

Presence of a cryptic hybrid zone explains spatial variability in population genetic structuring of a colonial nesting seabird

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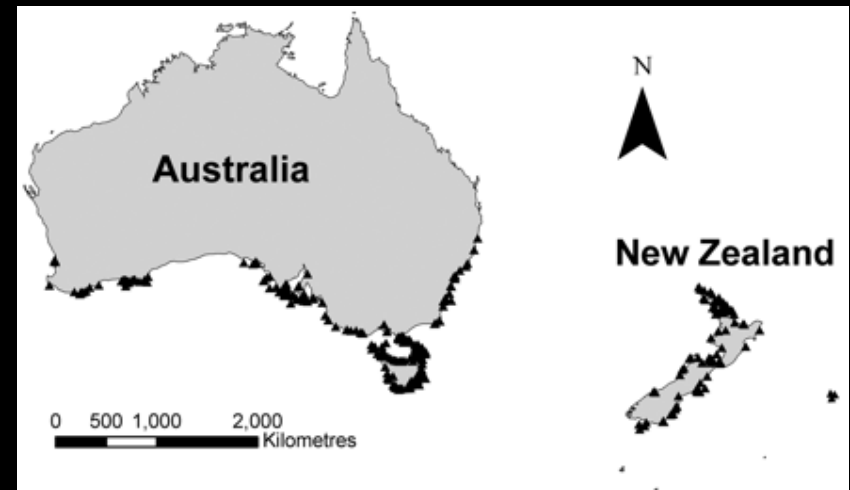




Eudyptula minor



- Little penguin (Korora)
- World's smallest penguin (~1 kg, 300 mm tall)
- Breeding colonies around New Zealand and Southern Australia
- First breeding at 2-3 yr
- Clutch: 2 eggs
- Longevity ~7 yr



Gene flow – Phillip Island

- Intensively studied for >40 years
- No fewer than 62,000 individuals banded
 - 23,686 fledglings



Sidhu et al. (2007). Mark-recapture-recovery modeling and age-related survival in Little Penguins (*Eudyptula minor*). *Auk* 124: 815-827

Where do banded birds go?

- 23,686 fledglings banded
 - 2979 subsequently observed (12.5%)
 - 1347 dead (45% of observations)
 - ~1600 returned alive to Phillip Island
- Observed adult philopatry also not particularly high (<50%)
- Occasional observations at non-natal colonies, but breeding rarely confirmed
 - But, low search effort at other colonies

Movements by living individuals

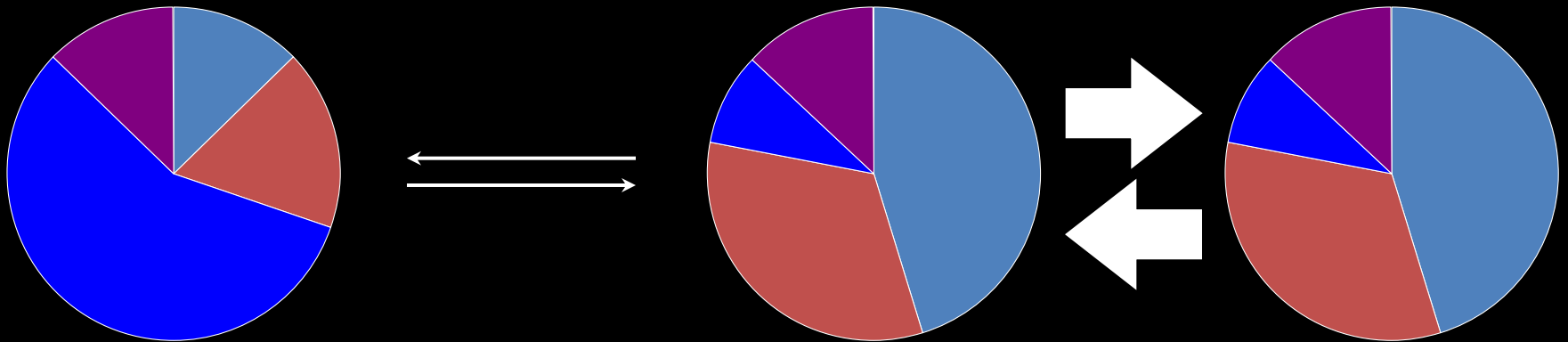


Question

What are the rates of movement between colonies?

Employ genetic methods to quantify recruitment dynamics

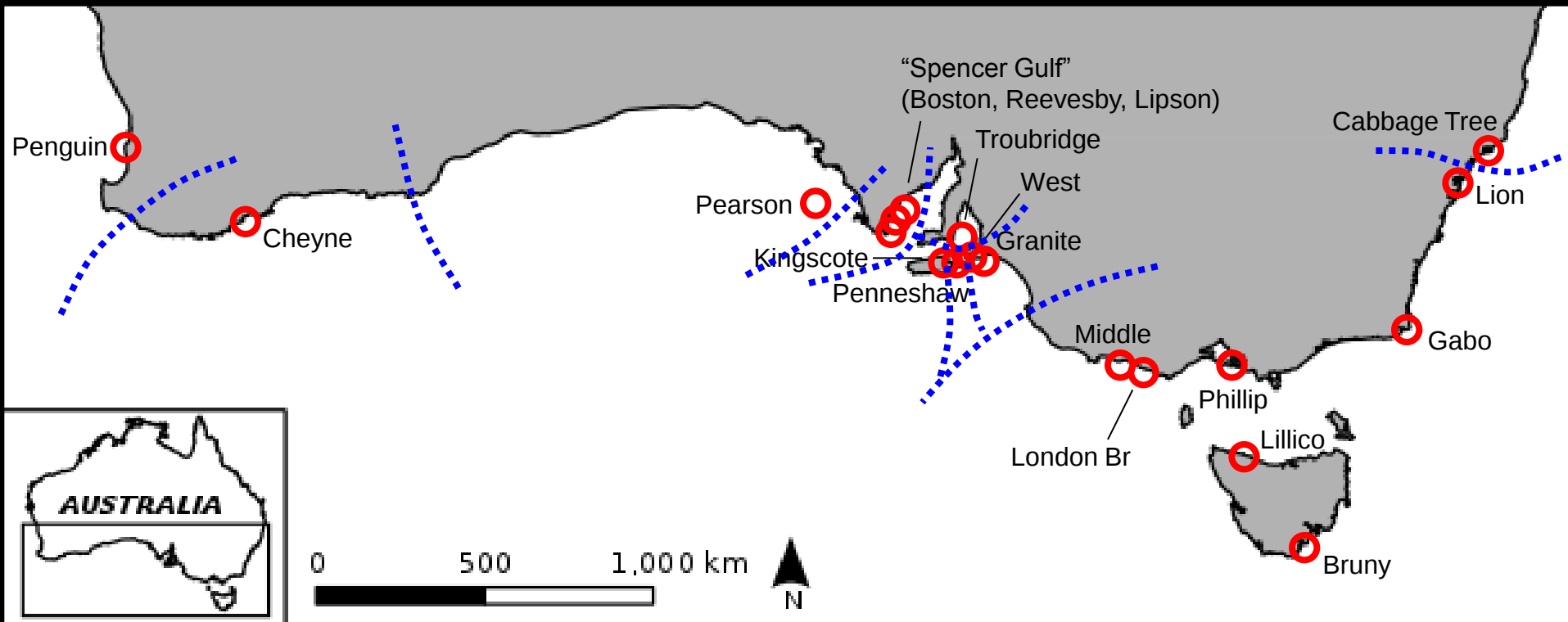
- Compare allele frequencies at putatively neutral markers among colonies
 - Dispersal (gene flow) will homogenise allele frequencies among colonies



