INTEGRATING GENETIC AND MORPHOMETRIC VARIATION IN SARDINE FROM THE NORTHEAST ATLANTIC AND THE MEDITERRANEAN SEA

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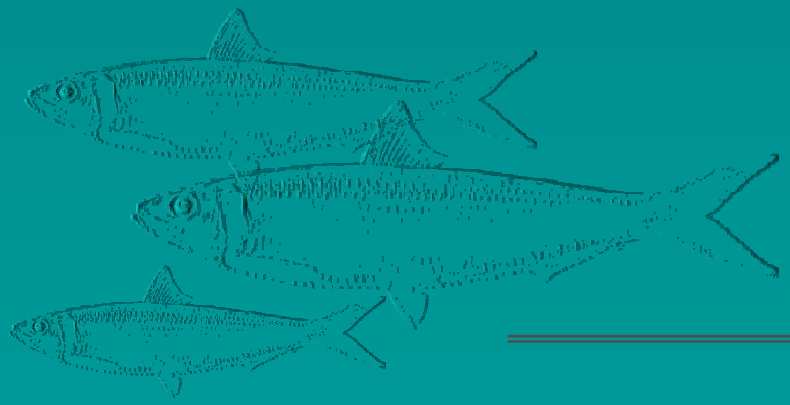
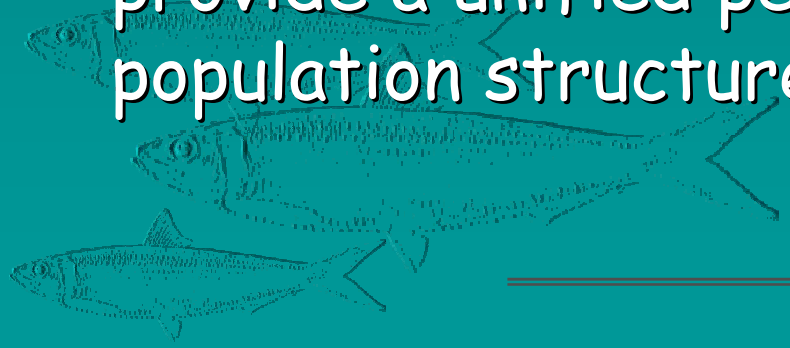


INRB-IPIMAR (Portugal)
HCMR (Greece)
Univ. Perpignan (France)

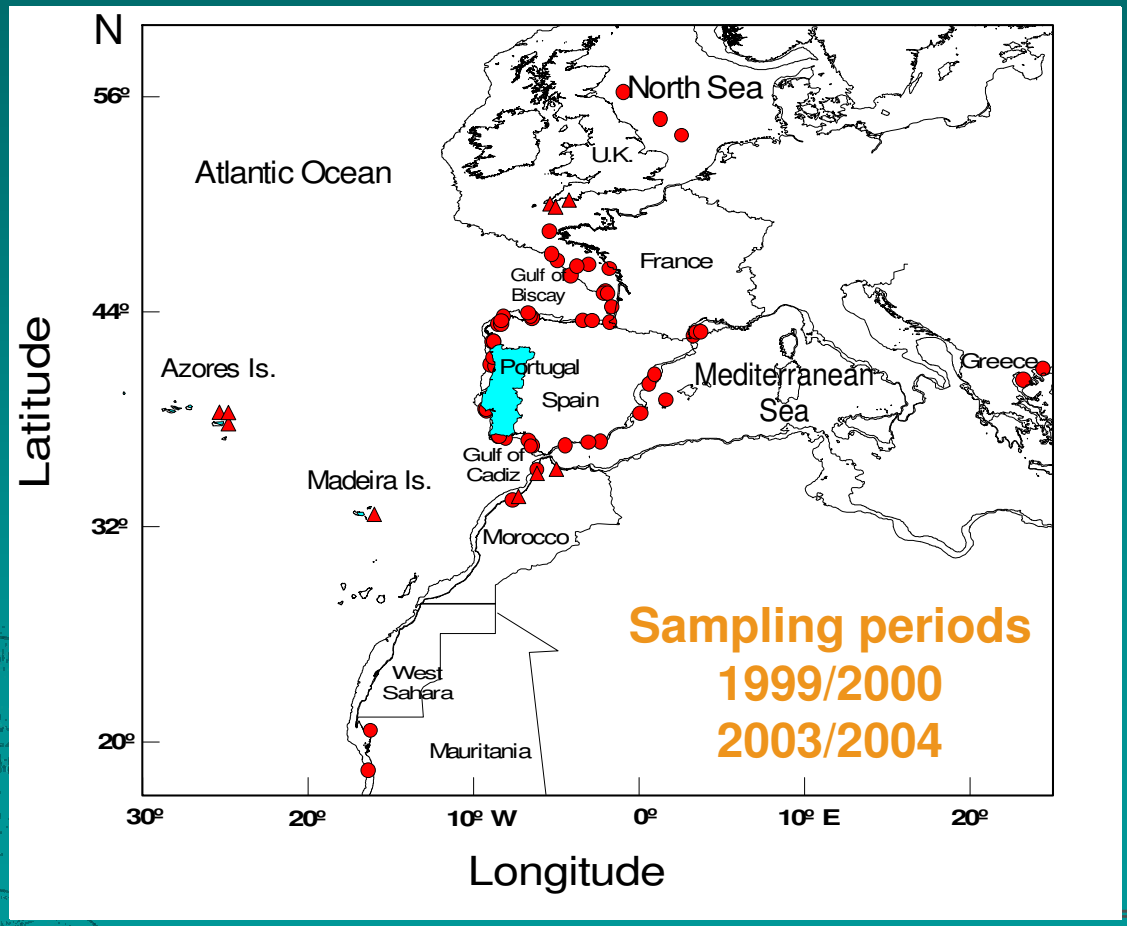
Aim of the study

- Describe the congruence between msatDNA, allozymic and morphometric variability of sardine in the NE Atlantic and Mediterranean Sea

- Integrate data from the three approaches to provide a unified perspective of sardine population structure

