_1$

Inbreeding

Alleles identical, but not *recent* copies of the same allele

$A_1\ A_1$

Homozygosity

What are the *genetic consequences* of inbreeding ?

Inbreeding changes the *frequency of genotypes*

Inbreeding { decreases Heterozygosity / increases Homozygosity } in direct proportion to *F*

Is there any experimental evidence that inbreeding is linked to extinction of populations?

Link between Inbreeding & Extinction - evidence from natural (wild) populations

Saccheri *et al*. (1998 *Nature)*

Clear evidence that inbreeding has a *significant effect* on extinction

Glanville Fritillary Butterfly

Multiple populations in Finland

Assessed heterozygosity in each population.

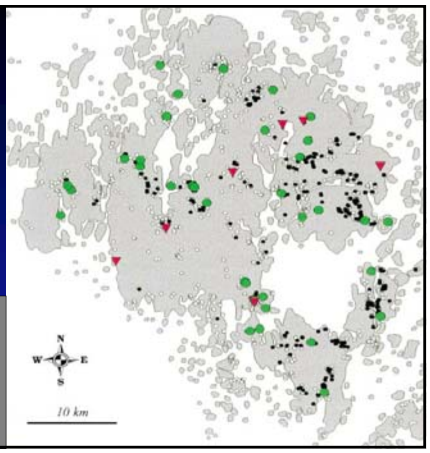
Monitored the trajectory of each population over time

Saccheri *et al.* (1998) *Nature*

- ○ Sites suitable for butterflies
- ● Site containing butterflies in 1995
- 42 sites sampled (green circles and red triangles)

Green circle = Populations that survived to autumn 1996

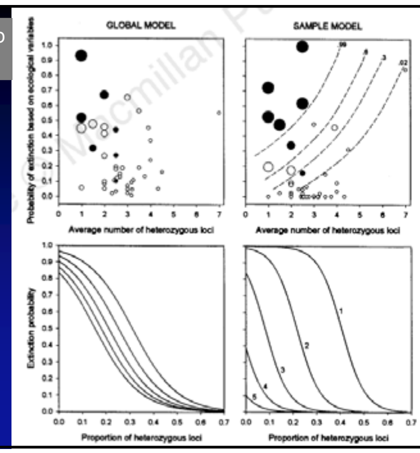
Red triangle = Populations that went extinct by 1996



○ Surviving pop
● Extinct pop

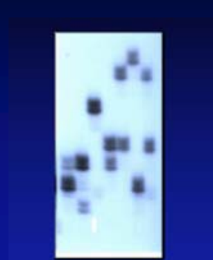
Probability of Extinction increased as average heterozygosity decreased

*21%** extinction explained by genetics



How can we measure Inbreeding?

Pedigree records



Genetic data

The Inbreeding Coefficient

Inbreeding can be measured within individuals and within populations

F = 0 to 1

F=0 parents are unrelated
F=0.25 parents are brother-sister

Inbreeding accumulates in closed populations

There is a close relationship between inbreeding & loss of genetic diversity

Increase in inbreeding per generation = Loss of genetic diversity per generation

$\frac{1}{2N}$ population size $\frac{1}{2N}$

There is a close relationship between inbreeding & loss of genetic diversity

Increase in inbreeding per generation = Loss of genetic diversity per generation

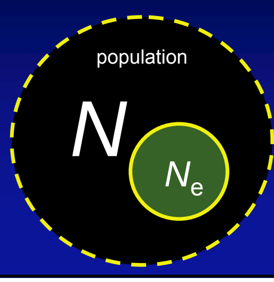
$\frac{1}{2N}$ population size $\frac{1}{2N}$

$\frac{1}{2N_e}$ effective population size $\frac{1}{2N_e}$

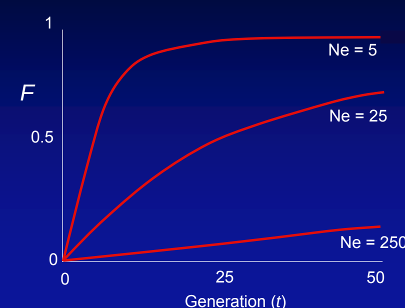
Effective population size (N_e)

Not all individuals in a population are genetically 'effective'

On average, N_e comprises only 10% of the total census population size.



