Paternity and population genetics of the lobster in Cornwall

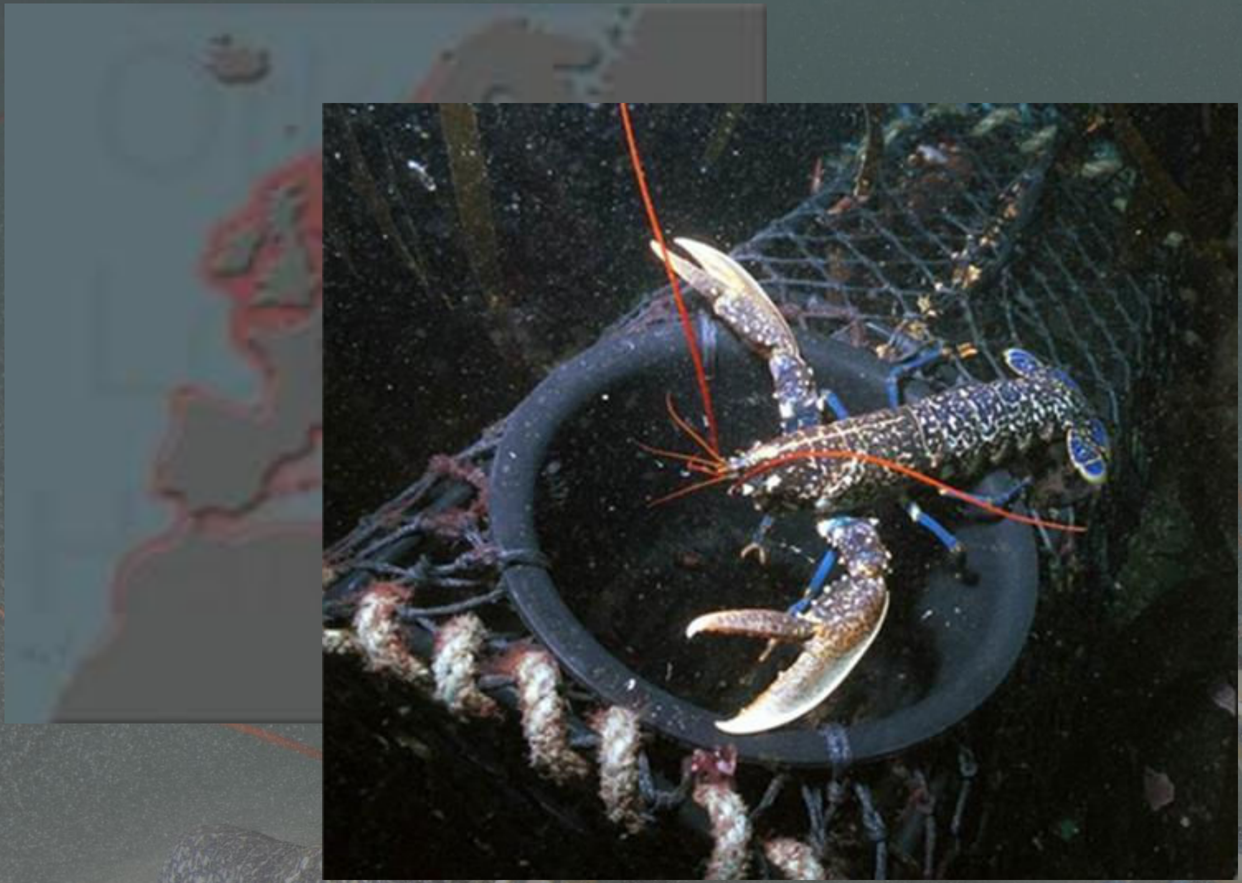

Charlie Ellis, PhD Student

- University of Exeter collaborating with the National Lobster Hatchery, Padstow
- Stock enhancement of the European lobster, *Homarus gammarus*

Overview

- Rationale
- Microsatellites
- Paternity
- Population structure
- Implications

- Coastal NE Atlantic range, including Mediterranean



- Extensive trap fishery
  - \- >75% of landings UK/Ireland
  - \- 370 Cornish vessels; mostly <10m
  - \- Large continental export value
  - \- Scandinavian stock collapse

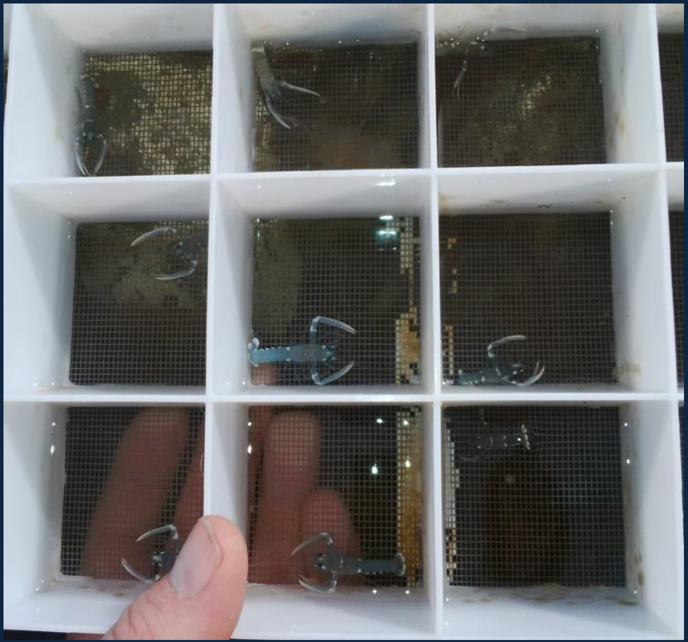
- Genera relatively well studied, but mostly from *H. americanus* and still considerable understanding gaps

- Need knowledge of molecular, reproductive and population ecology to conserve species and fisheries

Hatchery stocking and genetics

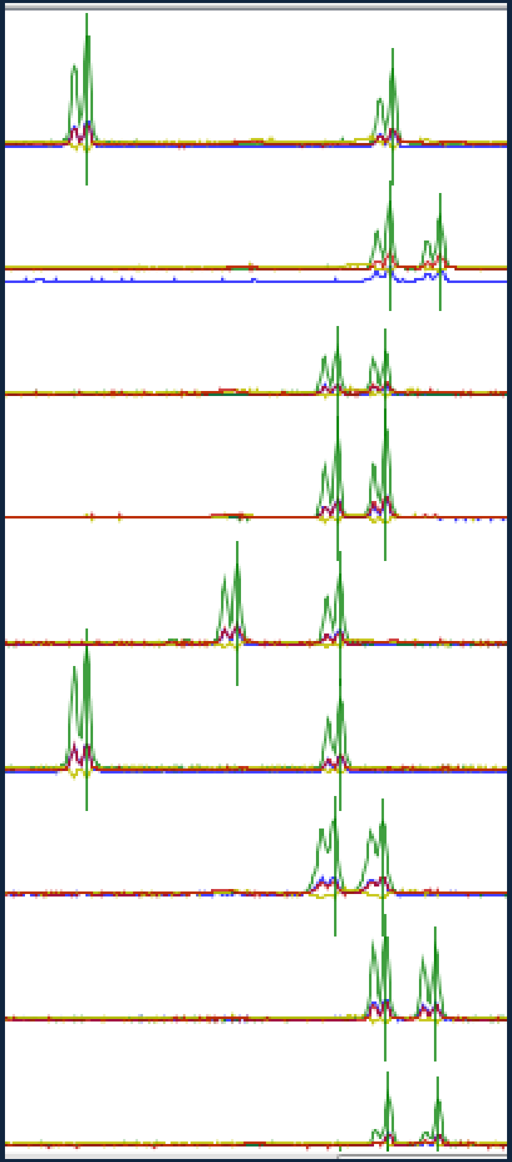
- Release of hatchery-reared juveniles to supplement or restore natural fisheries
- Overcomes recruitment bottleneck of planktonic larval phase in captivity
- Undertaken in UK, Ireland, Norway, Germany, France, Spain and Italy
- National Lobster Hatchery in Cornwall released 60K juveniles in 2014

- Increased awareness of need for genetic management in stocking wild populations
- Negative impacts in other species (e.g. inbreeding depression, domestic selection, loss of diversity/adaptation/structure/fitness)
- Genetic tools
  - > risk assessment / mitigation
  - > reference for genetic impact
  - > tagging via parentage
  - > ecology and management



Microsatellite DNA genotyping

- Variable regions of DNA
- Bi-parental inheritance
- Sections vary in length
- Can be amplified with fluorescent tags to measure
- Powerful tool to discriminate individuals and populations when combined



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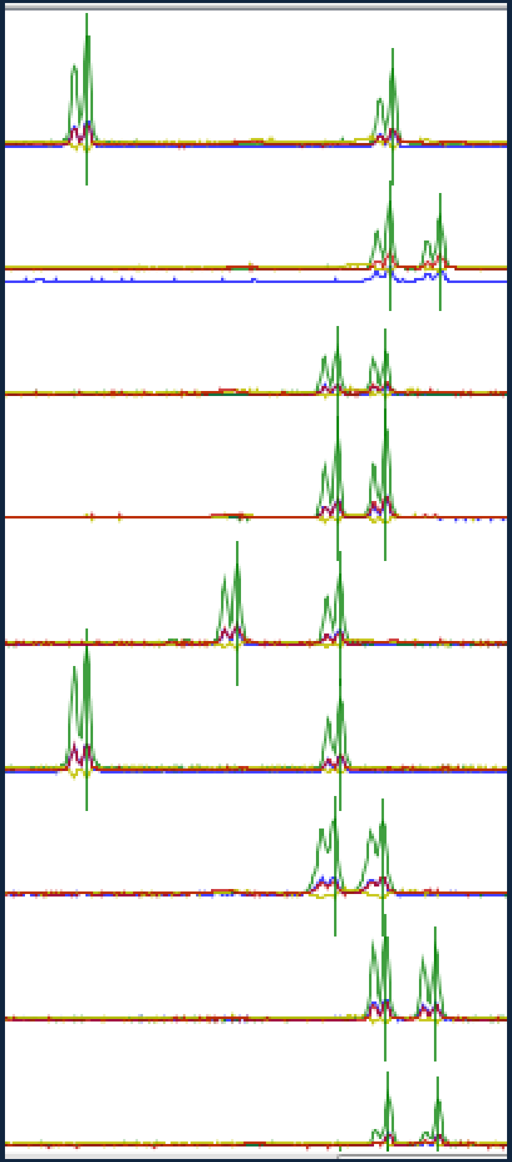

