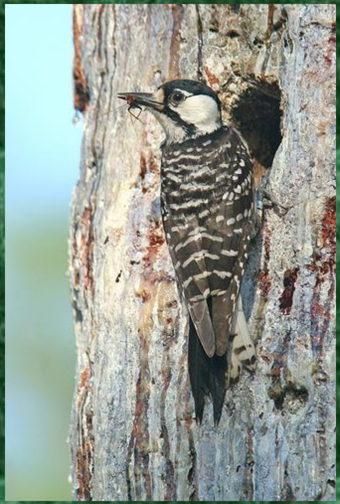
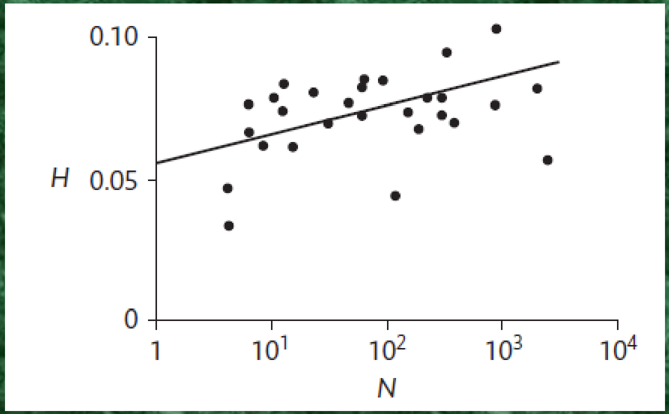
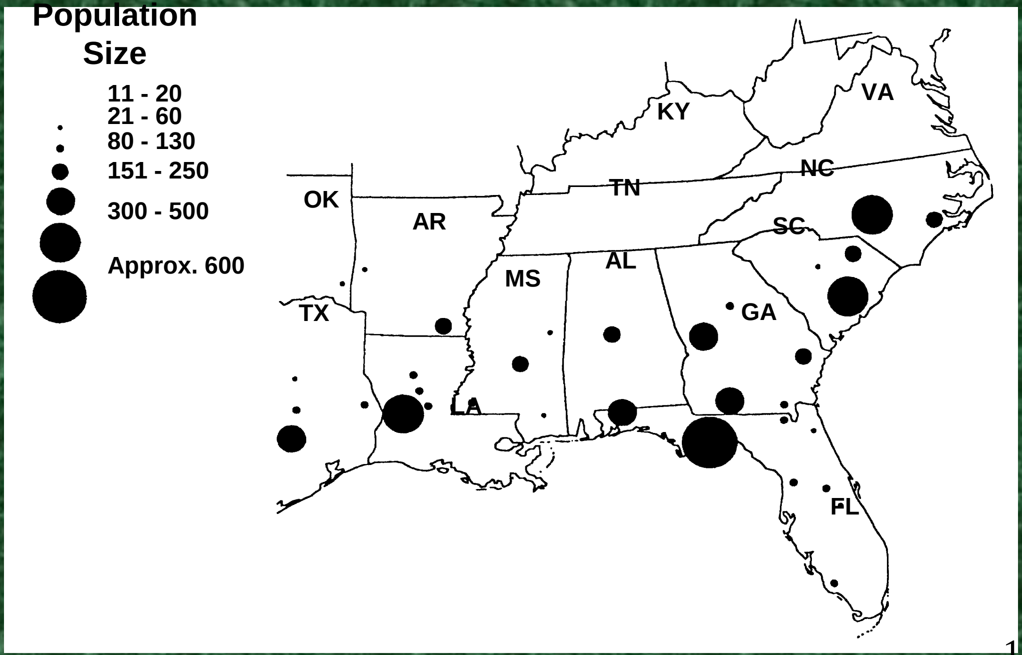
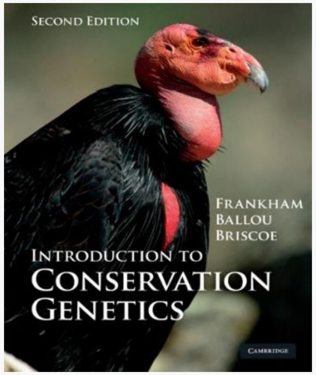
BIOL3110