Rates of inbreeding accumulation depend on population size



What are the *genetic consequences* of inbreeding ?

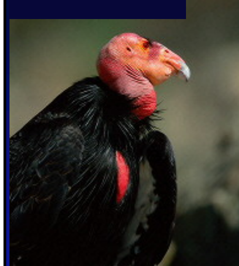
Inbreeding CHANGES the proportion of genotypes in a population from one generation to the next

Inbreeding DOES NOT change the allele frequencies

BUT, in small populations, allele frequencies will change due to *genetic drift*

Inbreeding exposes rare deleterious alleles

Californian Condor

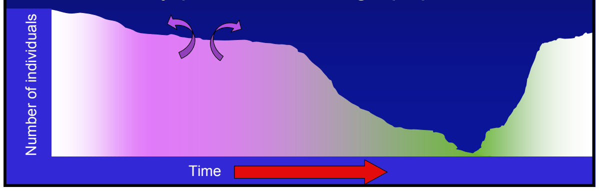


Genetic diversity (alleles) are produced by random mutation

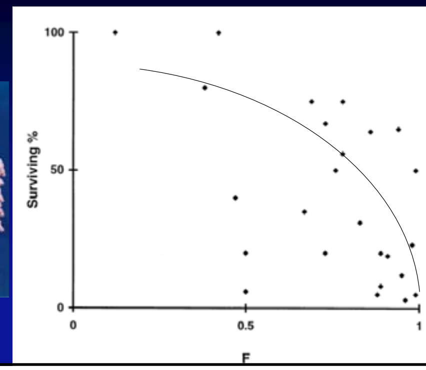
Not all alleles are good (i.e. evolutionarily useful)

lethal alleles	mildly deleterious alleles

Constantly produced in large populations



Generally, for inbred small populations…



When *F* increases by 25% what happens to fitness characters?

Previous studies

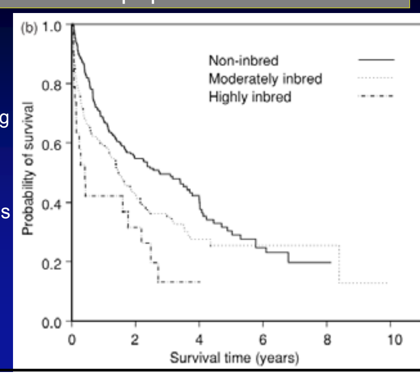
Humans	IQ	⇩ 11%
	Height (@ 10yrs)	⇩ 4%
Chickens	Survival	⇩ 26%
Turkeys	Reproductive survival	⇩ 38%
Mice (domesticated)	Litter size	⇩ 18%
Mice (wild)	Litter size	⇩ 10%
Zebra fish	Hatchability	⇩ 89%

Inbreeding depression is cumulative in small populations

Mauritius Pink Pigeon

Effect of inbreeding on survival of free-living birds

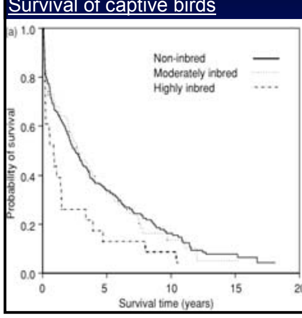
Highly inbred birds are likely only to survive for half as long as non-Inbred birds



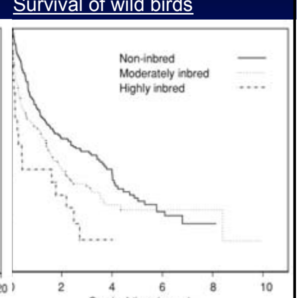
Inbreeding depression is more acute the in wild