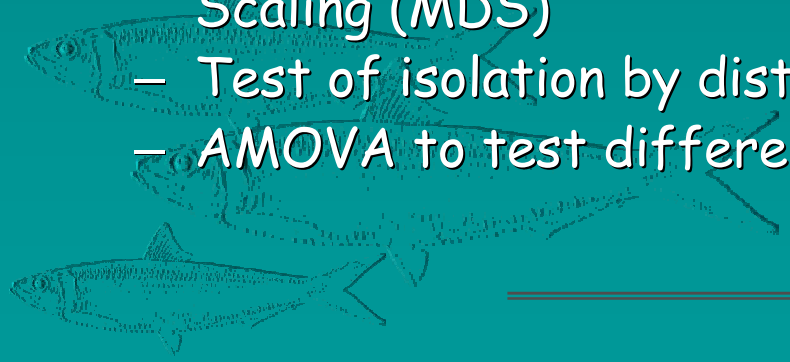


Study area


N
56º
44º
32º
20º
Latitude
North Sea
U.K.
Atlantic Ocean
France
Gulf of Biscay
Azores Is.
Portugal
Spain
Mediterranean Sea
Greece
Gulf of Cadiz
Madeira Is.
Morocco
West Sahara
Mauritania
Sampling periods
1999/2000
2003/2004
30º
20º
10º W
0º
10º E
20º
Longitude

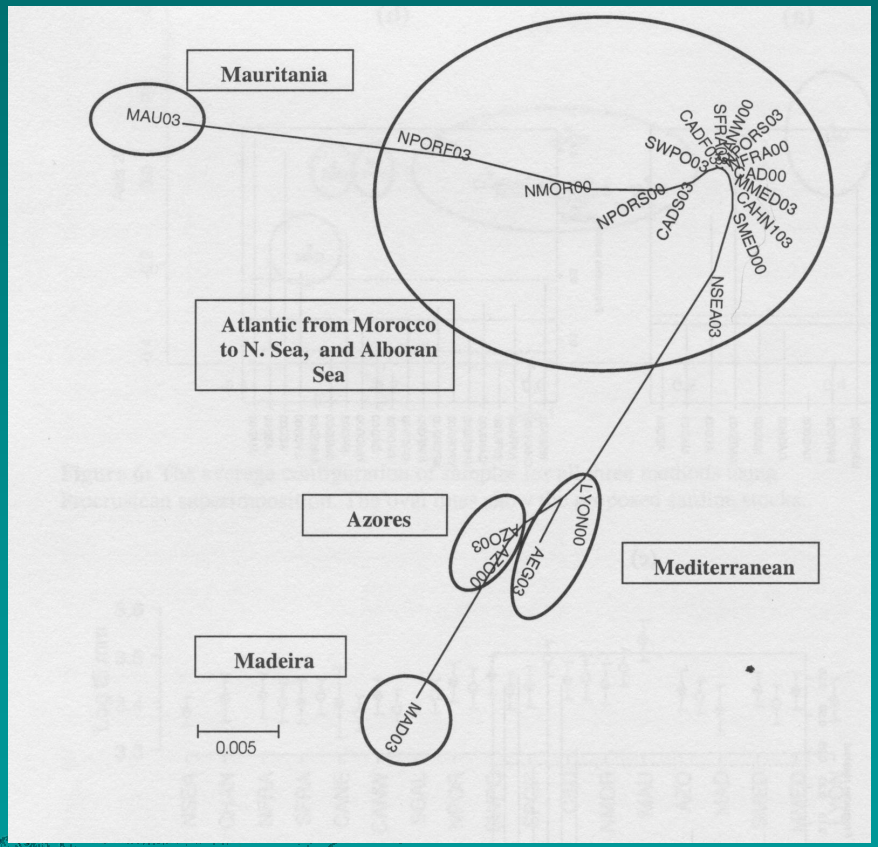
Genetics: Material & methods

- 21 samples of 100 individuals (2000-2004) for msatDNA
- 15 samples of 50 individuals in allozymes (2003/2004)
- 5 loci (msatDNA) and 27 loci (allozymes) scored
- Genetic structure:
  - Allelic frequencies (Fisher's exact test)
  - Fst (permutation test to obtain p-level)
  - Fst used in neighbour-joining dendrogram and Multi Dimensional Scaling (MDS)
  - Test of isolation by distance (allozymes)
  - AMOVA to test different sample groupings (msatDNA)



Genetic differentiation: msatDNA analyses

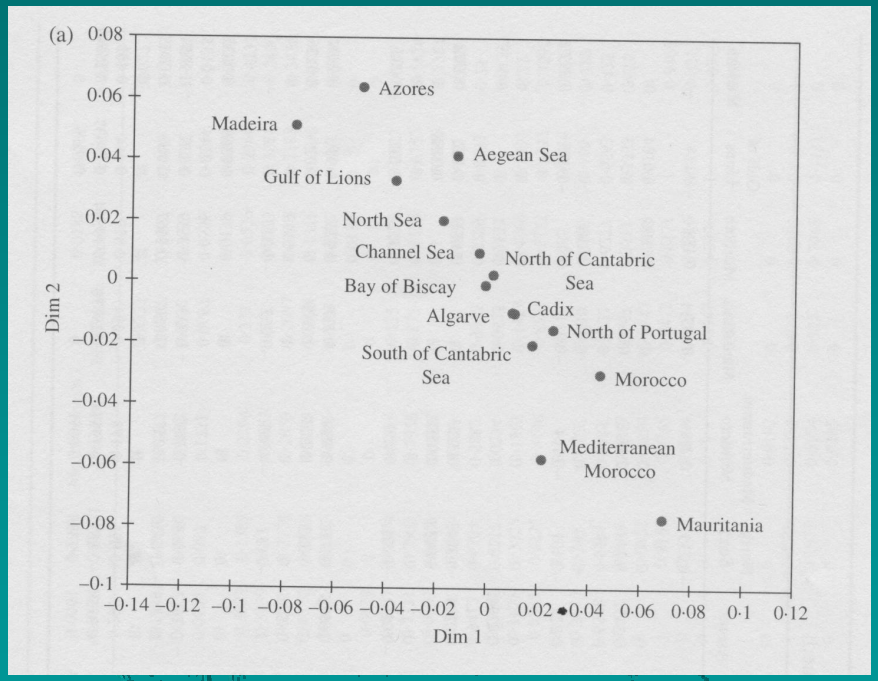
Neighbor-joining tree of pairwise F_{st}



- Differentiation of Mauritania, Mediterranen, Azores, and Madeira;
- Large group from north Morocco to North Sea (with SW Mediterranean);
- Suggests 5 sardine populations
- Genetic differentiation mainly driven by locus sapi22

