Population pedigree process of the Chatham island black robin: A case of human-assisted spread of a maladaptive behavior in a critically endangered bird

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Parts are Joint work with: James Briskie, Marie Hale, Melanie Massaro, Don Merton, Anthony Poole

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Chatham Islands – Geography & Ecological History

Ecological History of Black Robins

Tests for Heritability of Rim-laying in 1980s

PVA with Behaviourially Realistic Population Pedigree Models

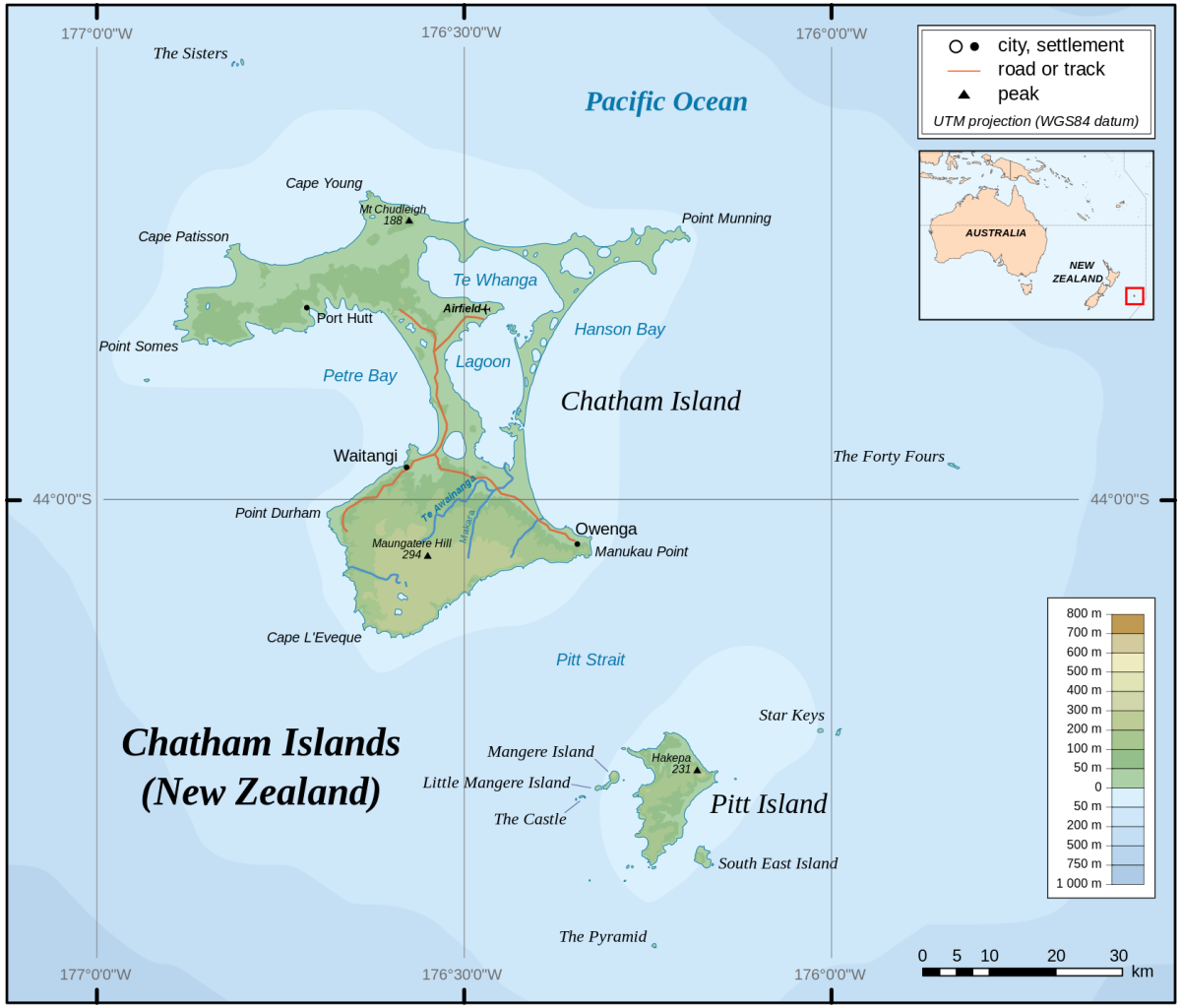
A Field Excursion

Part I

Map of Antarctica (English / French)

Chatham Islands (New Zealand)

Topographical Map

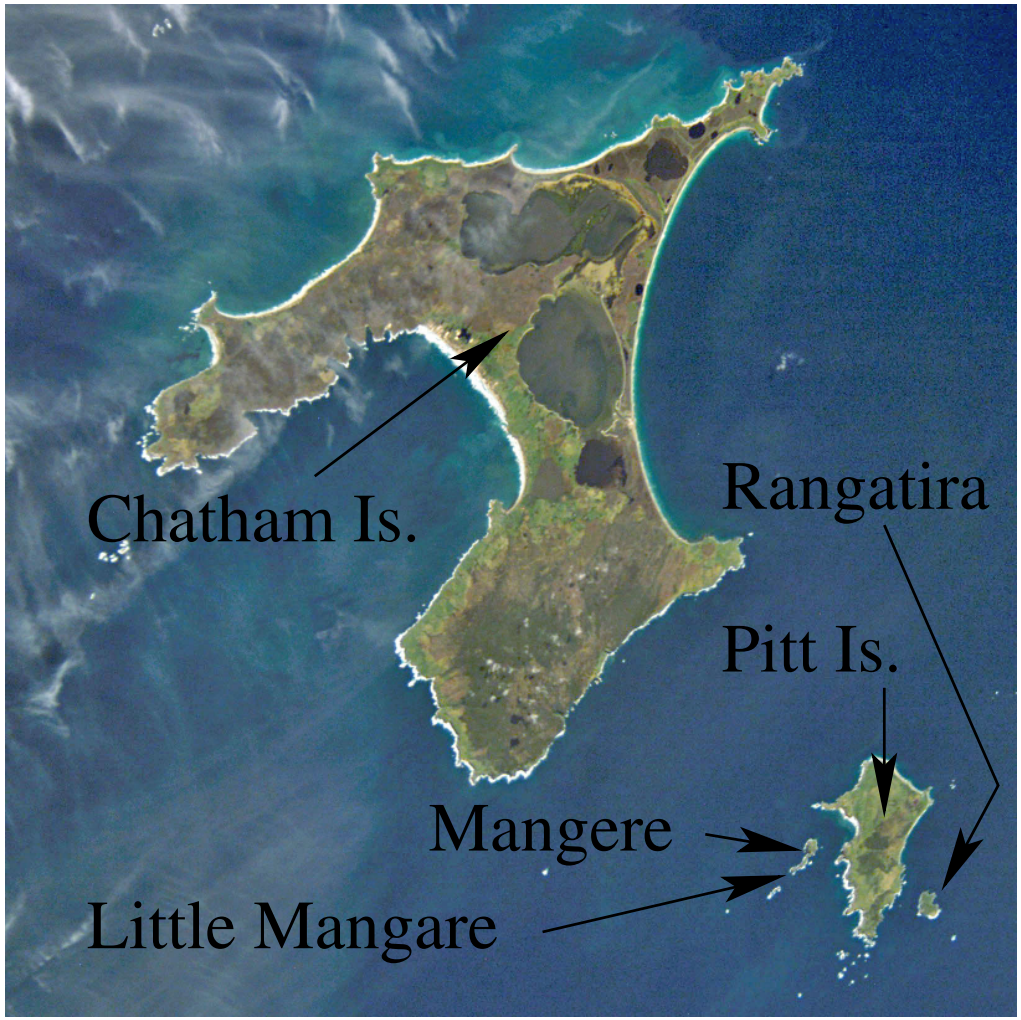


Chatham Islands (New Zealand)

- The Chatham Islands lie 767 kilometres south-east of mainland New Zealand.
- There are two main islands – Chatham Island and Pitt Island
- and many smaller islands – including Little Mangere, Mangere and Rangatira
- The islands have only emerged above sea level in the last 4 million years and are part of the Chathams rise connected below ocean to NZ.
- The climate is cool and wet with salt-laden winds all year round.

Chatham Islands (New Zealand)

Chatham Islands From Space



Chatham Islands (New Zealand)

Rangatira Island

- is the third largest island in the Chatham Islands
- covers an area of 218 hectares (539 acres)
- is a gazetted nature reserve since 1953
- is now home to many endemic species
- is home to black robins – saved from near extinction by team led by Don Merton in the 1980s

A Chatham island Black Robin in Rangatira today

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- The environmental and ecological consequence on the Chatham islands was massive
- the accompanying sheep and cattle farming and the feral rabbits and pigs released by sailors resulted in over-grazing and destroyed the indigenous flora
- the introduced predators such as cats, rats and stoats destroyed the indigenous fauna (especially birds that evolved in the absence of land-based predators)

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- The more ecologically devastated Mangare island was also turned into a nature reserve with an ecological restoration effort of native flora

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- Managements ceased when the population reached about 100 birds