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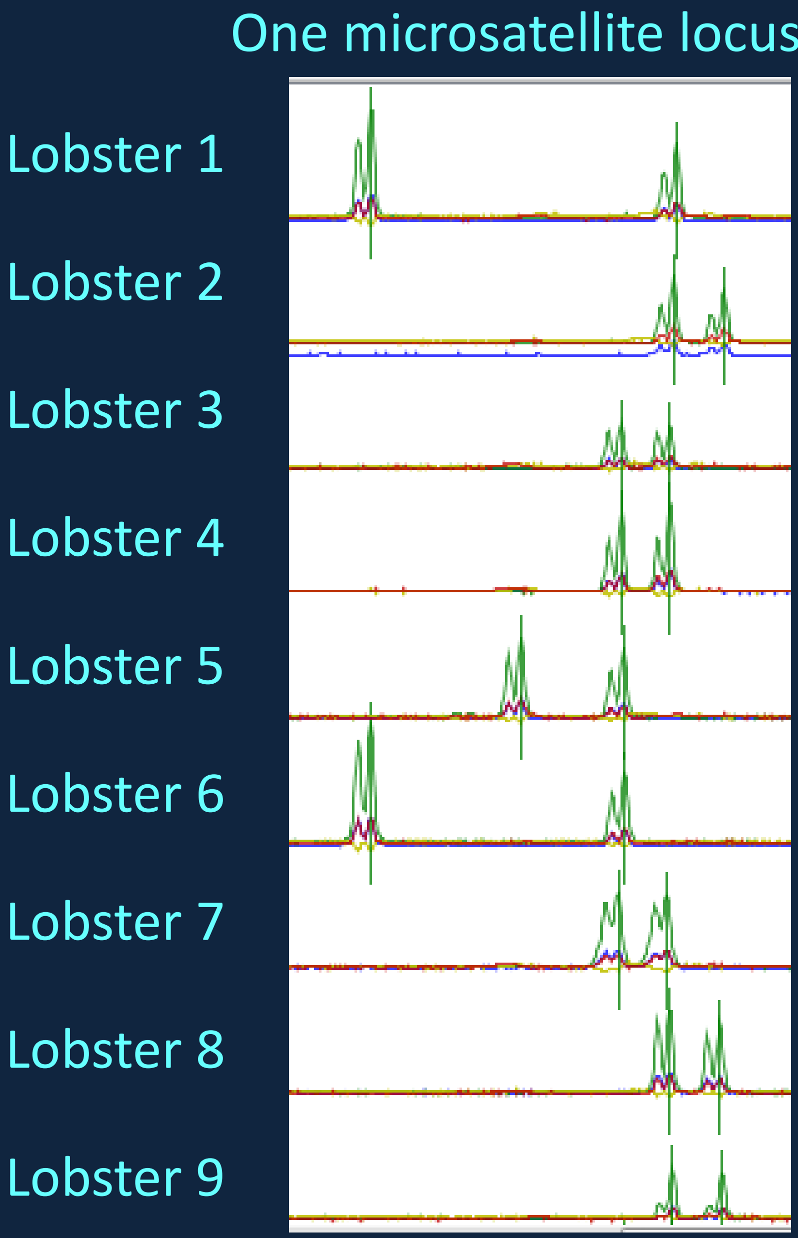
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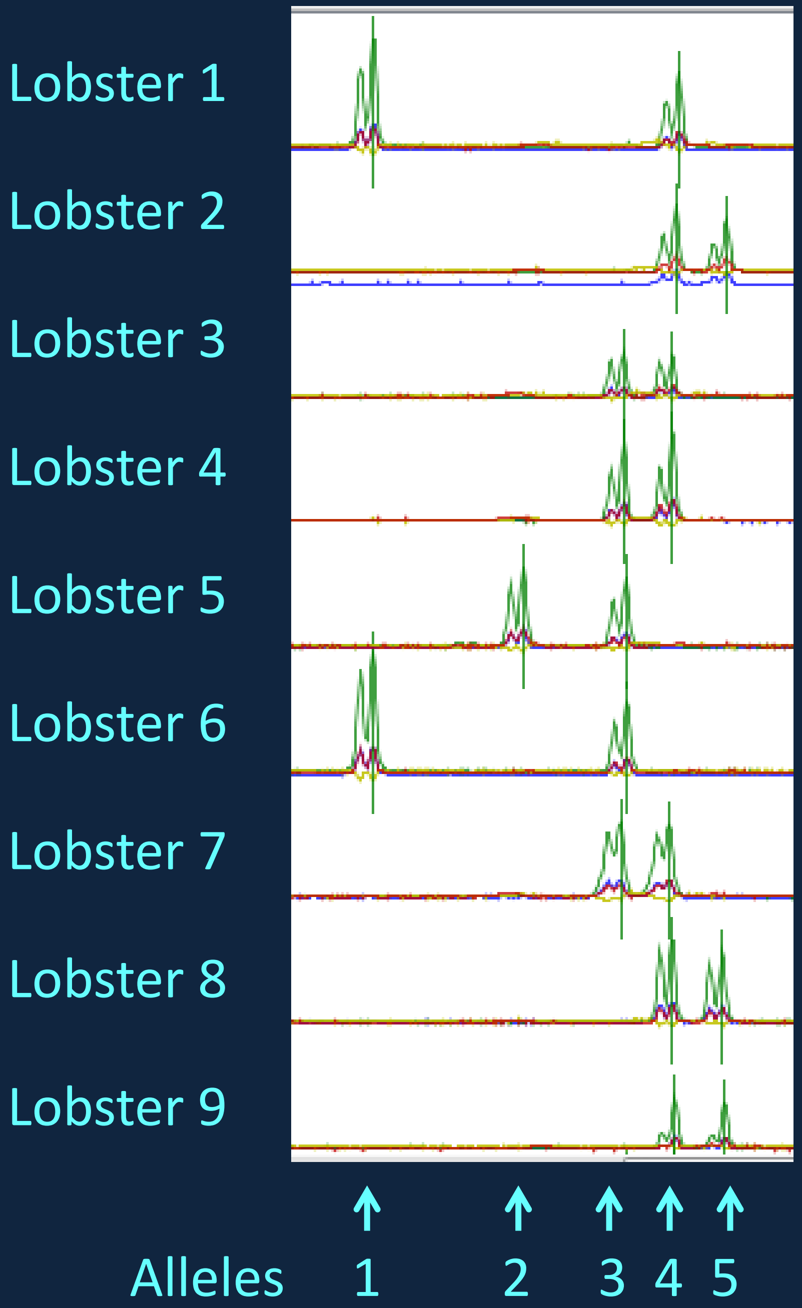

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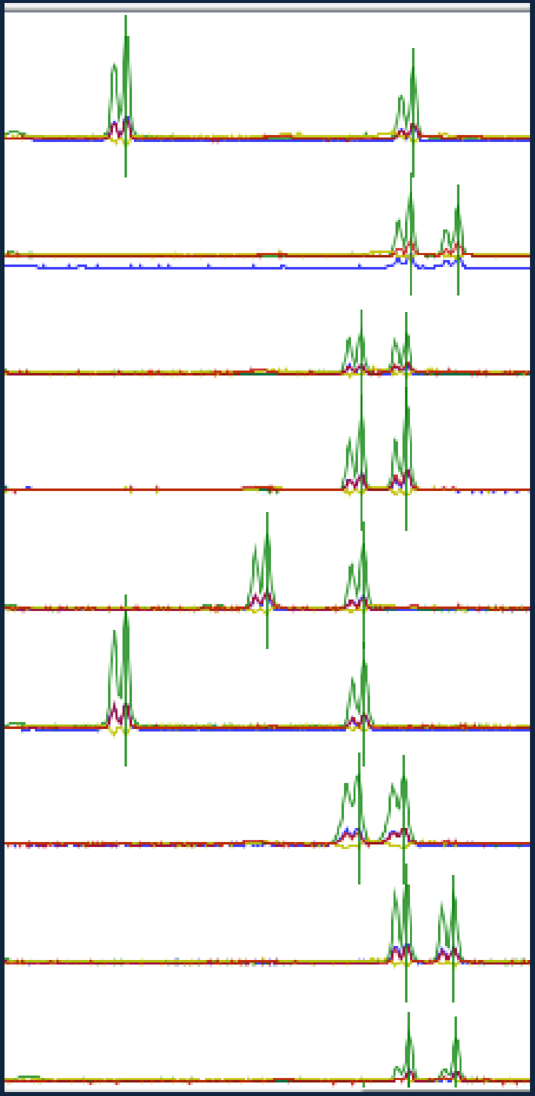
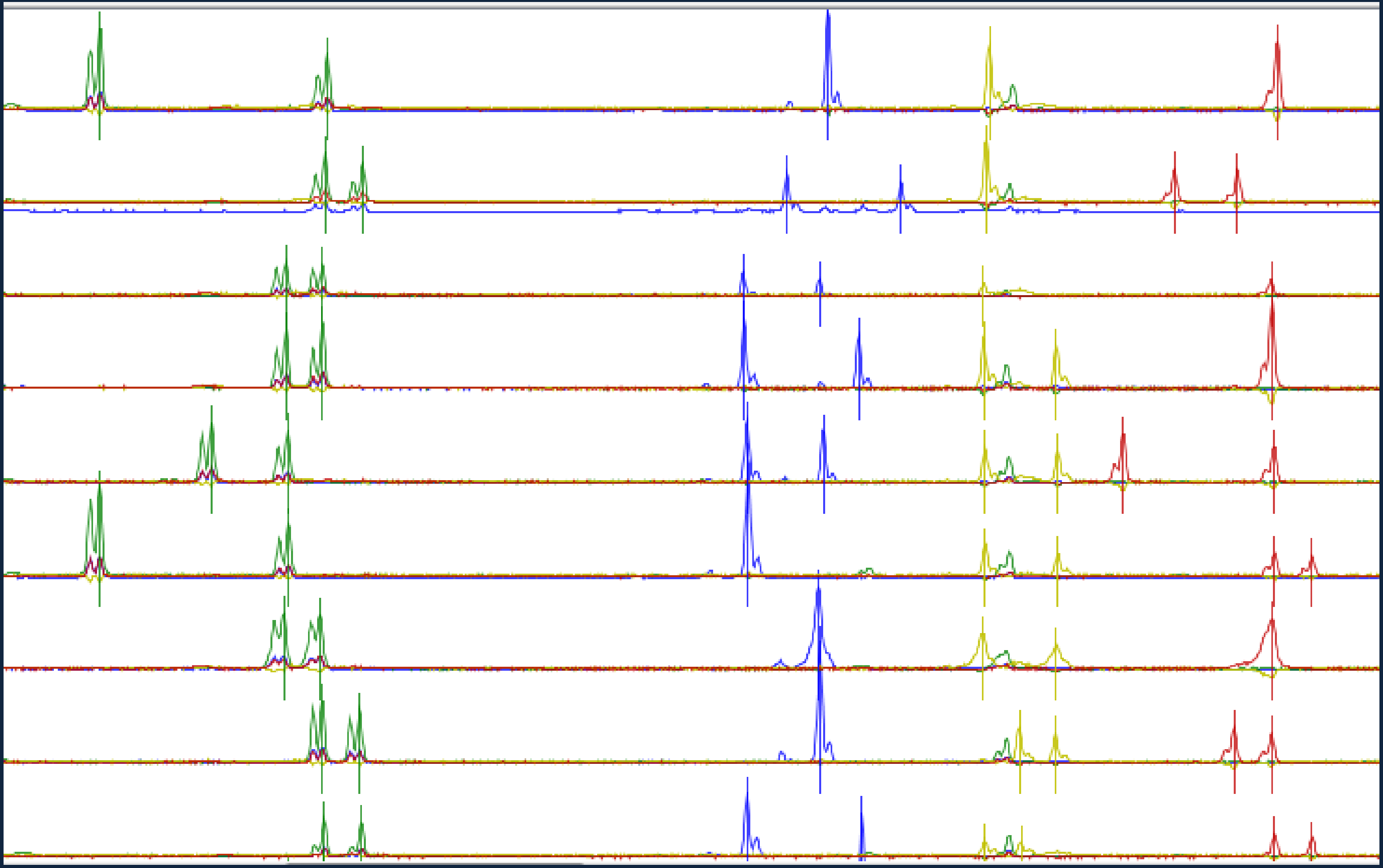
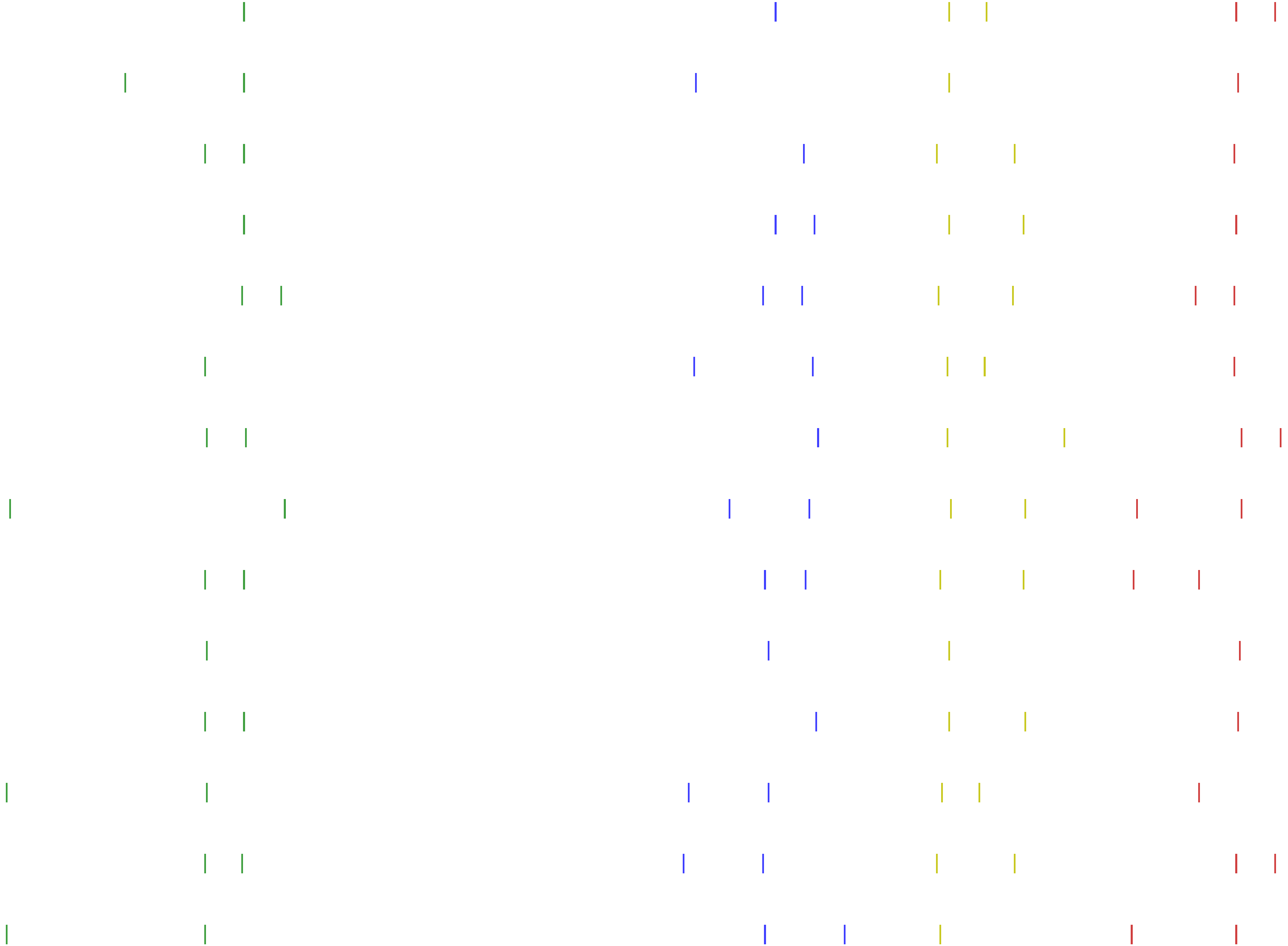