Genetic differentiation: allozyme analyses

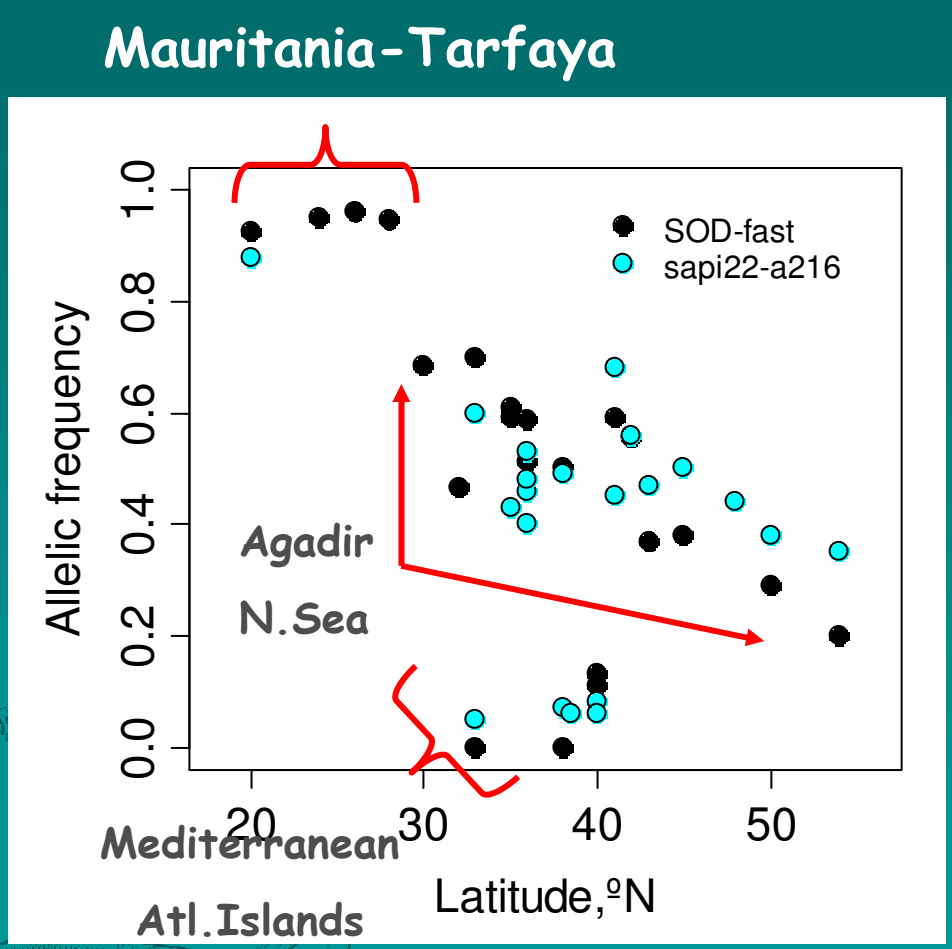
MDS of the pairwise Fst



Laurent et al. 2007. Journal of Fish Biology, 71 (Supplement A), 1-17.

- Driven by samples from the extreme range: Mauritania, Azores, and Madeira;
- Mediterranean partially isolated
- European Atlantic consistent with isolation by distance model;
- Driven by a single locus (SOD*)

Link between two genetic loci



- Cline from Mauritania to North Sea;
- Steep change in central Morocco
- Southwestern Mediterranean, Azores and Madeira in a separate cluster.
- Are these loci under selection ?

Kasapidis, unpublished data

Laurent et al 2007

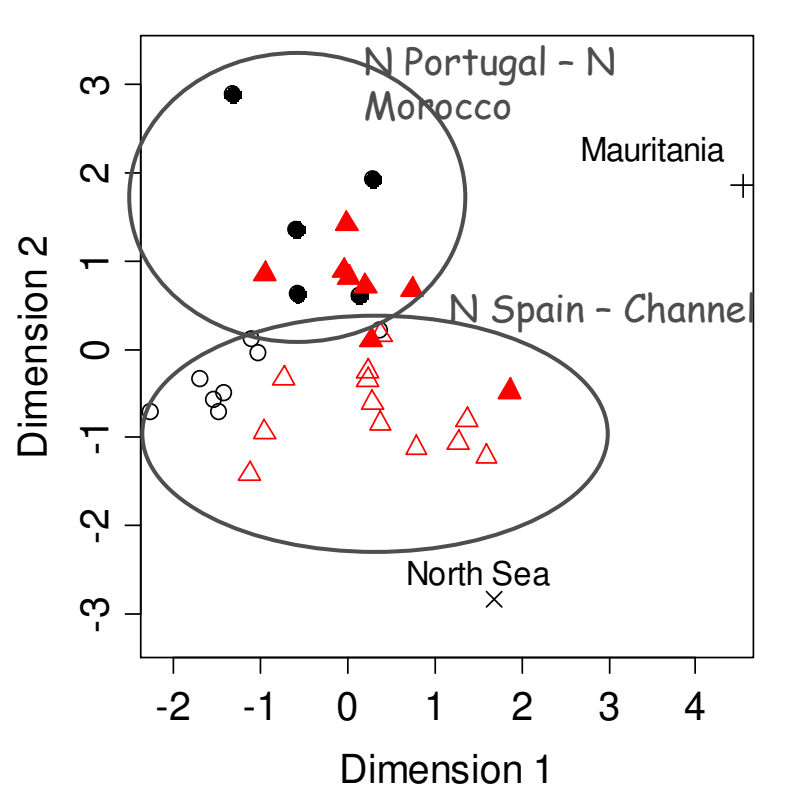
Chlaida et al 2006

Morphometry: Material & Methods

- 35 samples of 50-75 individuals (2000-2004)
- 9 variables (head dimensions) from a truss network
- Size correction (mean of each variable)
- Mahalanobis distances between samples
- Metric MDS

Morphometric differentiation

MDS of the pairwise Mahalanobis distances



- Substantial separation of Mauritania and North Sea;
- Some difference between periods (2000/2001 in black and 2003/2004 in red)
- Shallow differentiation between two groups separated off western Iberian Peninsula;
- Mediterranean and Atlantic Islands closer to the northern group;

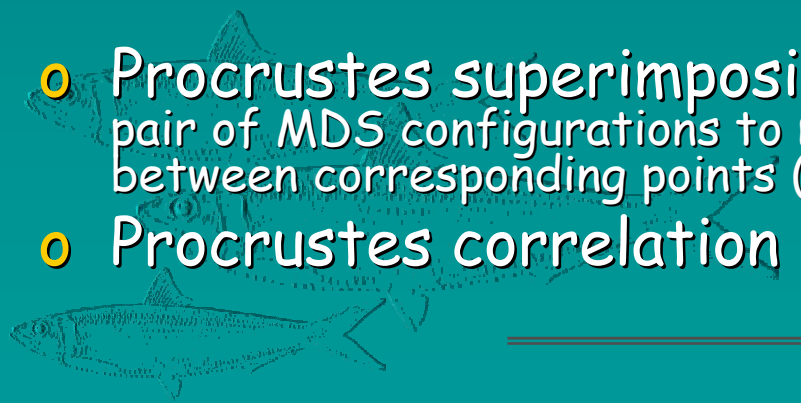
Silva, 2003. ICES J. Marine Science, 60, 1352-1360.