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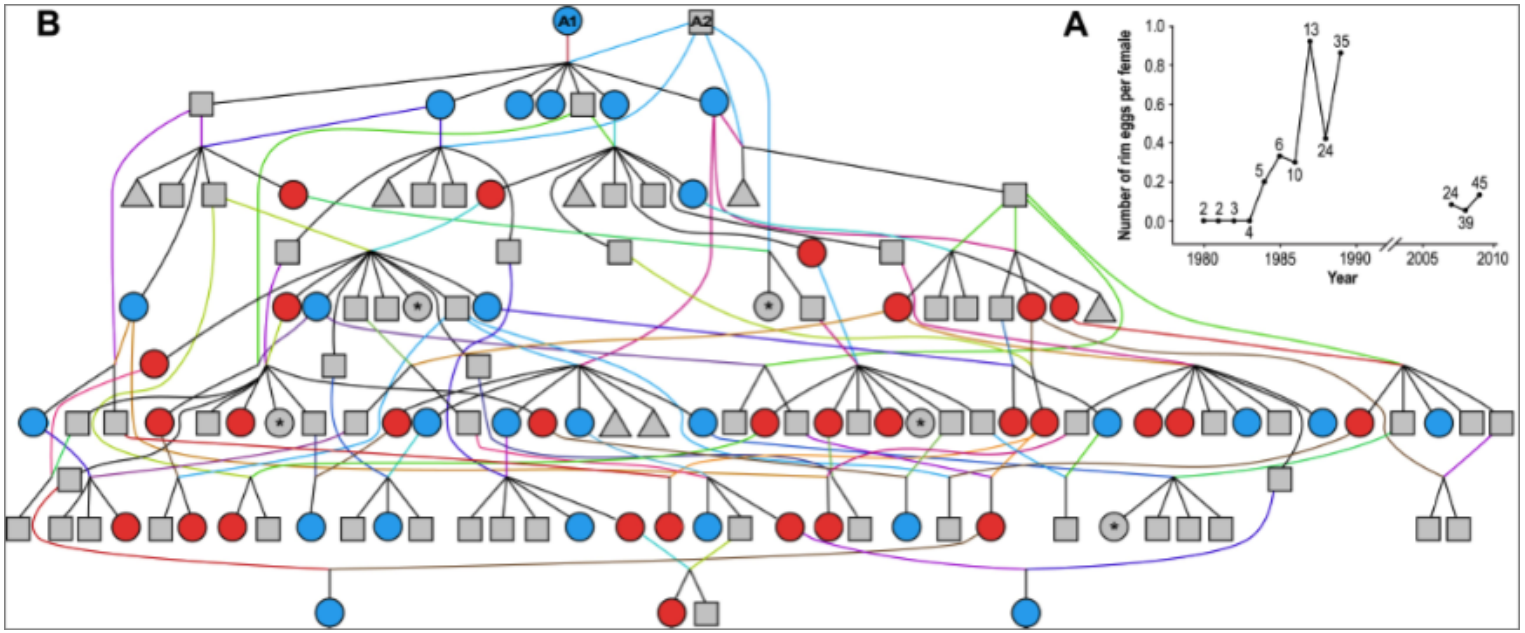
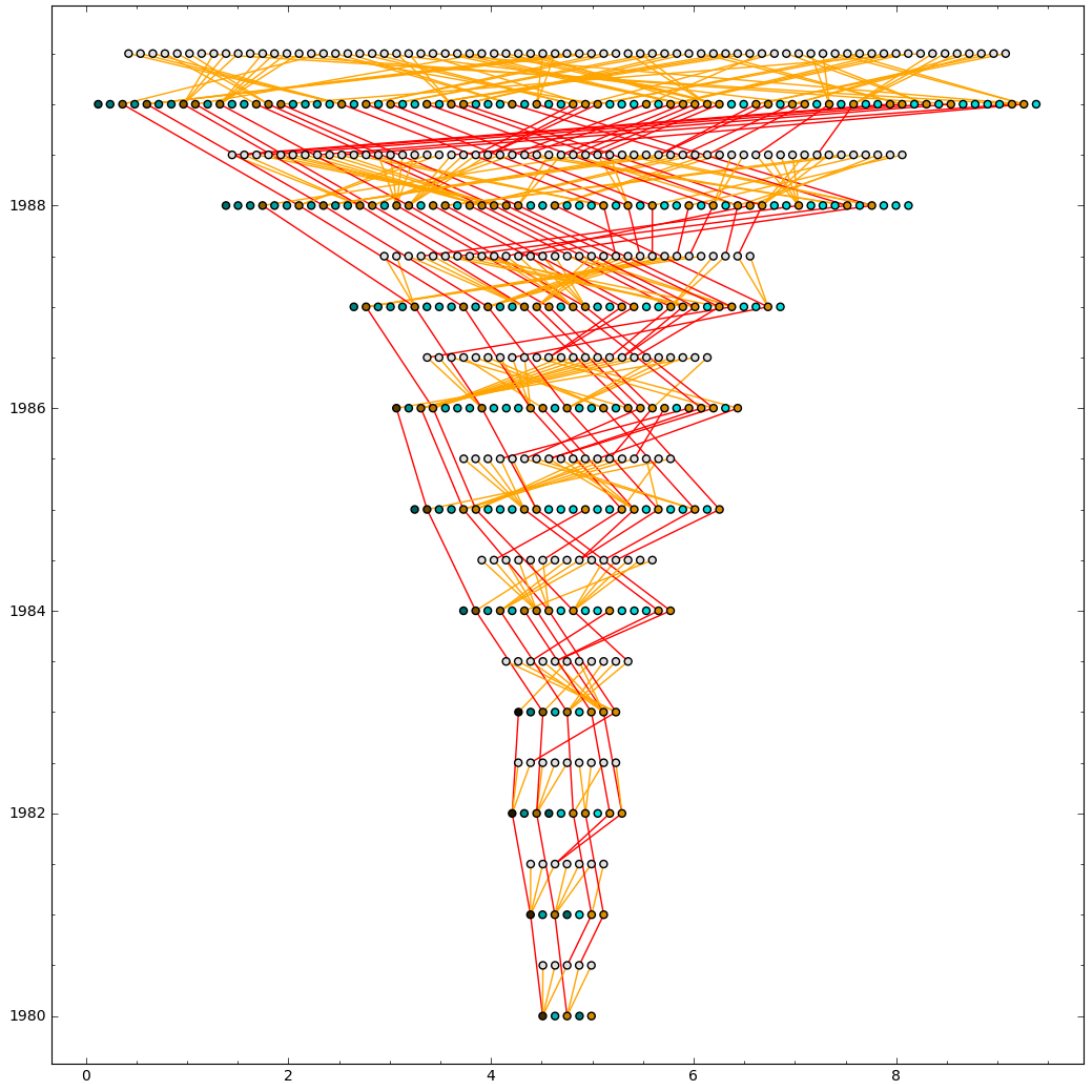
- In the sequel, we will add temporal and spatial aspects to the classical notion of pedigree

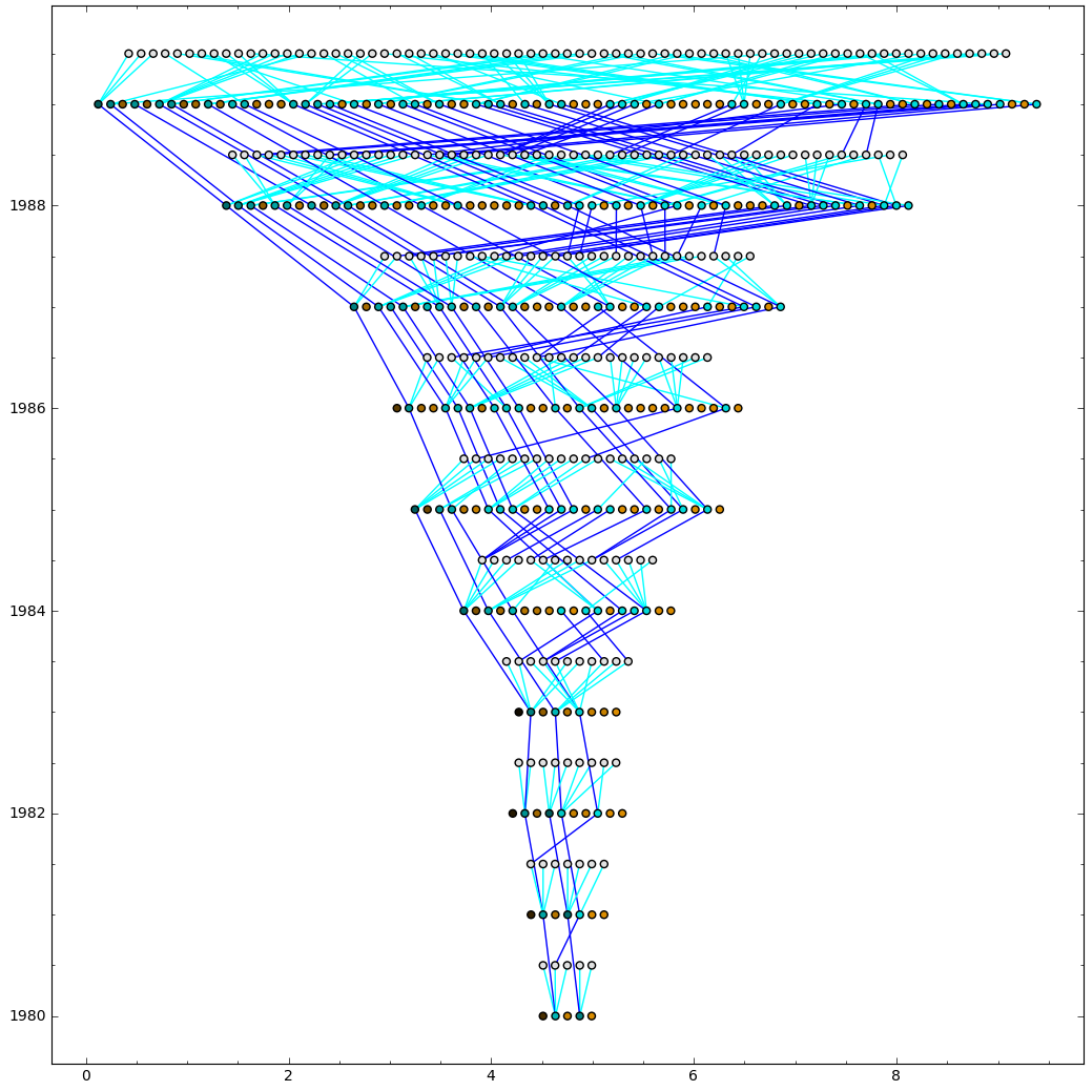
Highly Looped Black Robin Pedigree in 1980s



cicle = female, square = male, traingle = unknown sex,
red circle = rim-layer, blue circle = non-rim-layer



Female Population Tree during Field Conservation in 1980s



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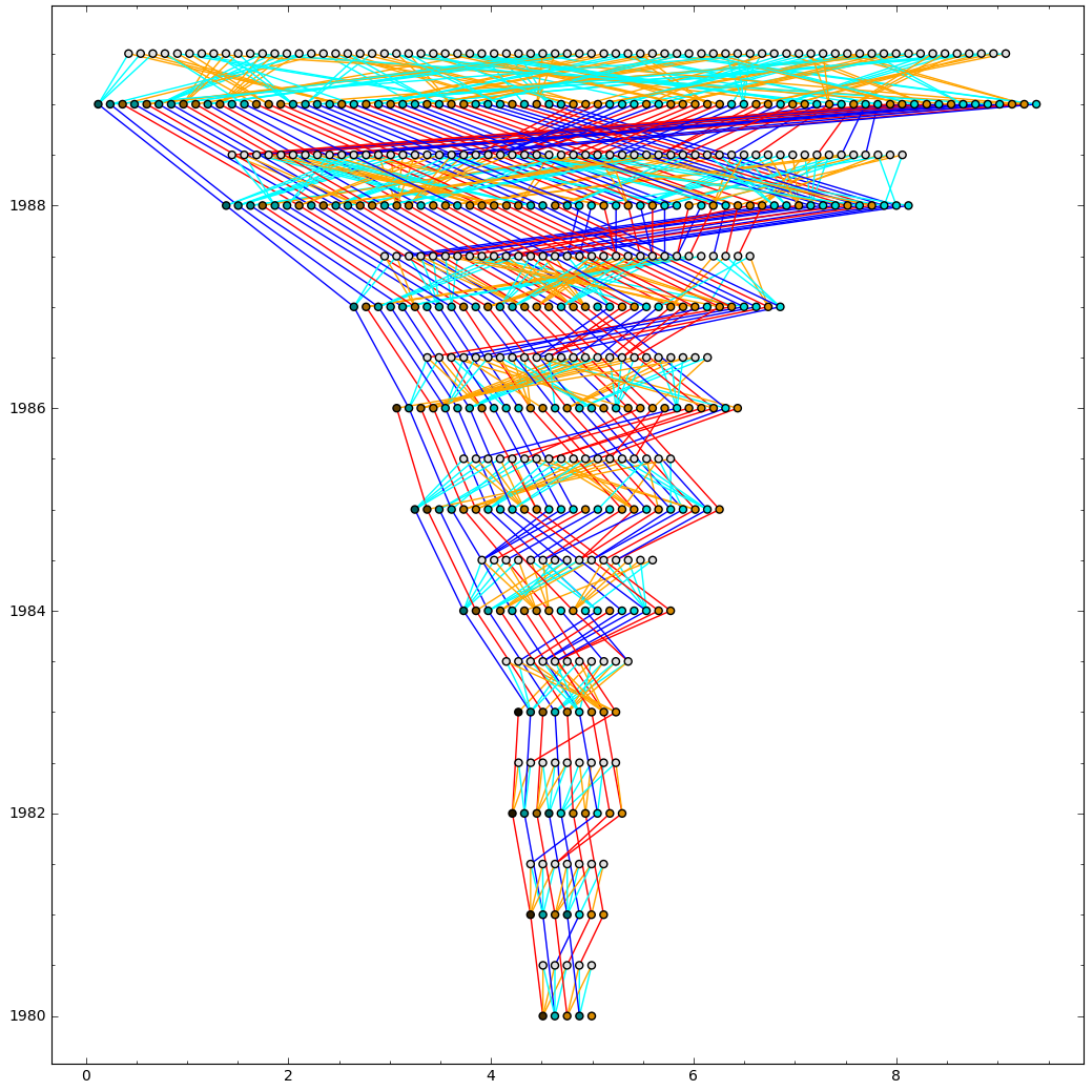

