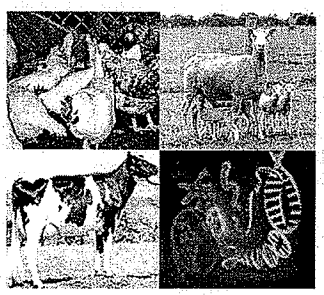
Genetics of small populations



Karen Marshall

UNE

IAEA, Korea, April, 2006

Issues relevant to small populations

Loss of genetic diversity

Characterizing population size (previous session)

Inbreeding (previous session)

Drift

Population fragmentation

Breeding strategies for conservation

Loss of genetic diversity

Less genetic diversity → less ability to evolve in response to environmental change

Threats include:

- Extinction of populations or species
- Inbreeding resulting in less heterozygosity
- Loss of alleles due to sampling
- Selection leading to allele fixation

(Frankham, 2002)

The main reason for loss of genetic diversity is restricted effective population size (Ne) over a number of generations

Small populations

Creation of genetic diversity

Genetic variation can be created by

- New mutations
- New epistatic gene combinations

Small populations

Small populations

Small population size lead to inbreeding and drift

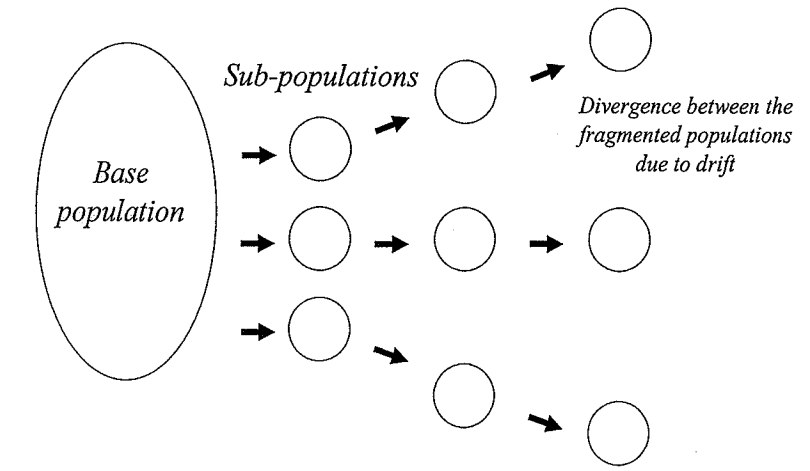
Inbreeding results from the joining of gametes with alleles that are IBD & leads to:

- Genetic similarity within small populations

Drift results from random sampling of gametes & leads to:

- Random change in allele frequencies
- Genetic divergence *between* fragmented populations

Population fragmentation



Drift at a single locus level

At the single locus level, genetic divergence (drift) is the variance in allele frequency between sub-populations

For example p=q=0.5, $Ne_{(sub\text{-}pop)}$=10

Generation	0	t = 1	t = 10	t = 100	t = infinity
$V_{q\ Between}$	0	0.0125 (pq/2Ne)	0.10	0.2485	0.25 (pq*)
$V_{q\ Within}$	0.25 (pq*)	0.2375	0.15	0.0015	0
$V_{q\ Total}$	0.25	0.25	0.25	0.25	0.25

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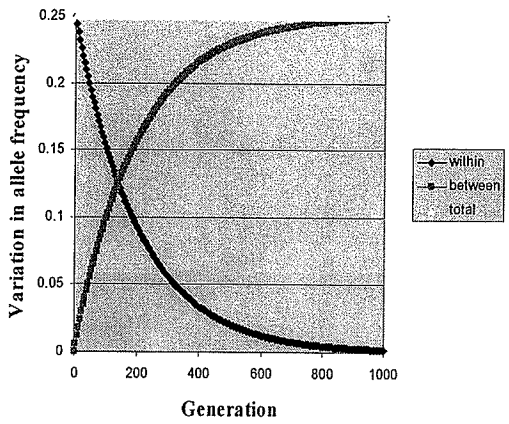
Change in allele frequency due to drift

For example, p=q=0.5, Ne(sub-pop)=100



Small populations

Drift increases trait variation across lines

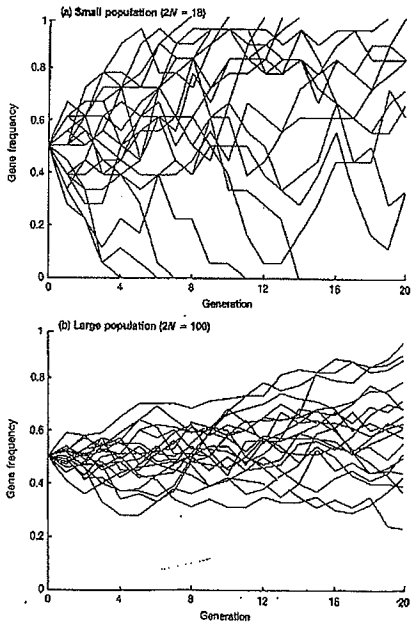
In previous graph, total variation in allele frequency remained stable

However, each sub-population is moving towards fixation (i.e. aa or AA, not aA), which results in an increase in trait variance

At the continuous trait level, genetic divergence (drift) is the variance between the trait means of the different sub-populations

- this can be predicted for traits of neutral fitness

Small populations



Bristle number for sub-populations of fruit fry.