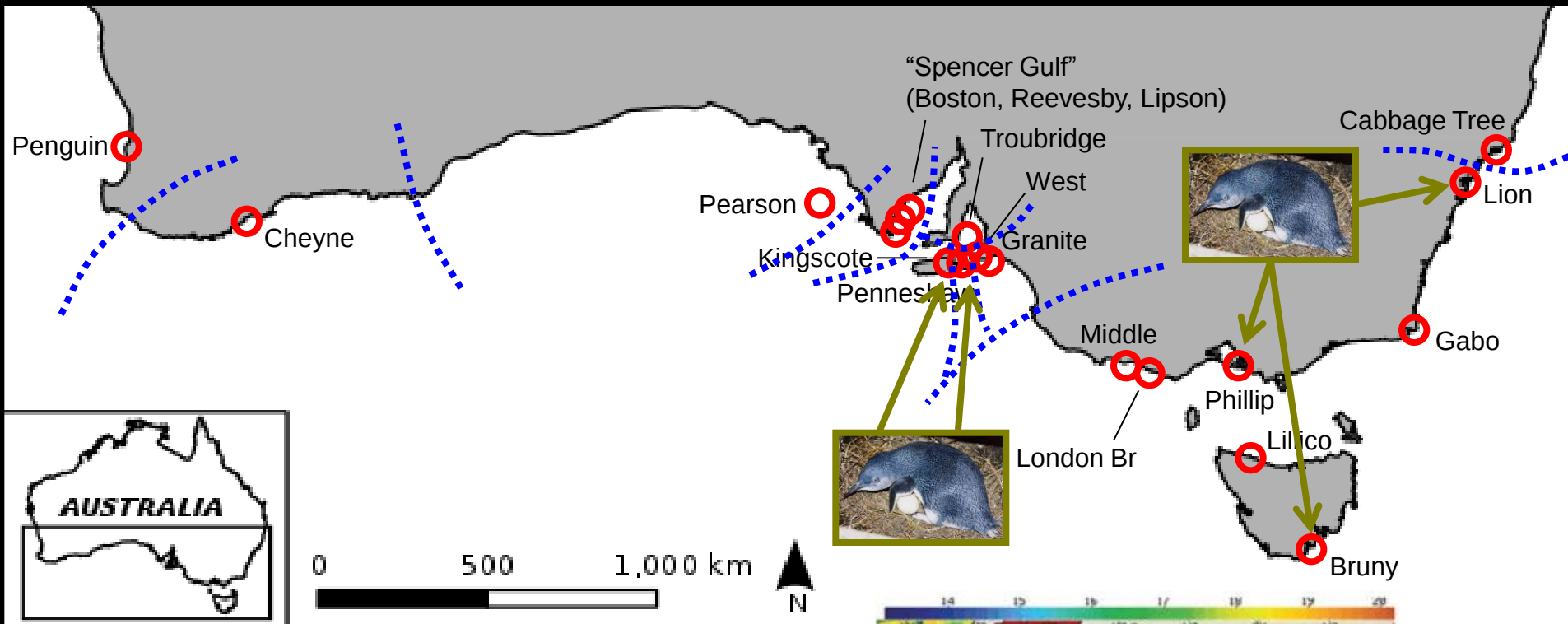
Methods

- 17 colonies of up to 50 individuals each
 - some pooling of colonies... “Spencer Gulf”
- 12 microsatellite loci, mitochondrial DNA
- Data analysis
 - Exact tests of allele frequency homogeneity
 - Isolation-by-distance (Mantel) test
 - Non-spatial Bayesian clustering