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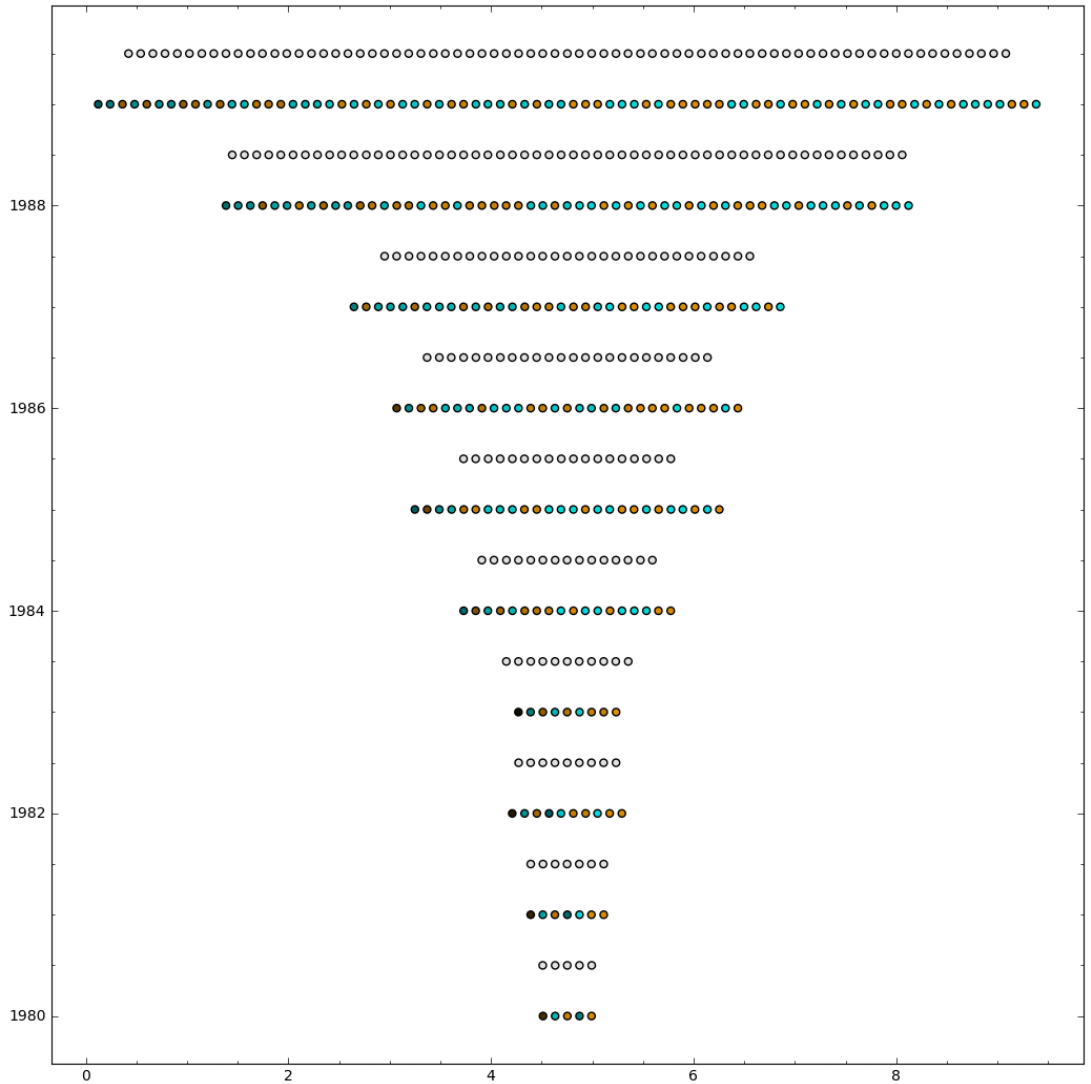
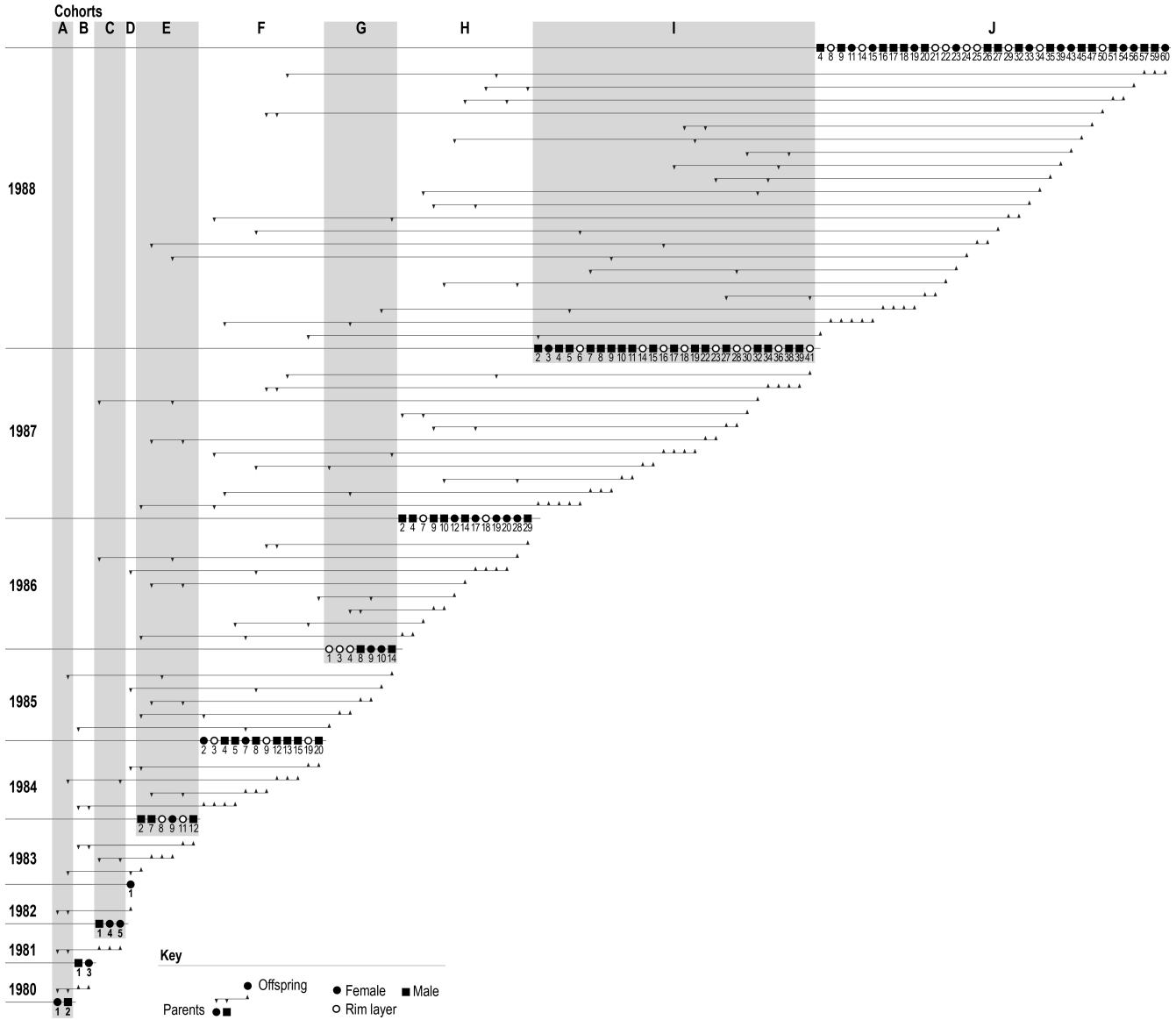
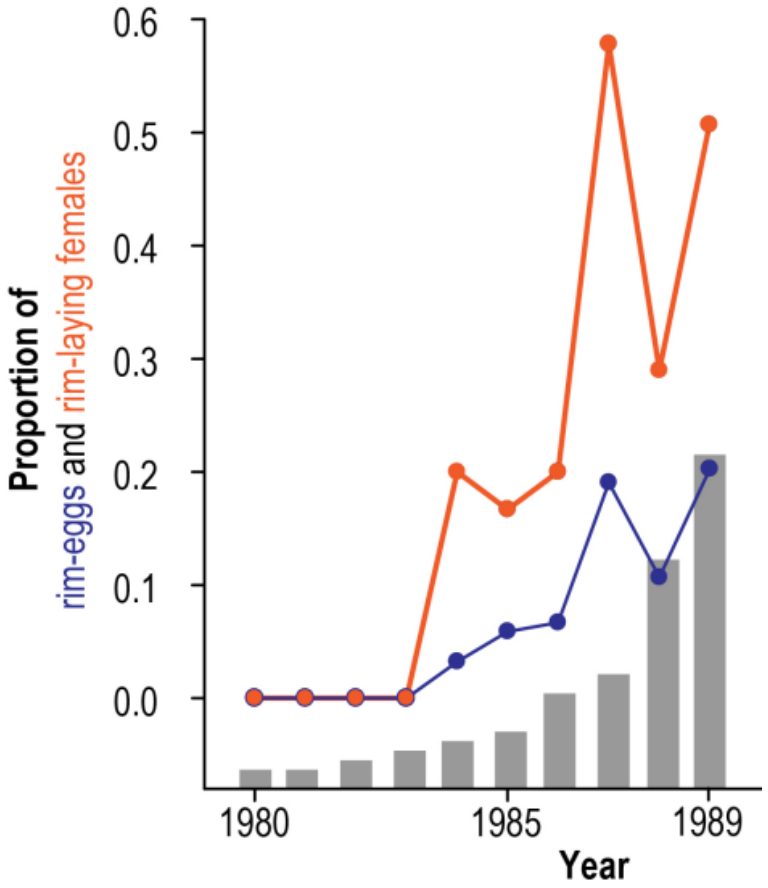


Coalescent Sub-Pedigree of the 1989 population

Rim-laying Behaviour during Field Conservation in 1980s

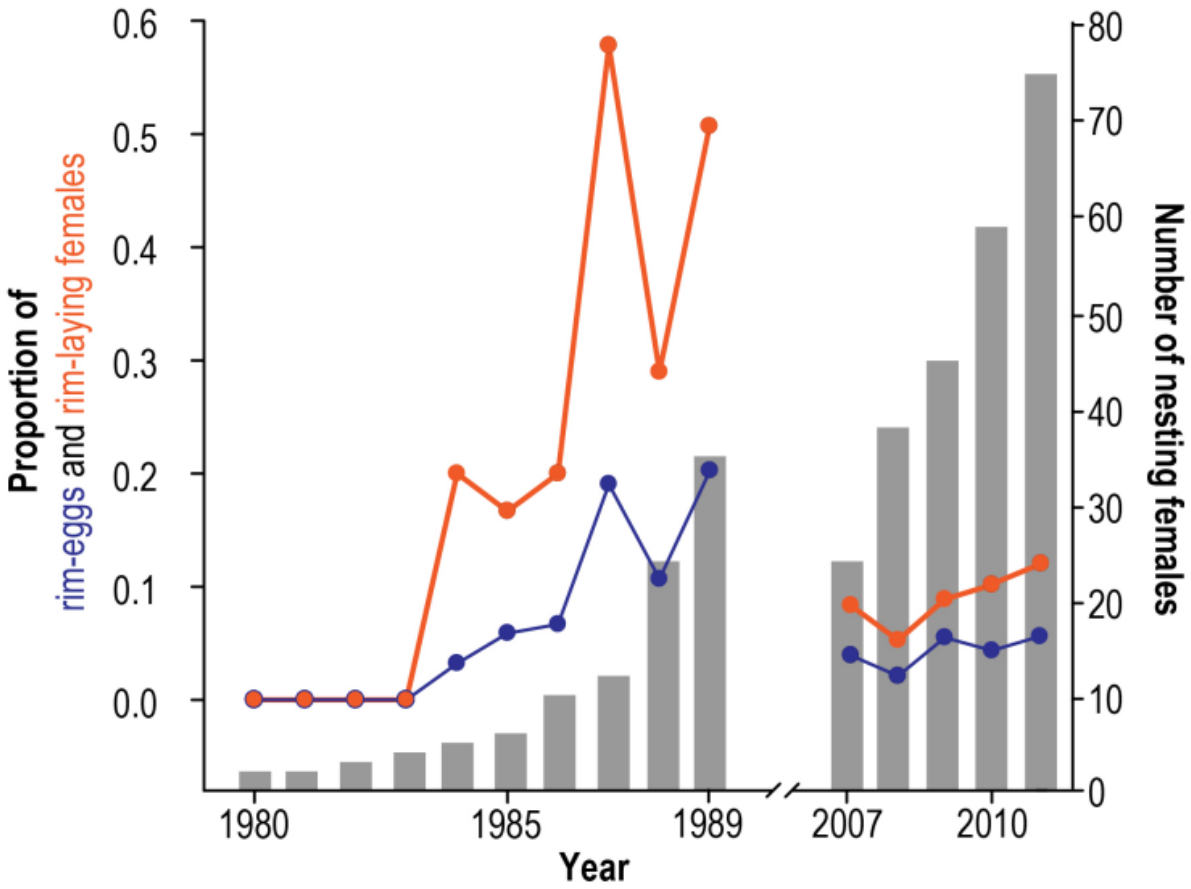


Temporal Pedigree (with rim-layers) during 1980s



Rim-laying increases in 1980s

- Conservation Dilemma – when to cease management?
- Need managed pop. size to ↑
- But rim-laying trait also ↑
- Don Merton's team ceased management when 50% of females were rim-layers by 1989
- Our Question: Is rim-laying a heritable trait?