Effect of population size (N) on the divergence and the rate of fixation of populations

http://www.wooster.edu/biology/mloveless/Drift.html

Small populations

Effects of drift and F following population fragmentation

Sub-populations will become divergent due to drift.

- increased genetic variance between the sub-populations

Within a sub-population individuals will become more alike due to inbreeding.

- reduced genetic variance within the sub-populations

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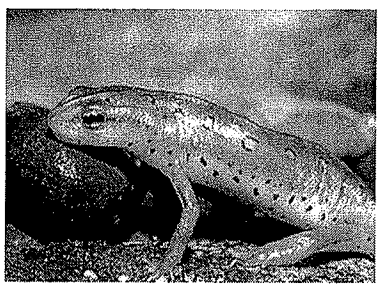
Problem

The 'lesser spotted blue newt' habitat the marshy environment of the Forgotten Flatlands.



The flatlands were drained, resulting in fragmentation into 6 small sub-populations.

Given that migration is not possible, what are the likely outcomes ?

Small populations

Answer: fate of the newts

Sub-populations become distinctive from each other: some are more blue, some have more spots

Variance within a sub-population is lower than in the original population: newts within a location look similar

Whilst total variation is now greater than before, F within each sub-population is increasing. This may lead to extinction of a sub-population, and possibly a net reduction in variance.

Maintaining genetic variation within populations

Attention to merit

- Merit may be adaptability, disease resistance, fecundity
- Can select parents of the next generation to result in a change in merit (directional selection) or not

Attention to Ne / diversity

- Both F and drift are effected by Ne
- Equalising the contribution of each family to the next generation increases Ne
- Can apply concept of optimal contribution theory
- Migration is also important

Balancing genetic merit & diversity

Select few individuals as parents of the next generation:

- Strong directional selection (high genetic gain) *but*
- Low Ne → high inbreeding and drift

Select many individuals as parents of the next generation:

- Weak directional selection (low genetic gain) *but*
- High Ne → low inbreeding and drift

Small populations

Maintaining genetic variation over populations

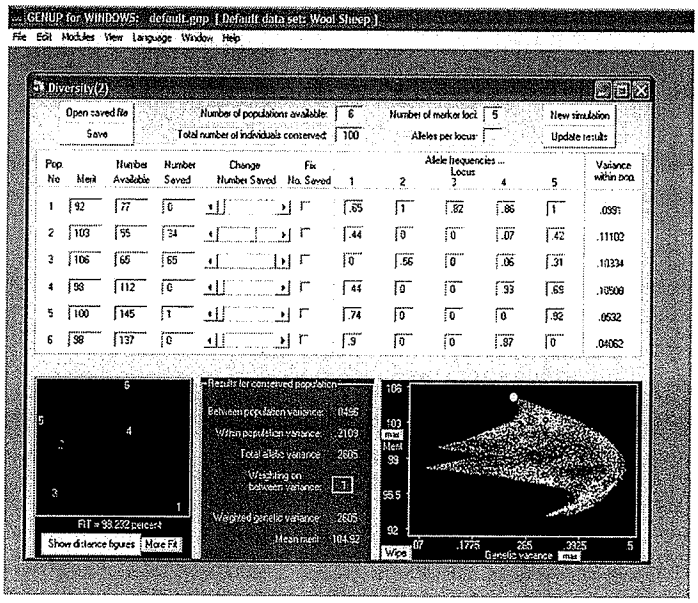
Need to determine both which sub-populations to select, and which individuals within these sub-populations

In some cases crossing between sub-populations may be advantageous

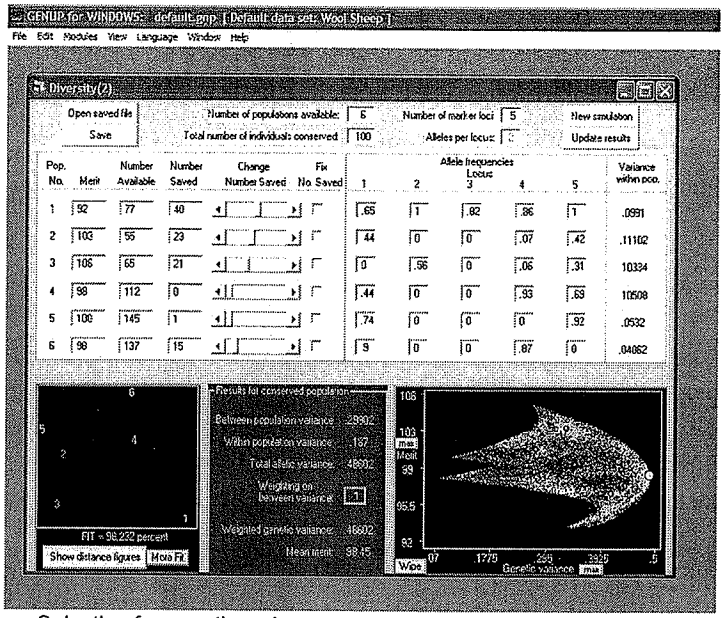
- e.g. when one population has few animals of one sex
- to re-create genetic variance