Mauritius Pink Pigeon: survival in wild birds is reduced by 50%

Survival of captive birds



Survival of wild birds

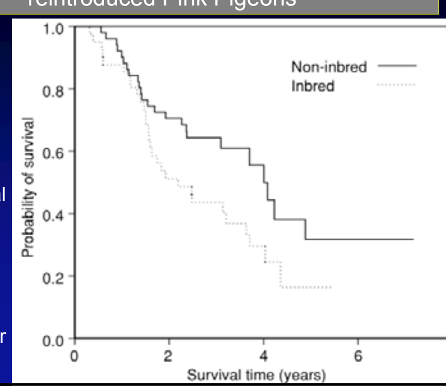


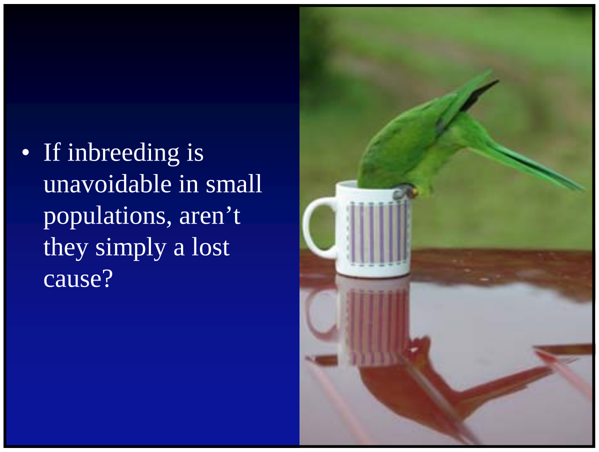
Inbreeding reduced post-release survival of reintroduced Pink Pigeons

Survival of released birds is relatively poor.

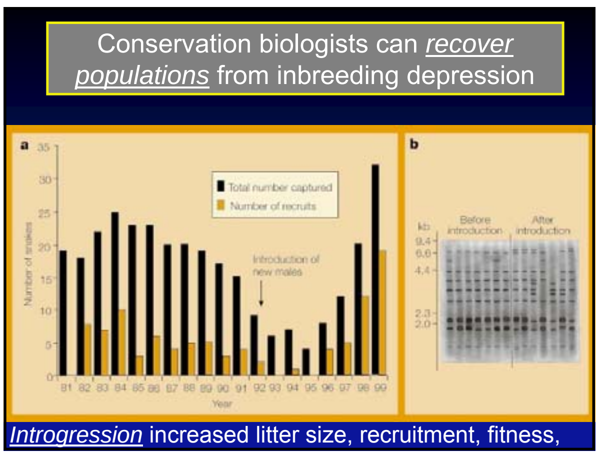
After 1.5 yrs of age, survival of inbred birds becomes drastically reduced.

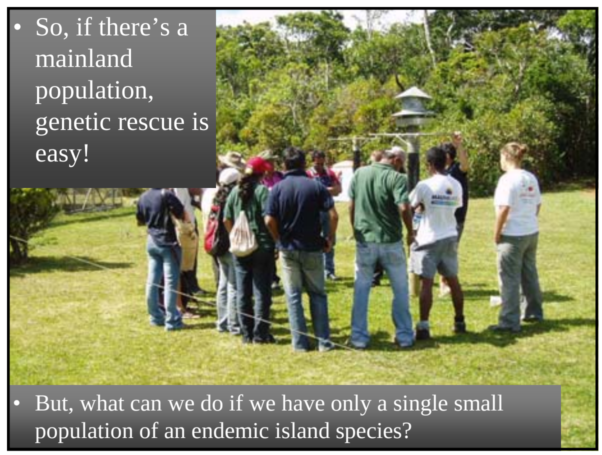
Implications for management?