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but between 2007 and 2011 (unmanaged phase) seems lower

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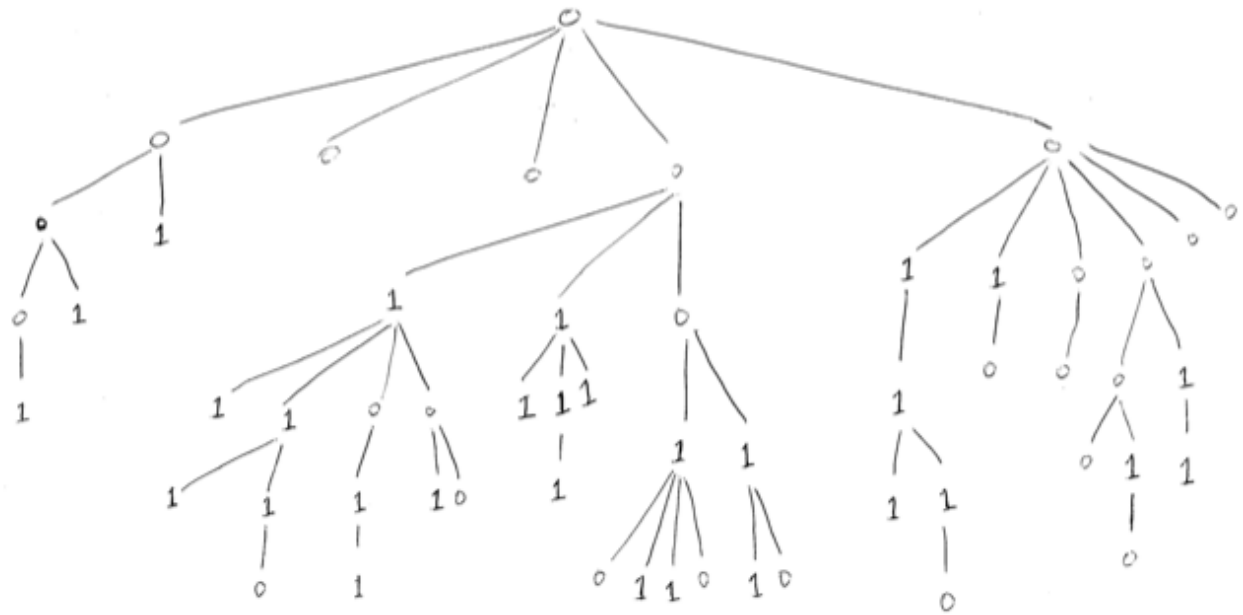
- Alternative Hypothesis H_1:
  The Rim-laying Phenotype has a first-order Markov dependence on Mother's trait

$$\mathbf{P} = \begin{bmatrix} p_{0,0} & p_{0,1} \\ p_{1,0} & p_{1,1} \end{bmatrix}$$

Mother-daughter Phenotype based Test

DATA: Mother-Daughter Phenotype Branching Diagram for Black Robins in 1980s



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- But this test ignores the pedigree within which phenoypes are expressible by genotypes in diploid individuals even under the simplest models of inherited Medelian traits

Pedigree Conditional Phenotype Randomization Test

Explain Idea on Board

Results:

Table S1. Proportion (*P*-value) of the null distribution of likelihoods calculated from randomized phenotypes (10,000 randomizations) being ≥ the likelihood value for the observed phenotypes, conditional on founder genotype combination and dominance model.

Founder Female x Male	**Model**	***P*-value (95% Confidence Interval)**
Aa x AA	Recessive	0.0108 (+/- 0.0020)
AA x Aa	Recessive	0.0211 (+/- 0.0028)
Aa x Aa	Recessive	0.1686 (+/- 0.0073)
aa x Aa	Dominant	0.8362 (+/- 0.0073)

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- Merton suspected rim-laying was heritable (persn. commn. to Massaro)

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- To appreciate the intensity of field operations and limitations of biomathematical models read: *The black robin: saving the world's most endangered bird*, David Butler and Don Merton, Oxford University Press, 1994.

Part II

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- i.e., I’ll try to show that every “turf-holding”, “mate-alluring”, “love-making” and “chick-rearing” event counts in the field!!!

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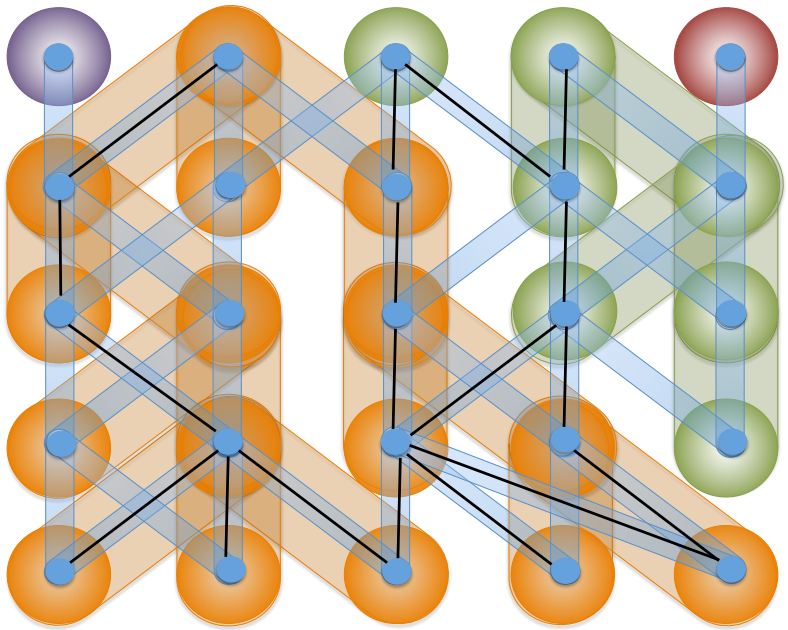
- VISION: Integrate behavioural ecology with population pedigrees for subsequent molecular evolutionary genetics

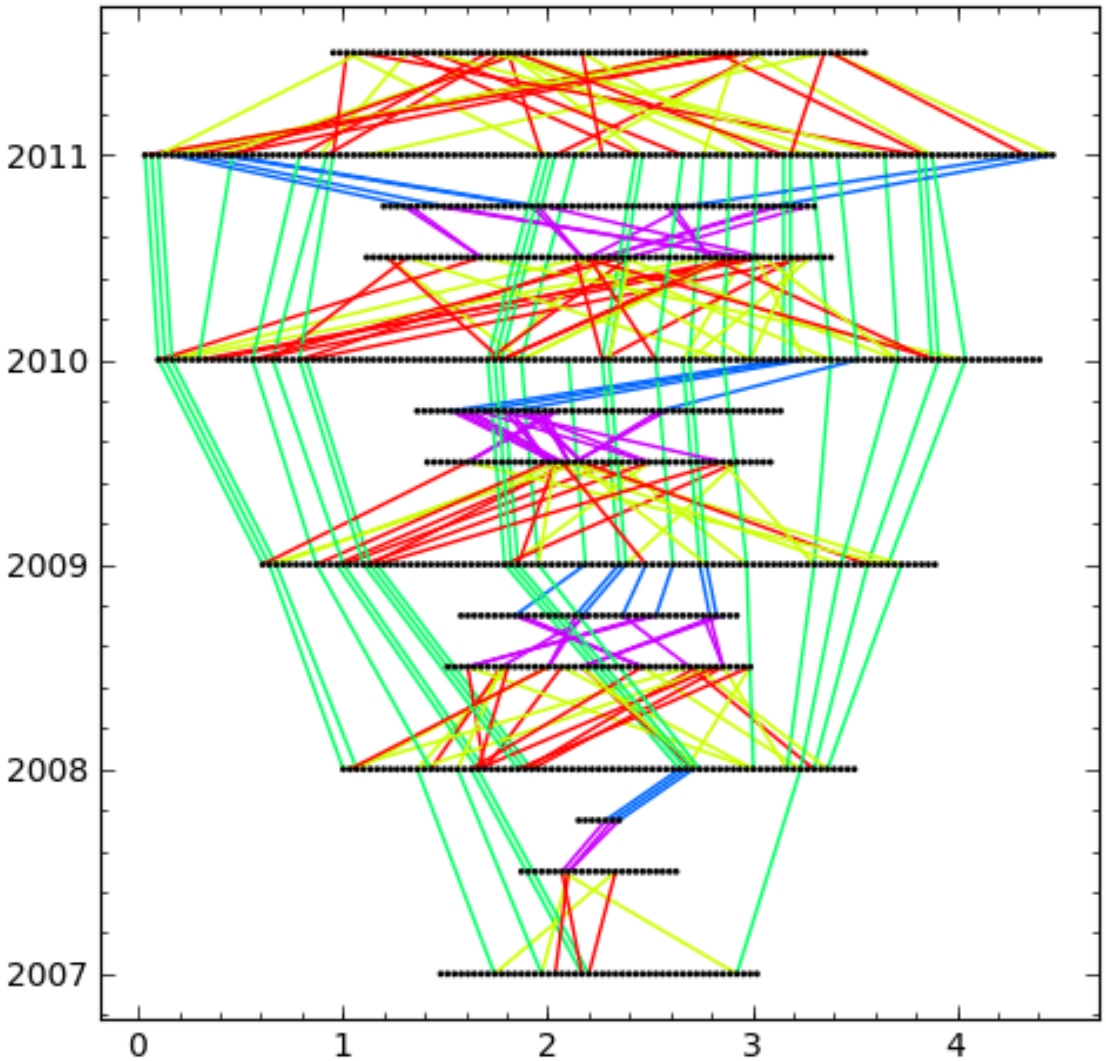
Notions of Molecular continuums within Population Pedigrees

a homotopy between Kingman Coalescent Trees and Chang's Pedigree (RS & Bhalchandra Thatte)

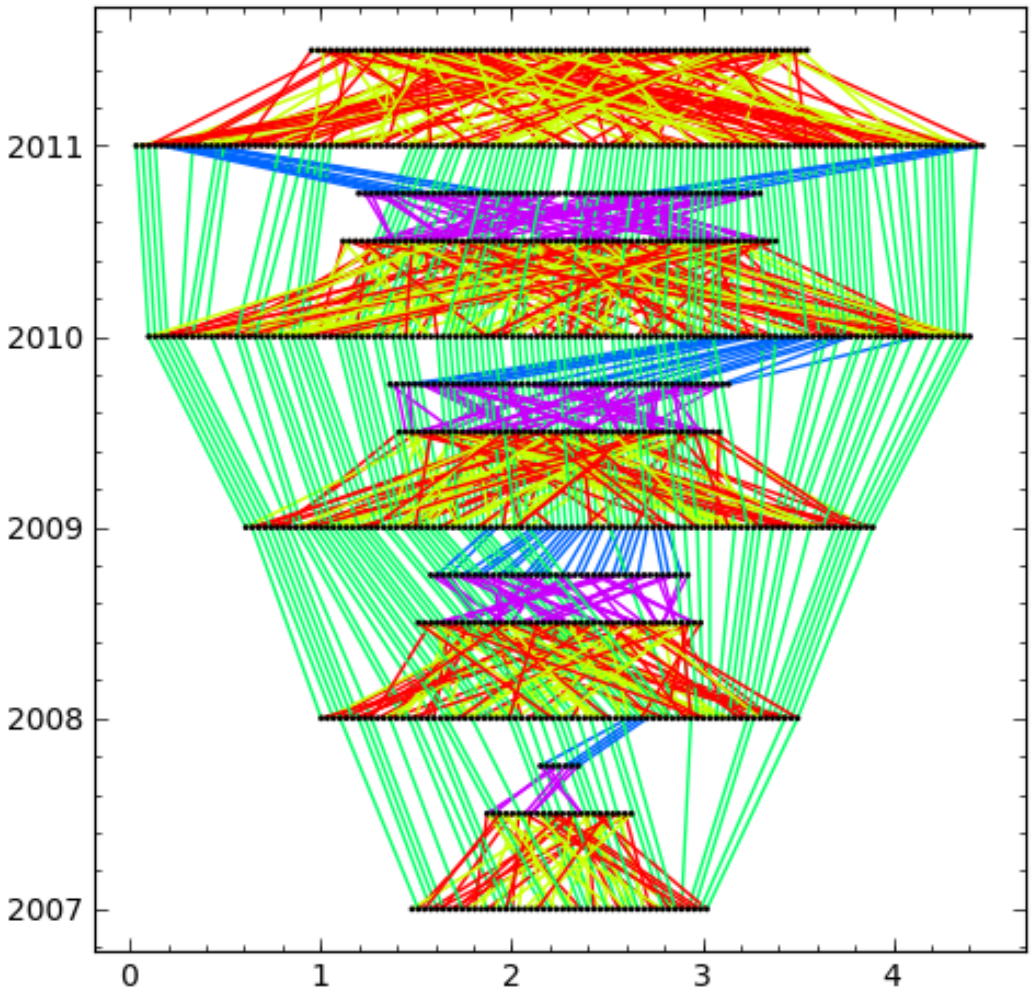


Zygotic, cytoplasmic, karyotic and sub-karyotic pedigrees of a Wright-Fisher population with five eukaryotic diploid individuals