Integration: Material & Methods

- Common samples (11 overall):
  - 12 for msatDNA-allozymes
  - 17 for morphometry-msatDNA
  - 14 for morphometry-allozymes

- Matrices of pairwise Fst and Mahalanobis distances using common samples/areas
- MDS analyses

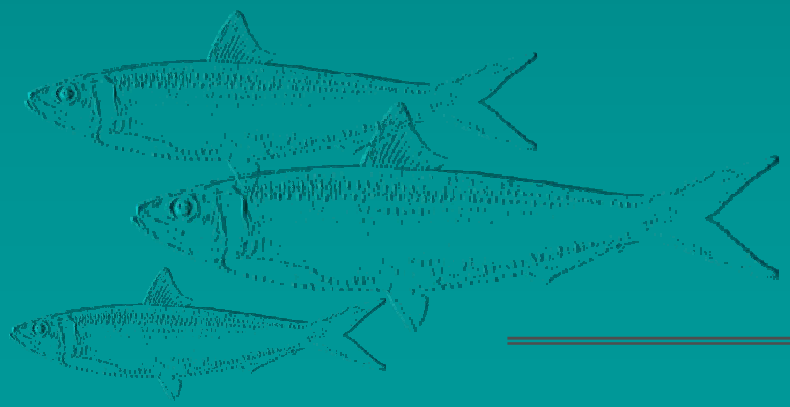
- Procrustes superimposition: scales, translates and rotates each pair of MDS configurations to minimize the sum of squared distances between corresponding points (samples)
- Procrustes correlation (permutation test)



Congruence between methods

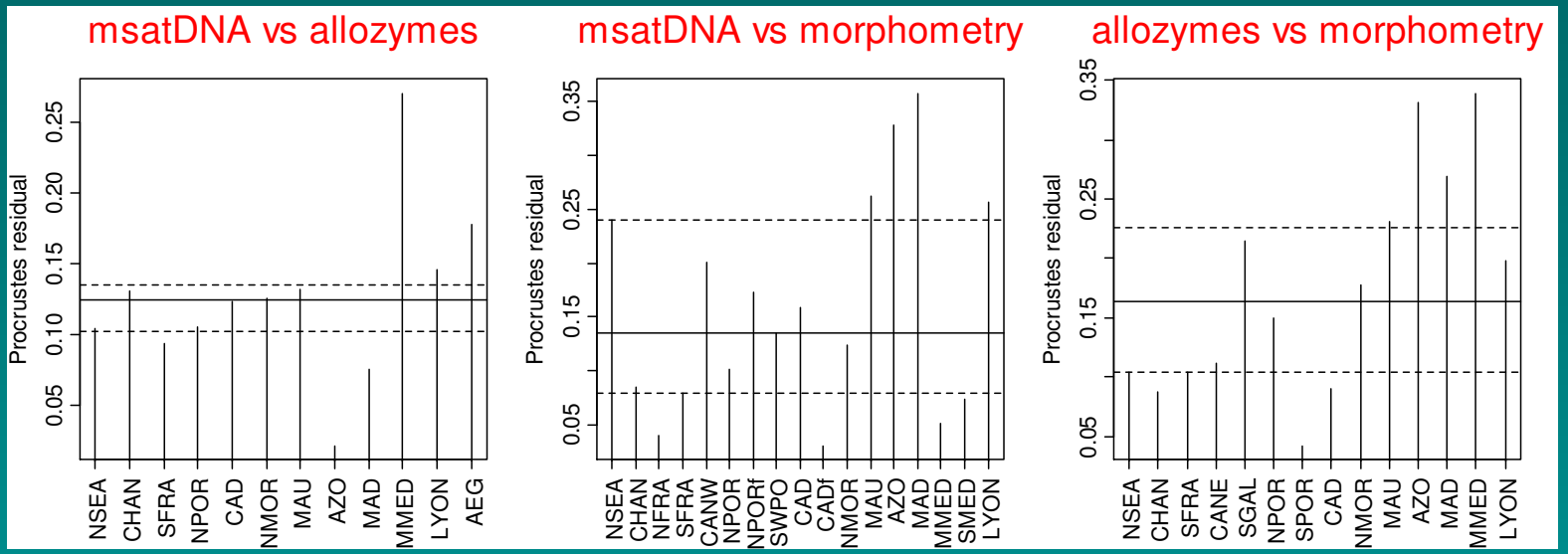
Procrustes correlation	msatDNA	Allozymes
Allozymes	0.88 (1)	
Morphometry	0.63 (2)	0.68 (1)

(1) $p<0.001$
(2) $p=0.002$



- Positive significant correlations;
- Higher PR between genetic approaches;
- Morphometry with better aggreement with allozymes than with msatDNA

