Small Pelagic Fish: New Frontiers in Science and Sustainable Management
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Spatial population dynamics of sardine in the Northeast Atlantic and the western Mediterranean Sea: defining areas, estimating movement rates and exploring spatial stock assessment models

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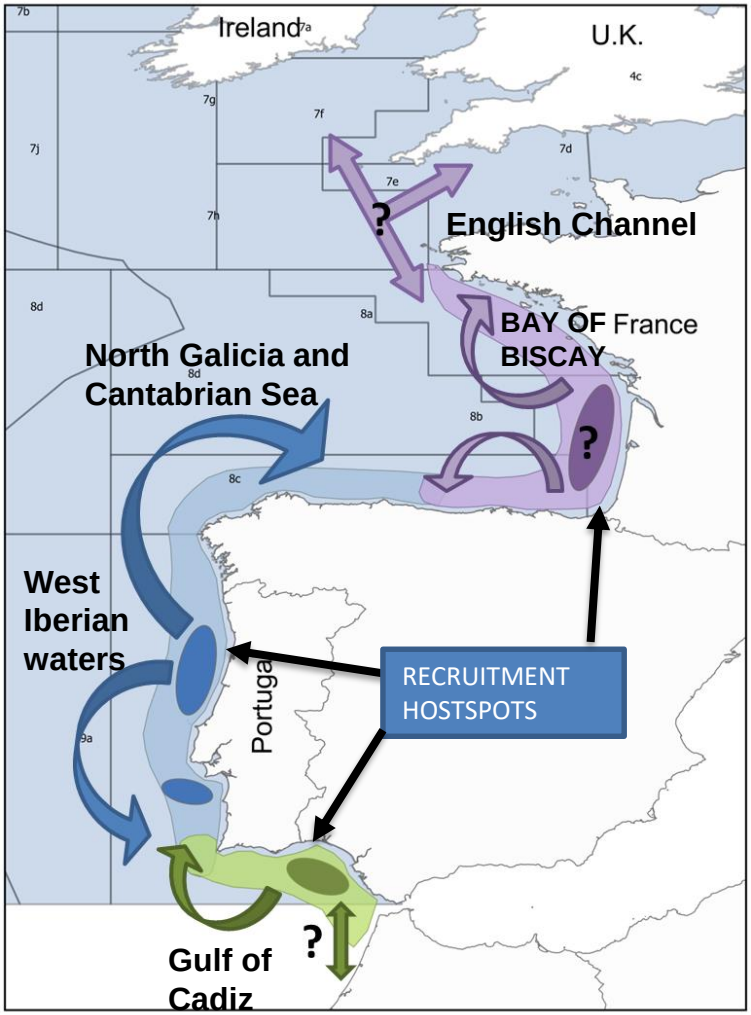
Why bother with spatial population dynamics in the case of sardine?

- Data show different trends in abundance among areas. Risk of local depletion ?
- Spatially-varying biological parameters
- Does stock assessment/advice improve when the spatial structure is taken into account?
- Decision makers may be interested in results reported by area (management already “broken-down” by country/region/area)