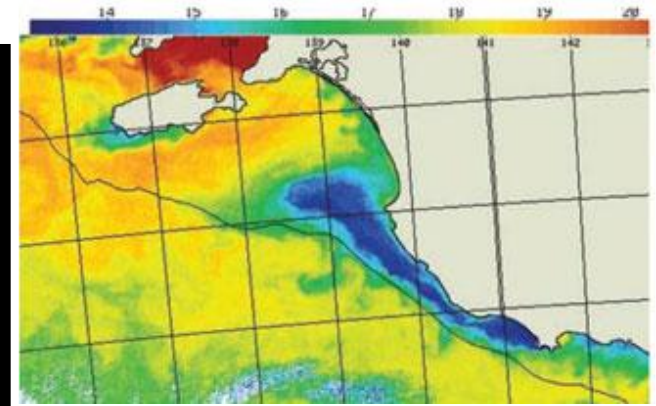
Allele frequency heterogeneity



Possible explanations

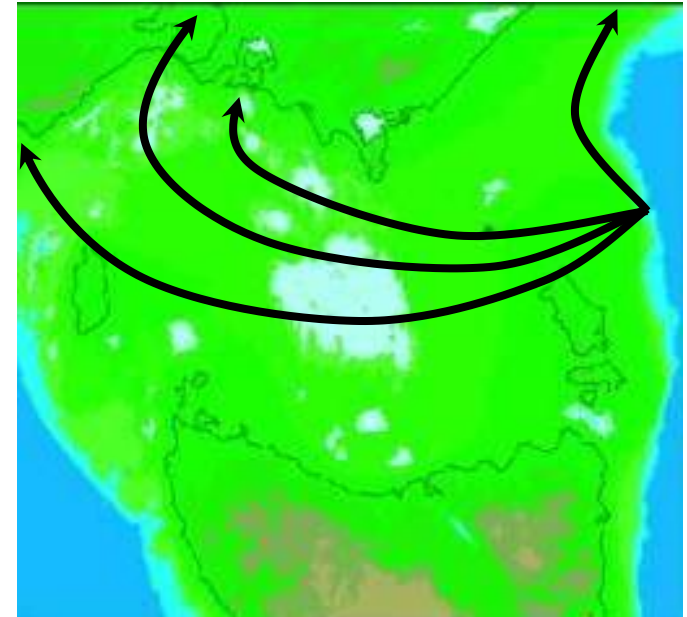
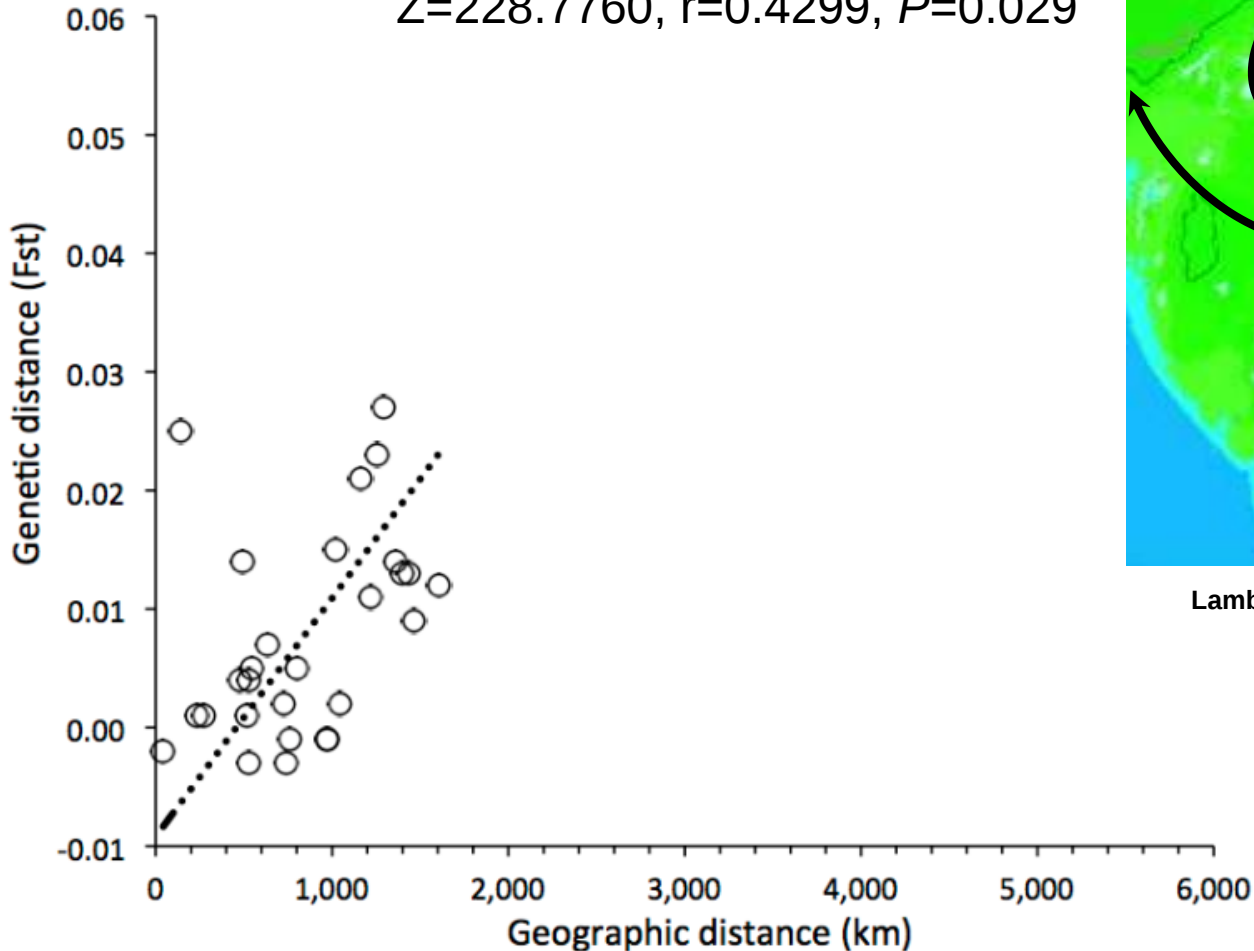


- Breeding phenology (✕)
- Oceanographic features (✕)



Mantel tests

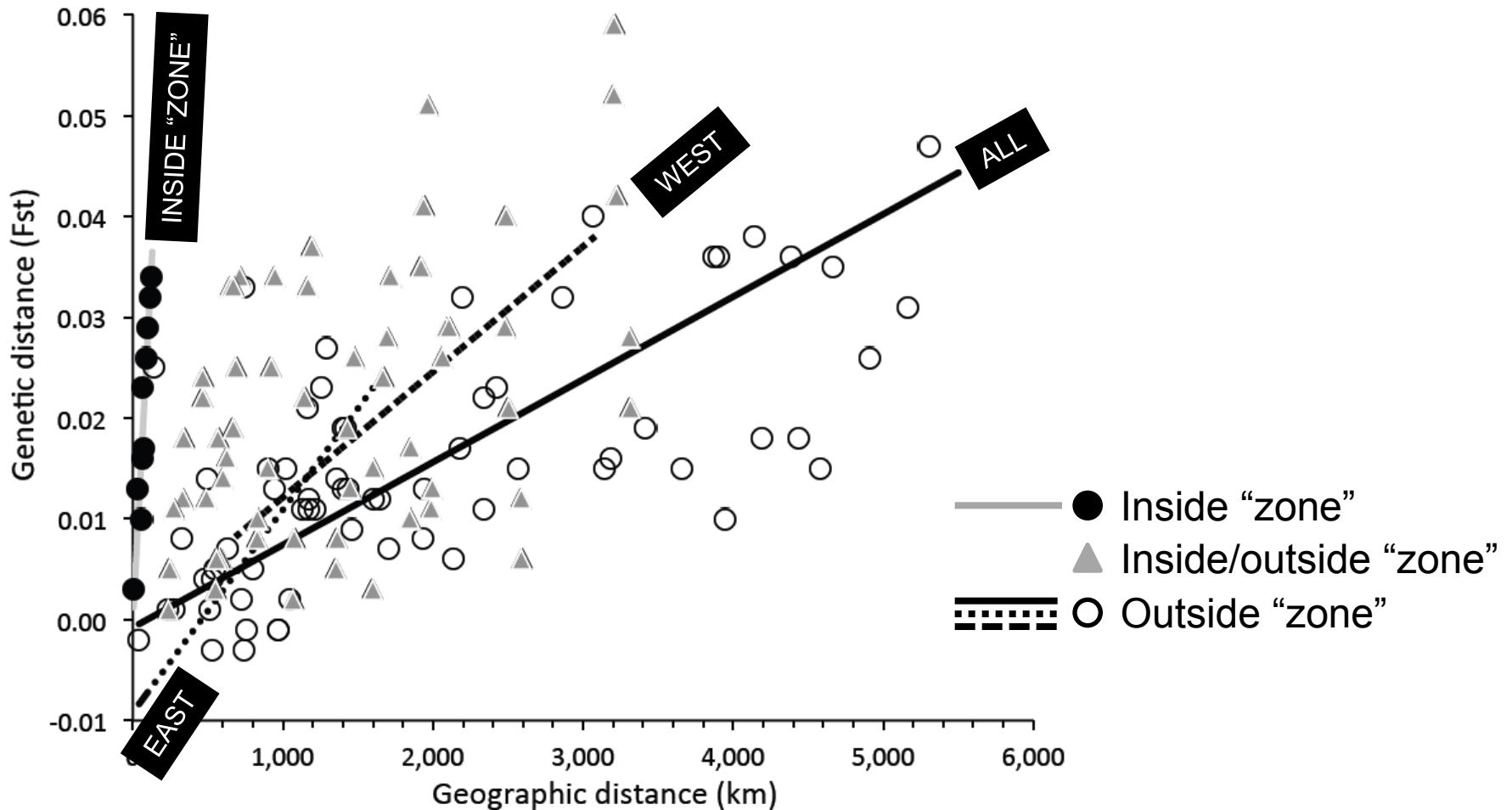
$Z=228.7760$, $r=0.4299$, $P=0.029$



Lambeck et al. 2001. *Science* 292, 679 - 686

○ Comparisons
east of “zone”