Genetic management of wild populations



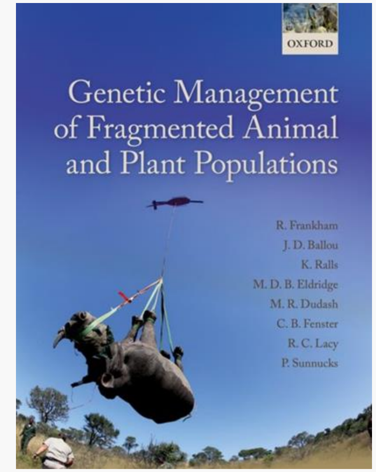




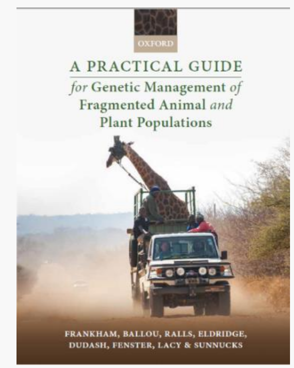


Genetic management of wild populations

Outline



- What genetic issues are faced by wild pops?
- How should we manage fragmented pops?
- How can we manage sp with 1 population?
- What management is required under global climate change?
- How does genetic management differ for species with diverse breeding systems & modes of inheritance?



References:

ICG2 Ch17

Frankham et al. 2017 Genetic management of fragmented animal and plant populations

What genetic problems are faced by wild populations?

- Taxonomic uncertainties & OD
- Inbreeding & reduced fitness
- Loss of genetic diversity & reduced ability to evolve
- Fragmentation & inadequate gene flow
- Consequences of global climate change
- Consequences of different mating systems & inheritance modes
- Genetic management of translocations
- Genetic effects of selective harvesting
- Genetic swamping from related species

What are the genetic goals of wild management?

- Minimise extinction risk
  - Maintain reproductive fitness
  - Conserve genetic diversity and the ability to evolve
- Maintain self-sustaining species

What genetic management can be applied to species with multiple population fragments?



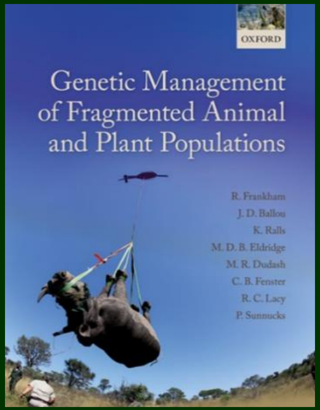




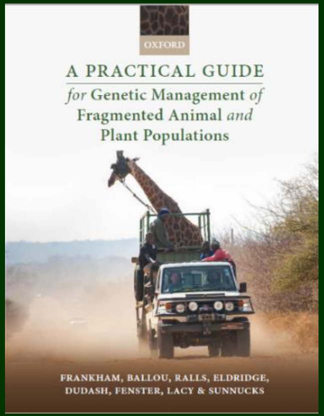


Why is fragmentation a problem?

- Inadequate gene flow
- No gene flow
  - Relevant N_e is that of the fragment, not species
  - Inbreeding, loss GD, reduced fitness & Ev potential worse than for single popn of same total size



- One of the major, largely unaddressed issue in conservation biology (our books)



Vast magnitude of the fragmentation problem

~ 1.4m pop fragments of thr species with genetic problems

~ 150m total pop fragments with G problems

~ 34 cases of conservation management to reverse the fragmentation problems

How should we genetically manage fragmented populations?

Genetic management

- Increase *N* to slow rate of deterioration
  - increase habitat size or quality
  - re-establish extinct populations
- Genetic rescue - re-establishing gene flow into inbred pops –
  - outcrossing
  - corridors
  - Rarely being done due largely to fears of OD
  - Outcrossing can be beneficial or harmful

What is outbreeding depression?