Main discrepancies between methods



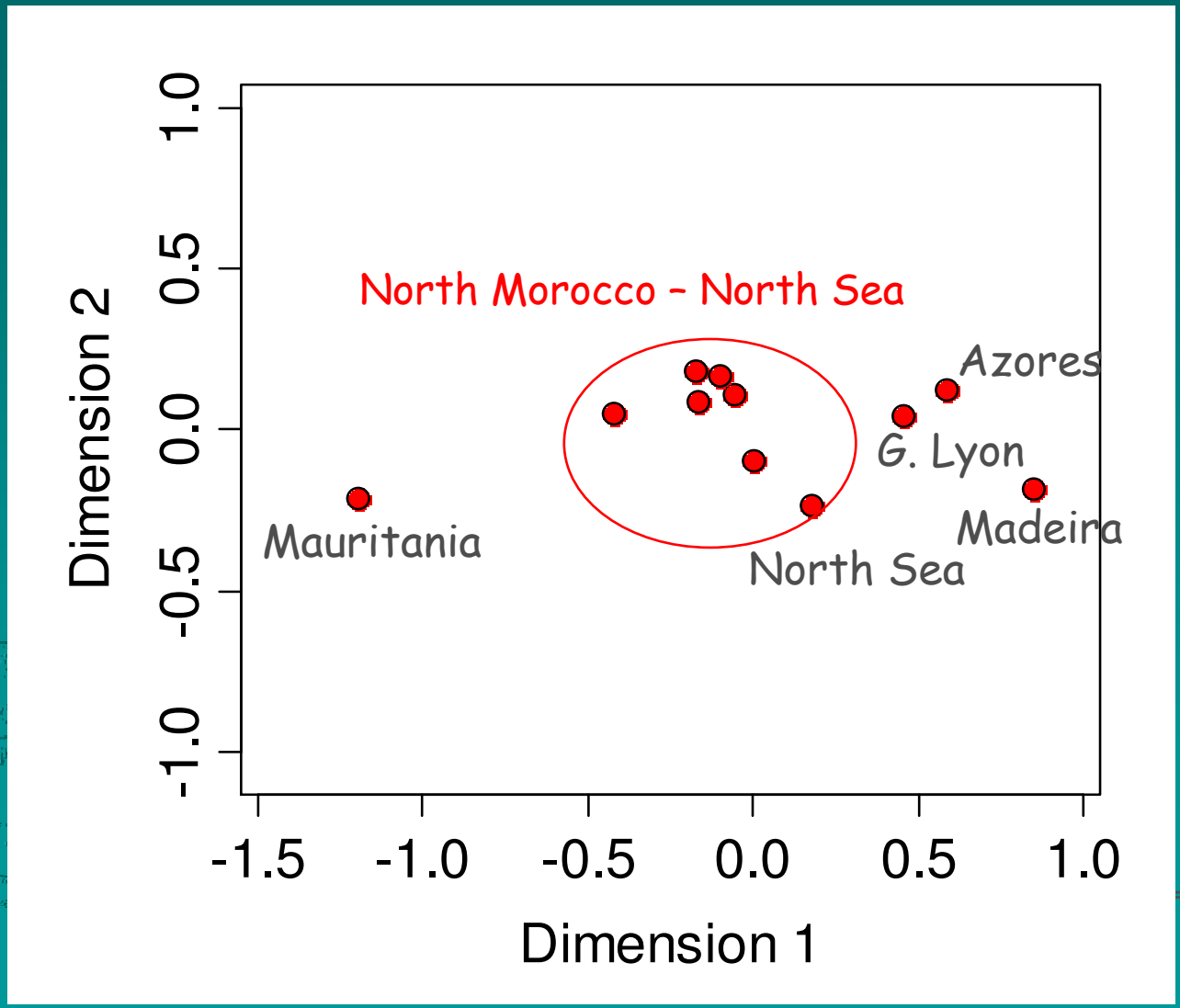
Mediterranean Morocco
Aegean Sea

Atlantic Islands
Gulf of Lyon

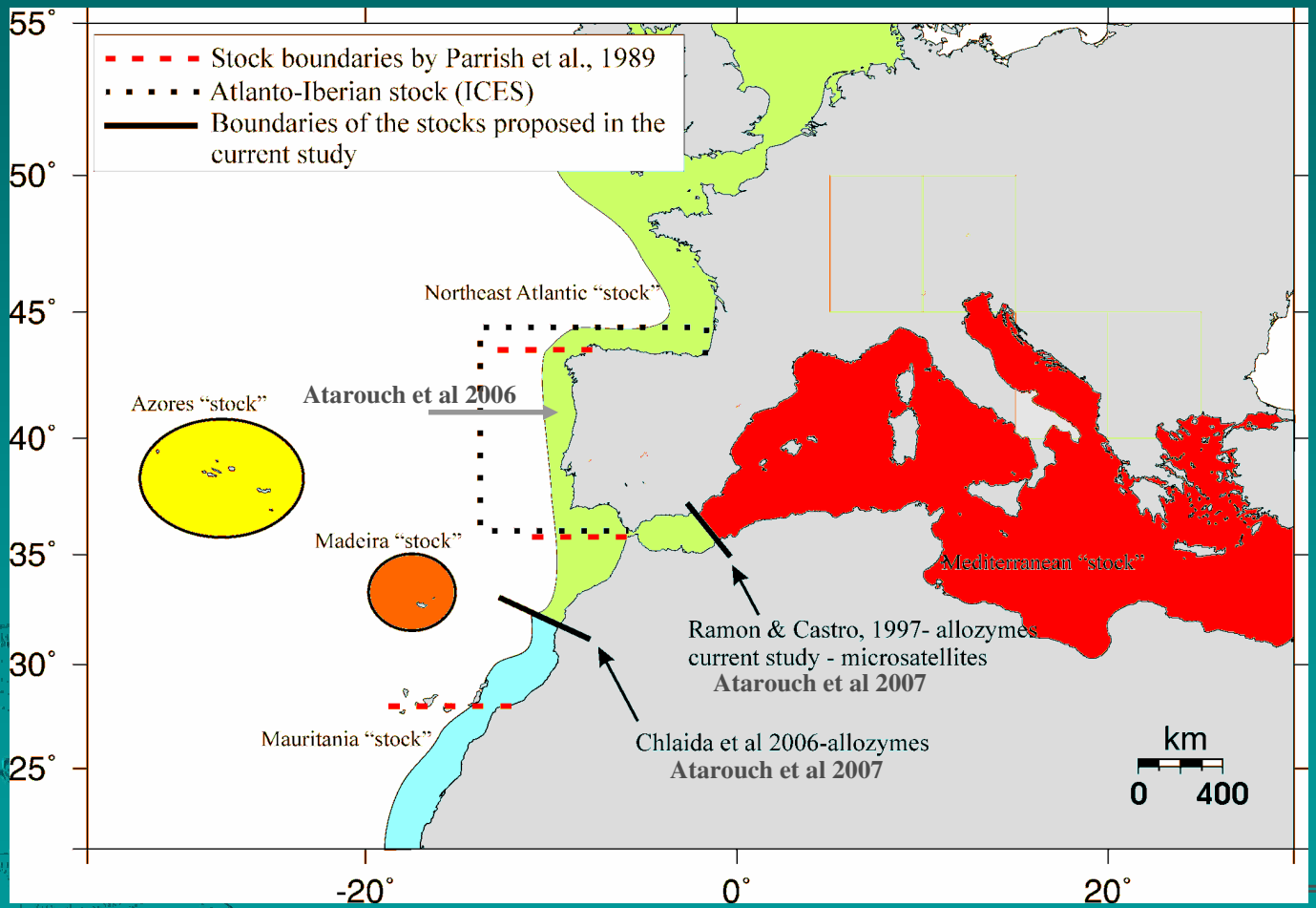
Atlantic Islands
Mediterranean Morocco

Generally good agreement for the Atlantic shelf areas

Integrated configuration

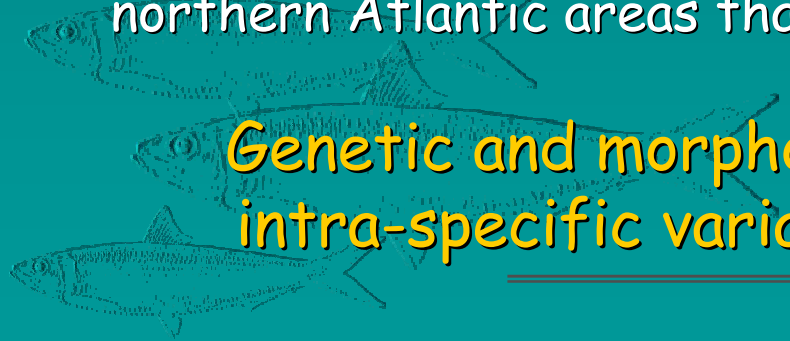


Evidence from other genetic and morphometric studies



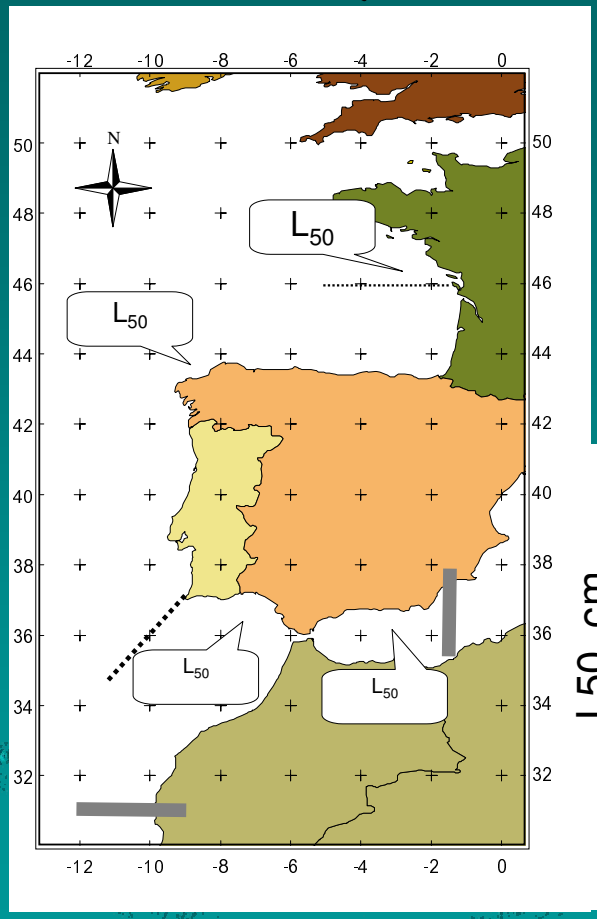
Conclusions

- Good congruence among the three approaches, although better between the genetic ones
- 5 morpho-genetic populations of sardine:
  - Mauritania-central Morocco?
