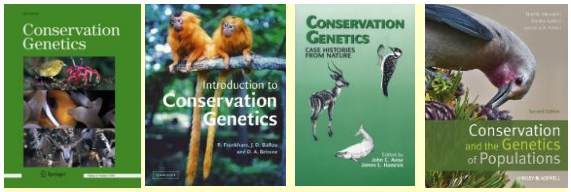
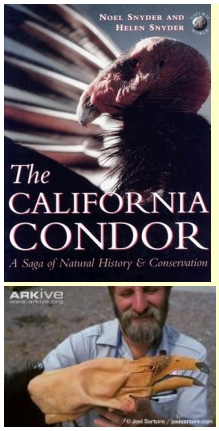


Conservation genetics

A fundamental level of biodiversity

A hypothetical example

- You're the manager of a conservation reserve housing the endangered "spectacled hummus marmoset"
- There are only two or three small populations left, each with < 50 individuals
- What are you concerned about from a genetic standpoint?
- What should you try to do about it?

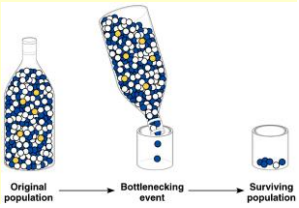


A real example

- 1982: 22 individuals
- 2016: 446 individuals
  - (276 in the wild)
- In 1987 all were in captivity
- Reintroduced in 1992
- Cost $35-40 million over last 20+ yr
- Do you think 22 birds have enough genetic diversity to keep a species going?

Conservation vs. "Normal" Ecology

- Just a reminder that we're focusing on situations of low population abundances (usually) caused by human actions
- Are there examples of low population numbers without humans involved?
  - Bottleneck effect
  - Founder's effect



Low numbers of individuals means…

- **Difficult to maintain genetic diversity**
- Effects of genetic drift become apparent
- A greater chance of inbreeding will occur

Genetics and Demography in Biological Conservation

Russell Lande

Science 1988

Why is low genetic diversity thought to be bad?

- Richard Frankham's (1995) review argued species with low variation would have "reduced ability to cope with environmental change during evolution, and so have shorter evolutionary lifespans." His evidence:
  - Selfing & asexual species are more prone to extinction than are outbreeders
  - Low variation is associated with increased susceptibility to diseases, pests, and parasites in domestic animals & plants, and weeds
  - Loss of variation led to increases in parasite load in fish in the wild
- Your critique of the evidence?

Low numbers of individuals means…

- Difficult to maintain genetic diversity
- **Effects of genetic drift become apparent**
- A greater chance of inbreeding will occur

Genetic drift

- Is…
- Occurs in ALL populations, but effects are most prominent in _____ populations
- A type of 'sampling error' that can lead to ____ of genetic diversity

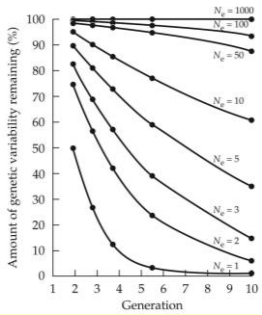


Fig. 11.3

Link

Low numbers of individuals means…

- Difficult to maintain genetic diversity
- Effects of genetic drift become apparent
- **A greater chance of inbreeding will occur**

Inbreeding effects first seen where?

- A few decades ago, inbreeding was ignored as a potential problem in conservation
- Ralls' data changed our views

Katherine Ralls

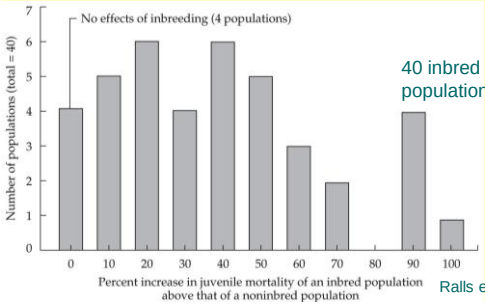
Inbreeding and Juvenile Mortality in Small Populations of Ungulates

Abstract. *Juvenile mortality of inbred young was higher than that of noninbred young in 15 of 16 species of captive ungulates. In 19 of 25 individual females, belonging to ten species, a larger percentage of young died when the female was mated to a related male than when she was mated to an unrelated male.*

Ralls et al. **1979**; *Science*

Inbreeding depression

- Is…
- Alleles in question are usually selected against in large populations, but maintained in low proportions



40 inbred mammal populations

33%

Ralls et al. (1988)

Reducing ID can be difficult. OD also can occur.

- OD is _____
- Primarily occurs because…
- And groups of co-adapted genes can be disrupted

Ibex

Species Survival Plans

- Successful captive breeding of imperiled species in zoos are subject to guidance from the Association of Zoos and Aquariums
- An important type of *ex situ* conservation
- One cautionary note:

Table 1 Meta-analytic effect size estimates of differences in reproductive success between wild-born and captive-born animals in captive environments

	Posterior mode (lnOR) [95% HPD CI]	% odds of captive-born reproductive success	% odds of wild-born reproductive success	N
Overall model*	−0.54 [−1.01, −0.10]	−42.3%	+74.2%	115
Overall model + phylogeny	−0.65 [−1.45, 0.04]	−47.7%	+91.3%	115
Captive environment				
Aquaculture*	−1.45 [−2.46, −0.56]	−76.7%	+328.7%	23
Conservation	−0.38 [−1.06, 0.30]	−31.8%	+46.6%	51
Research	−0.34 [−1.08, 0.35]	−29.0%	+40.8%	40
Other	1.84 [−0.98, 4.49]	+527.6%	−84.1%	1
Trait type				
Fertility and hatchability	−0.38 [−0.94, 0.15]	−31.5%	+45.9%	30
Reproductive yield	−0.52 [−1.06, 0.05]	−40.6%	+68.4%	28
Offspring quality*	−1.22 [−2.01, −0.46]	−70.5%	+238.8%	8
Offspring survival*	−1.26 [−1.85, −0.65]	−71.5%	+250.9%	33
Reproductive phenology	−0.04 [−0.69, 0.57]	−3.5%	+3.6%	16

Posterior mode gives the meta-analytic log odds ratio (lnOR) estimate from the MCMCglmm models with lower and upper 95% higher posterior density credible intervals given. Estimates with the 95% HPD CI excluding zero are marked with *. Percentage odds refers to the % increase (+) or decrease (−) in the odds of reproductive success of captive-born or wild-born animals, relative to the other group

Farquharson et al. (2018) *Nature Communications*

So, should we care?