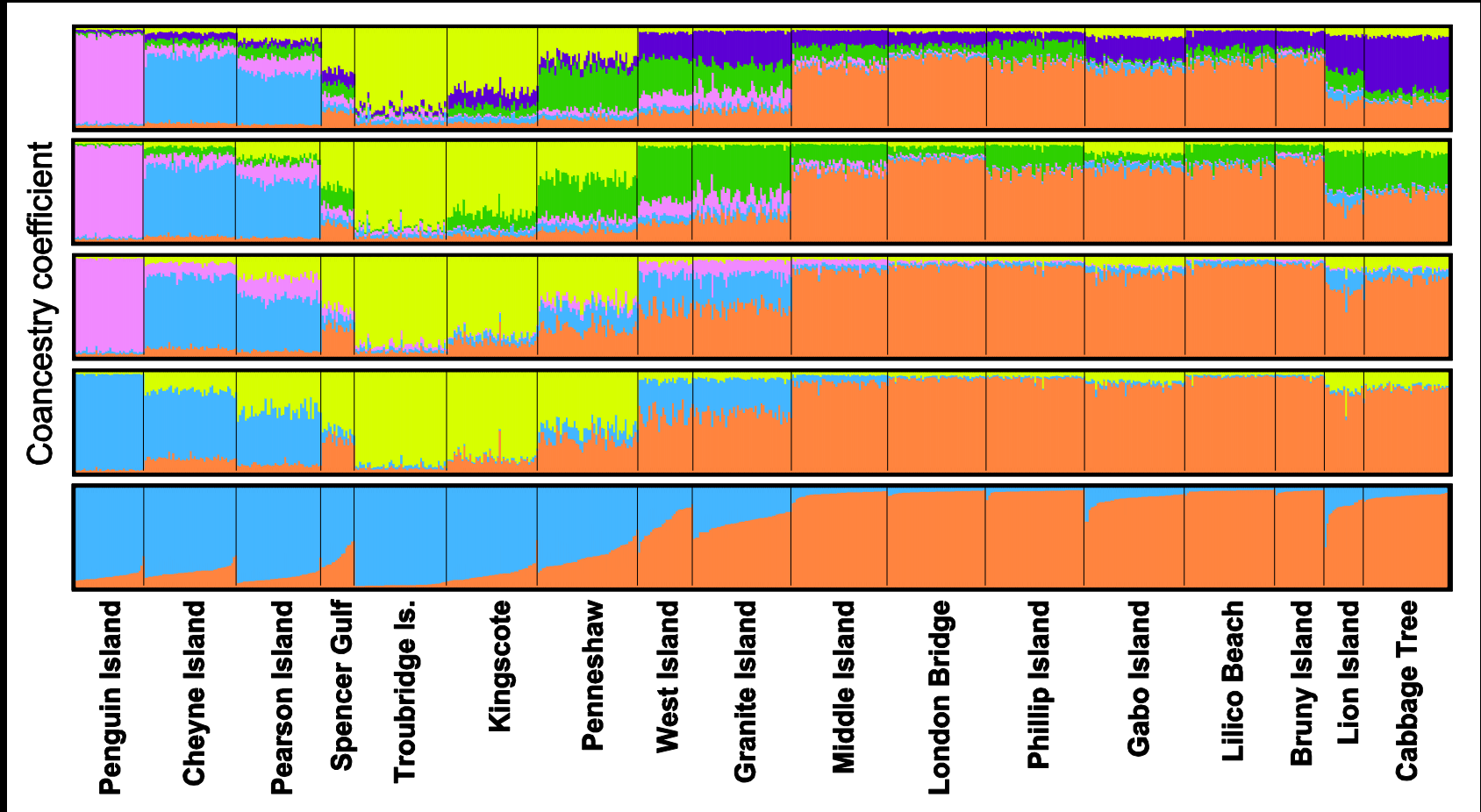
Mantel tests



How to explain?

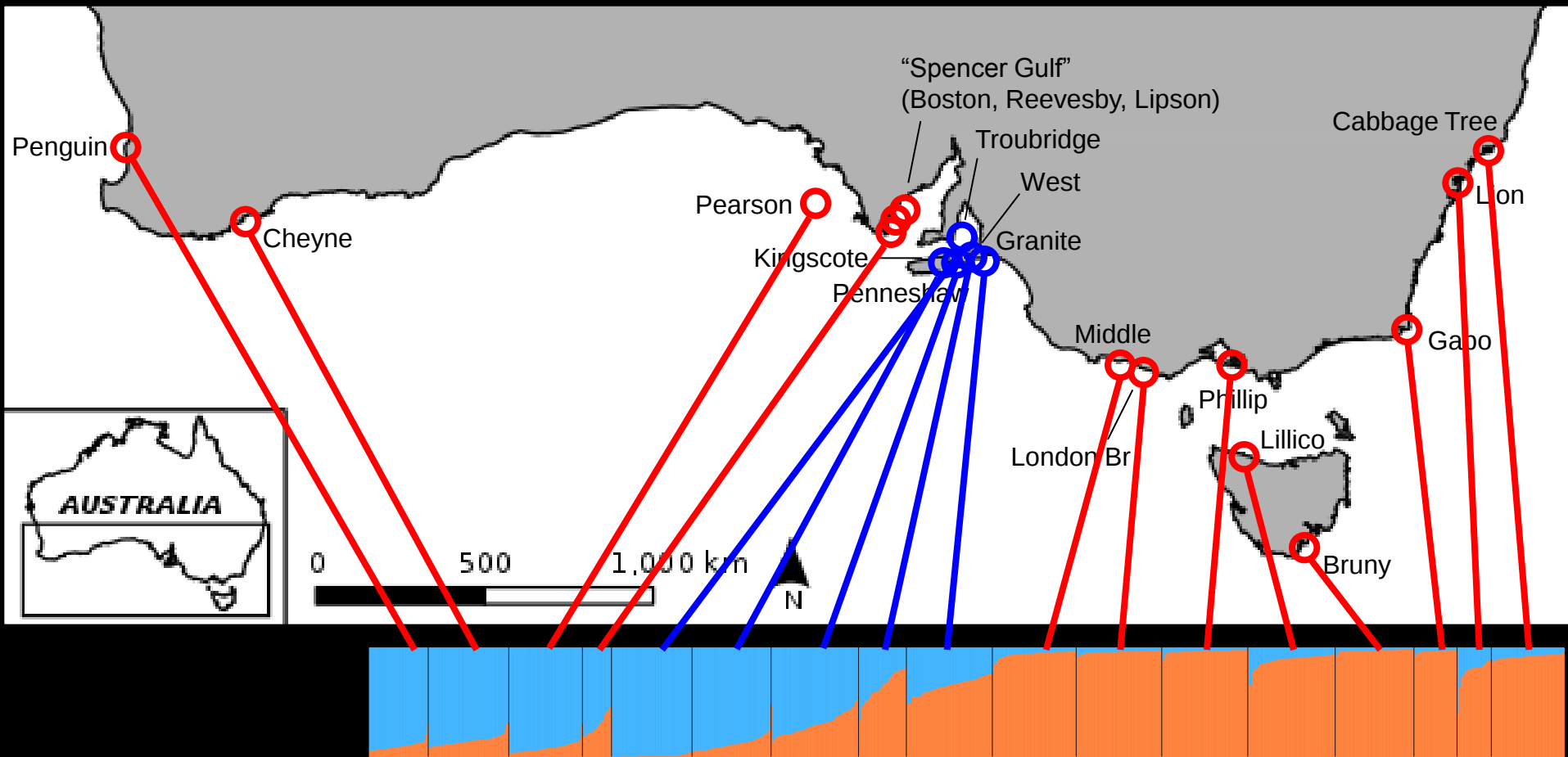
- Gene flow related to distance, but different relationships in different regions
 - Different foraging distances in different regions
 - Nesting habitat specialisation and spatial heterogeneity in habitat
 - *Some magic factor that influences the relationship between gene flow and geographic distance*