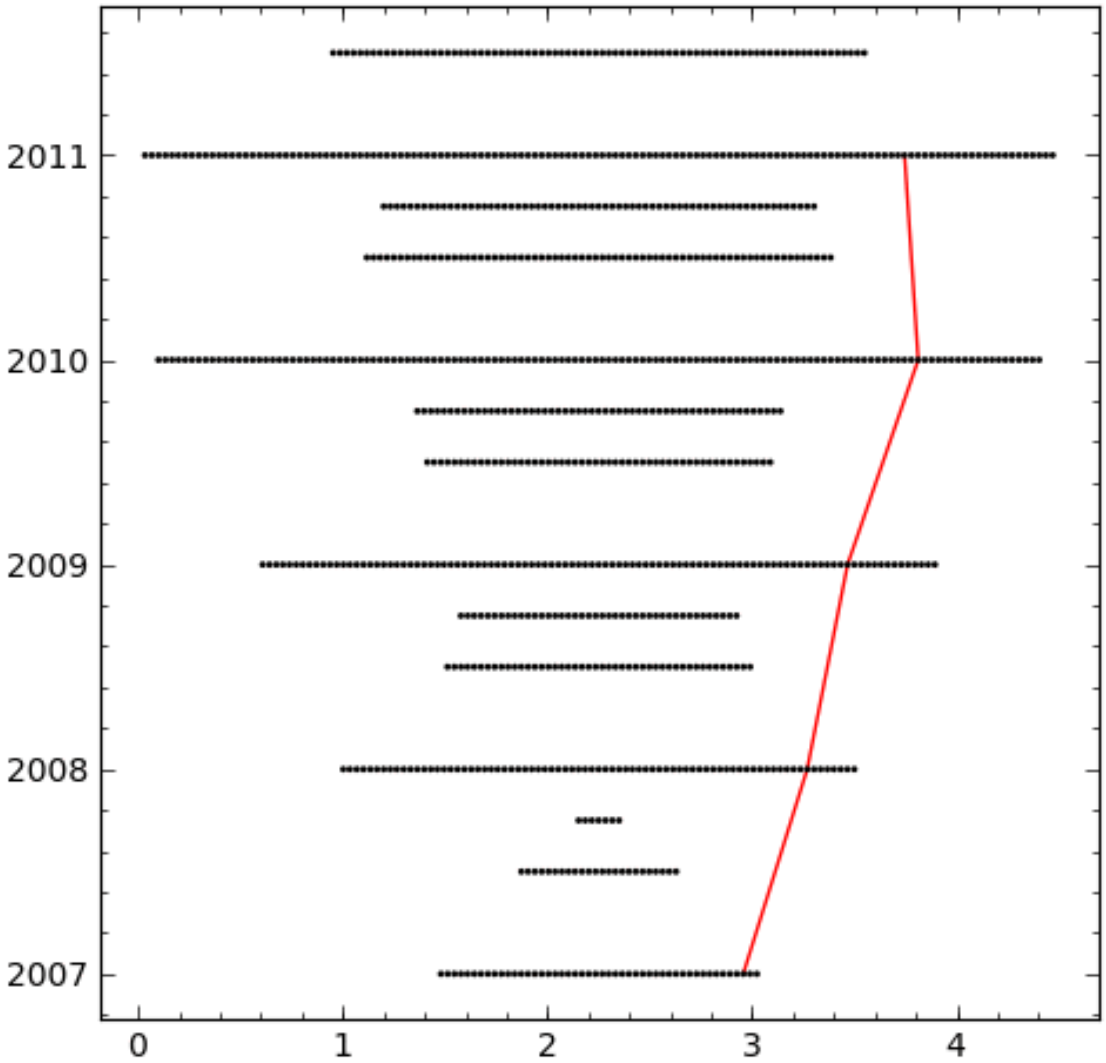
39 Connected Components (sub-pedigrees) in Pedigree Survey 2007-2011



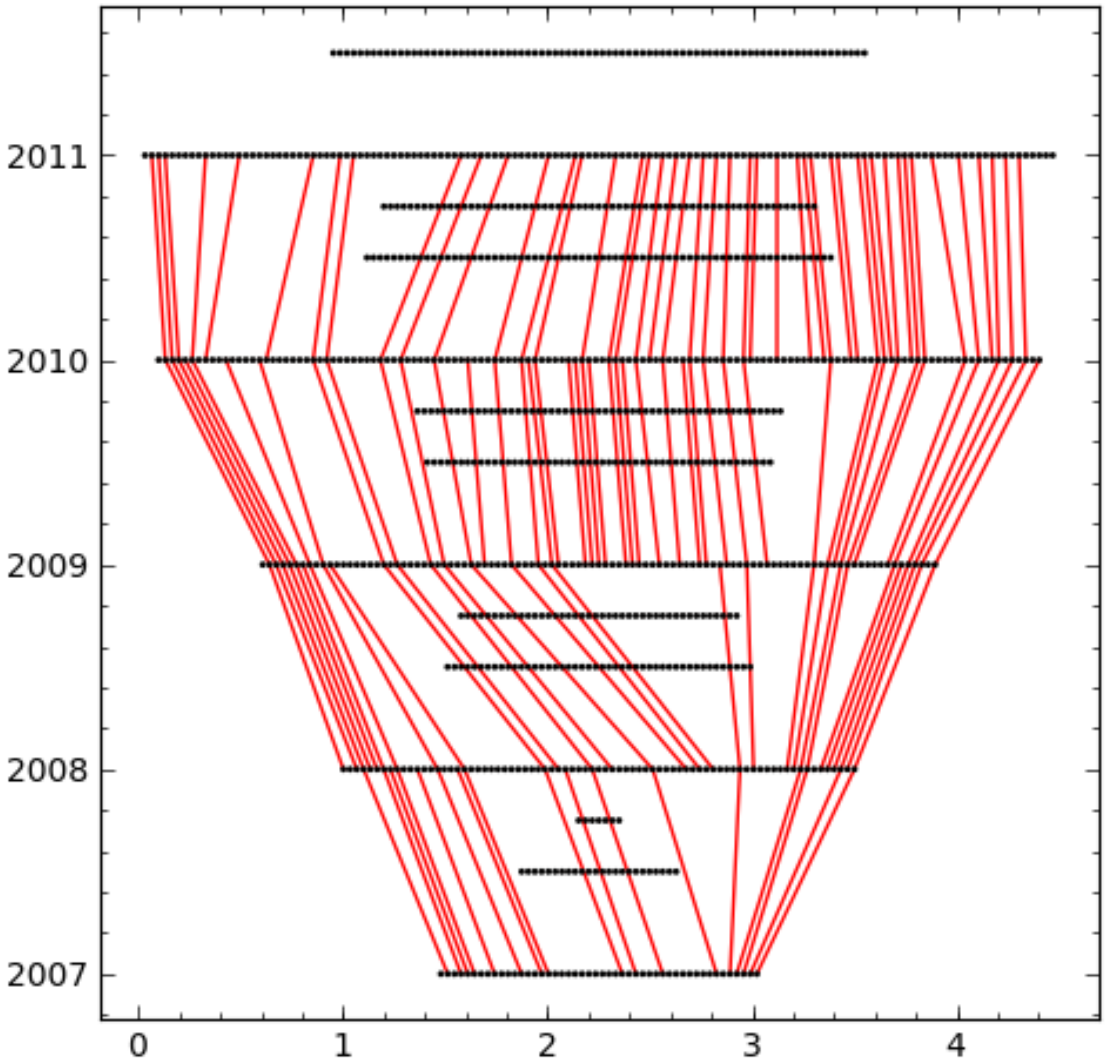
All 39 Connected Components (sub-pedigrees) in Pedigree Survey 2007-2011



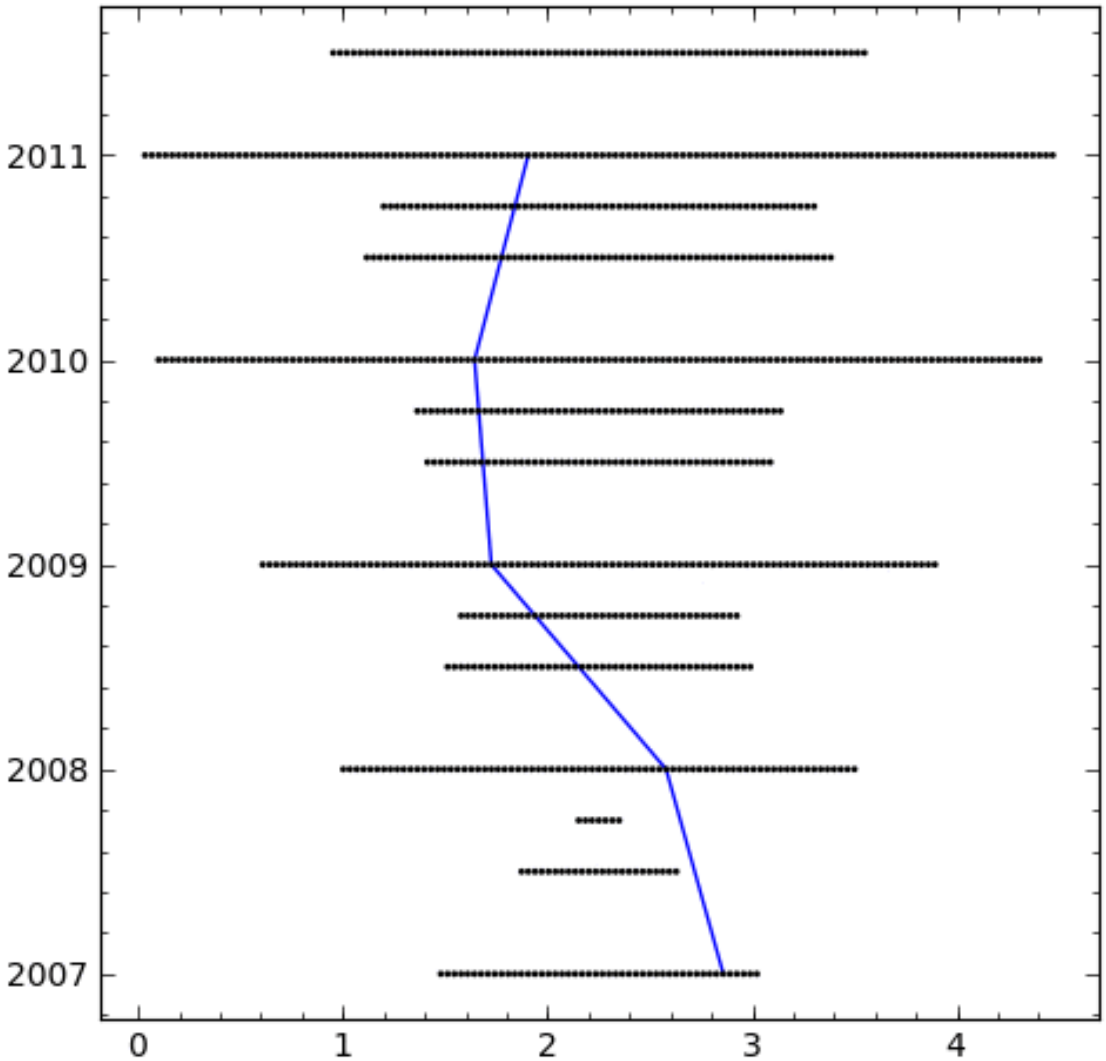
111 Maternal Life-Line Components in Pedigree Survey 2007-2011