  - Azores
  - Madeira
  - Mediterranean Sea
  - NE Atlantic shelf: North Morocco to North Sea
- Some north-south differentiation in the NE Atlantic shelf group
- Higher affinity of Mediterranean and Atlantic islands with northern Atlantic areas than with southern Iberian areas



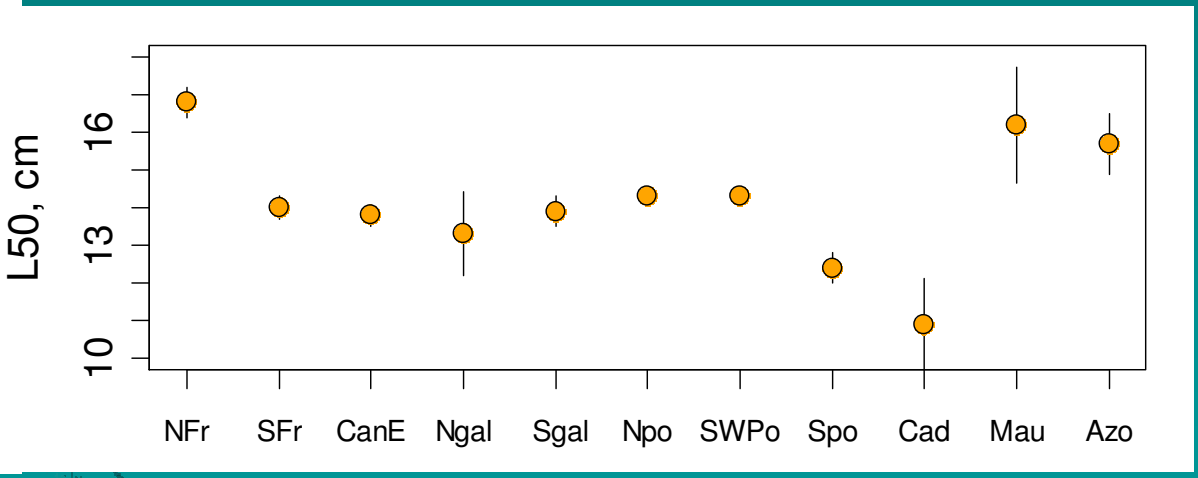
Genetic and morphometric methods uncovered intra-specific variability at large spatial scale

Population structure at small spatial scale
(focused on the Iberian Peninsula)



EVIDENCE FOR

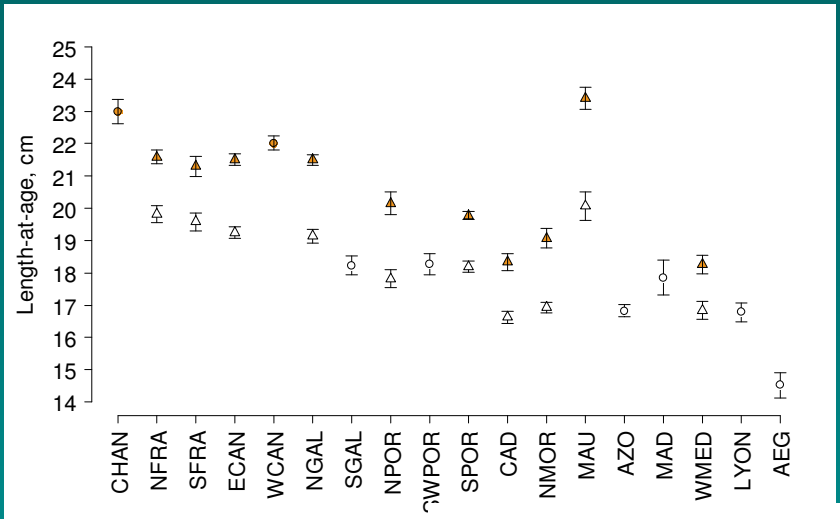
- Geographic variation in the maturation pattern
  (Silva et al 2006)