A different perspective

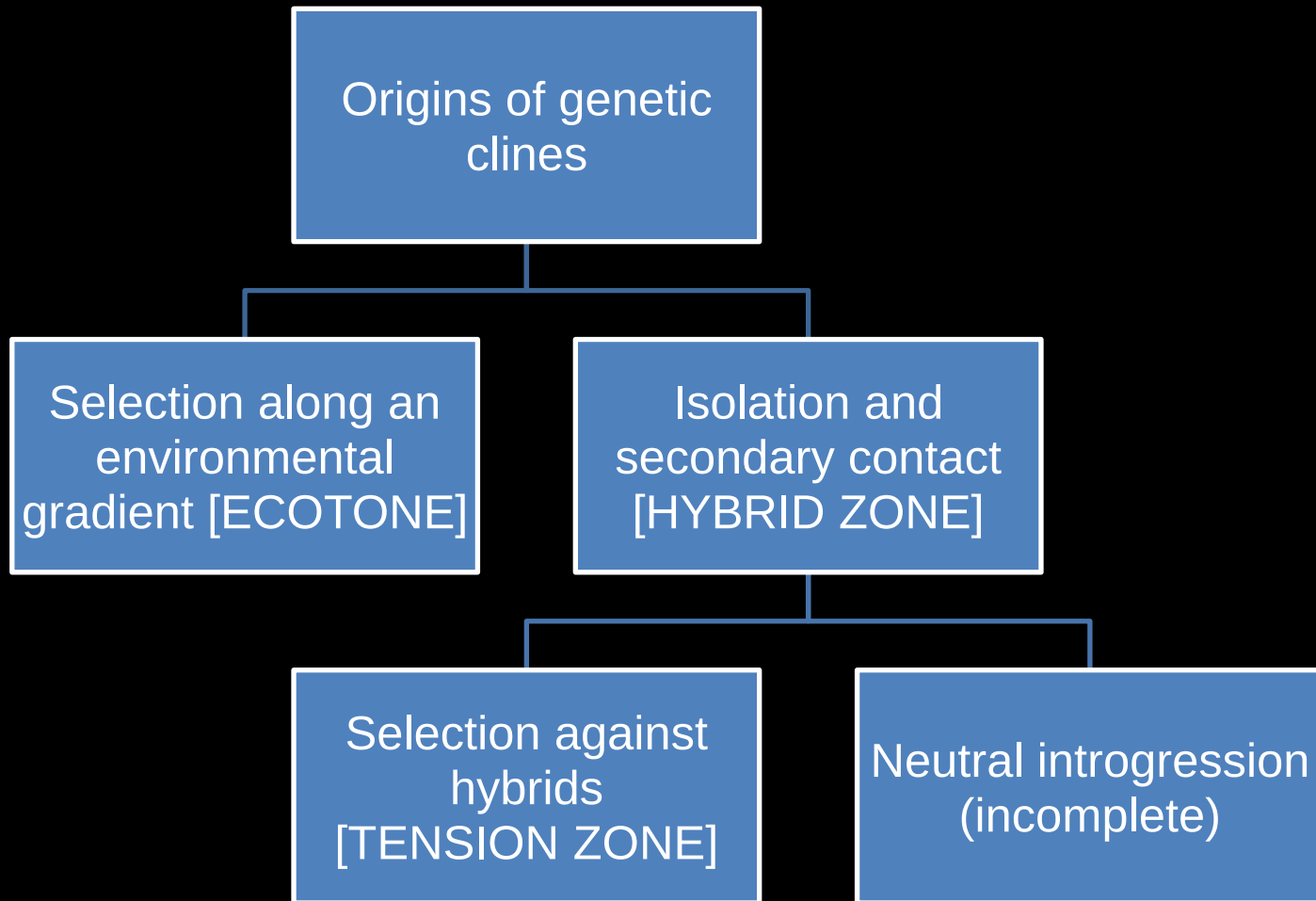


- Non-spatial Bayesian clustering of individuals
 - “STRUCTURE” analysis

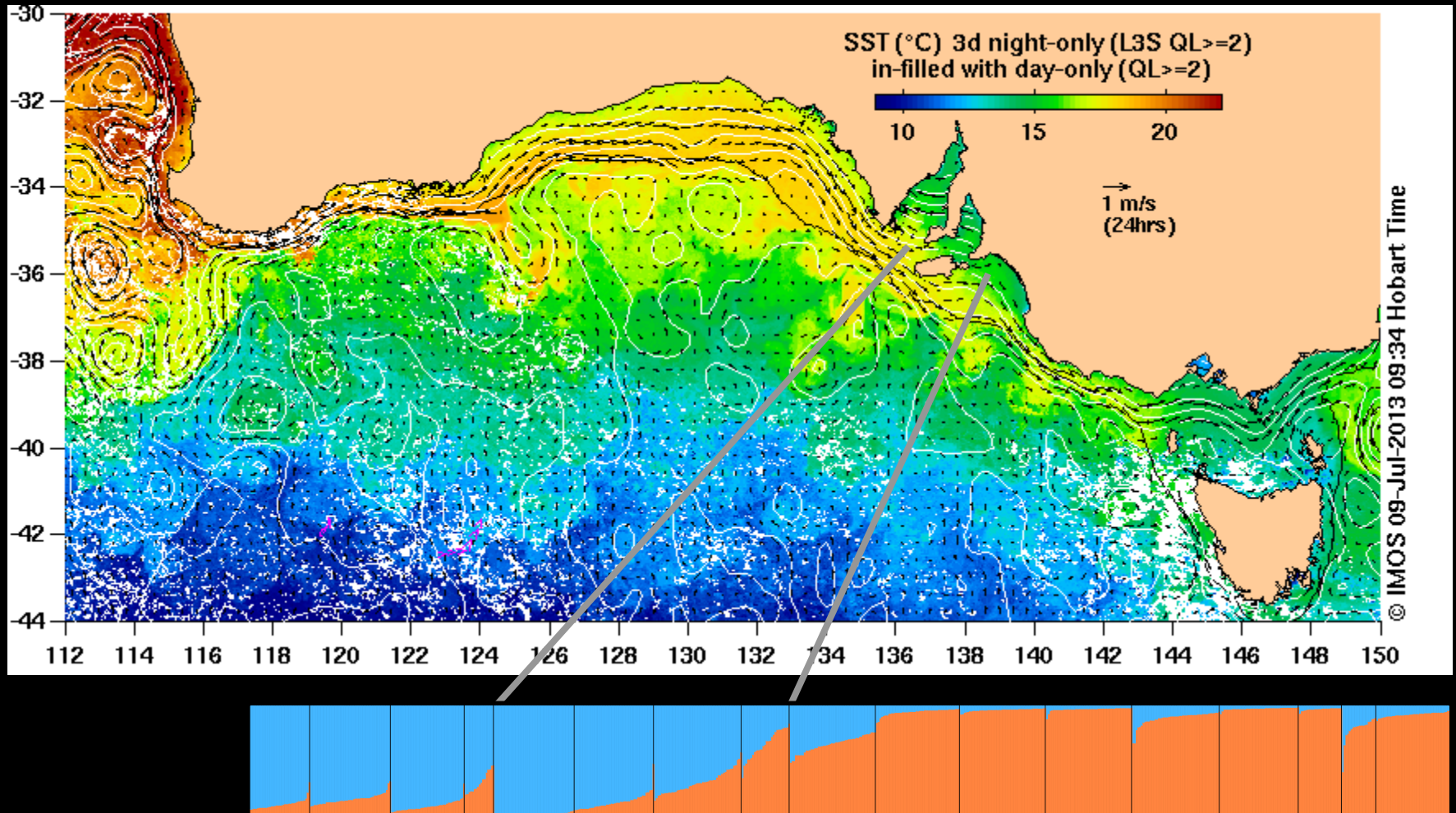
A genetic cline!



Possible origins



Environmental gradients?



Isolation and secondary contact

- Northern range shift suspected for many temperate Australian marine taxa during Pleistocene glaciation