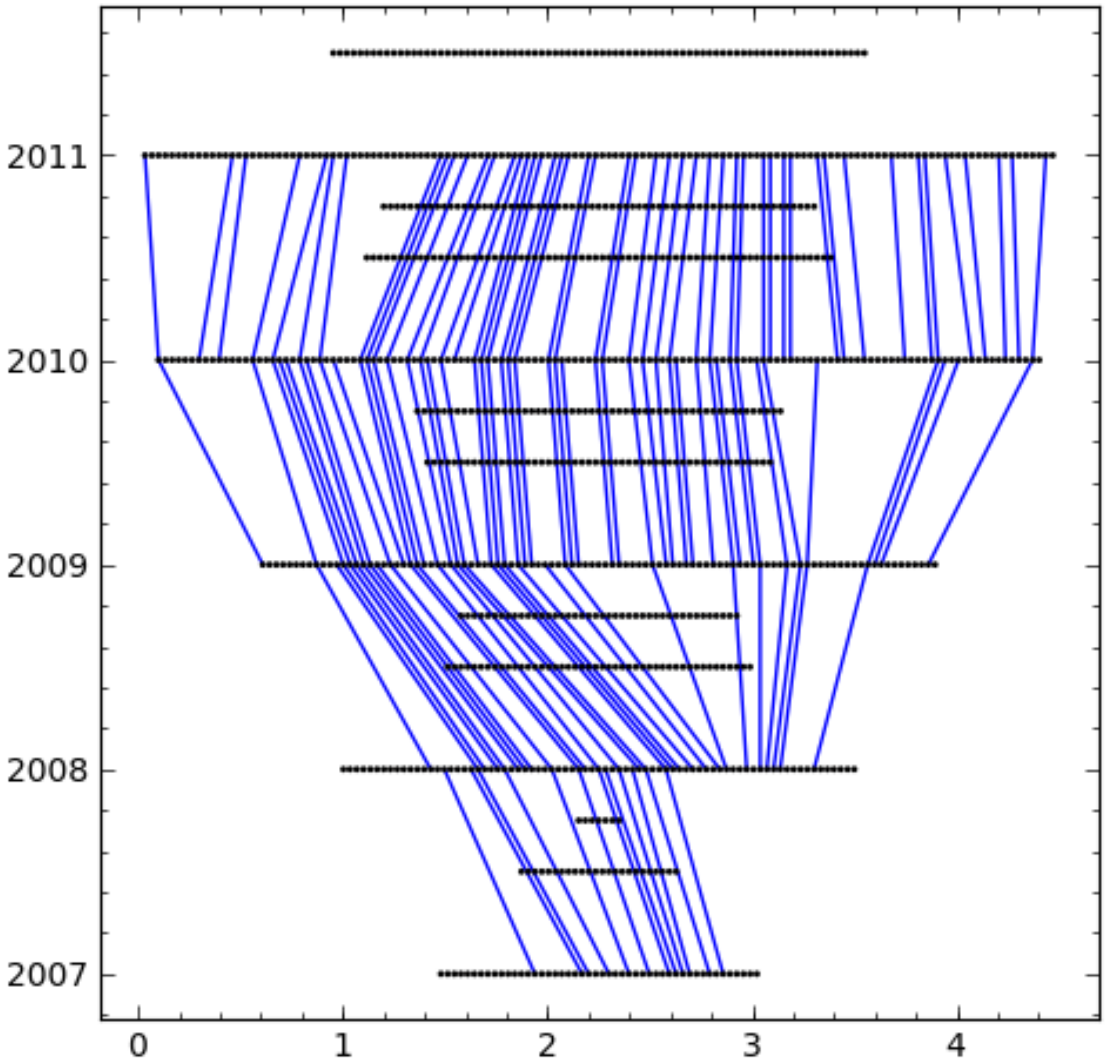
Life-Lines of all 107 Mothers in Pedigree Survey 2007-2011



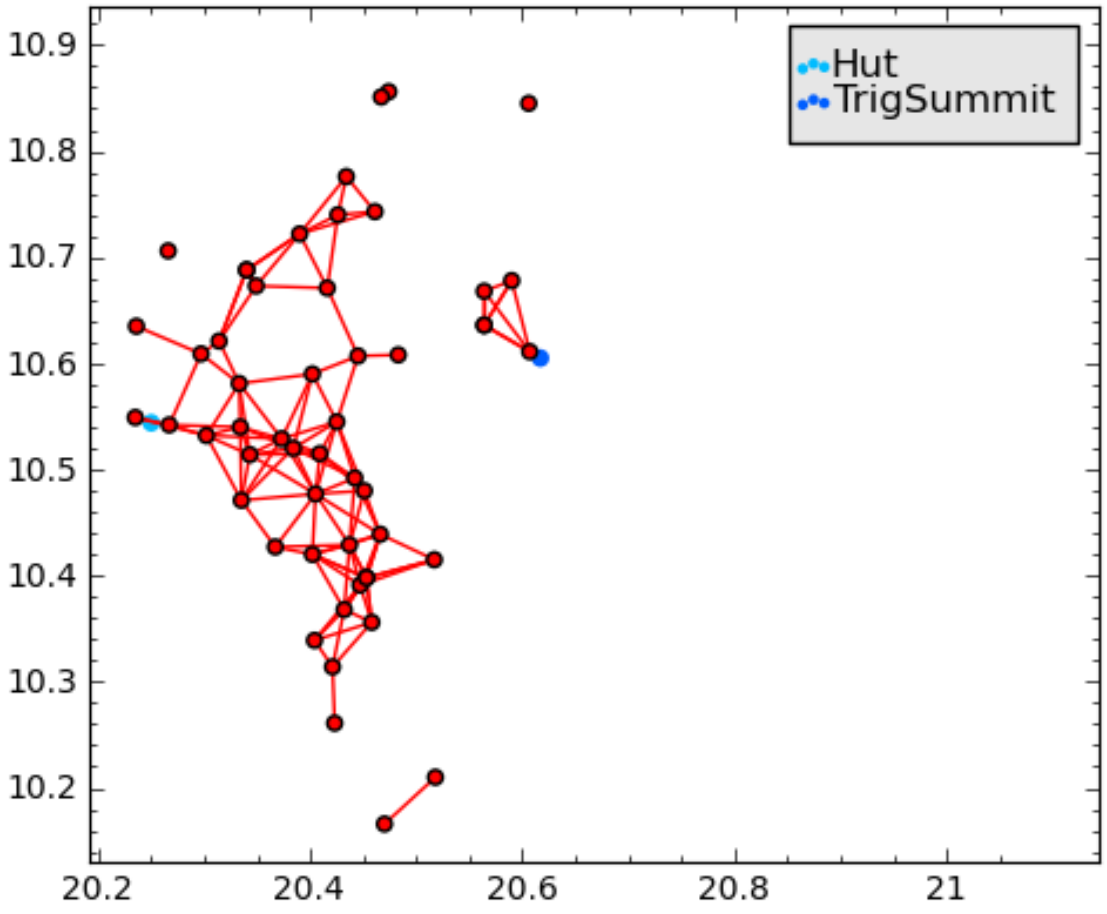
117 Paternal Life-Line Components in Pedigree Survey 2007-2011



Life-Lines of all 113 Fathers in Pedigree Survey 2007-2011



Male Territory Graphs by year



2009 (eye-balled by a ball graph)

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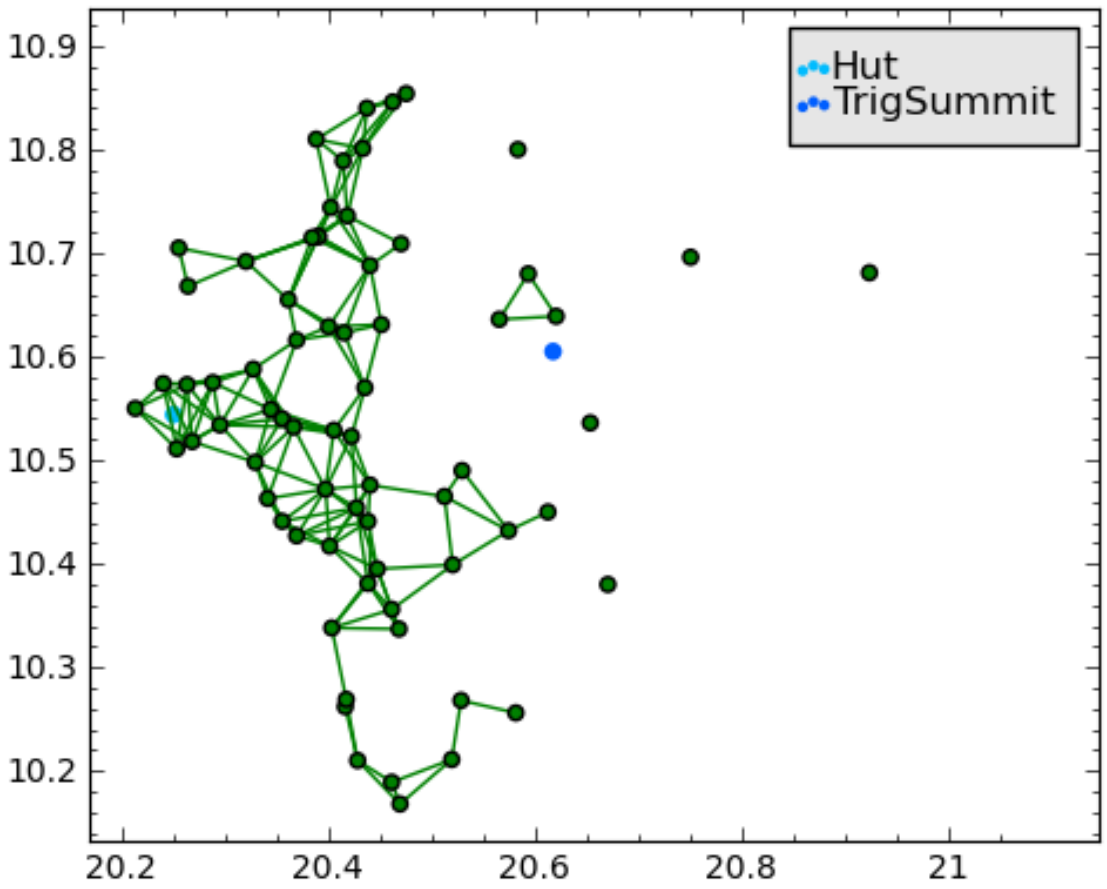