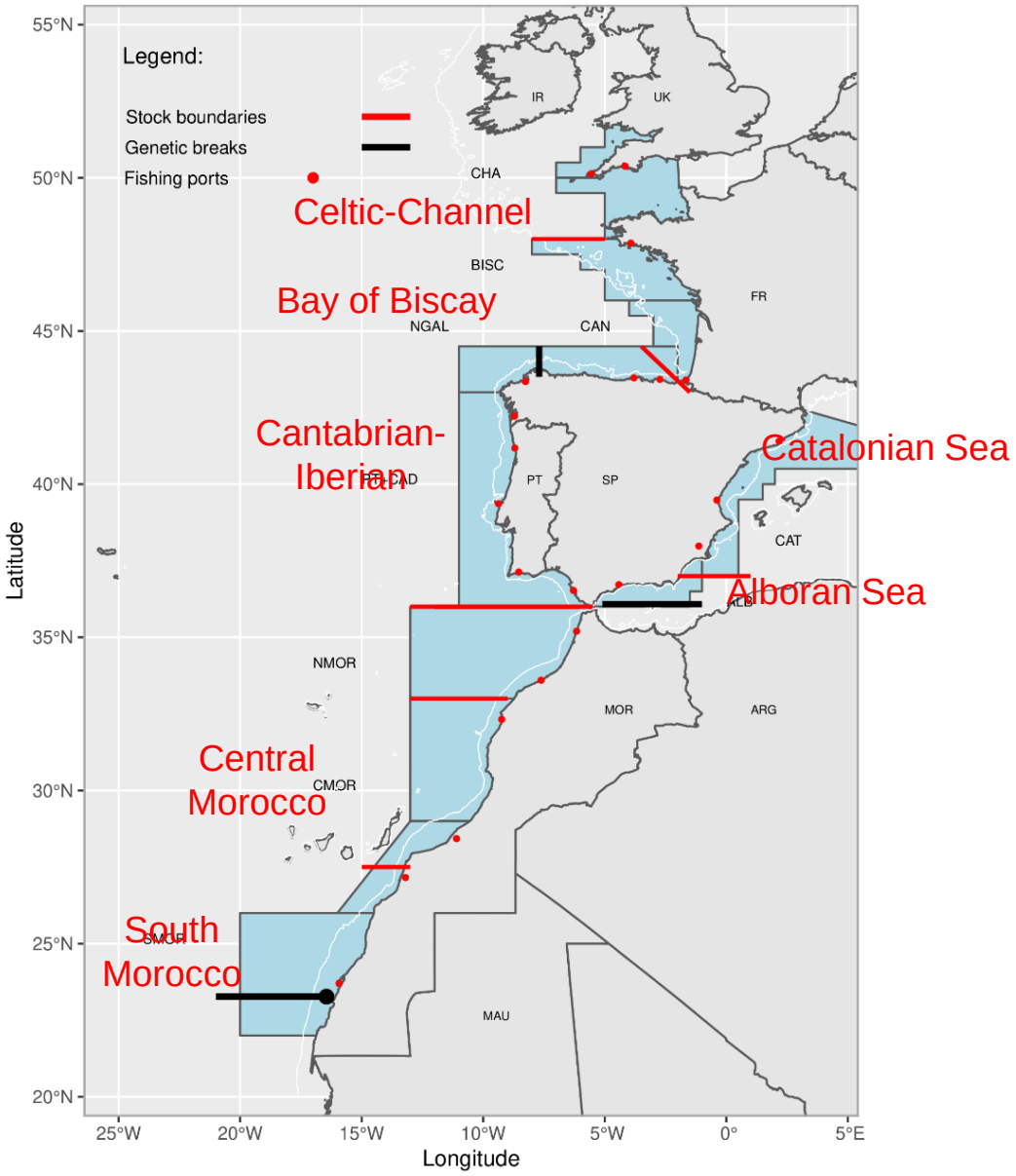
Punt et al.2019

Spatial structure and connectivity the adult phase



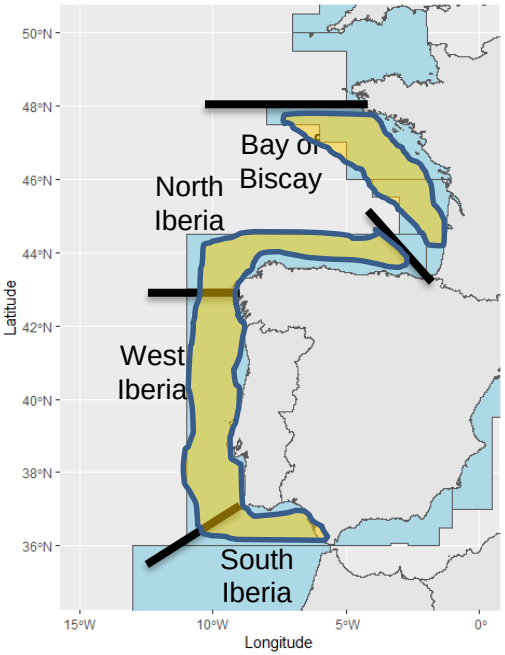
- Spatial structure:
  - Persistent recruitment hotspots
  - Areas dominated by old adults (3+)
- "source-sink" dynamics from recruit to adult areas
- High % of young individuals moving from west to North and South Iberian waters
- Limited movement from the Bay of Biscay to the Iberian Peninsula
- Movement driven by recruitment strength
- Limited information from Celtic Seas/Channel, Morocco and Mediterranean

Silva et al. 2019.

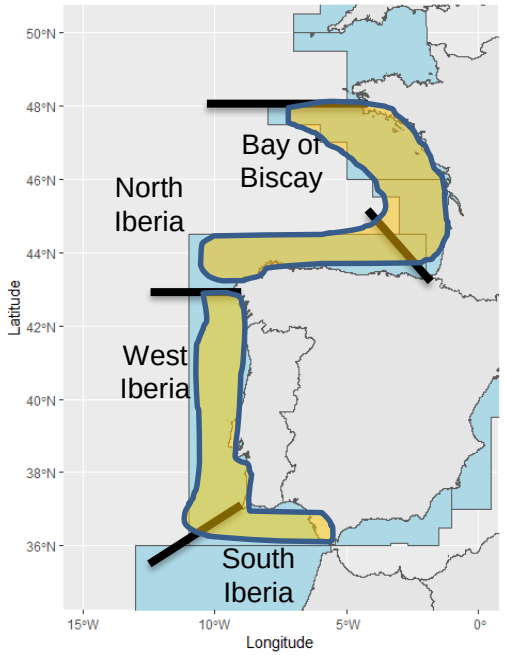

Legend:
Stock boundaries
Genetic breaks
Fishing ports
Celtic-Channel
Bay of Biscay
Cantabrian-Iberian
Catalonian Sea
Alboran Sea
Central Morocco
South Morocco
IR
UK
CHA
BISC
FR
NGAL
CAN
PT
SP
CAT
NMOR
MOR
ARG
CMOR
MAU
55°N
50°N
45°N
40°N
35°N
30°N
25°N
20°N
25°W
20°W
15°W
10°W
5°W
0°
5°E
Latitude
Longitude

Stock-area structure

Current-like



Genetic-like



- 4 areas: Bay of Biscay, North Iberia, West Iberia, South Iberia
- 2 stocks:
  - -Bay of Biscay and Iberia
  - - Bay of Biscay+Cantabrian and West+South Iberia
- Movement from source to sink areas

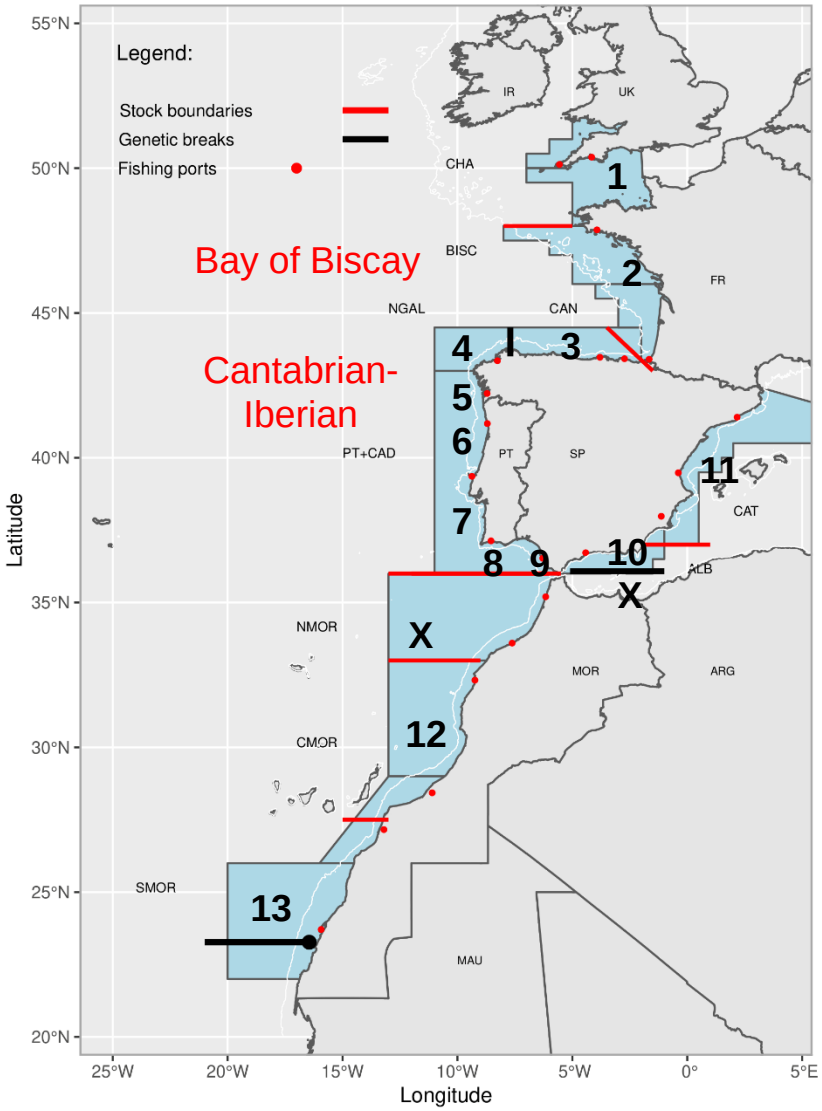
Aim of the study

1. Update the study of population structure and demographic connectivity in the Iberian-Biscay region and extend it to the North, to Western Mediterranean Sea and to Moroccan waters
2. Apply a population dynamics model (Stock Synthesis) to test 2 hypotheses of stocks-areas: “current-like” against “genetic-like”
3. Compare results of spatial and non-spatial stock assessments conducted in the region.