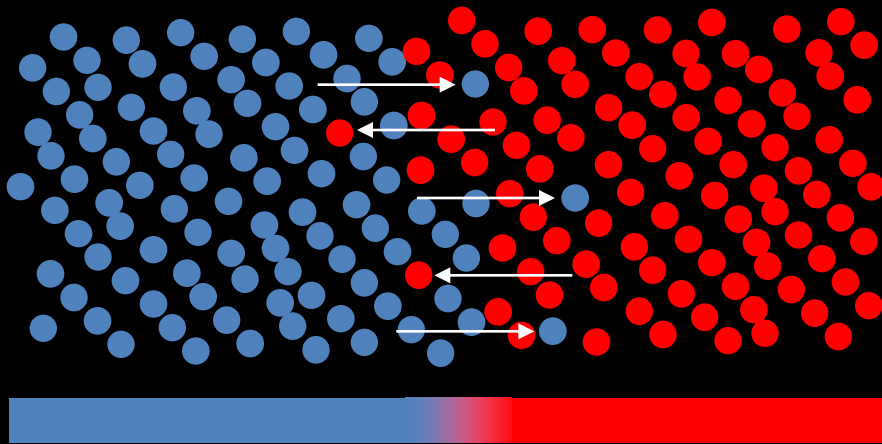


De Deckker et al. (2012) *Nature Geoscience* 5, 266–269

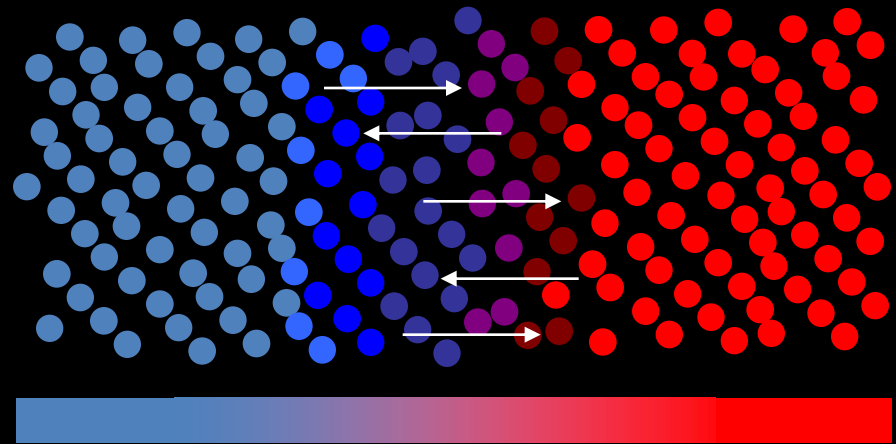
- Chance bifurcation of Australian range; loss of geographically intermediate colonies

Isolation and secondary contact

- Hybrids are inferior (“tension zone”)



- Neutral introgression [prior to equilibrium]



Isolation and secondary contact

Test via...