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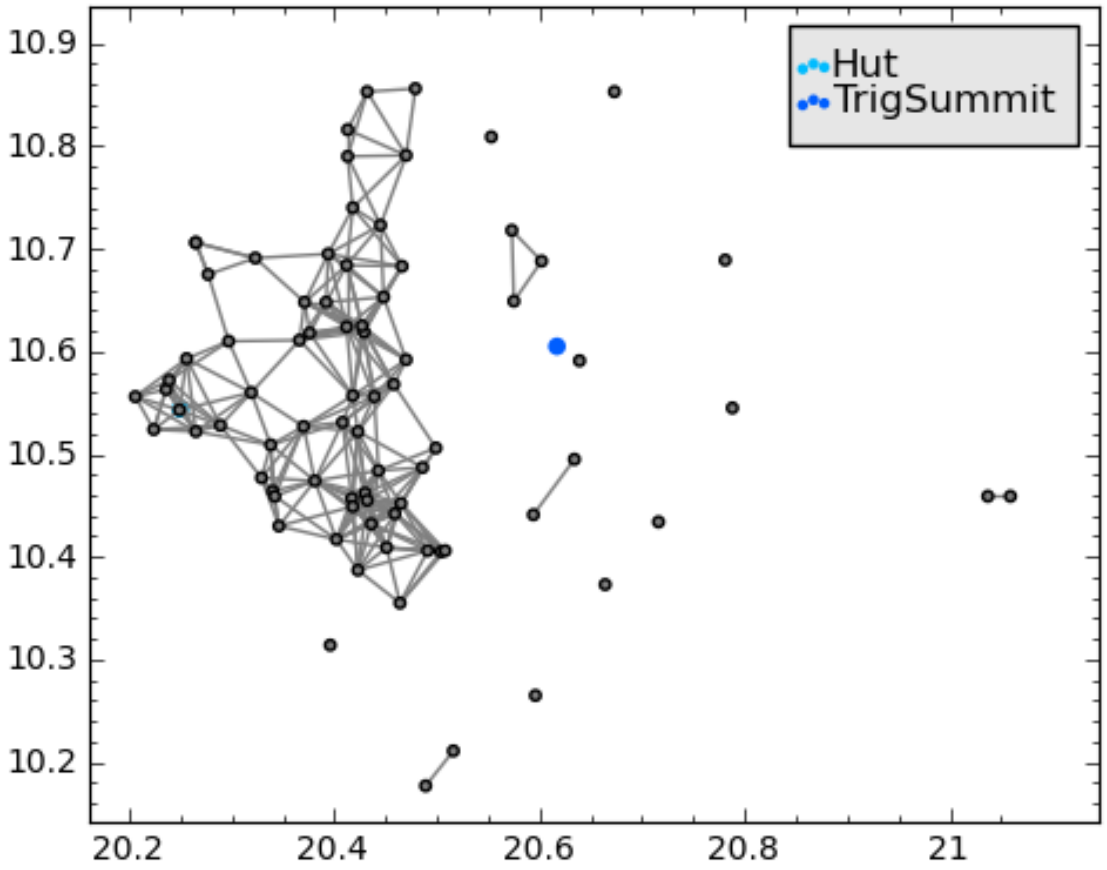
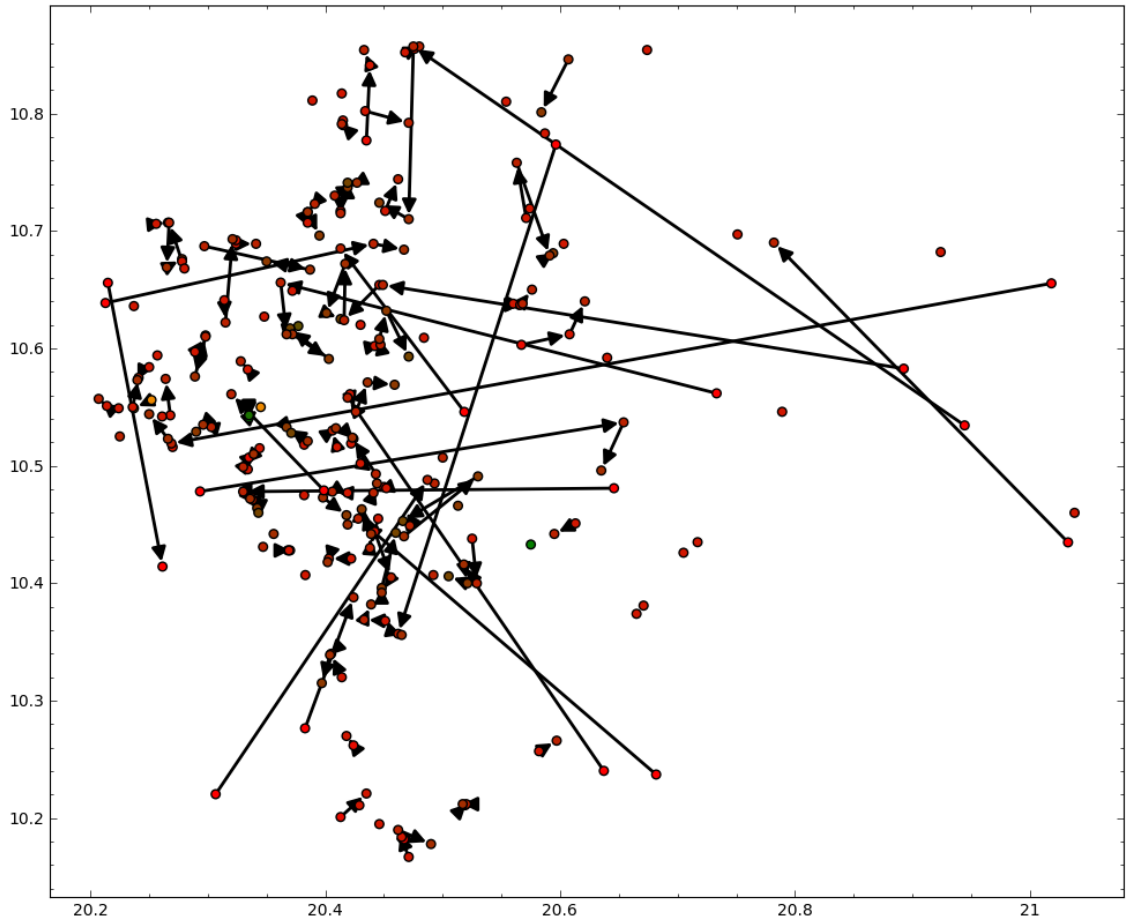


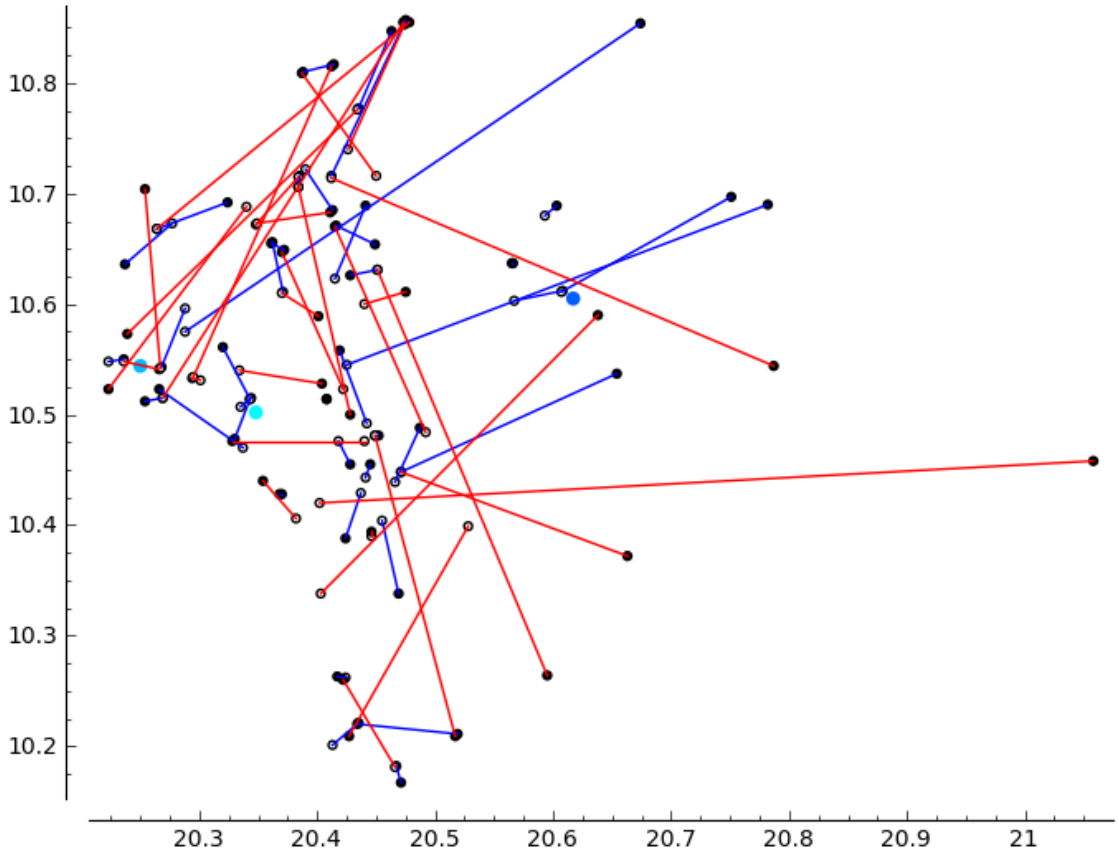
2011 (eye-balled by a ball graph)

Male Territorial Dynamics – yearly nest site relocation



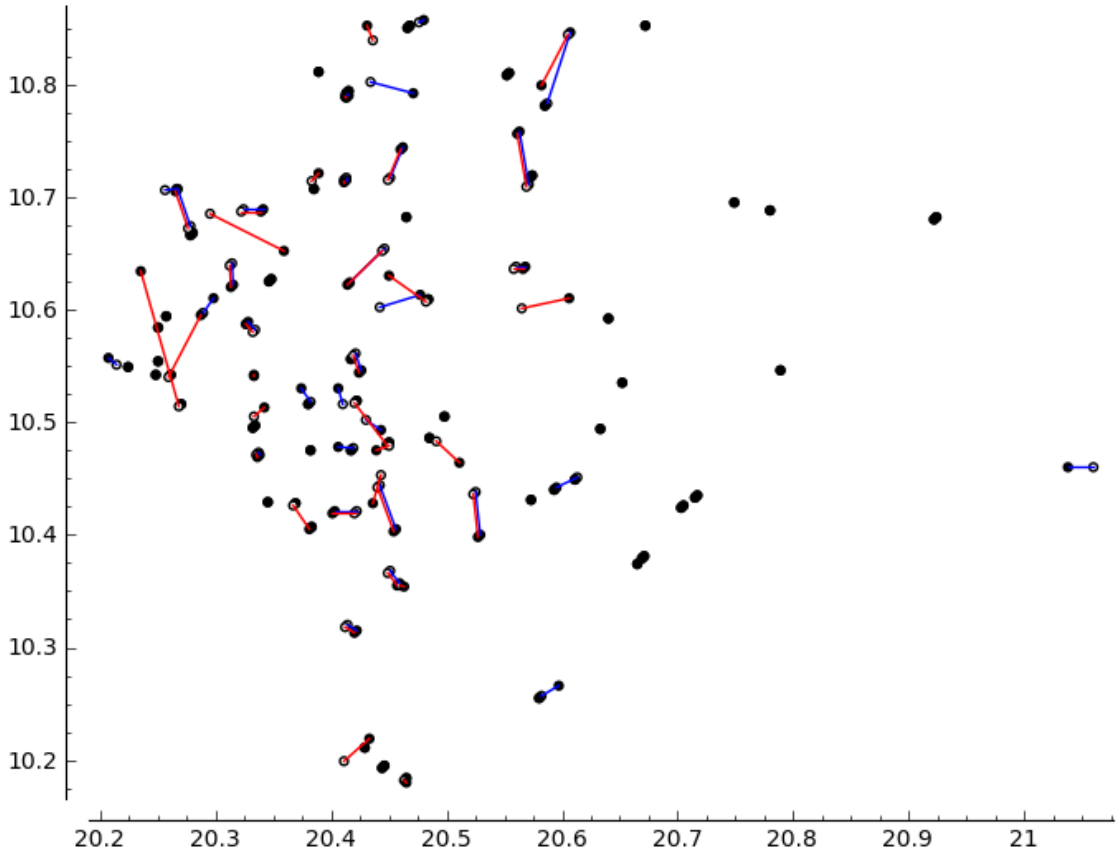
Male / Female yearly nest to nest distance