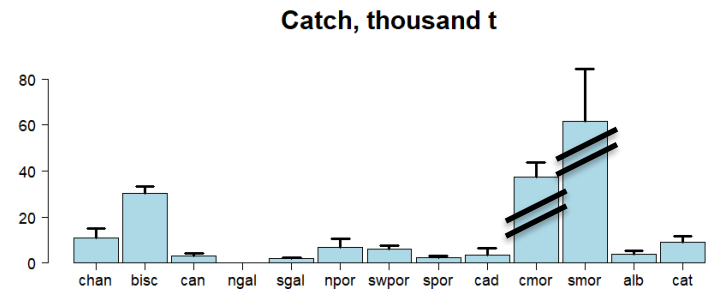
Exploratory analyses

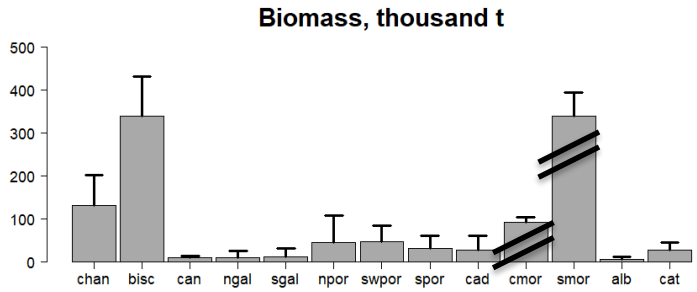
Data

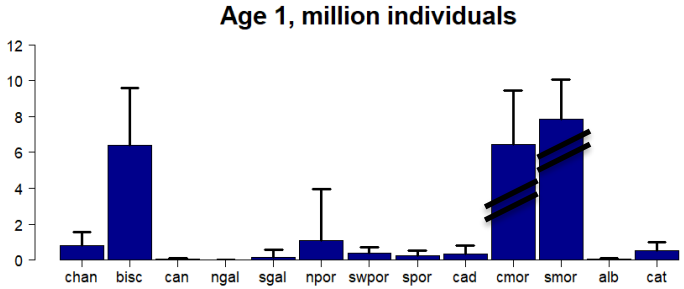
- 13 areas from the English Channel to southern Morocco and Western Mediterranean:
  - Abundance-at-age (surveys)
  - Catch biomass
  - Catch-at-age
  - Biological data
- 2002 – 2021 for Bay of Biscay and Iberian areas
- 2007-2020 Morocco
- 2013 – 2020 Mediterranenan and Channel
- No data from North Morocco (Mediterranean or Atlantic)

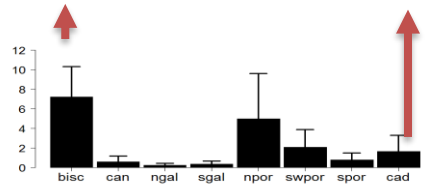


Catches, biomass, and recruits abundance by area (2013 – 2020)