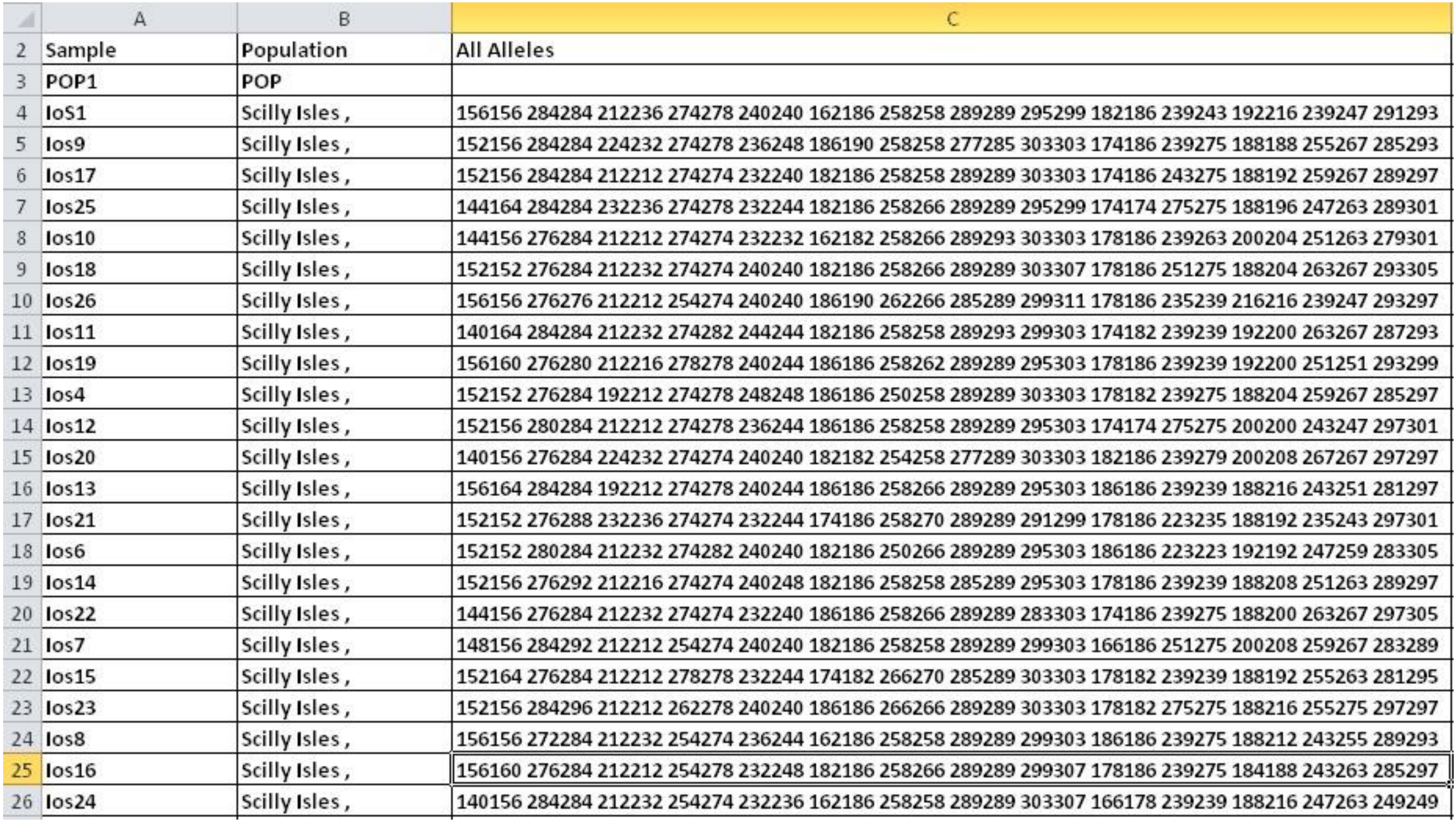
- Genotype at one locus isn’t very insightful

- More loci = greater resolution

- Powerful tool to discriminate individuals and populations







	A	B	C
2	Sample	Population	All Alleles
3	POP1	POP	
4	IoS1	Scilly Isles ,	156156 284284 212236 274278 240240 162186 258258 289289 295299 182186 239243 192216 239247 291293
5	Ios9	Scilly Isles ,	152156 284284 224232 274278 236248 186190 258258 277285 303303 174186 239275 188188 255267 285293
6	Ios17	Scilly Isles ,	152156 284284 212212 274274 232240 182186 258258 289289 303303 174186 243275 188192 259267 289297
7	Ios25	Scilly Isles ,	144164 284284 232236 274278 232244 182186 258266 289289 295299 174174 275275 188196 247263 289301
8	Ios10	Scilly Isles ,	144156 276284 212212 274274 232232 162182 258266 289293 303303 178186 239263 200204 251263 279301
9	Ios18	Scilly Isles ,	152152 276284 212232 274274 240240 182186 258266 289289 303307 178186 251275 188204 263267 293305
10	Ios26	Scilly Isles ,	156156 276276 212212 254274 240240 186190 262266 285289 299311 178186 235239 216216 239247 293297
11	Ios11	Scilly Isles ,	140164 284284 212232 274282 244244 182186 258258 289293 299303 174182 239239 192200 263267 287293
12	Ios19	Scilly Isles ,	156160 276280 212216 278278 240244 186186 258262 289289 295303 178186 239239 192200 251251 293299
13	Ios4	Scilly Isles ,	152152 276284 192212 274278 248248 186186 250258 289289 303303 178182 239275 188204 259267 285297
14	Ios12	Scilly Isles ,	152156 280284 212212 274278 236244 186186 258258 289289 295303 174174 275275 200200 243247 297301
15	Ios20	Scilly Isles ,	140156 276284 224232 274274 240240 182182 254258 277289 303303 182186 239279 200208 267267 297297
16	Ios13	Scilly Isles ,	156164 284284 192212 274278 240244 186186 258266 289289 295303 186186 239239 188216 243251 281297
17	Ios21	Scilly Isles ,	152152 276288 232236 274274 232244 174186 258270 289289 291299 178186 223235 188192 235243 297301
18	Ios6	Scilly Isles ,	152152 280284 212232 274282 240240 182186 250266 289289 295303 186186 223223 192192 247259 283305
19	Ios14	Scilly Isles ,	152156 276292 212216 274274 240248 182186 258258 285289 295303 178186 239239 188208 251263 289297
20	Ios22	Scilly Isles ,	144156 276284 212232 274274 232240 186186 258266 289289 283303 174186 239275 188200 263267 297305
21	Ios7	Scilly Isles ,	148156 284292 212212 254274 240240 182186 258258 289289 299303 166186 251275 200208 259267 283289
22	Ios15	Scilly Isles ,	152164 276284 212212 278278 232244 174182 266270 285289 303303 178182 239239 188192 255263 281295
23	Ios23	Scilly Isles ,	152156 284296 212212 262278 240240 186186 266266 289289 303303 178182 275275 188216 255275 297297
24	Ios8	Scilly Isles ,	156156 272284 212232 254274 236244 162186 258258 289289 299303 186186 239275 188212 243255 289293
25	Ios16	Scilly Isles ,	156160 276284 212212 254278 232248 182186 258266 289289 299307 178186 239275 184188 243263 285297
26	Ios24	Scilly Isles ,	140156 284284 212232 254274 232236 162186 258258 289289 303307 166178 239239 188216 247263 249249

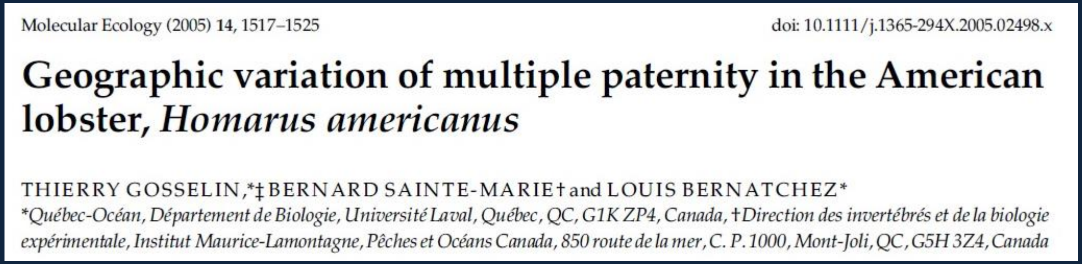
= Multi-locus genotypes

Dynamic paternity in lobsters

♂ = 1

or

♂ = >1



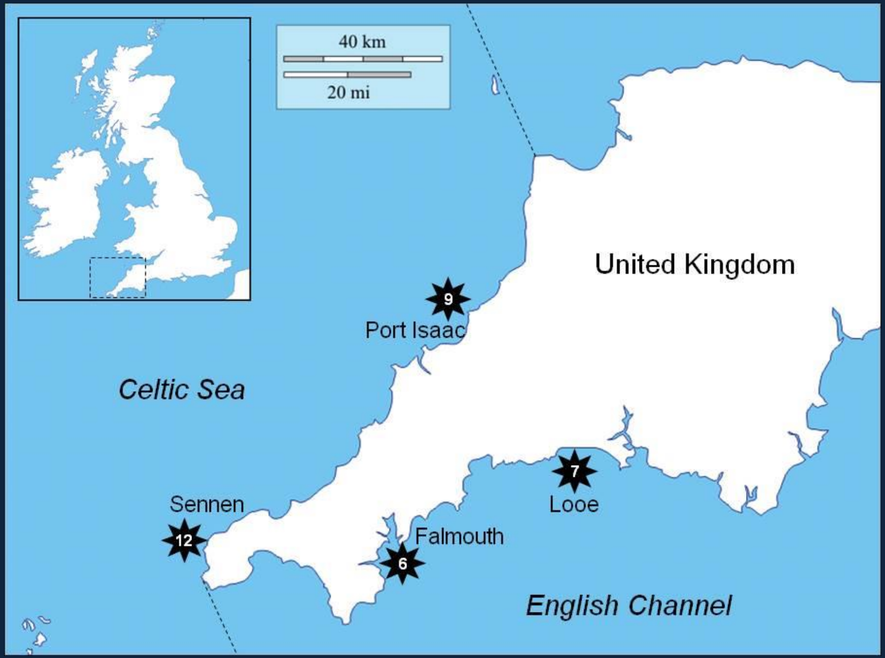
Molecular Ecology (2005) 14, 1517–1525 doi: 10.1111/j.1365-294X.2005.02498.x

Geographic variation of multiple paternity in the American lobster, *Homarus americanus*

THIERRY GOSSELIN,*‡ BERNARD SAINTE-MARIE† and LOUIS BERNATCHEZ*
**Québec-Océan, Département de Biologie, Université Laval, Québec, QC, G1K 7P4, Canada, †Direction des invertébrés et de la biologie expérimentale, Institut Maurice-Lamontagne, Pêches et Océans Canada, 850 route de la mer, C. P. 1000, Mont-Joli, QC, G5H 3Z4, Canada*