- Harmful effects on fitness that are sometimes found upon crossing of populations within or across species (≡ reproductive isolations)
  - Observed in F_1 or later generations
  - Occurrence predictable

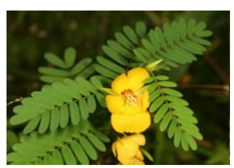
The causes of outbreeding depression are known

Different species     

Fixed chromosomal differences

Adapted to different environments

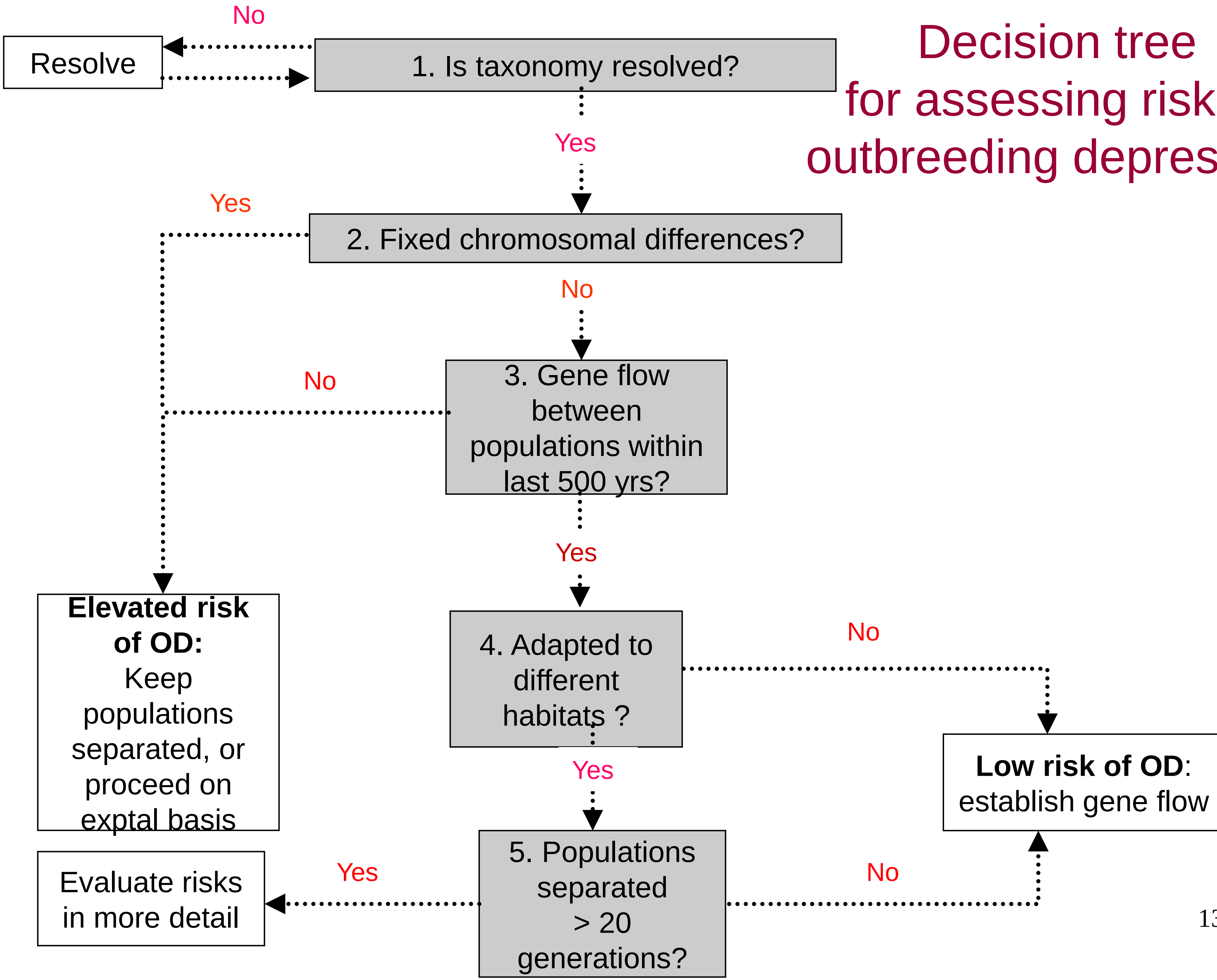
Long isolation

(Frankham et al. 2011 Cons Biol)

We used this information to predict the risk of outbreeding depression

(Frankham et al. 2011 CB)

Decision tree for assessing risk of outbreeding depression



The decision tree works

- Preliminary evaluation: identified high risk cases
- Meta-analysis: screened for low risk: 156 cases, 145 +: 2 =: 9 –
  - OD modest at worst (≤ 14%)
  - (1 true OD)

- Highly effective

Genetic rescue of inbred pops by outcrossing

SPECIES SPOTLIGHT...