Genetic boundaries

Phenotypic boundaries

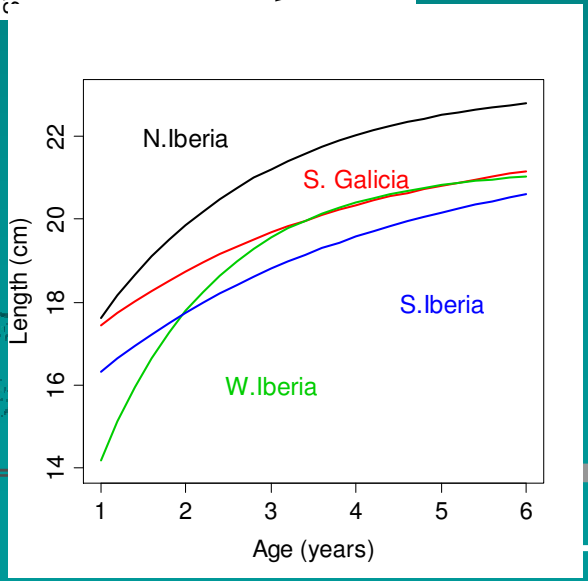
Population structure at small spatial scale
(focused on the Iberian Peninsula)

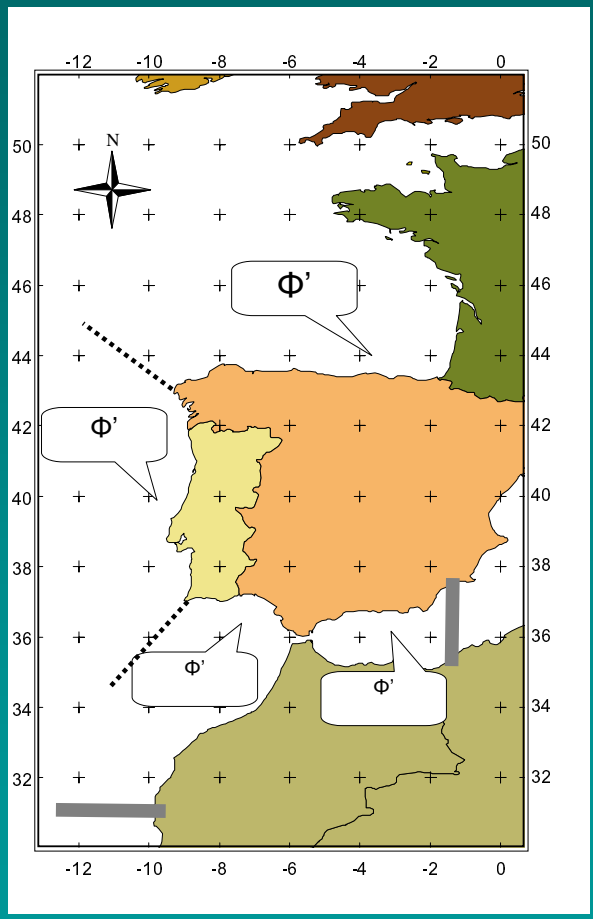


EVIDENCE FOR

Geographic variation in growth

Silva et al 2007



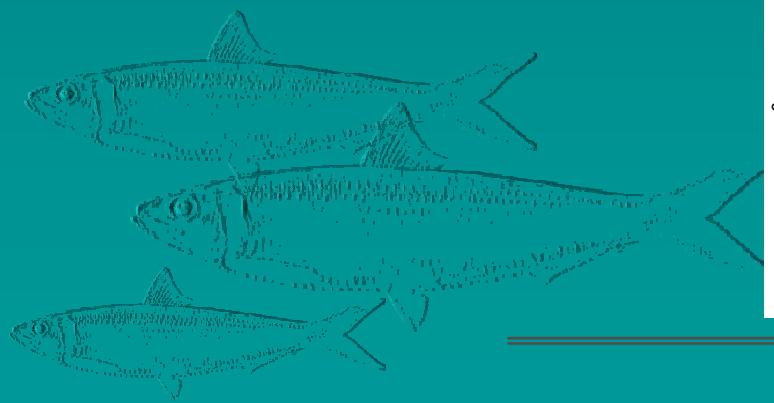


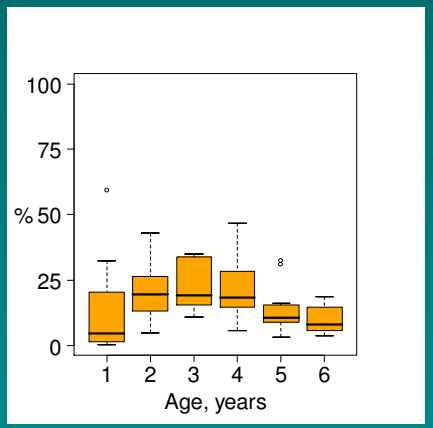
Genetic boundaries

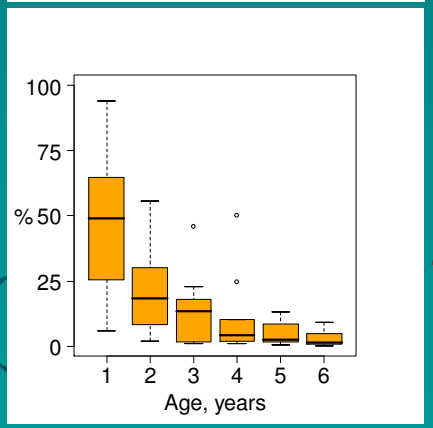
Phenotypic boundaries

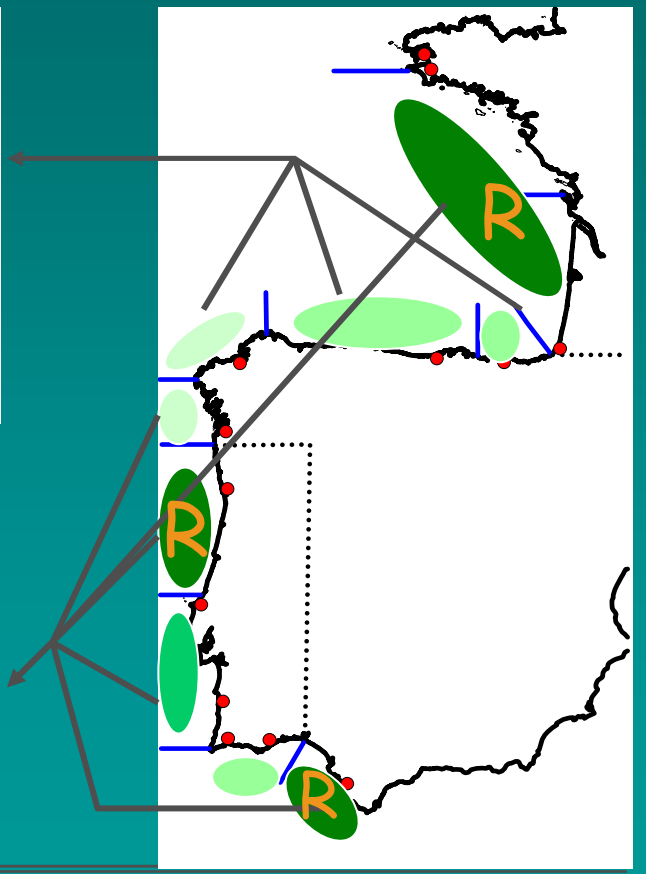
Population structure at small spatial scale
(focused on the Iberian Peninsula)

- Demographic structure; recruitment areas intermingling with adult areas (ICES 2006)





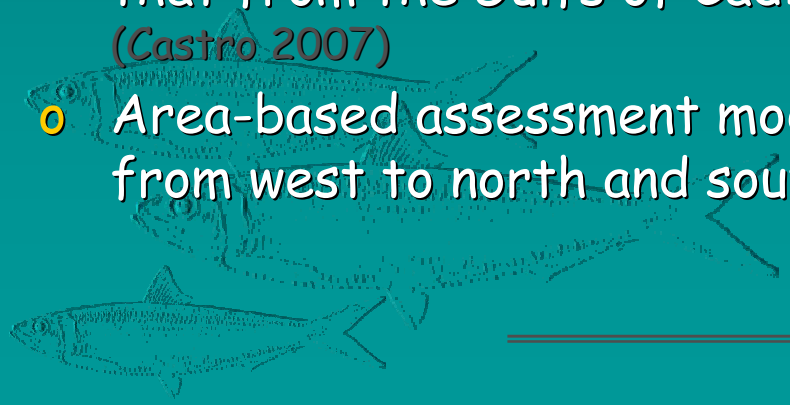




Population structure at small spatial scale
(focused on the Iberian Peninsula)

EVIDENCE AGAINST

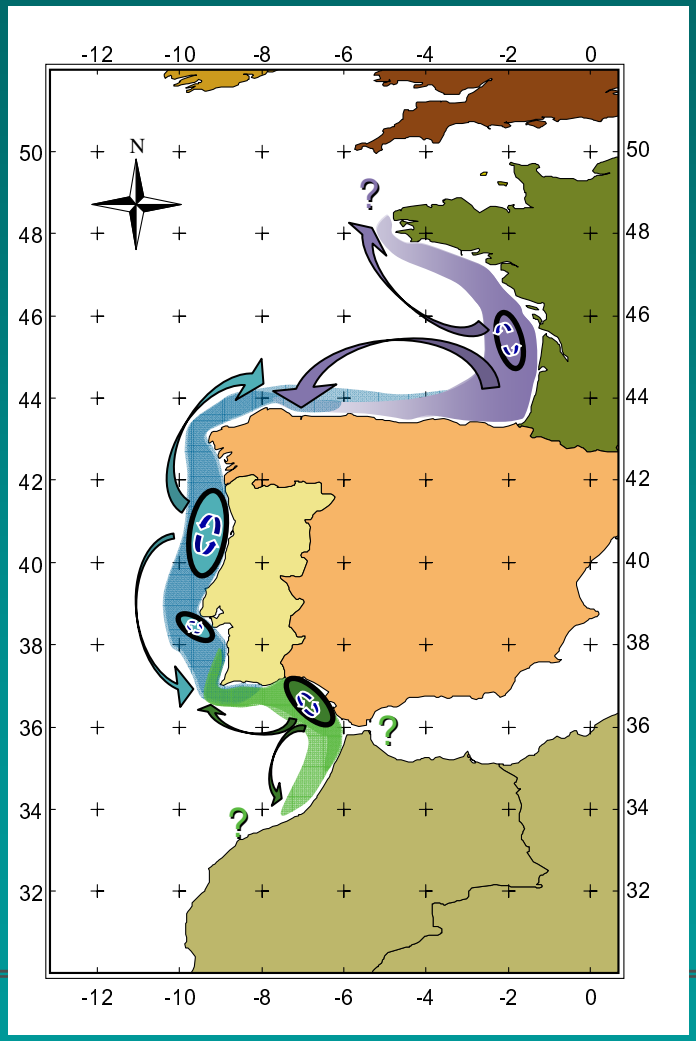
- No localized spawning areas; instead spawning is continuous across the shelf (Bernal et al 2007)