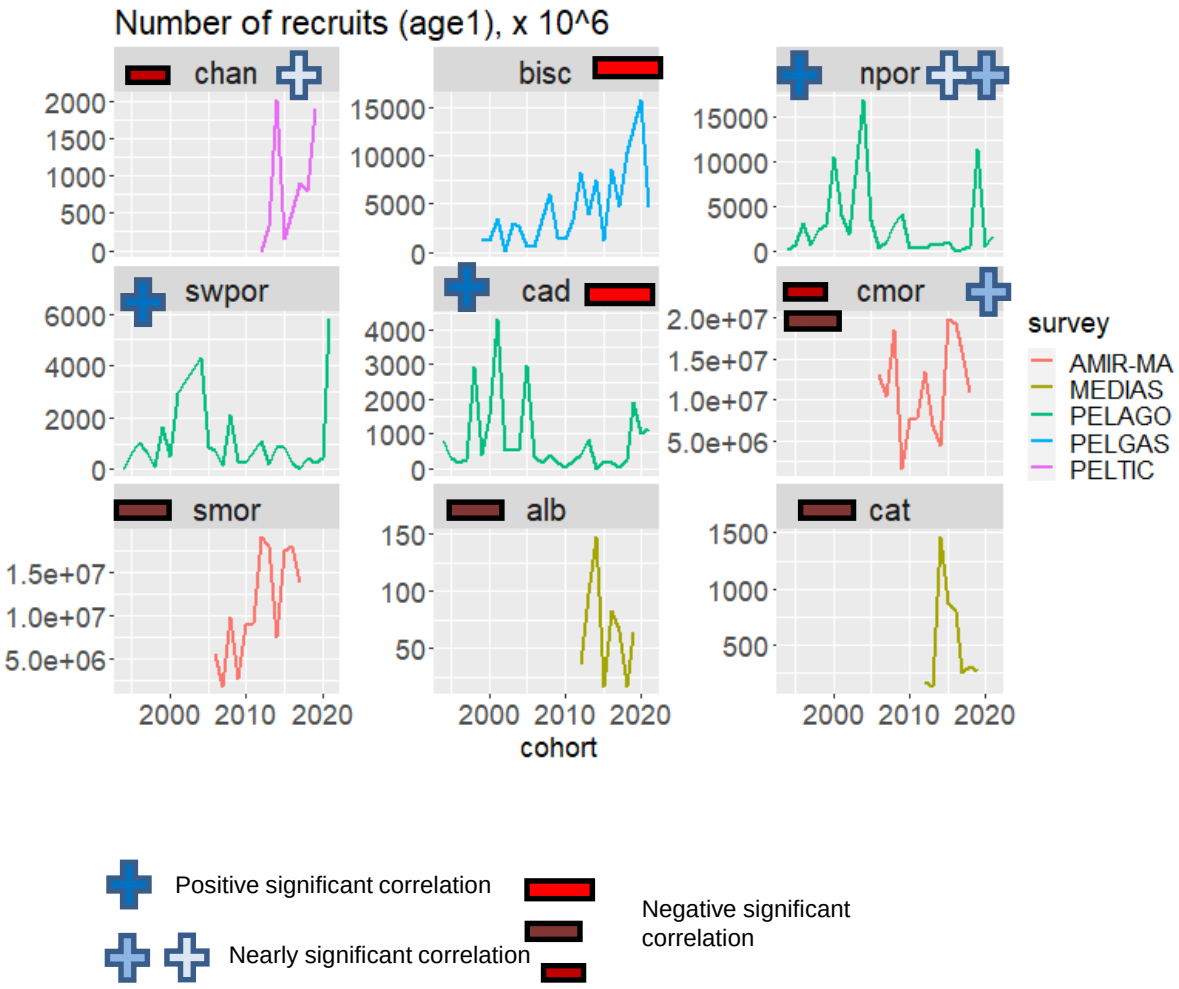


Silva et al. 2019. (2005-2015).

- Survey and catch biomass in Morocco one order of magnitude higher that in European waters (e.g. Bay of Biscay, Channel)
- Mediterranean comparable to Atlantic Iberian areas; decrease from north to south
- Distribution changed in European Atlantic waters: sardine abundance decreased off the Iberian Peninsula and increased in the Bay of Biscay

NOTE: In Morocco areas, numbers were divided by 2000 and biomass by 10

Cross-correlation of recruits abundance among areas

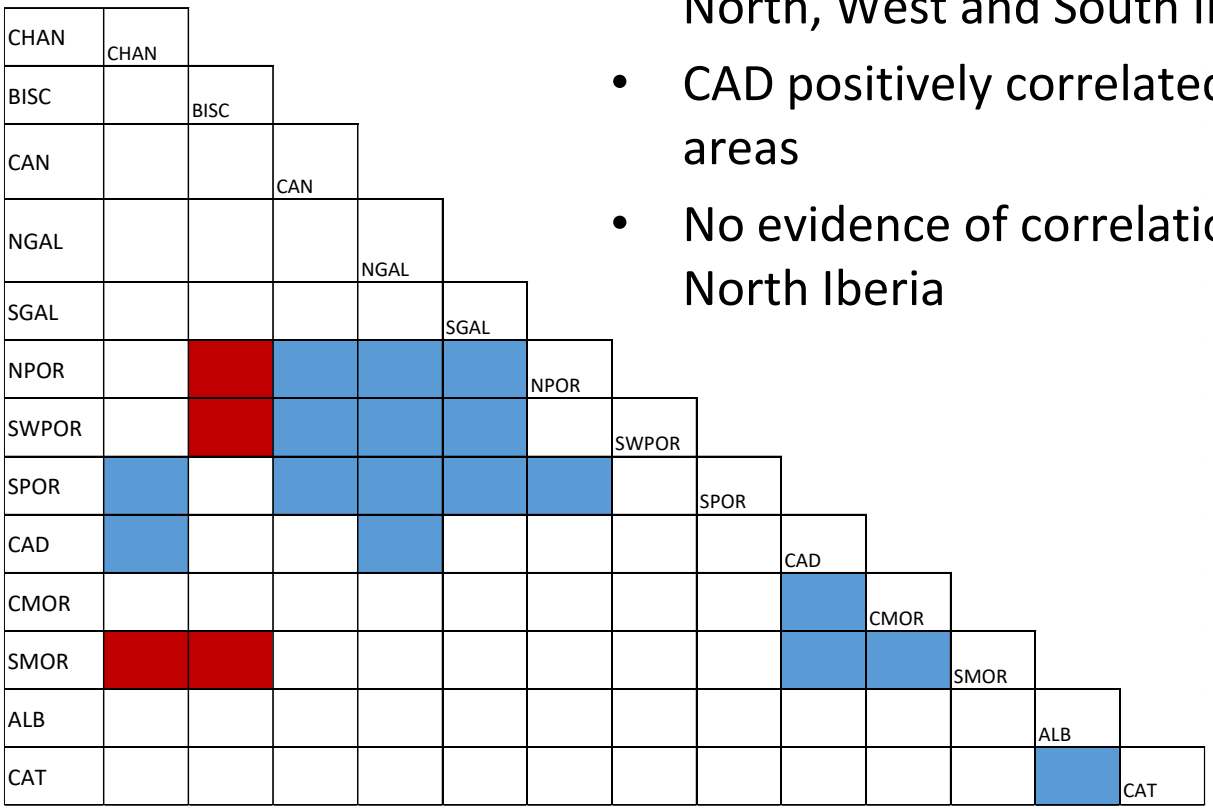


Lagged correlations:

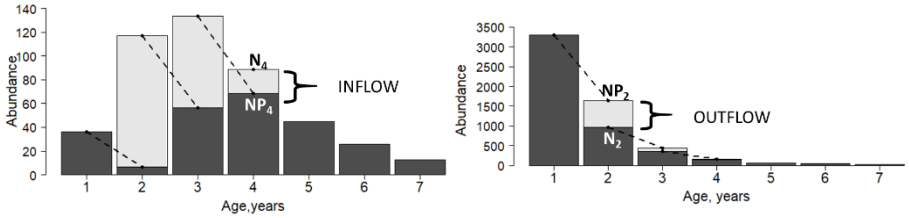
- CAD good/bad recruitments 1 year after those in NPOR
- Opposite trends in BISC and WPOR
  - Significant negative correlation at lag=-2; good recruitment in BISC follows poor recruitment in NPOR 2 years