Large and consistent benefits of outcrossing on fitnes

(Frankham 2015 ME)

- Inbred & screened to have low risk of OD
  - 92.9% beneficial
  - 148% increase in fitness in wild, 45% in captivity
- Benefits persist over gens in outbreeding species
  - F_1 (91%), F_2 (100%) & F_3 (94%)
- Recommend outcrossing of inbred population, provided risk of OD is low

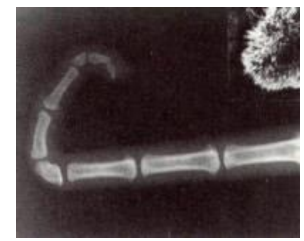
Recovery from inbreeding & restoration of genetic diversity following crossing of inbred populations

Population	Genotype	*F*	Heterozygosity
Inbred a	A_1A_1	1	0
Inbred b	A_2A_2	1	0
F_1 (a x b)	A_1A_2	0	1
F_2 (F_1 x F_1)	¼ A_1A_1: ½ A_1A_2: ¼ A_2A_2	½	½

Case study:
Florida panther

Taxonomy
Population bottleneck (min $N = 6$)
Low genetic diversity & ID – undescended testis, sperm, disease & kinked tails

Sub-species	Allozymes H	DNA fingerprint H
Florida (authentic)	1.8	10.4
Western US	4.3	46.9
Other felids	3-8	45.9



Action: Outcrossed to Texas indiv - recovery
F1 benefits: survival: adults +26%, pups +99%
litter size +6.8%
Overall F_1 fitness benefit 168%

1/2

Unrelated individuals used for genetic rescue can be:

1. Outbred from within same species
2. Inbred, but genetically distinct

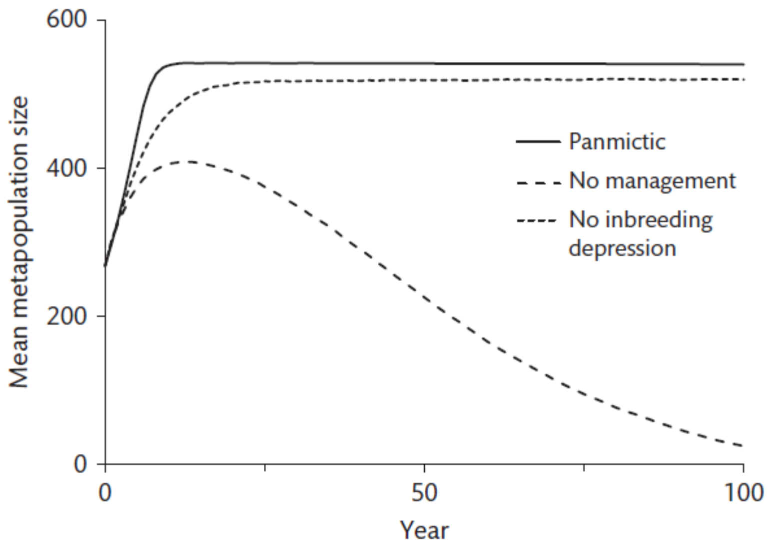
Choosing donor popn for crossing

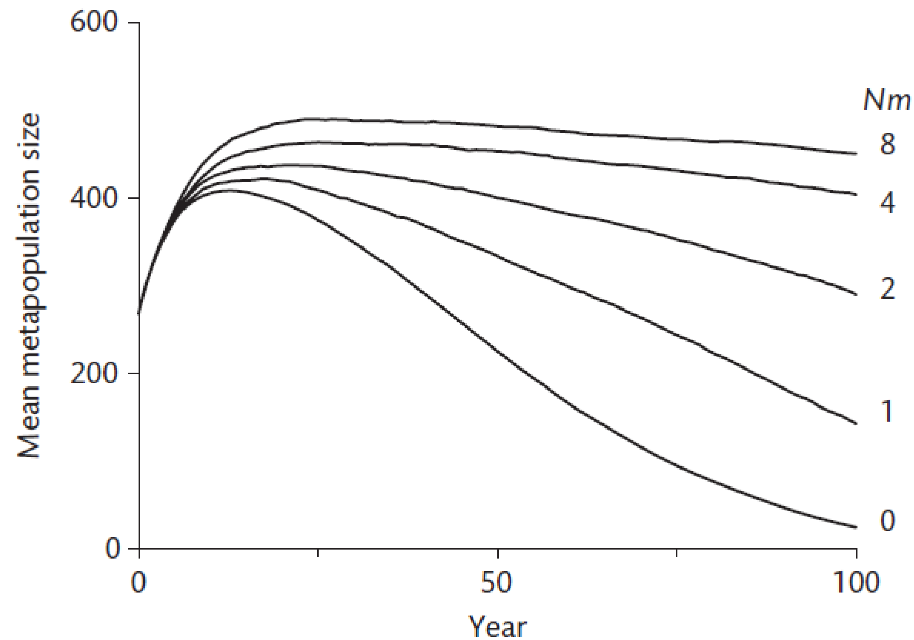
- No genetic data
  - Any is better than none
  - Large *N* better than small
  - Longer isolation better than shorter
  - Several pops better than one
- Extensive genetic data
  - Lowest mean kinship with recipient

How much gene flow is desirable?

- Any better than none
  - 1 contributing migrant/gen – too few
  - ~ 5/gen needed
- Computer modelling
- Minimizing mean kinship

Computer simulation: Allegheny woodrat





(Frankham et al. 2017)

Managed translocations	Mean probability of sub-population extinction	Final metapopulation N	Mean inbreeding (F)
$Nm = 0$	0.81	26	0.37
$Nm = 1$	0.18	144	0.24
$Nm = 2$	0.02	288	0.18
$Nm = 4$	0.00	404	0.14
$Nm = 8$	0.00	450	0.11
Panmixia	0.00	540	0.09

Kinship

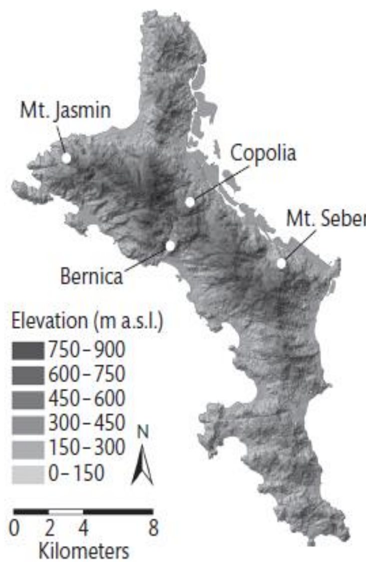
Kinship for 2 individuals is the *F* of offspring (if they had them)

Kinships in wild pops without pedigrees can be estimated using (many) genetic markers

Managing by minimizing mean kinship

- Favours populations (and indivs) with lowest kinship to all others
- retains maximal genetic diversity
- effective in minimizing inbreeding

Managing by mean kinship:
CR jellyfish tree (Seychelles)



	Mt Jasmin	**Copolia**	**Mt Sebert**	**Bernica**
Mt Jasmin (2)	0.57	0.07	0.02	-0.02
Copolia (3)		0.17	0.09	-0.02
Mt Sebert (7)			0.41	**-0.04**
Bernica (78)				0.004

Cross of Bernica x Mt Sebert resulted in 151% improvement in fitnes

What management can be applied to species with single population & low GD?

Few genetic remedies to reverse

Reverse cause of decline & increase *N*

- Ban hunting
  - Indian rhino
  - N elephant seal
- National Park & cattle removed
  - N hairy-nosed wombat
- Predator proof fence
  - Bilby & N hairy-nosed wombat
- Ban DDT
  - Mauritius kestrel
  - Bald eagle
  - Peregrine falcon
- Exterminate introduced predators
  - Lord Howe Island woodhen
- Improve habitat
  - Red-cockaded woodpecker
- Translocations to establish new pops, or re-establish extinct ones

Case study
Wollemi pine

- < 100 adults in 3 pops in Wollemi National Park, NSW
- all individuals genetically identical for nuc (1 genetic pop)
- likely to be ‘fragile’
  - Susceptible to fungal disease