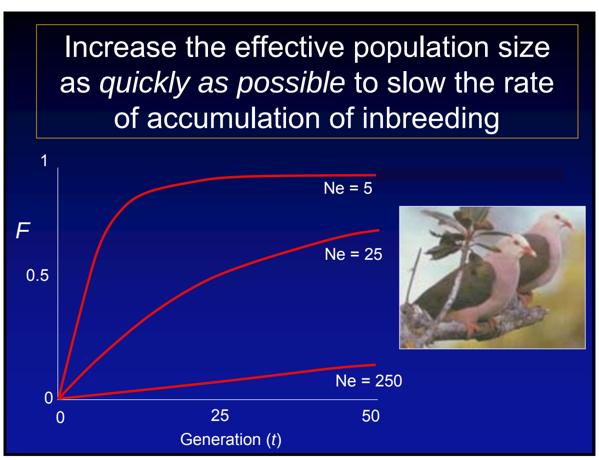


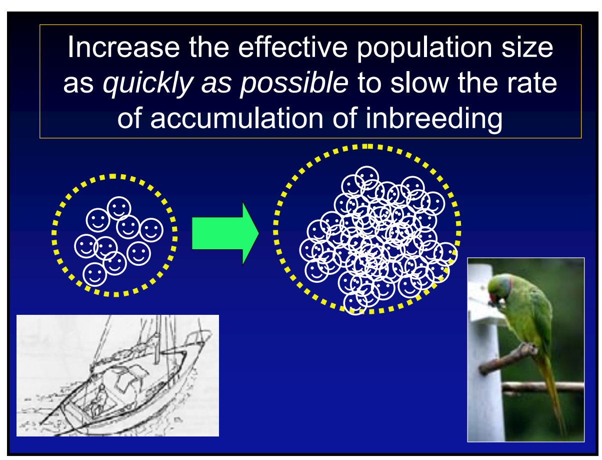

• If inbreeding is unavoidable in small populations, aren't they simply a lost cause?


Conservation biologists can recover populations from inbreeding depression


Conservation biologists can recover populations from inbreeding depression
a
b
Total number captured
Number of recruits
Introduction of new males
Number of snakes
Year
Before introduction
After introduction
Introgression increased litter size, recruitment, fitness,


• So, if there's a mainland population, genetic rescue is easy!
• But, what can we do if we have only a single small population of an endemic island species?


Increase the effective population size as quickly as possible to slow the rate of accumulation of inbreeding
F
1
0.5
0
Ne = 5
Ne = 25
Ne = 250
0
25
50
Generation (t)


Increase the effective population size as quickly as possible to slow the rate of accumulation of inbreeding

Effective population size (N_e)

Not all individuals in a population are genetically 'effective'

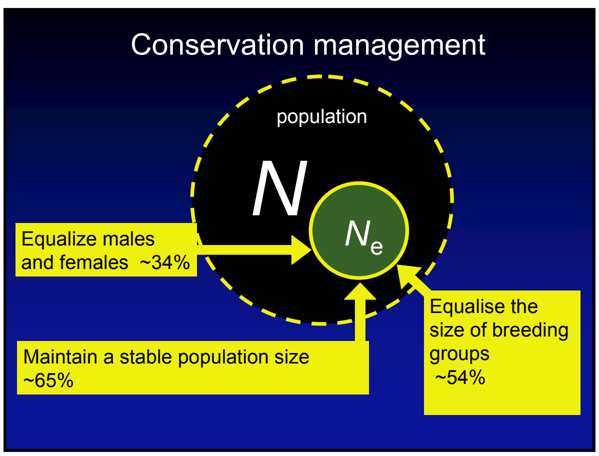
On average, N_e comprises only 10% of the total census population size

WHY?

- Unequal number of males and females
- Unequal size of family groups
- Unequal numbers of offspring per generation

How can we increase the number of genetically effective individuals?

- Stabalize the population
- Equalise family sizes
- Equalise numbers of males and females



So, how does our conservation management fit in then?

- Control of predators
- Supplementary feeding
- Nest management
- Manipulation of breeding pairs