Cross-correlations of adults abundance among areas

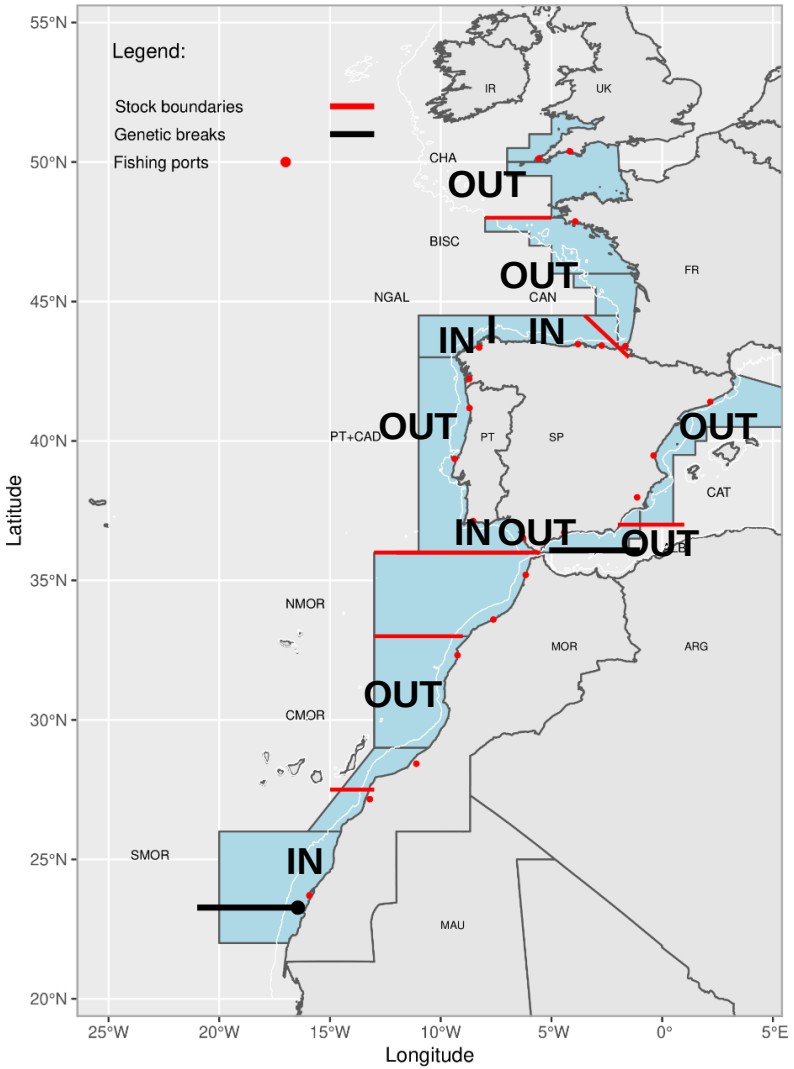
- Population variability correlated among North, West and South Iberian areas
- CAD positively correlated with Moroccan areas
- No evidence of correlation between BIS and North Iberia



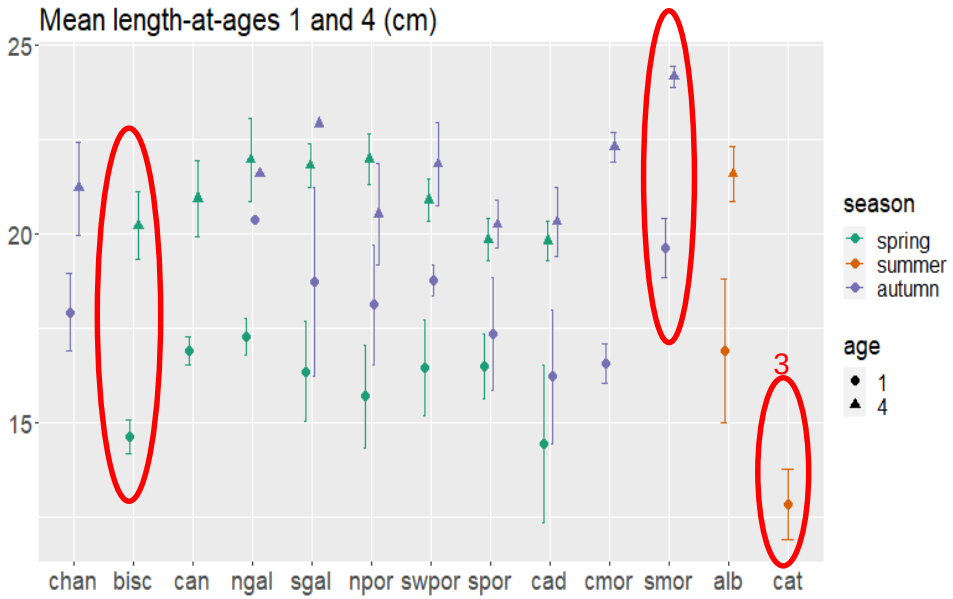
AGE STRUCTURE BY AREA



Areas with age structure typical of **IN**FLOW or **OUTFLOW**



Growth and natural mortality (2013 – 2020)



area	M
7ef	0.6467596
8ab	0.5456087
8ce	0.5041972
8cw	0.5008329
9acn	0.6738588
9acs	0.6170261
9an	0.5278175
9asa	0.4903218
9asc	0.6559732
gsa1	0.7668976
gsa6	1.3446207
morab	0.7489062
morc	0.9261675

M calculated with the Gislason formula

- Gradual decrease of LAA along Iberian waters
- Lower in CAD and CAT
- Marked difference from CAD to CMOR and ALB
- Significantly higher in SMOR

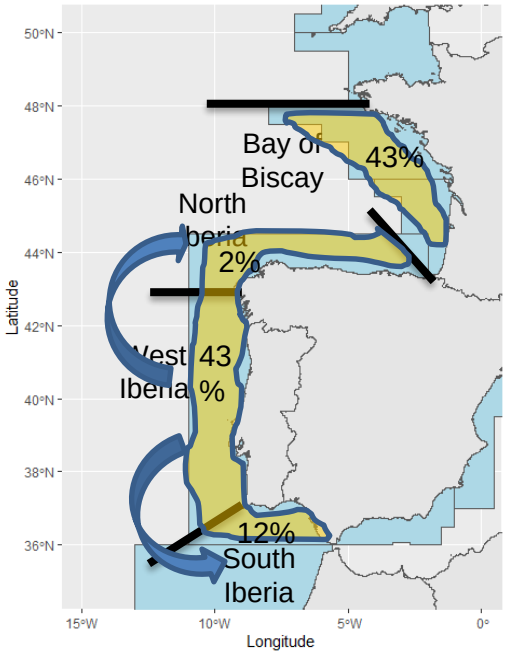
- In BISC and CAN (?) lower length-at-age than in the first half of the 2000s
- BISC different from neighbour areas

Modelling population dynamics

Stock-area structure

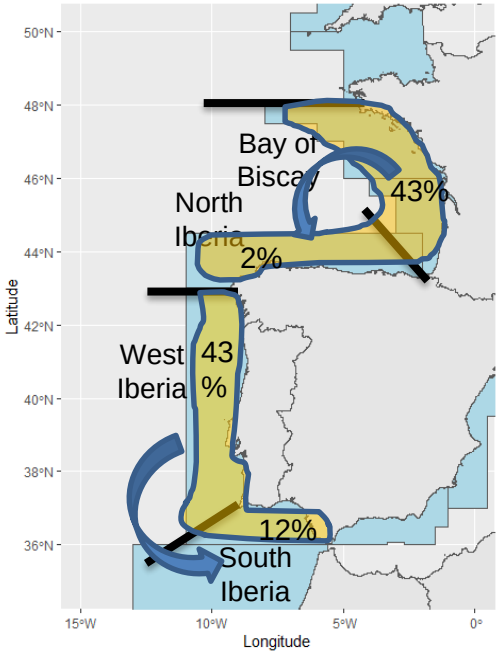
Recruitment distribution deviates over time in areas 1 and 4.