- Management:
  - Location secret
  - Restricted access & site hygiene
  - Fire management
  - Cuttings from all adults
  - *Ex situ* conservation & sale
  - Research (genetics & fungi)

Case study
Black-footed ferrets

- Extinct in wild (eliminating prey + disease)
- Captive populations (18 founders)
- Low genetic diversity
- likely to be ‘fragile’

- Risk management:
  - 10 reintroduced pops (N = 1500)
    - Actually reintroduced into 24 locations
      - Only 4 self sustaining
  - avoid catastrophes

Future genetic improvement

- Use gene editing to selectively “cure” major ID defects or add useful genetic variants
- Gene editing has already been used experimentally to cure several genetic diseases (e.g. DuMD dogs, mice & human cells, + others)
- Gene transfer to confer disease R in Am Chestnut

Managing under global climate change

Options:

- Adapt *in situ*
    - Improve ability to adapt
        - Adding genetic diversity by outcrossing
- Move

Need for gene flow even more pressing

How is genetic management altered with diverse mating systems or modes of inheritance?

Frequencies of diverse mating systems & modes of inheritance

- Asexual/clonal (obligate rare, partial common)
- Selfing (10-15% plants habitual & 40% mixed)
- Self-incompatible (~ ½ Angiosperms)
- Haplo-diploids (Hymenoptera ~ 15% animals)
- Polyploids (most plants & some animals)

Genetic management of asexual species

- No inbreeding depression or OD
- Accumulation of harmful mutations is a threat
- Many individuals may have identical genotypes
- Genetic diversity among clones

- Examples: some lizards, fish & plants
  - *Haloragodendron lucasii* (N. Sydney)
  - 53 plants = 7 clones

- Management:
  - Identify clones
  - Conserve clones
  - If 1 clones, often ‘fragile’

Genetic management of selfing species

- Less heterozygosity within pops
- Greater differentiation among pops
- Less inbreeding depression
- Possibly more OD
- Lesser genetic rescue

- G Management:
  - Conserve distinct populations

Self-incompatible species

- SI alleles are lost in small populations
- Loss of SI alleles decreases proportion of ovules fertilised
- Loss of SI alleles decreases fitness
- Also suffer ID, more susceptible to low *N*
- Re-establish gene flow & augment GD
- Increase *N*

Haplo-diploids (♂ n / ♀ 2n)

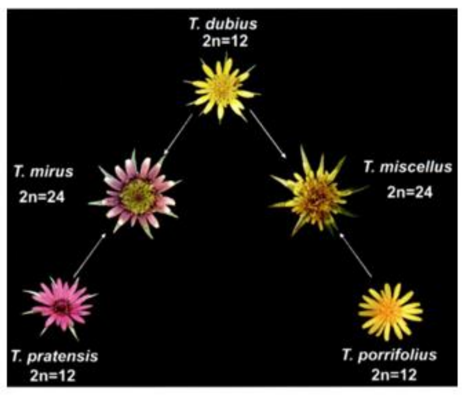
- Highly susceptible to loss of CSD alleles
- N_e = ¾ diploid
  - Eusocial sp have sterile workers, N_e ~ 2-4 # colonies
- Low susceptibility to ID
- OD more likely

- G Management
  - retain & augment genetic diversity (outcross)
  - Increase N

Genetic management of autopolyploids

- Less affected by small *N*
  - Slower loss of genetic diversity than diploids
  - Slower incr in inbreeding (homozygosity) and less inbreeding depression

- G management
  - As for diploids, but less concern about *N*
  - Avoid crossing diff ploidies e.g. 4n x 2n



Genetic management of allopolyploids

- Often behave as diploids (amphidiploids)
  - Most loci duplicated
  - Likely less susceptible to ID than diploids
  - May have better ability to evolve
- G management
  - Similar to diploids
  - Avoid crossing diff ploidies e.g. 4n x 2n

Very little practical genetic management is being done in wild pops

1. Taxonomic uncertainties & ESU – lots
2. Inbreeding & loss of genetic diversity –
   very little except diagnosis
3. Fragmented populations & G rescue – very little
   - corridors or outcrossing
4. Diverse breeding systems & inheritance modes– very little

Field is in its infancy

Messages

- Genetic management of wild populations involves
  - resolving any taxonomic uncertainties
  - increasing *N*
  - genetically rescuing small inbred population fragments suffering ID & low genetic diversity
  - modifying genetic management regimes for species that are not outbreeding diploids

Questions?