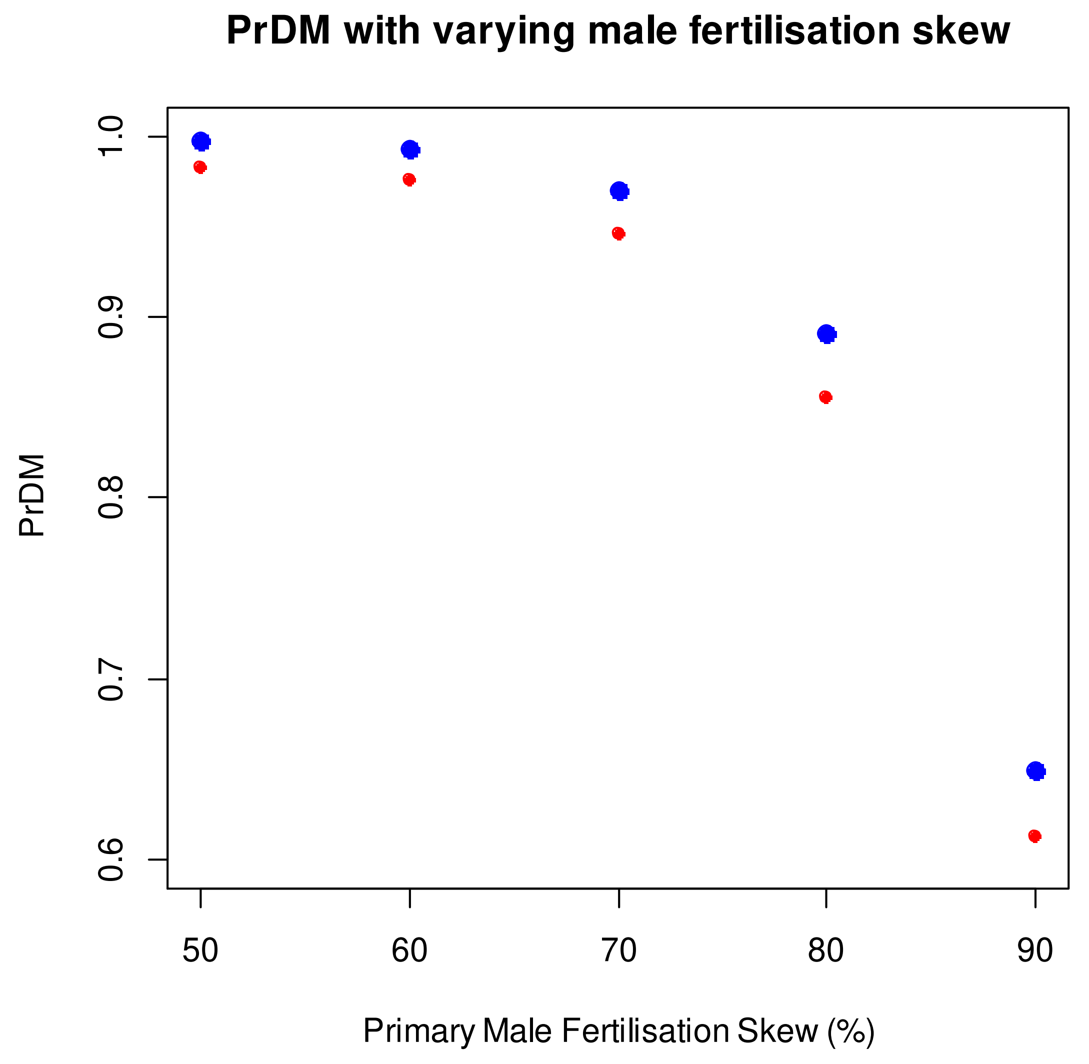
- ○ Single paternity is regular in *H. americanus*, but multiple paternity detected and exhibits spatial variation in frequency
- ○ Correlates to exploitation rate
- ○ Does overfishing cause sperm limitation or breakdown in male hierarchy?
- ○ Could paternity be a reference point?
- ○ Can sex-biased management work?

Paternity assessment



- Genotyping maternal and progeny tissues to reconstruct paternal contribution
- 34 females across two sites on each coast
- 10 eggs per female, spatially sampled
- Genotyped at 13 microsatellite loci

PrDM and fertilisation skew



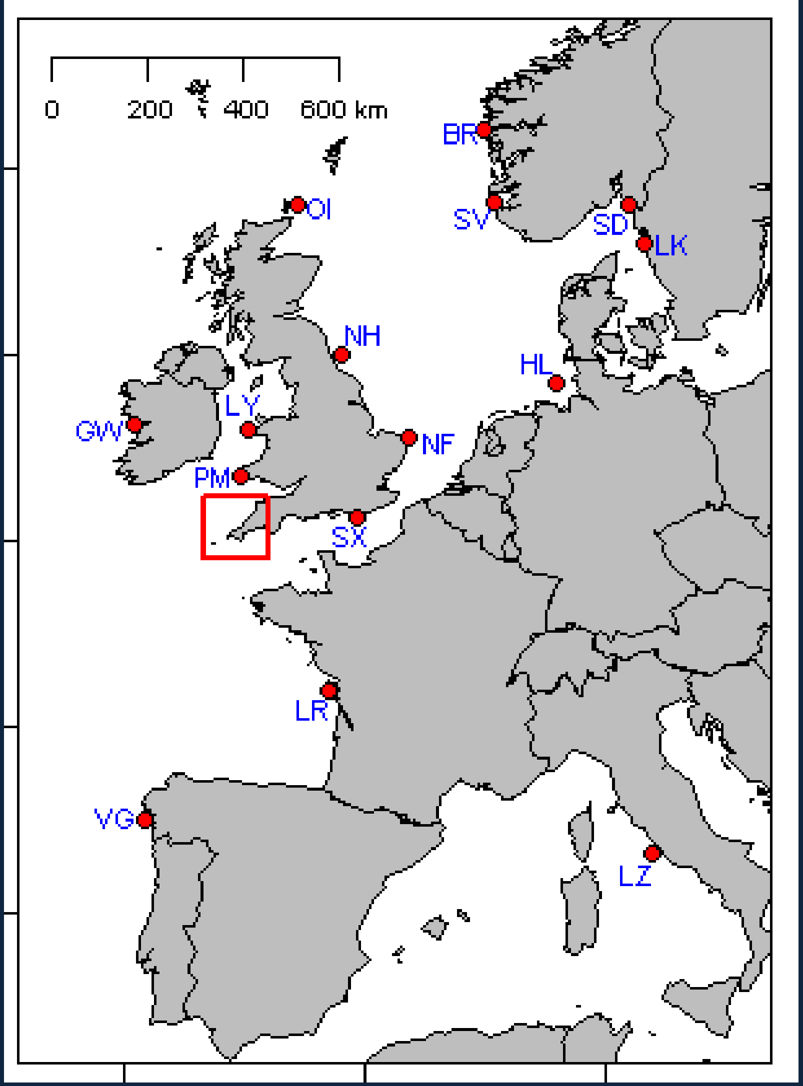
- PrDM diminished by skews of male fertilisation success
- PrDM
  >0.99 when ♂ 50:50
  >0.95 when ♂ 74:26
  =0.65 when ♂ 90:10
- Even at highest skew (90:10) and least frequent incidence (11%) in *H. americanus*, expect three occurrences of multiple paternity (with one missed)
- Not a big reduction in PrDM with only 3 most informative loci

Single paternity in Cornish lobsters

- For all 34 females, one paternal reconstruction explained all progeny
- 34 different males
- Reconstruction method conservative, but heterozygosity of males matched females, suggesting single paternal contributions not underestimated
- Multiple paternity likely to be absent, or rare with fertilisation highly skewed in favour of a single male
- Mechanism preserving ♂=1 is presumed to be monandrous mating, but post-copulatory processes too?
- Need to check other locations to test whether fishing pressure / demographic differences disrupt single paternity in *H. gammarus*

- Fine-scale – within Cornwall
- Broad-scale – across Europe
- Important application to spatial range of hatchery stocking

Population genetic structure



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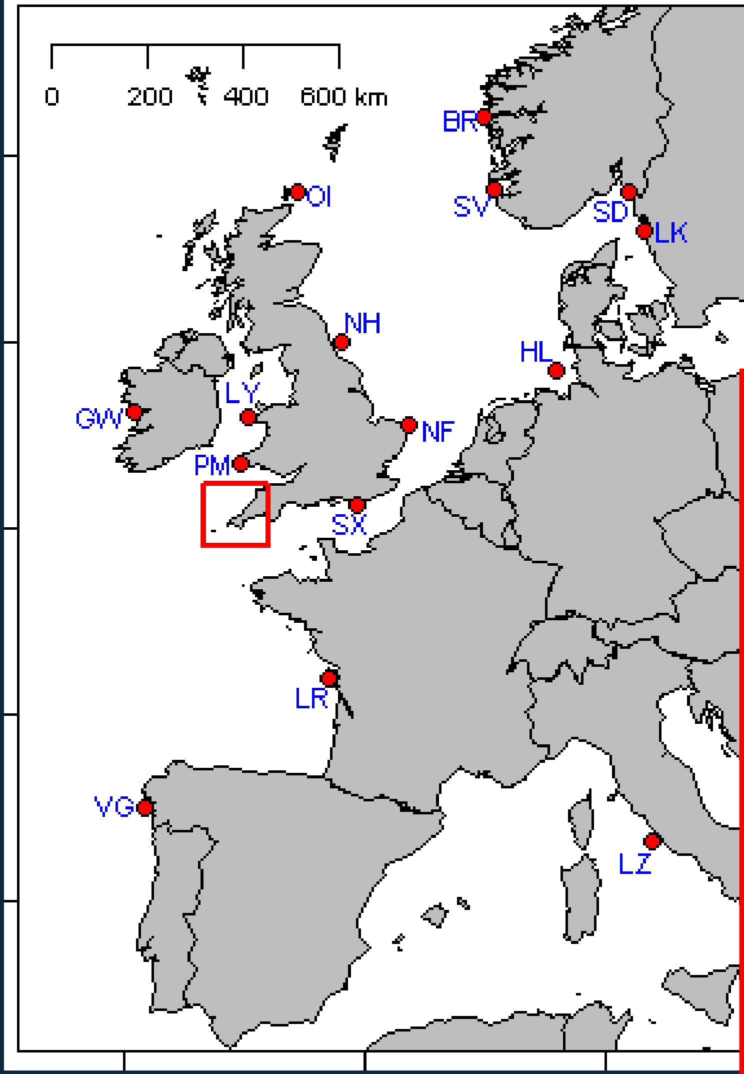
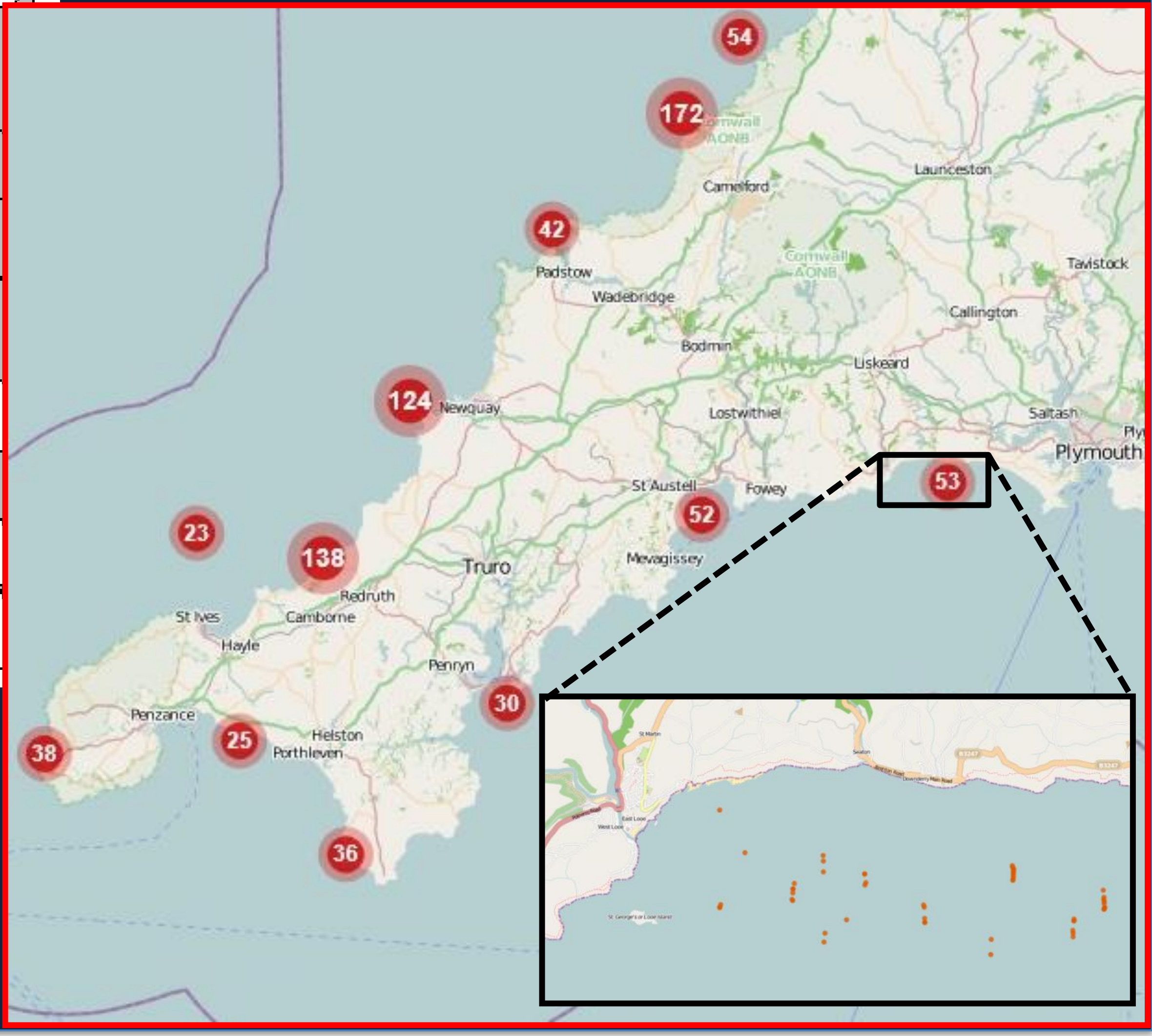
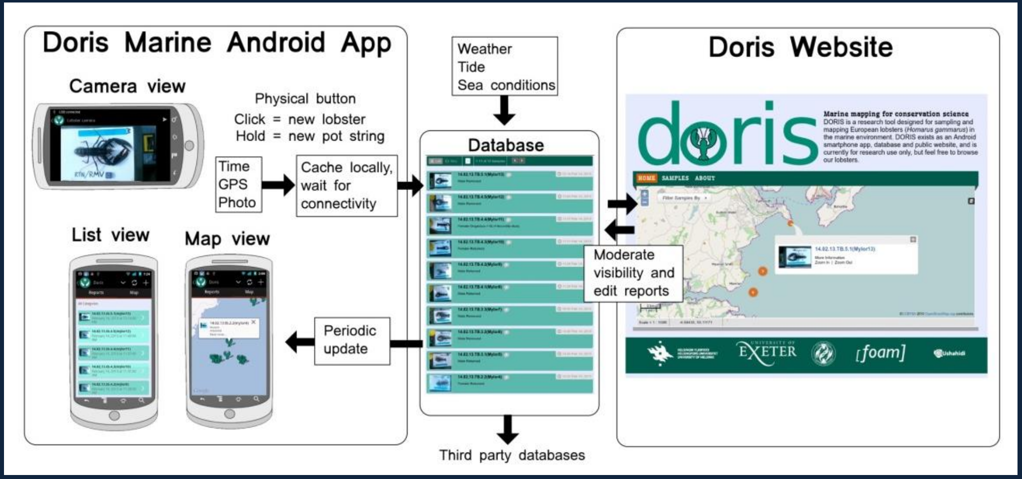