Current-like



Movement assumed to increase from age 0 to age 2 and then stay constant.

Genetic-like



Recruitment distribution deviates over time in areas 1 and 2.

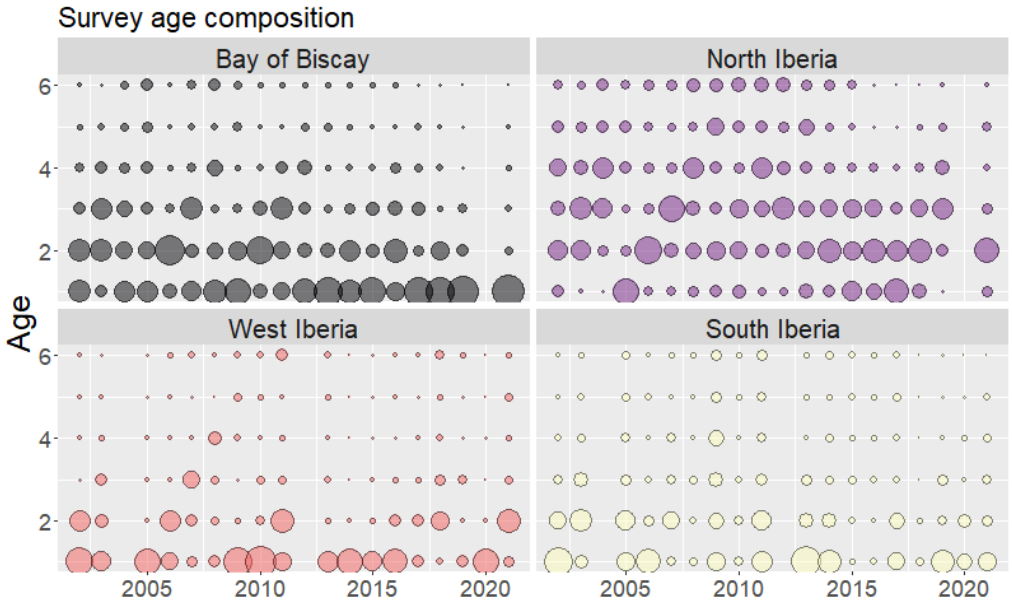
- 4 areas: Bay of Biscay, Cantabrian+Galicia, West Iberia, South Iberia
- Catch and survey data split into those areas
- 2 stock definitions, 2 movement scenarios
- Recruitment distribution among areas varies over time (initial values derived from spring acoustic surveys)

Other assumptions

Survey catchability estimated, selectivity assumed to be equal at all ages (as in ICES stock assessments)

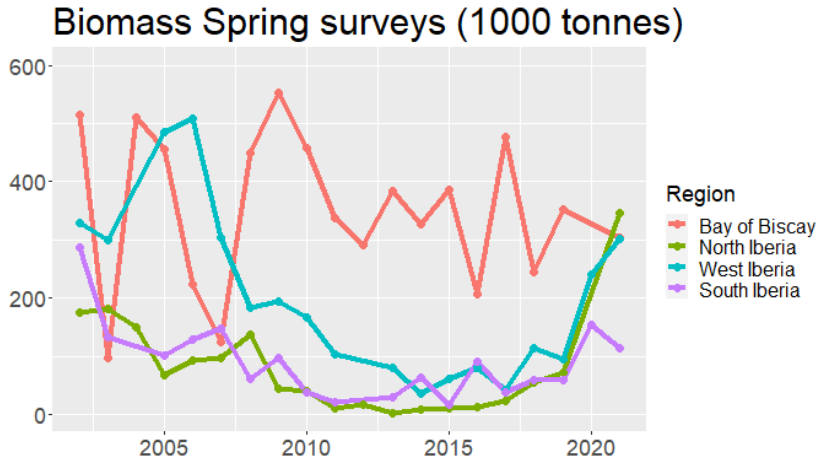
Fleet selectivity estimated for ages 0-2, assumed to be equal from age 2 onwards (similar to ICES assessments).

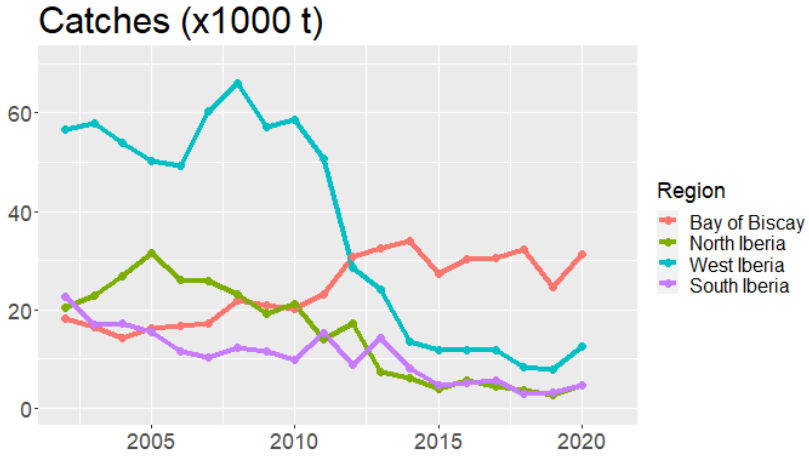
Recruitment from a single SR relationship (no alternative in SS), distributed among areas.



Stock-area input data

One Spring acoustic survey in each area. One Autumn acoustic survey in areas 3 and 4. DEPM surveys not used.
Period 2002 – 2021.