How should we manage genetically to cope with global climate change?

Selective harvest

What are the genetic consequences of selective harvest?

- Evolutionary change (& possibly reduced fitness)
- Reduce N_e
  - Distorted sex-ratios
  - Change in breeding system (higher selfing)

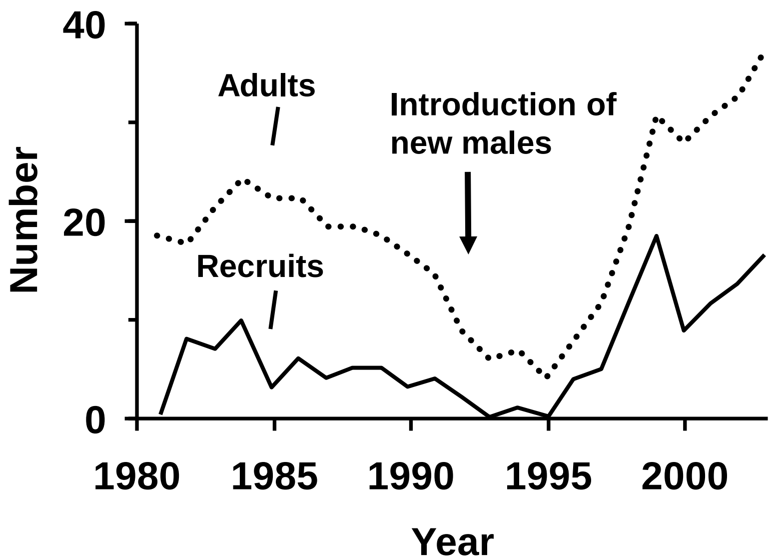
Distortion of sex-ratio by poaching in Asian elephants

- Ivory poaching
- Periyar Reserve, India
  - 6 males : 605 females
  - $N_e = 24$
  - Females that do not breed early, remain barren

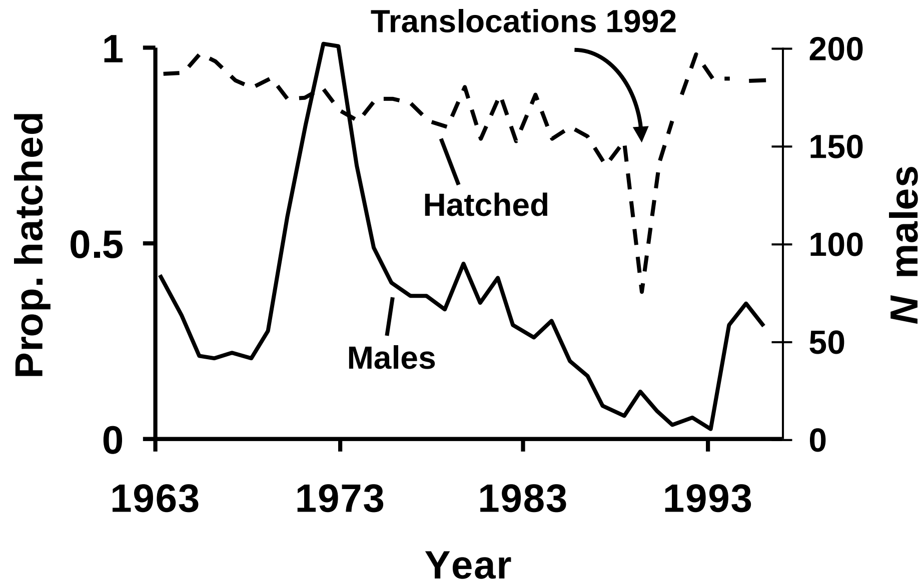
What can be done to avoid the adverse effect of selective harvest?

- Alter harvest regime
- Keep some pops without harvest (e.g. marine protected areas)
- Problem: often illegal & difficult to police

(a) Swedish adders



(b) Greater prairie chickens



Decision tree for assessing risk of outbreeding depression