Population genetic structure

Population sampling

- Multi-locus genotypes (13 µsats) for
  - 312 fine-resolution Cornish samples
  - 300 samples of European outgroups
- Unique alleles and differences in allele frequencies used to measure genetic diversity and estimate gene flow
- Search for population structure at local and continental scales



Doris Marine Android App

Camera view

Physical button
Click = new lobster
Hold = new pot string

Time
GPS
Photo

Cache locally, wait for connectivity

List view

Map view

Periodic update

Weather
Tide
Sea conditions

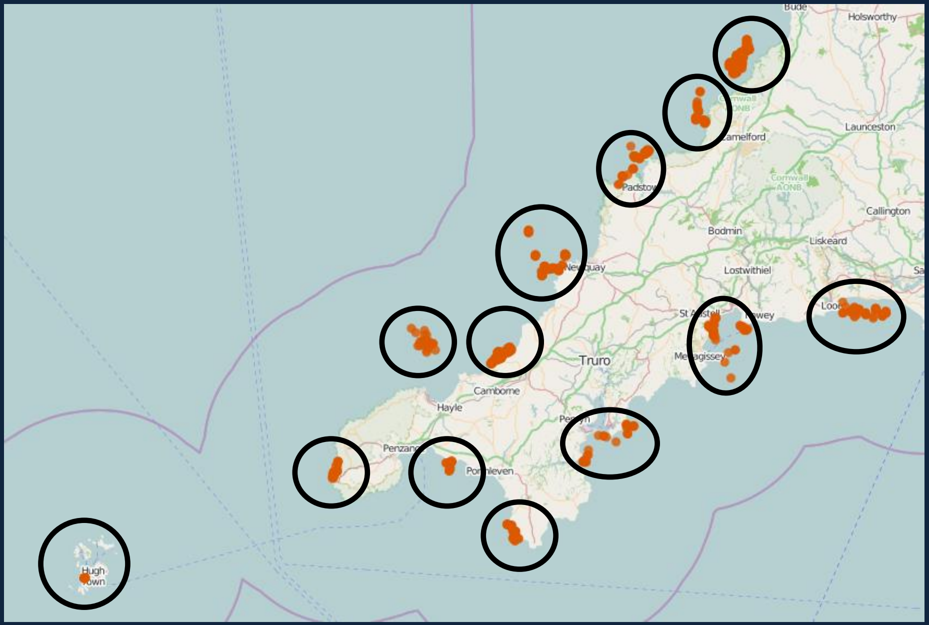
Database

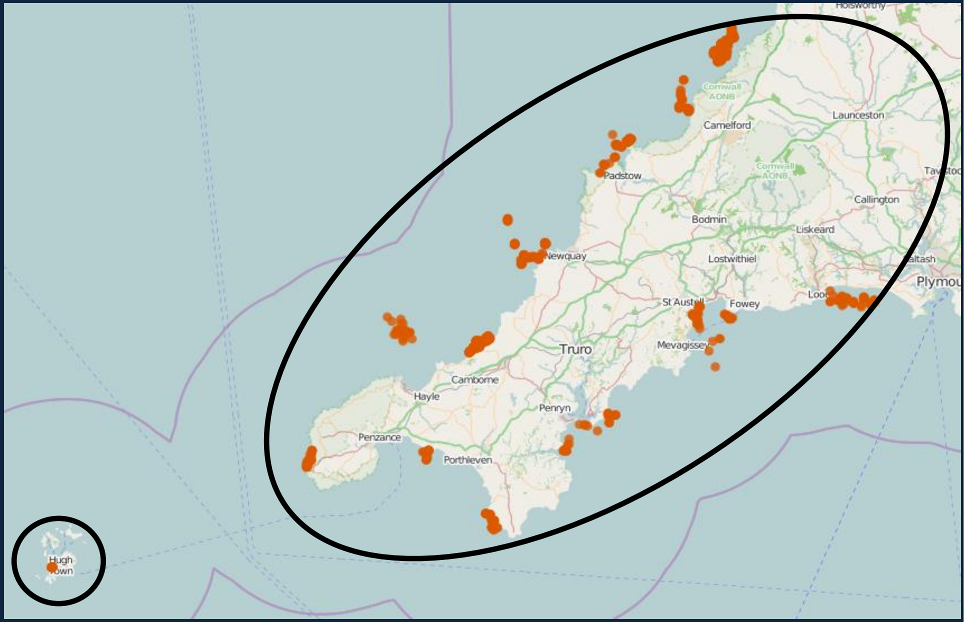
Third party databases

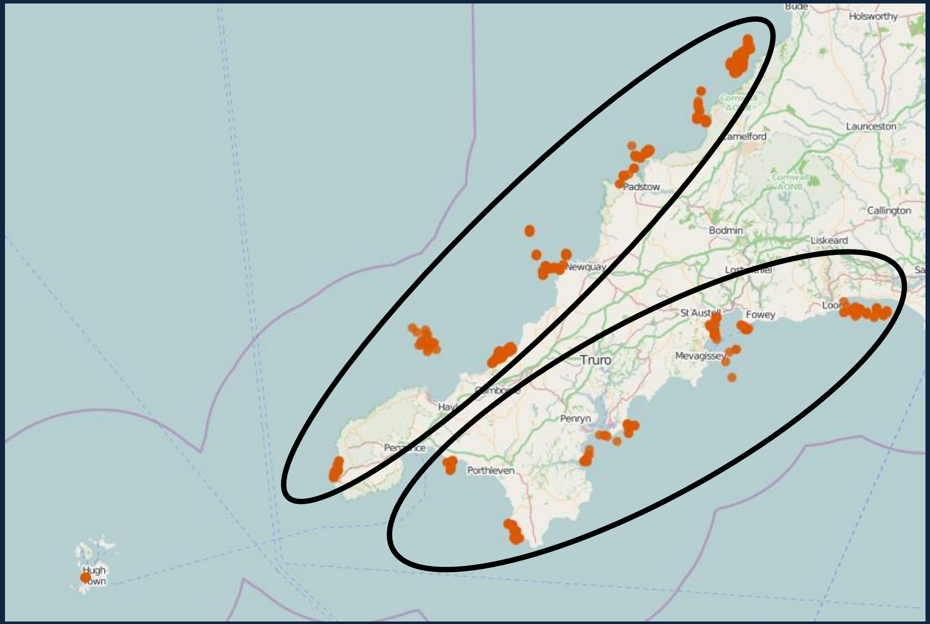
Moderate visibility and edit reports

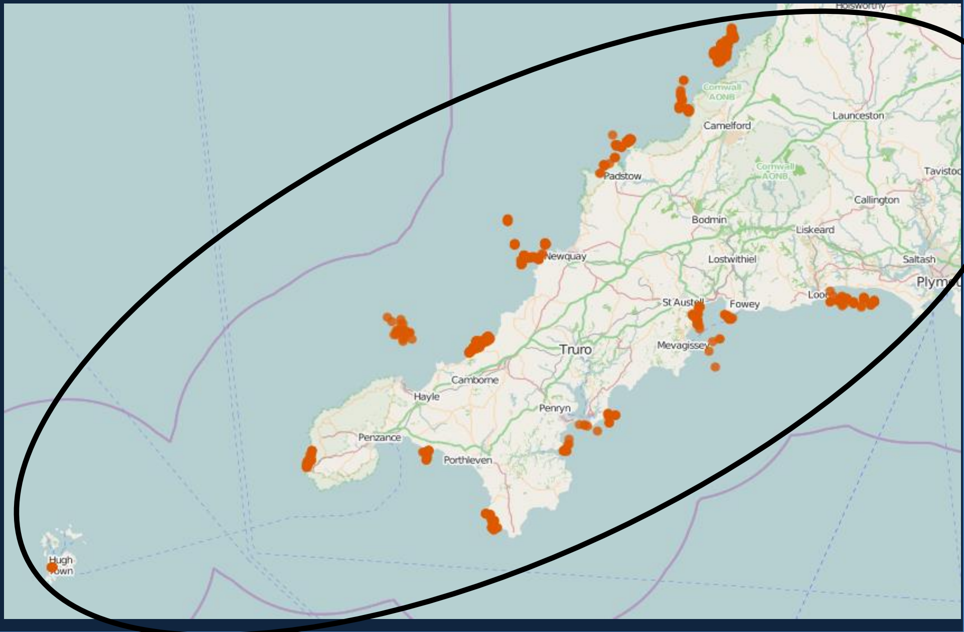
Doris Website