- Temporal overlap in spawning season between adjacent areas (Coombs et al 2006, Stratoudakis et al 2007)
- Otolith micro-elemental composition suggest age-related migrations: similarity between sardine from western Portugal with that from the Gulfs of Cadiz and Biscay increases with fish size (Castro 2007)
- Area-based assessment models suggest age-related migrations from west to north and south Iberian waters (Anon. 2006)



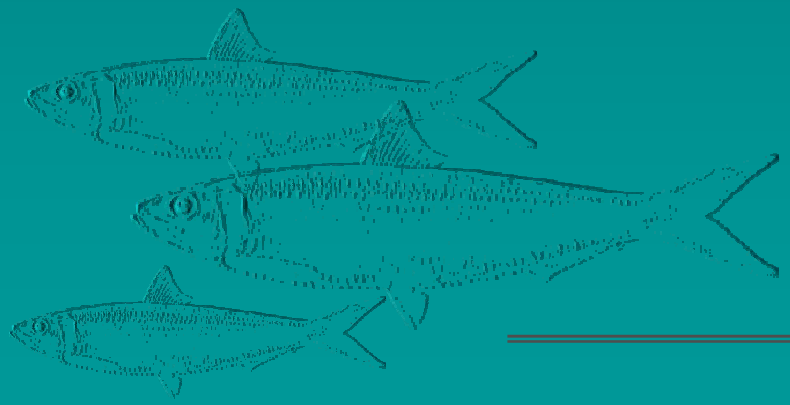
Conceptual model of population structure

(adapted from ICES 2005, Anon. 2006)

- 3 recruitment "hotspots"
- Young fish promote spatial structure
- Large fish disrupt spatial structure
- Movement of large fish seems to be limited
- There are preferred directions of movement
- These may change over time



Many thanks for
your attention



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