But it can also be detrimental (loss of adaptive alleles - 'outbreeding depression')

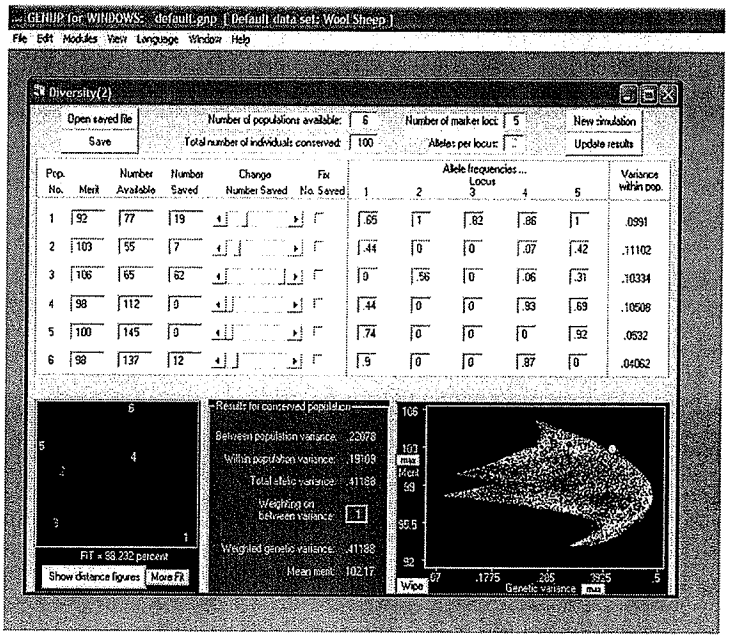
Small populations



Selection for merit



Selection for genetic variance



Selection for a compromise

A simulated example

- 12 breeds with 1000 animals available in each
- Resources to conserve 120 animals only
- Genetic variation both within and between breed was determined by molecular markers (5 microsatellite loci with a maximum of 5 alleles each)
- Diversity is taken as: $V_{\text{within-breed}} + 5 \times V_{\text{between-breeds}}$
- Merit of each breed has been quantified
- Need to determine which breed to select and which animals within the breed: maximise merit + λ diversity

Chaiwong and Kinghorn, AAABG 13: 365

Results – # of individuals selected from each population

weight on diversity (λ)	Population number											
	1	2	3	4	5	6	7	8	9	10	11	12
Merit	*108*	*99*	*101*	*107*	*109*	*114*	*111*	*104*	*112*	*95*	*102*	*104*
0	-	-	-	-	-	120	-	-	-	-	-	-
15	-	-	-	4	14	63	2	-	37	-	-	-
23	-	-	-	18	15	45	28	-	14	-	-	-
34	1	-	-	25	15	39	30	-	8	-	2	-
48	6	-	-	31	8	31	-	-	-	-	11	-
69	6	2	-	32	4	26	-	-	-	-	18	-
110	12	10	-	33	-	22	-	-	-	-	22	-
225	11	16	-	33	-	21	-	-	-	-	24	-

λ is Weight on diversity

Small populations

Summary

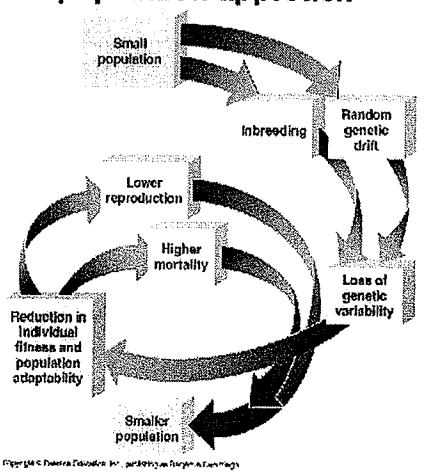
Breeding strategies for conservation aim to balance genetic merit and diversity but should also accommodate other constrains e.g. cost of transportation

Within a sub-population this can be managed by the application of optimal contribution theory

Over populations you need to consider which sub-population and which animals within a sub-population

Small populations

The extinction vortex of the small-population approach



http://io.uwinnipeg.ca/~simmons/CHAP5598/sld039.htm

Small populations