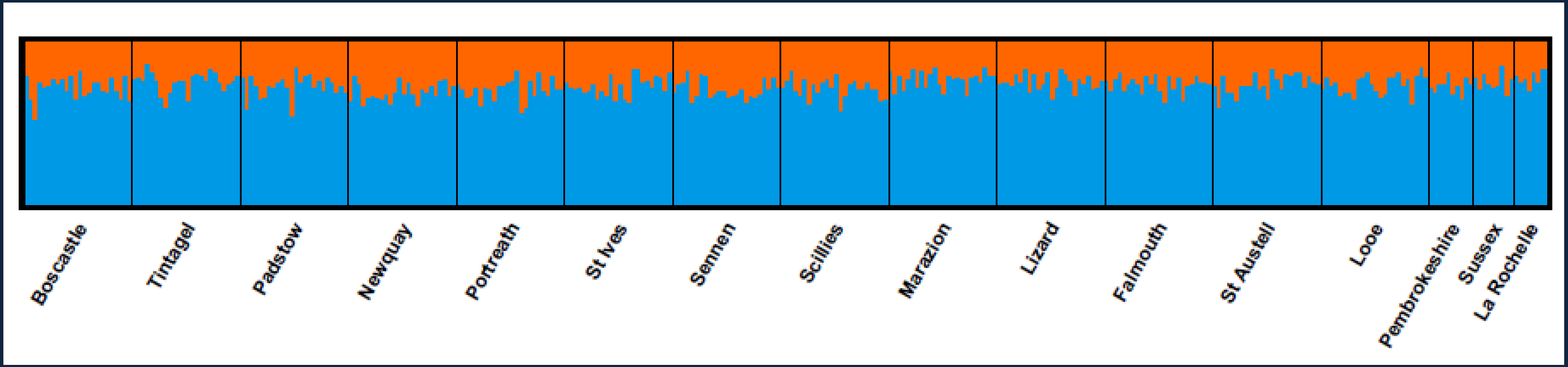
Fine-scale structure in Cornwall



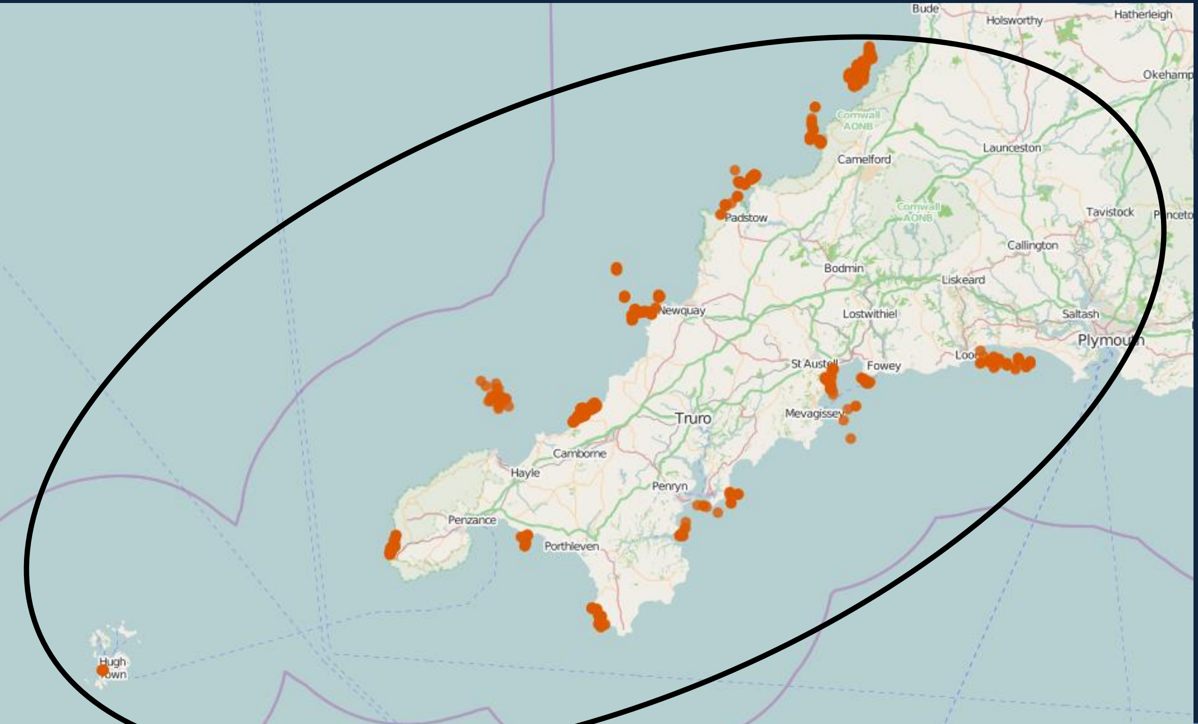


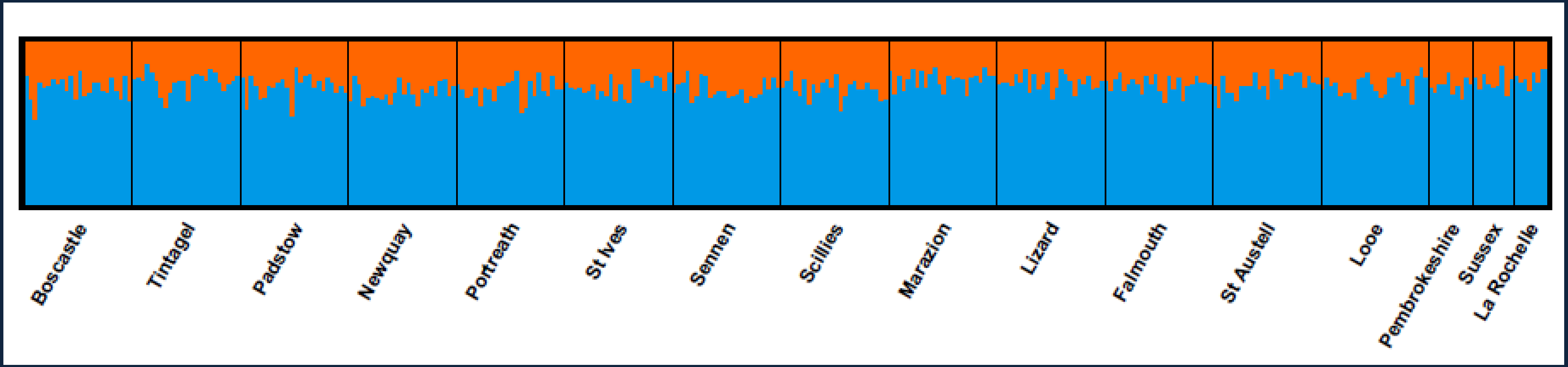






- No evidence of regional sub-populations





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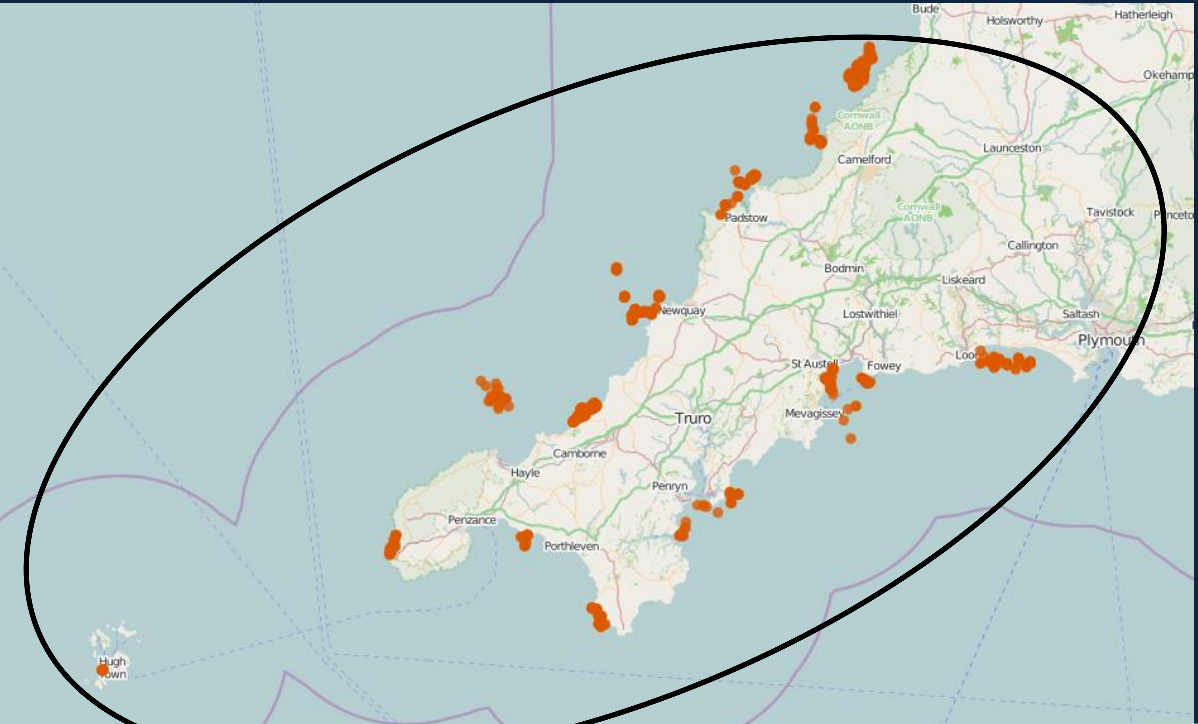
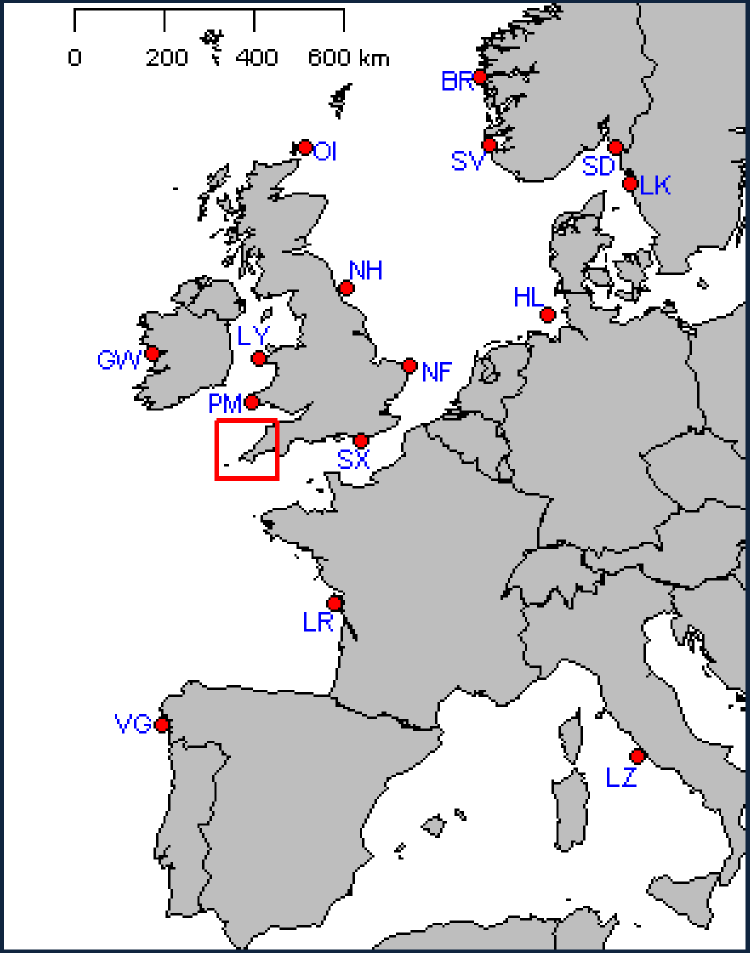


- Overall F_{ST} low (0.0005)

  low, but higher than similar area in Skagerrak

- No significant pairwise F_{ST} (0.012 to -0.007)
- No divergence via coalescent clustering
- Geographic vs genetic distance – not significant

European scale structure



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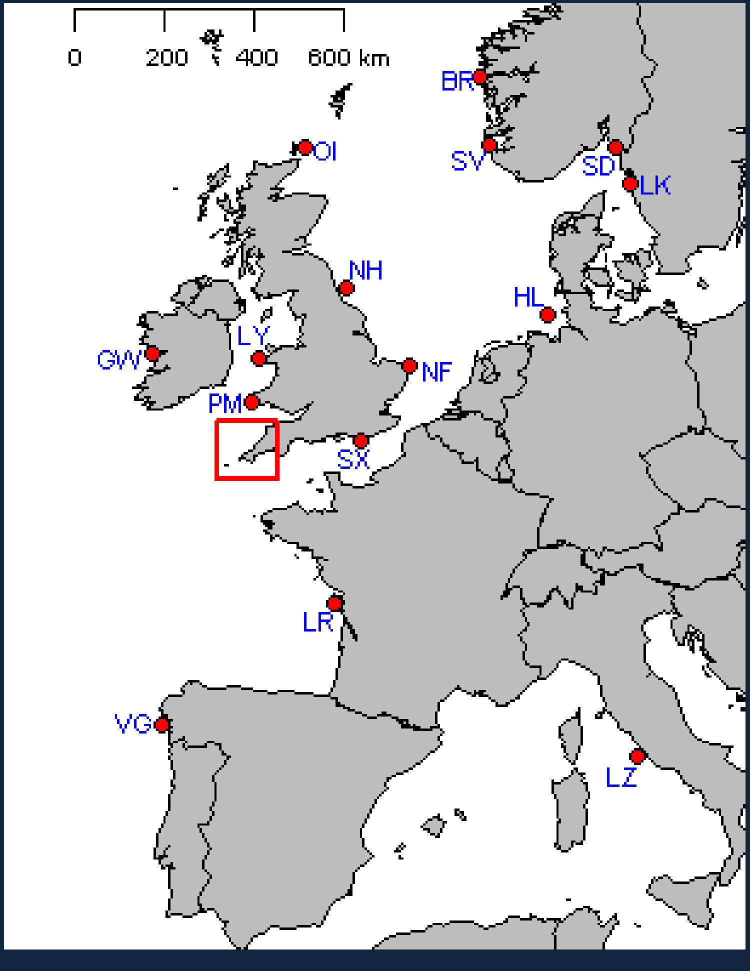
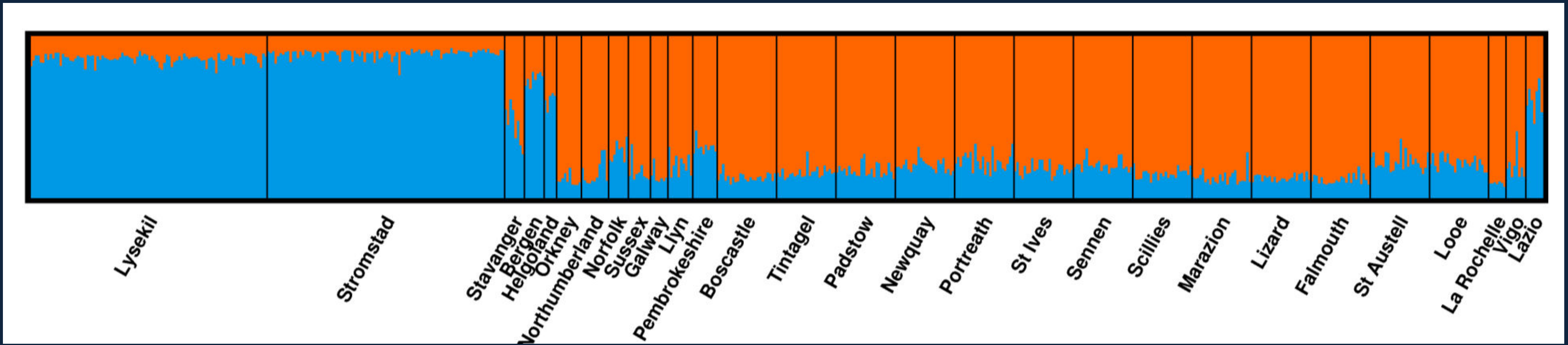
- Strong evidence of differentiation between two population clusters