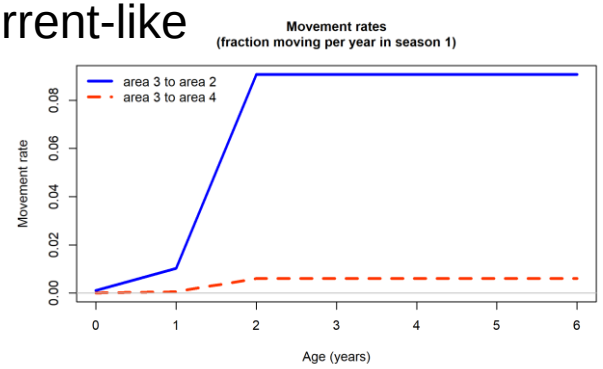




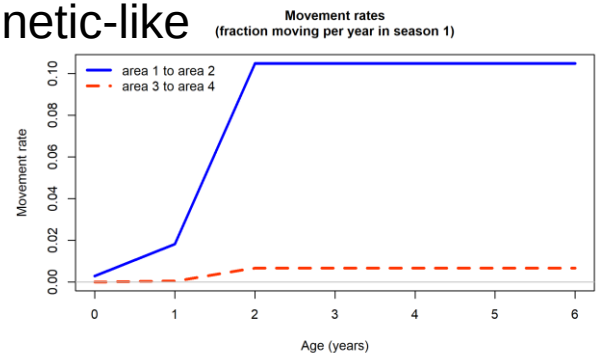
Results

- LogLikelihood	Model		Difference
	Current-like	Genetic-like	GL-CL, %
TOTAL	335.39	376.04	12.12
Catch	0.10	0.16	66.81
Equilibrium_catch	0.16	1.72	1001.69
Survey	0.53	20.97	3891.13
Age_comp	312.73	339.10	8.43
Recruitment	-2.02	-1.05	47.99
Parm_priors	5.87E-12	9.36E-13	-84.070
Parm_softbounds	0.01	0.01	0.23
Parm_devs	23.89	15.12	-36.71

Current-like



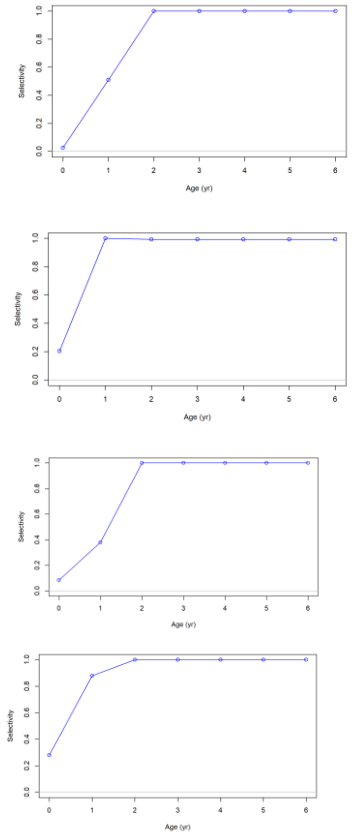
Genetic-like



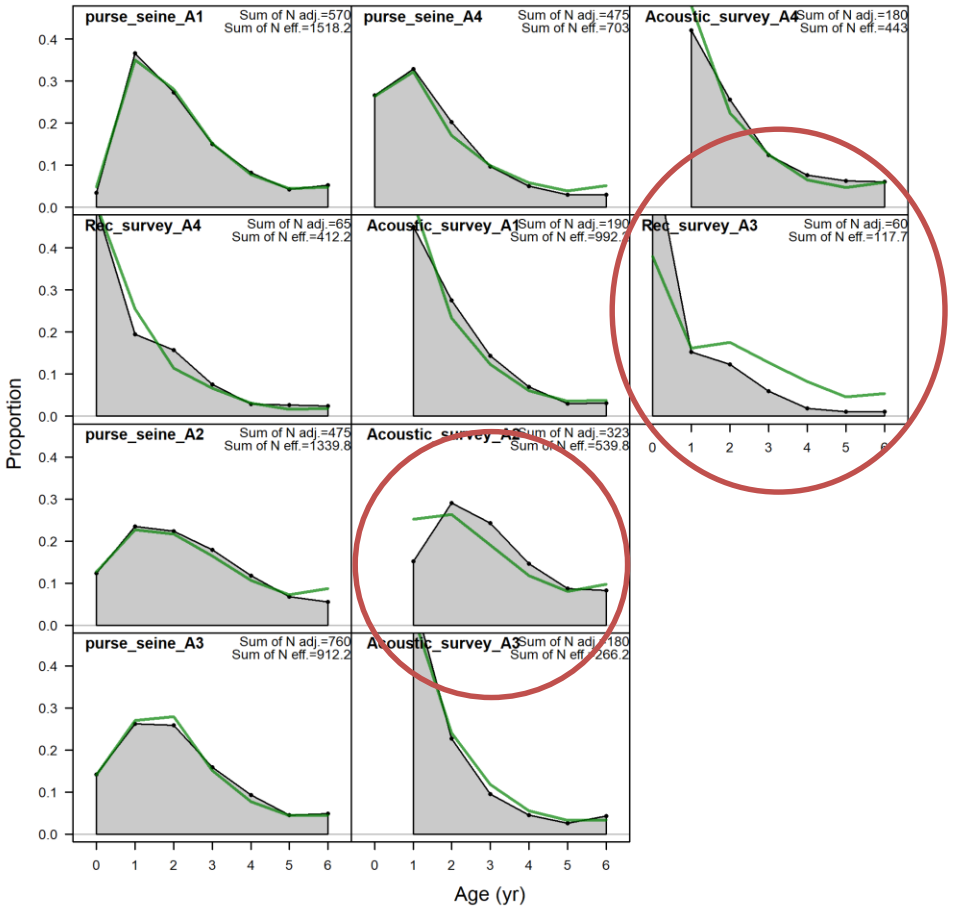
- Current-like model 12% more likely than genetic-like model
- Genetic-like model with slightly poorer fit to Spring acoustic surveys in Biscay and Cantabrian Sea, and to autumn survey in West Iberia
- Movement rates below 10% from source West Iberia (Current-like) or Bay of Biscay (Genetic-like) to the Cantabrian “sink” area; movement from West to south Iberia below 1%

Fitting (Current-like model)