1) Tension zone

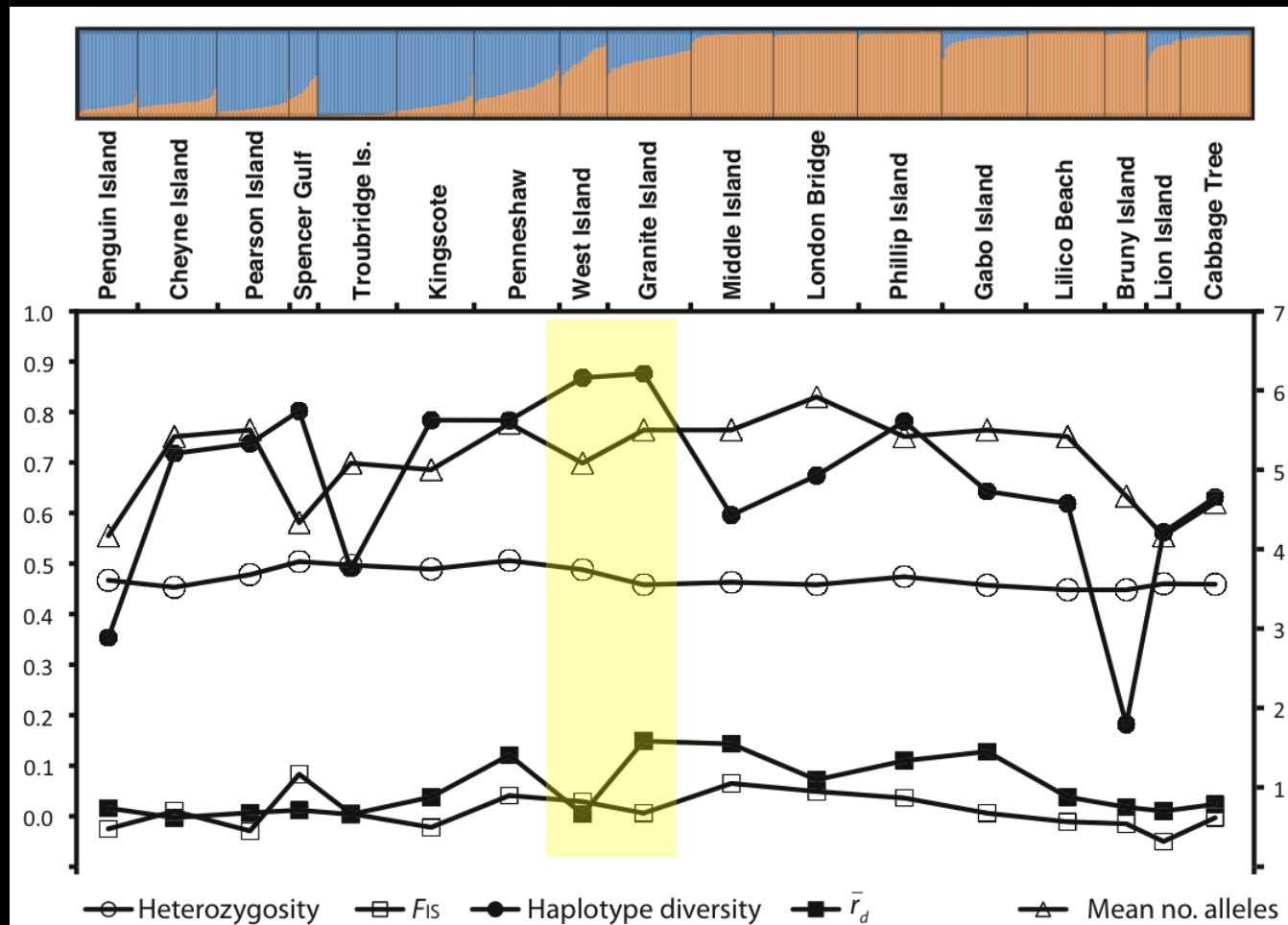
- coincidence of cline centres among loci
- signatures in genetic variation

2) Neutral introgression

- likely persistence of cline given duration of secondary contact

Tension zone

- No supporting signatures of genetic variation



Neutral introgression

- Assume isolation during glacial stages
- Secondary contact ~15 kya
- 2-3 yr generation time
- Degradation of cline:



$$T = 0.35 \left(\frac{w}{l} \right)^2$$

Time since secondary contact (generations)

Cline width (1/max slope)

Gene flow (mean parent-offspring geographic distance)

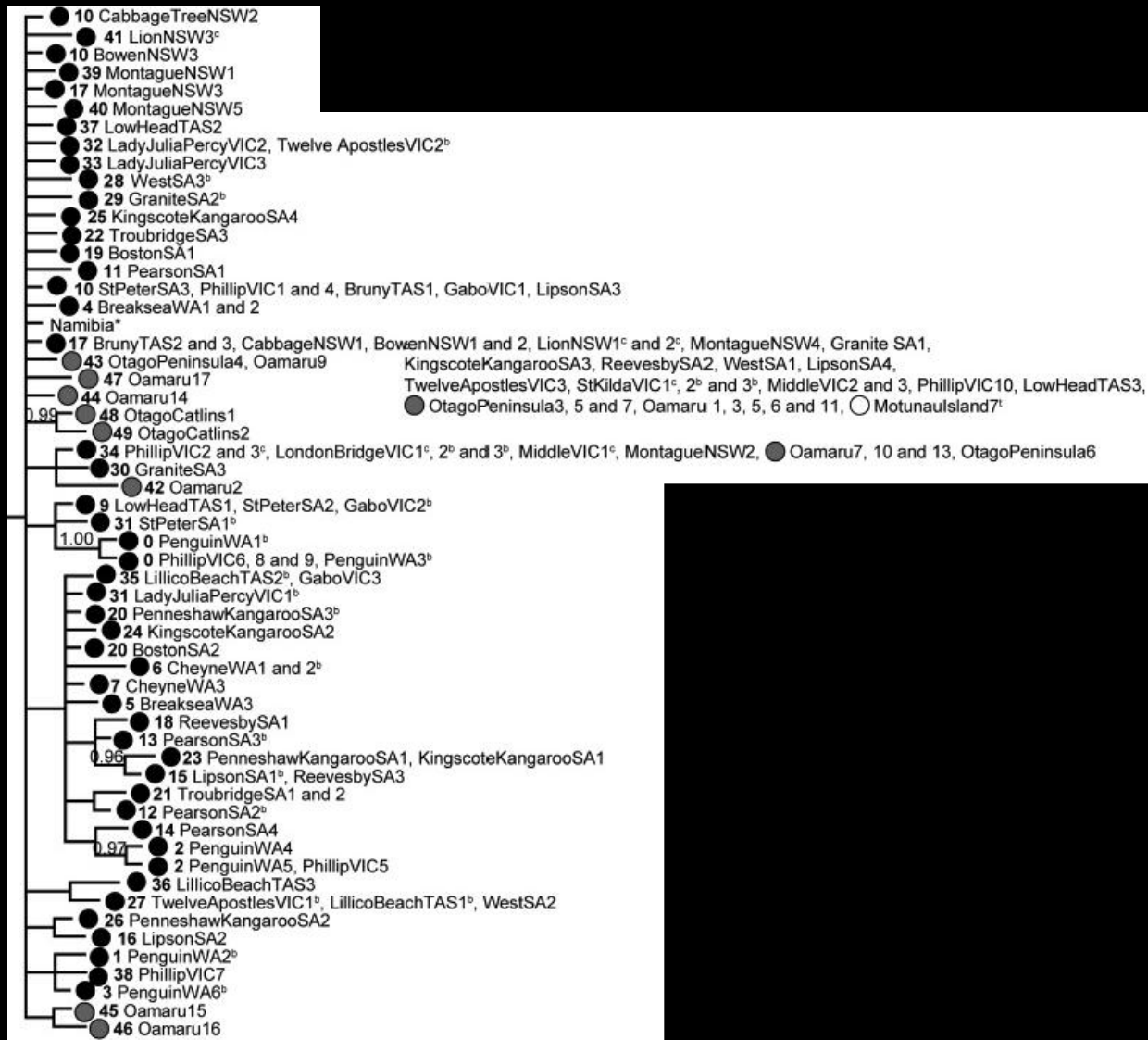
Endler (1977)



Neutral introgression

- Observed hybrid zone width compatible with
 - contact established 15 kya (2-3 yr generation time)
 - mean parent-offspring dispersal <240 m
- Plausible under a situation of leptokurtic dispersal—high natal philopatry and occasional dispersal to adjacent colonies
 - can accommodate higher dispersal if contact more recent (1 km if contact 1 kya) or generation time longer

Lack of phylogeographic structuring



Summary: *E. minor*

- Regional differences in genetic structuring may only reflect a historical legacy of isolation and secondary contact
 - Contemporary gene flow (per unit distance) could be the same across the study range
- Genetic difference increases with geographic distance
 - Predominance of self/local recruitment

The “so what?”