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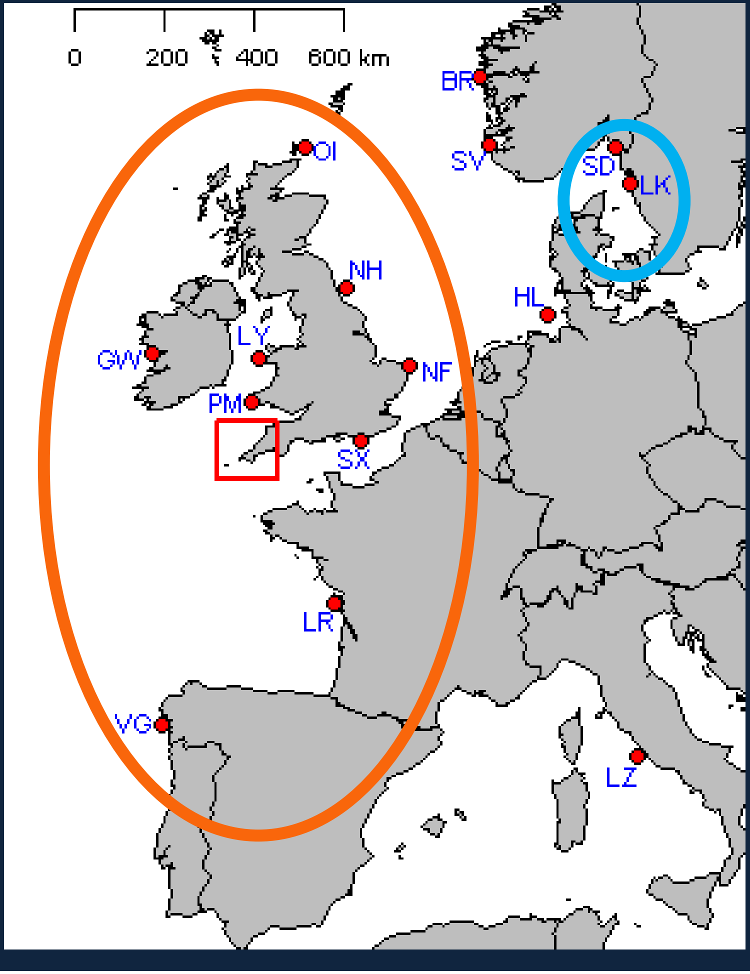

- ○ Strong evidence of differentiation between two population clusters
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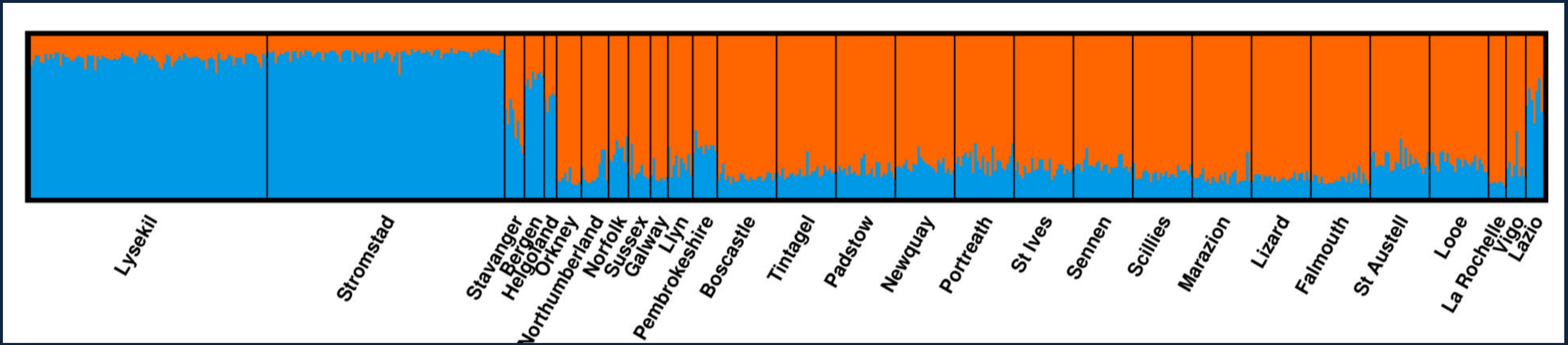
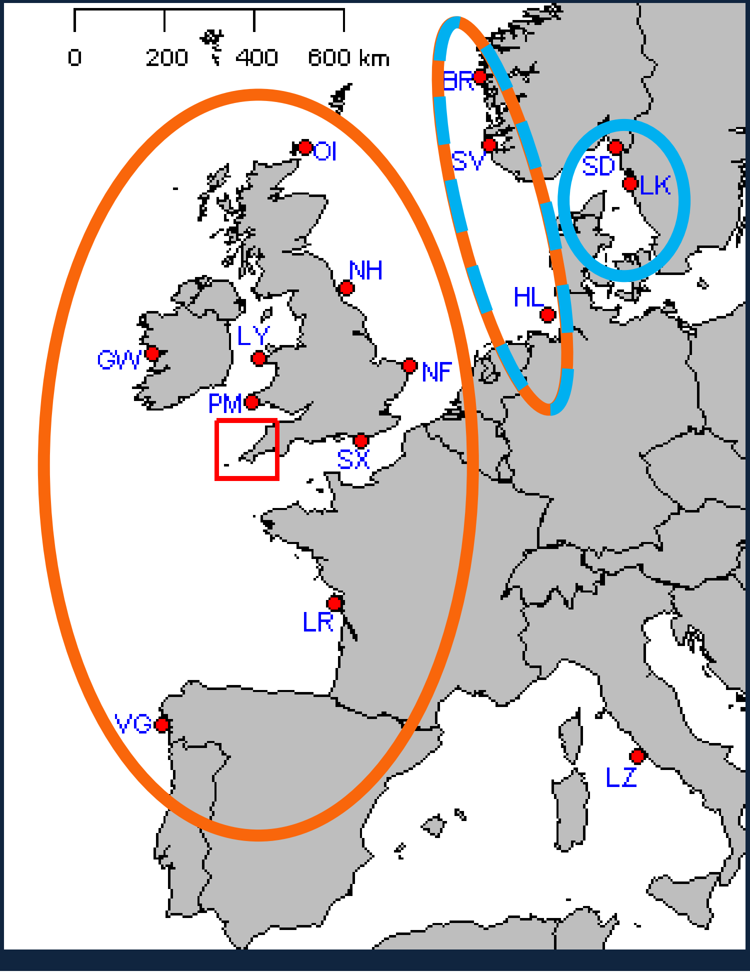
    - > western Sweden





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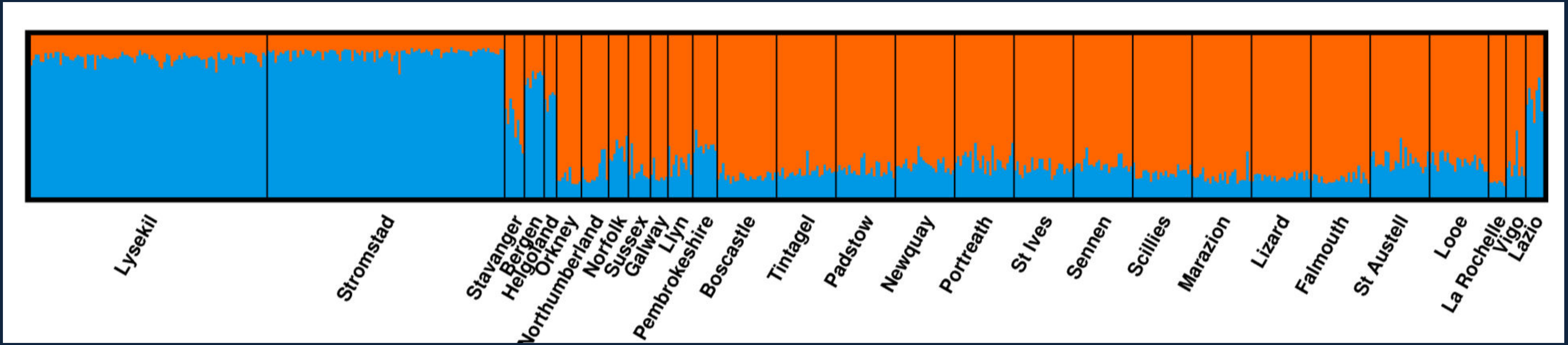

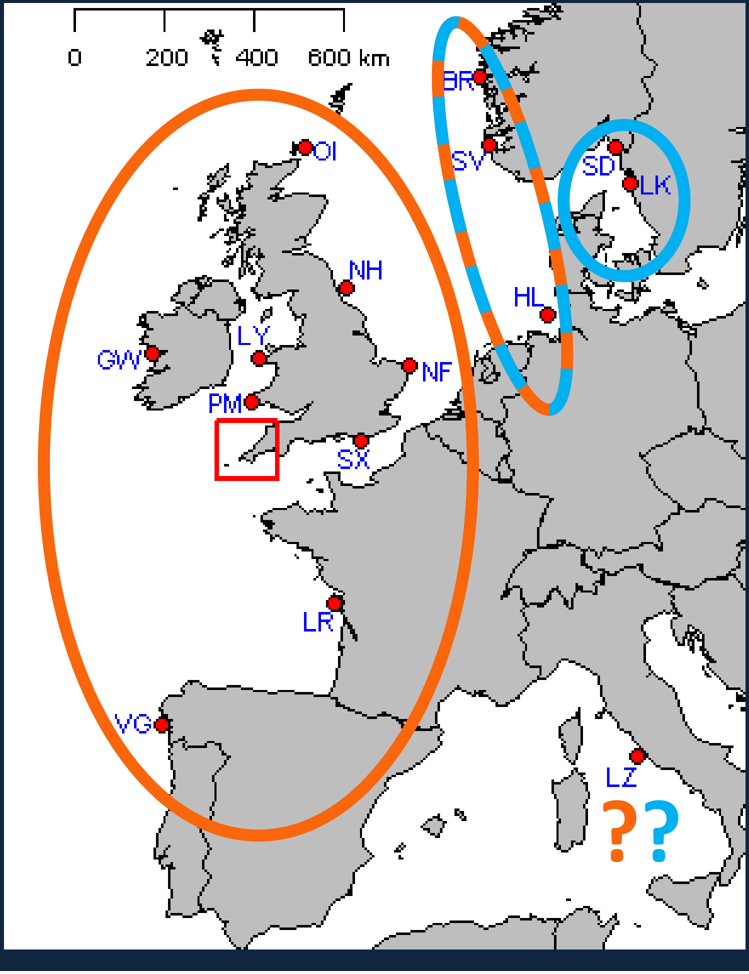

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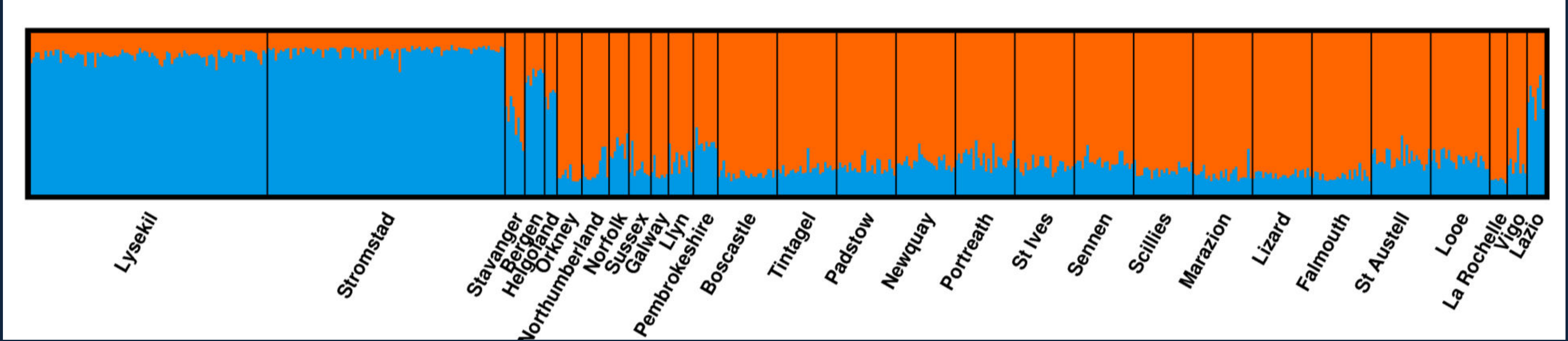