- Maintaining genetic diversity is important, but it's often more complicated than simply ensuring inbreeding does not occur
  - Remember, natural selection often _____ genetic variation present by selecting for best adaptations (e.g., directional and stabilizing selection)
- Nevertheless, resource managers must act to protect species, especially if the species is listed as Threatened or Endangered
- What can managers do to ensure genetic diversity is maintained even when they do <u>not</u> have the resources to conduct genetic testing?

Effective population size

- (Genetically) effective population size, $\mathbf{N_e}$, equals the …
- Richard Frankham's review of several studies found N_e to be __% of N, or the typical census size

Minimum viable population size

- So, from a genetic diversity perspective, what is the minimum number of breeding individuals needed to maintain genetic diversity for some time in the future?
- MVP estimates the population size that should be sufficient for some time interval, often set at 100 years

Rules of thumb for population sizes to maintain genetic diversity (1)

- 50/500 rule (Franklin 1980)
  - 50 individuals (N_e) to offset inbreeding depression
  - 500 individuals (N_e) to offset genetic drift
- How is loss of genetic diversity offset?
  - _____ in these different sized populations adds new genetic diversity to offset <u>drift</u>
- Where did the estimates of _____ rates come from?
  - Lab populations of *Drosophila melanogaster*; variation in numbers of abdominal bristles
- Where did the 50 come from?

Rules of thumb for population sizes to maintain genetic diversity (2)

- 500/5000 rule (Lande 1995)
- Why the increases?
  - Offsets are usually deleterious (90%), while only 10% are 'quasi-neutral' and provide potentially useful genetic variation
- Theory vs. data…

Traill et al. (2010)'s suggestions

- Most population estimates based on the best science and those for the long-term are around 5,000 individuals
- If we go lower than this (i.e., 50/500), we're probably only ensuring a 100-yr window of safety against extinction
- Scientists are not policy makers, rather they provide scientifically-defensible options with explicit assumptions that can be examined by all stakeholders
  - Analogous to climate scientists providing predictions of future conditions given various assumptions
- Policy-makers can then decide whether or how much to act based on science, economics, politics, etc.

A dose of reality

- Genetic diversity of small populations can be important, but…
  - It typically takes several generations of reduced numbers before inbreeding depression really takes effect
  - Natural processes can offset loss of genetic diversity (although it takes many generations)
  - Heterozygosity by itself is not as important as being adapted to your environment
  - It's irrelevant if your entire habitat is lost
- Genetic diversity must be combined with demographics and habitat considerations to safely conserve a species

Lande (1988)

One more dose of reality

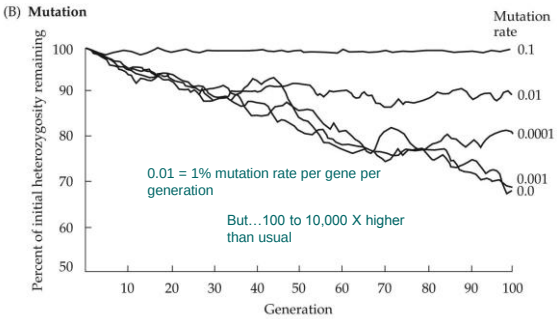
- How do you reconcile the problem of little genetic diversity when species persist…
  - For 10,000 years, cheetahs have had 90-99% less variation than other cats (O'Brien et al. 1983)
  - Endangered Iberian lynx have had extremely low genetic variability for 50,000 years based on genetic data of old remains (Rodriguez et al. 2011)
  - The 200,000 northern elephant seals alive today descended from about 20 following over-hunting in the mid-1800s
  - Mauritius kestrel; 4 individuals in 1974; today > 800

Current Biology
Report
2016

Genomic Flatlining in the Endangered Island Fox

Jacqueline A. Robinson,[1] Diego Ortega-Del Vecchyo,[2] Zhenxin Fan,[3] Bernard Y. Kim,[1] Bridgett M. vonHoldt,[4] Clare D. Marsden,[1] Kirk E. Lohmueller,[1,2,5,6] and Robert K. Wayne[1,6,*]

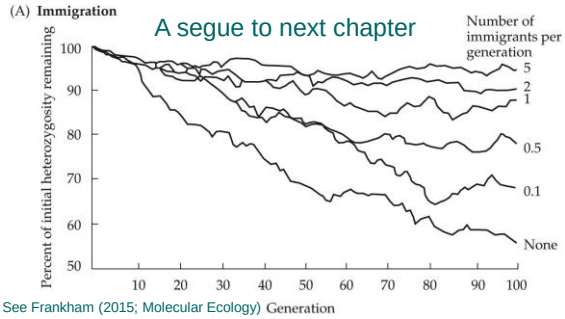
Offsetting loss of genetic diversity (1)



Offsetting loss of genetic diversity (2)

"Genetic rescue"

A segue to next chapter



See Frankham (2015; Molecular Ecology)