1. Hybrid zones increasingly reported at the species-level
 - Likely to be common at the intraspecific level



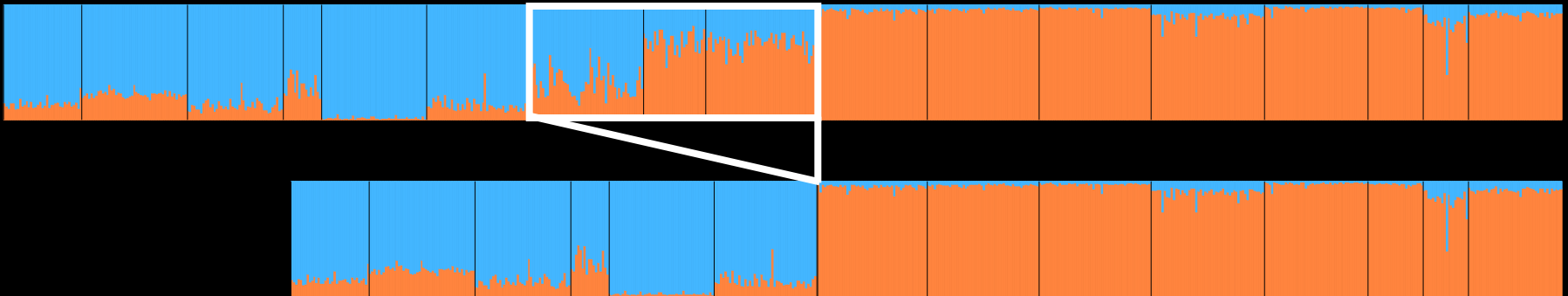
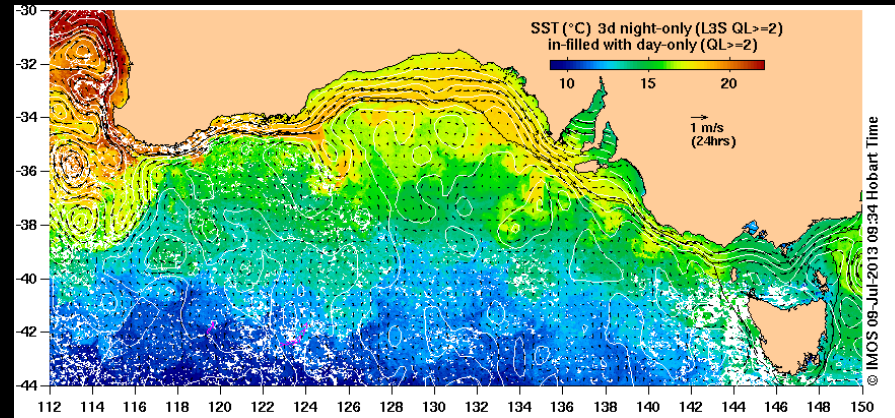
X



Larus occidentalis x *glaucescens*

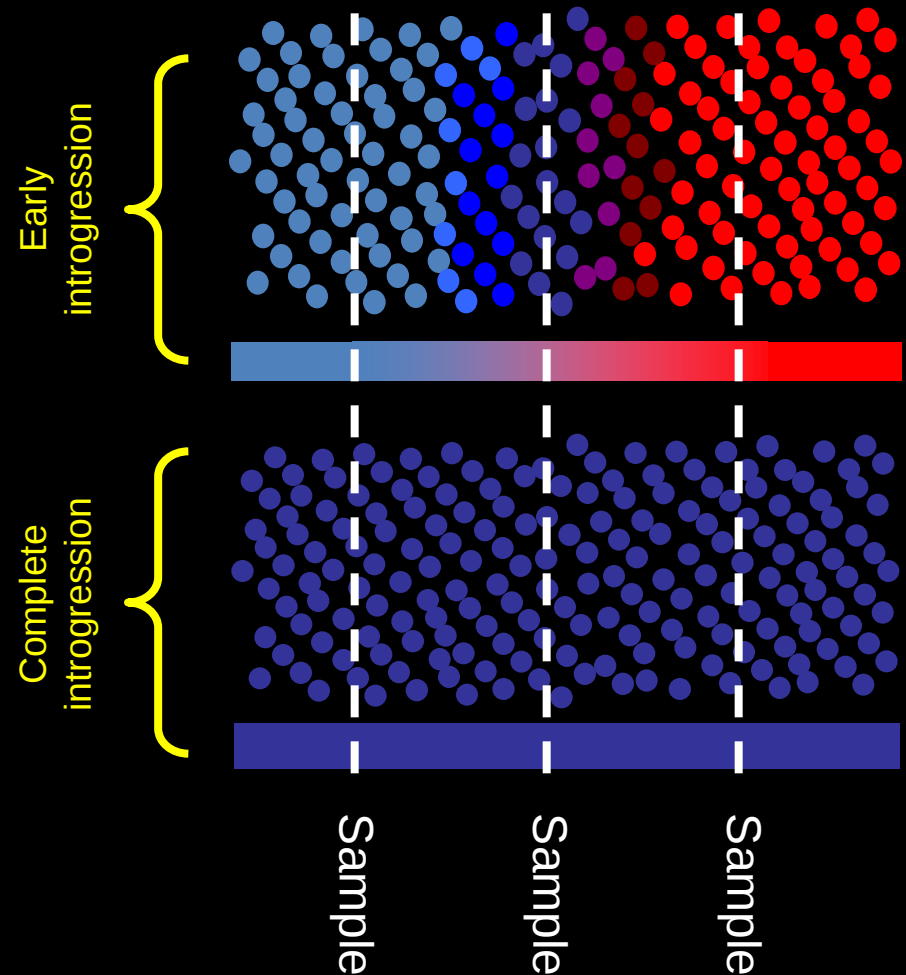
The “so what?”

2. Failure to recognise hybrid zones may lead to spurious correlations regarding gene flow
 - Importance of spatial sampling



The “so what?”

3. Historical legacies may also lead to the under-estimation of contemporary gene flow, rather than just the over-estimation



Acknowledgements



- Holsworth Wildlife Research Endowment
- Fieldwork volunteers

Tension zone

- Microsatellite and mtDNA clines coincident
 - 27 km apart; $\chi^2=0.034$, d.f.=1, $P=0.84$
- Analysis suited to bi-allelic loci
 - “Coincident coincidence”?