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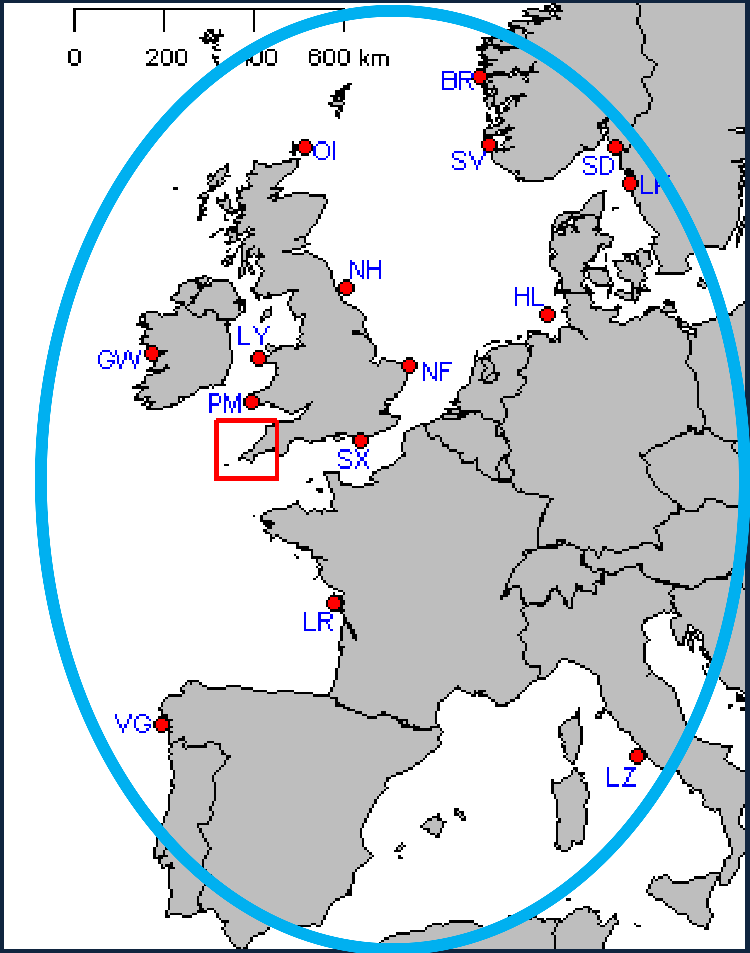

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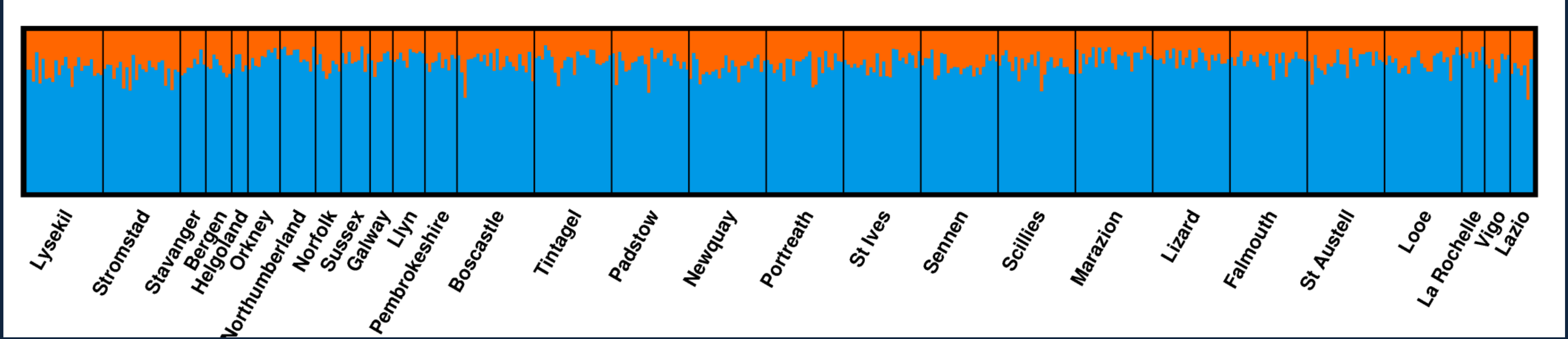
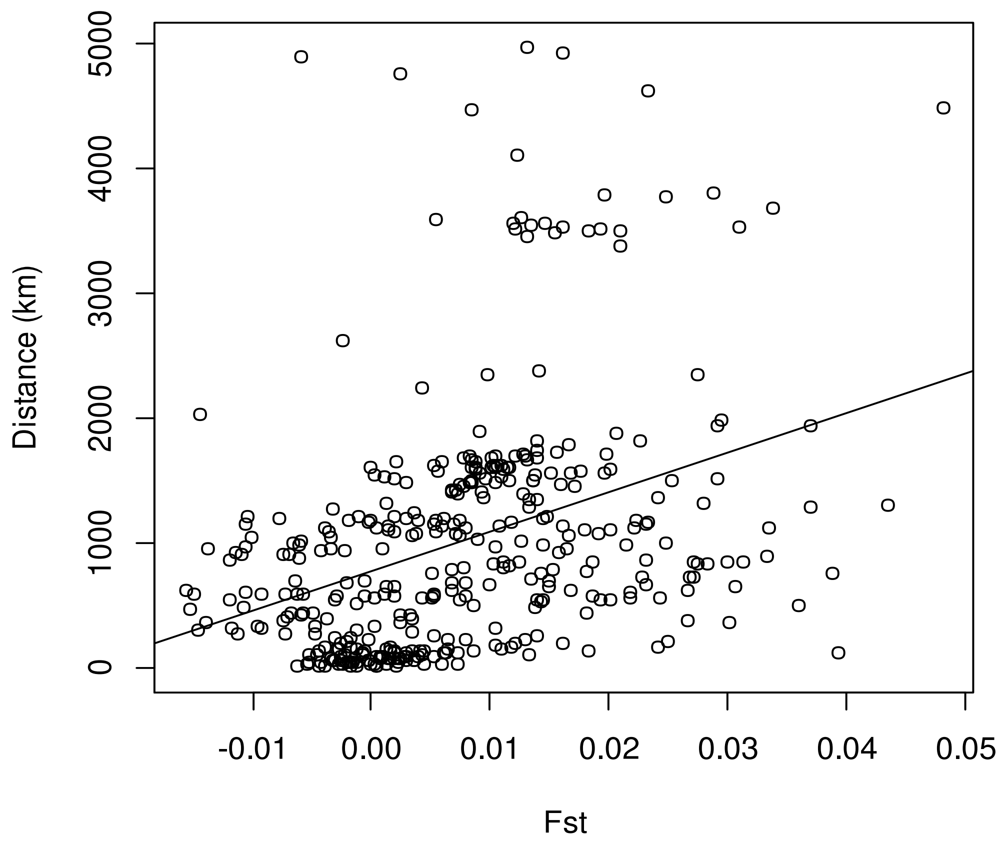
- Signal lost when Swedish sample sizes reduced to low number of individuals



Connectivity, gene flow and diversity



- Genetic diversity high among all samples (H_O = 0.60-0.72)
- Divergence supported by significant overall F_{ST} (0.007), some pairwise F_{ST} values (0.048 to -0.016) and AMOVA
- Isolation by Distance highly significant across all geographic samples (p = 0.0001)
- Increased sampling may reveal further structure

- Some regional structuring and strong IBD
- No reduction in diversity in Scandinavia
- Stepping stone model of gene flow
- Larval dispersal limited in 2-4 week duration
- Direct connectivity of distant areas unlikely

Towards informed appraisal of stocking

- Robust frameworks exist for a 'Responsible Approach' to hatchery stocking
  – Blankenship & Leber (1995), Lorenzen *et al.* (2010)

  - ➢ Ensure that released hatchery fish can be identified
    - o Use an empirical process for defining optimal release strategies
    - o Define management plans with clear targets and measures of success
  - ➢ Use genetic resource management to maximize effectiveness of enhancement and avoid deleterious effects on wild populations
    - o Assess and manage ecological impacts

ICES Journal of
Marine Science

ICES International Council for the Exploration of the Sea
CIEM Conseil International pour l'Exploration de la Mer

ICES Journal of Marine Science; doi:10.1093/icesjms/fsu196

European lobster stocking requires comprehensive impact assessment to determine fishery benefits

Charlie D. Ellis[1,2]*, David J. Hodgson[3], Carly L. Daniels[2], Dominic P. Boothroyd[2], R. Colin A. Bannister[4], and Amber G. F. Griffiths[1]

[1] *Environment and Sustainability Institute, University of Exeter, Penryn Campus, Penryn, Cornwall TR10 9FE, UK*
[2] *National Lobster Hatchery, South Quay, Padstow, Cornwall PL28 8BL, UK*
[3] *Centre for Ecology and Conservation, University of Exeter, Penryn Campus, Penryn, Cornwall TR10 9FE, UK*
[4] *Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, Suffolk NR33 0HT, UK*

**Corresponding author: tel: +44 7940 316348; fax: +44 2326 254243; e-mail: cde204@exeter.ac.uk*

Ellis, C. D., Hodgson, D. J., Daniels, C. L., Boothroyd, D. P., Bannister, R. C. A., and Griffiths, A. G. F. European lobster stocking requires comprehensive impact assessment to determine fishery benefits. – ICES Journal of Marine Science, doi: 10.1093/icesjms/fsu196.

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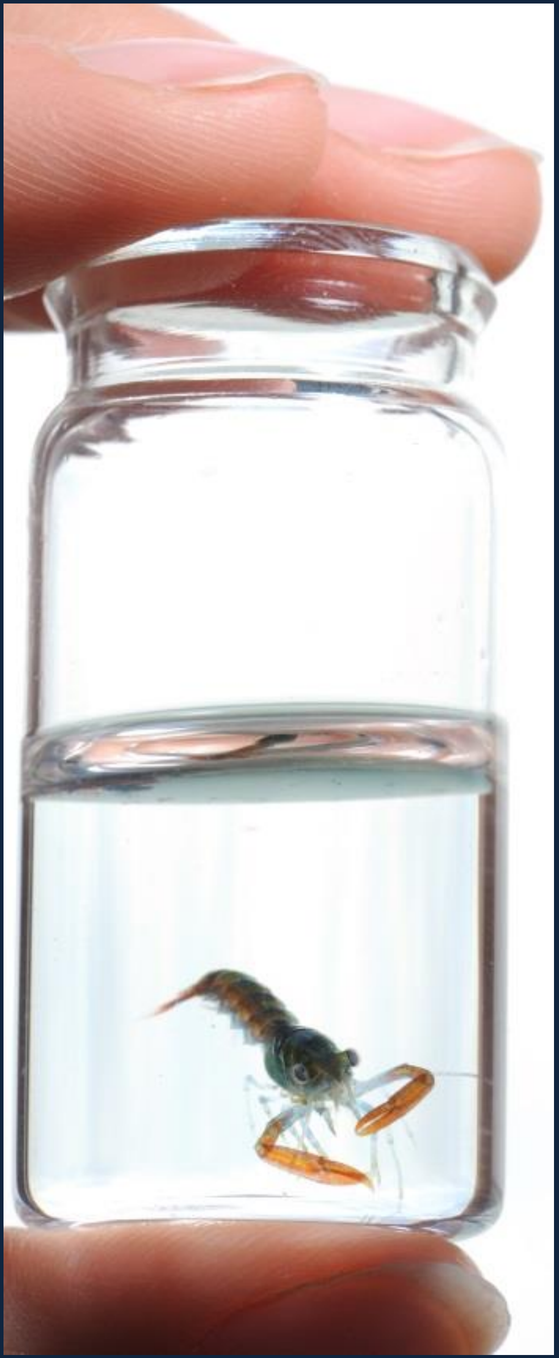
- Use of local broodstock to rear juveniles for release in distant areas inadvisable without empirical evidence of high natural genetic connectivity



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DOWN THE LINE

- High genetic diversity and single paternity suggest parentage assignments can effectively identify hatchery lobsters in the wild – tissue archiving underway for future impact assessment
- Molecular tools available to assess unknown dynamics of the rearing environment

THE FISHMONGERS' COMPANY

AL WORSHIP BE TO GOD ONLY

European Union
European Social Fund
Investing in jobs and skills

convergence
for economic
transformation

UNIVERSITY OF
EXETER

THE NATIONAL LOBSTER HATCHERY

[foam]
KERNOW

doris