sex-specific distance between home nest and first nest



Male / Female yearly nest to nest distance

sex-specific distance between nest at age ≥ 1 and next nest



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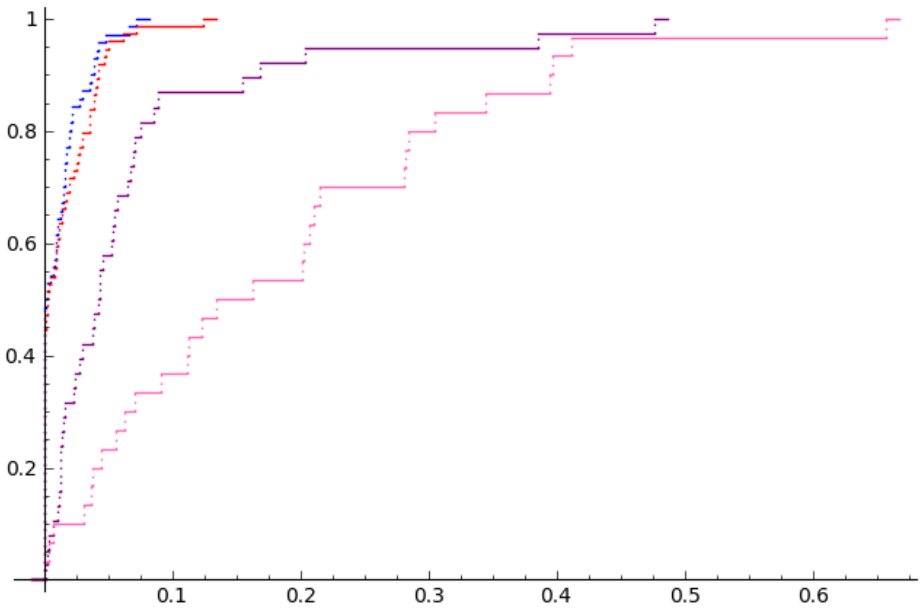
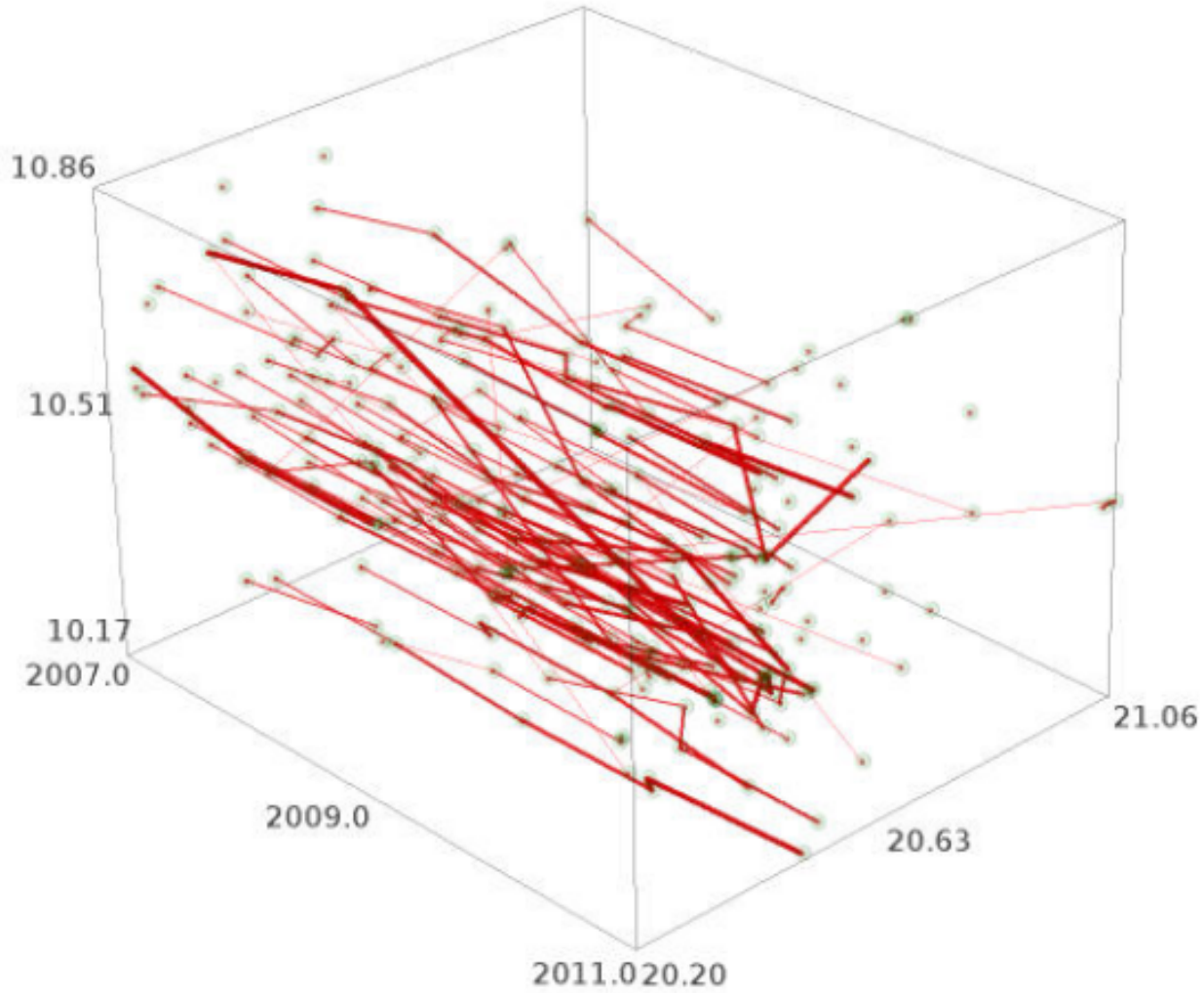


- Permutation Test to Reject H_0 : male dist = female dist (10^5 MC samples)
- Strongly reject H_0 for home to first nest (pv = 0.00025)
- Fail to reject H_0 for nest at age ≥ 1 to next nest (pv = 0.14)

male / female distance from home nest to first nest

male / female distance from nest at age ≥ 1 to next nest

Need Models of Spatio-temporal Population Pedigrees



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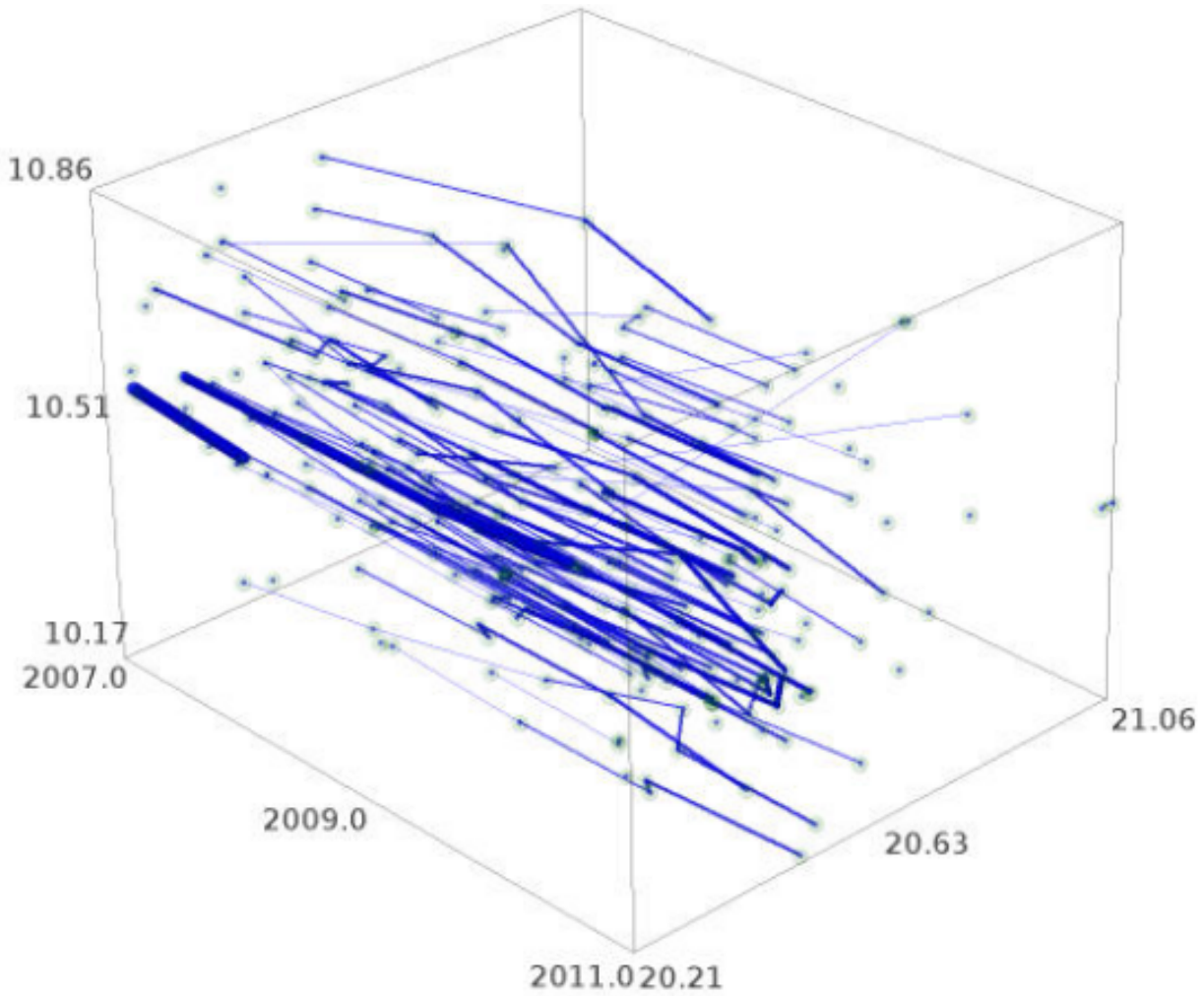

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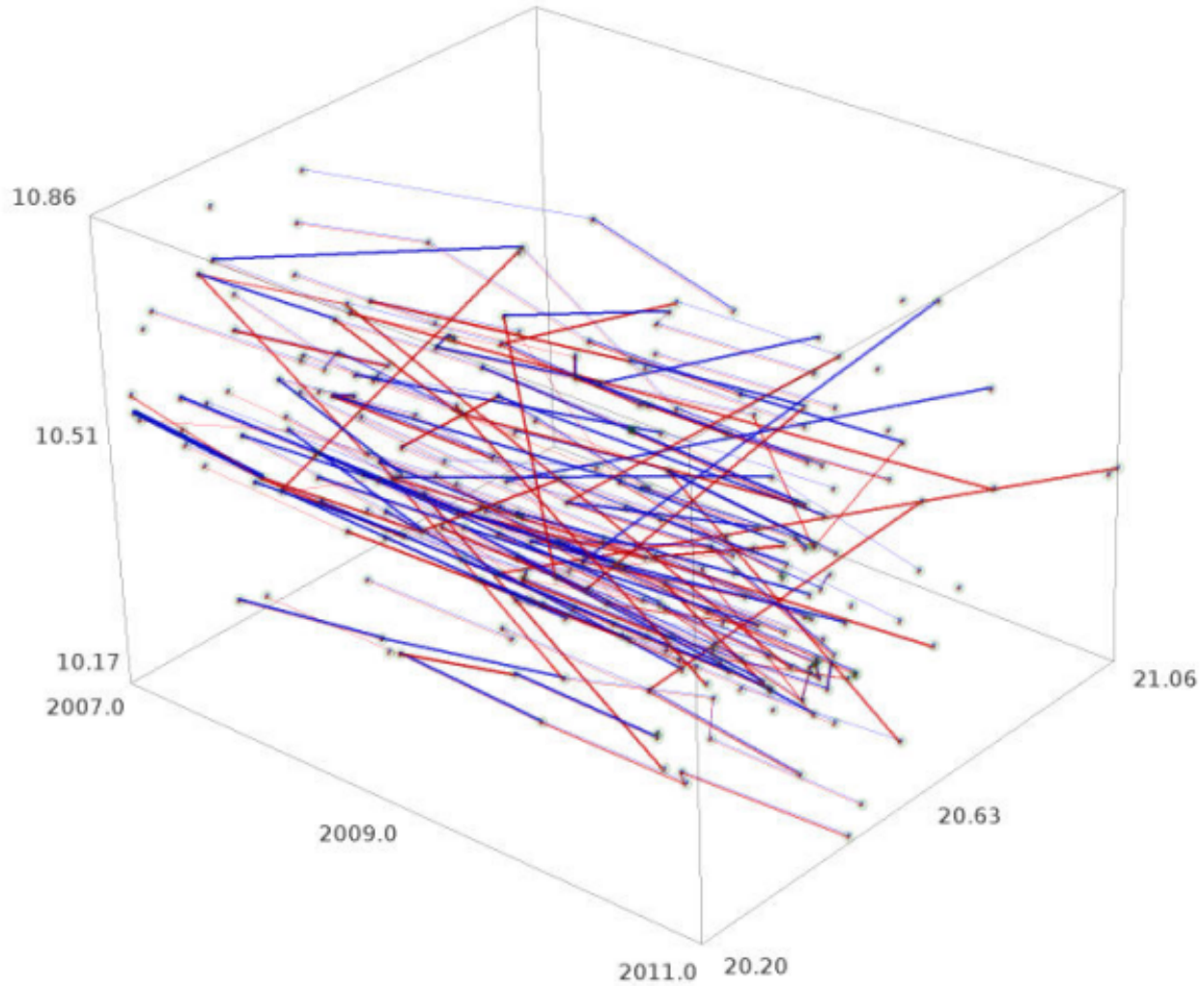

Conclusions - Part II

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- PLAN: continue to work on Part 2 next year during my visit to CMAP in 2013

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- The effect of such assumptions on extinction probability computations in PVA is the natural judge
- Besides possibly robustifying PVA using realistic models of pedigree processes we believe such models will pave the way for the fusion of behavioural ecology and evolutionary genetics
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Thank you!