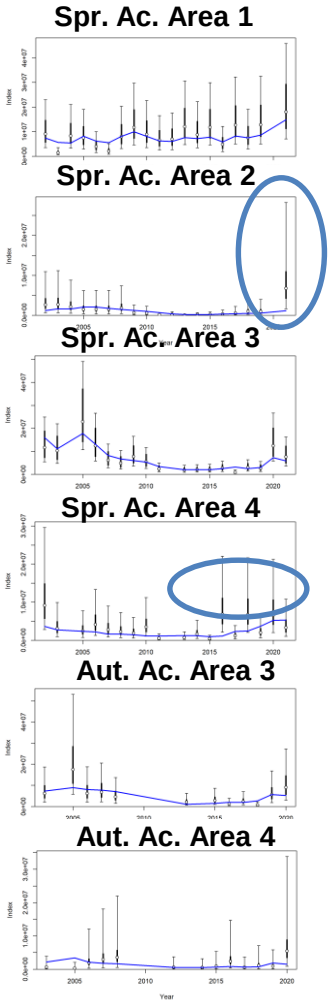
Fishery selectivity at age



Fitting to fishery and survey age distributions

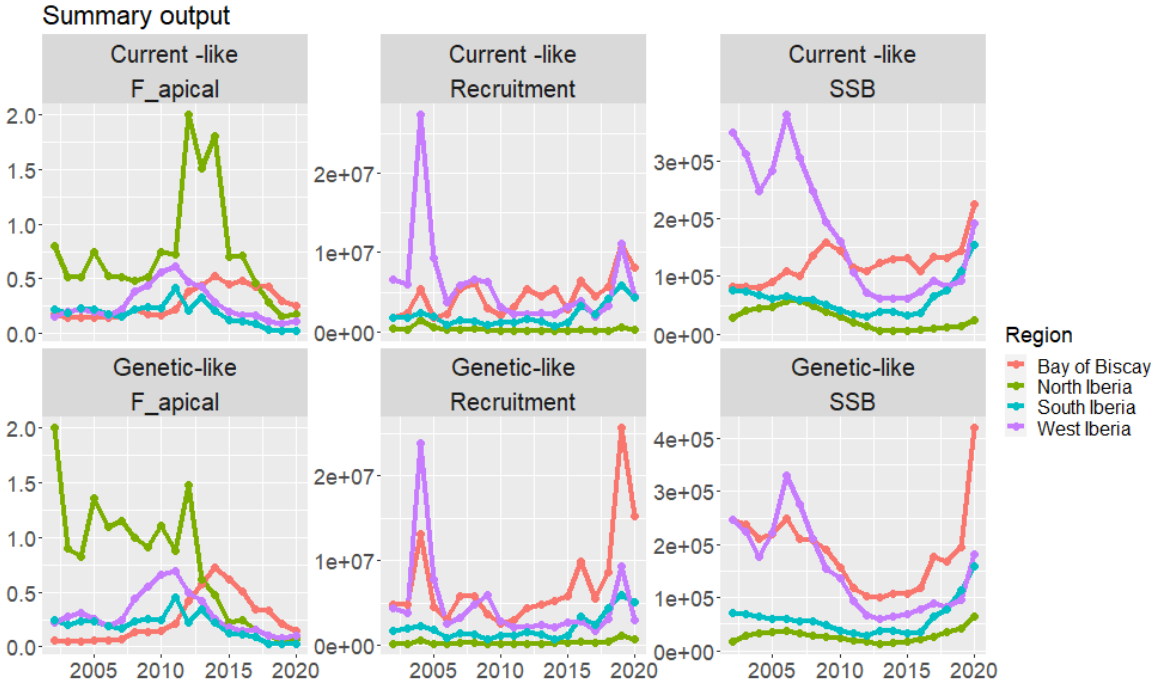


Fitting to survey indices



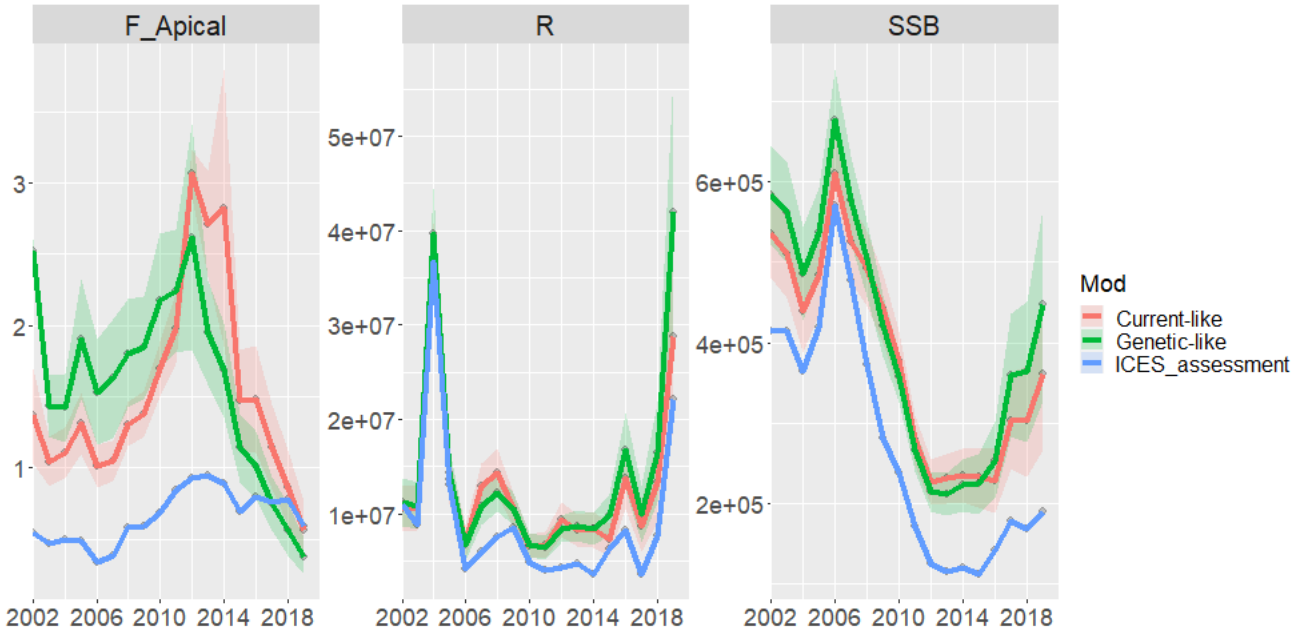
Poor fitting to the age composition of spring acoustic survey in area 2 (Cantabrian Sea) and autumn acoustic survey in area 3 (West Iberia) age composition.

SSB, recruitment and fishing mortality by area



- Major differences between spatial models:
  - fishing mortality in North Iberia
  - recruitment and SSB in Bay of Biscay
- Recruitment and SSB of spatial models highly correlated with that of ICES assessment for the Iberian stock (all $r>0.94$, $p<0.01$)
- In the Bay of Biscay, the correlation is significant ($r=-0.63$, $p<0.05$) only for the Current-like model

Results



- Spatial models provide a perception of SSB and recruitment in the whole region (Bay of Biscay to Gulf of Cadiz), comparable to that obtained by the sum of ICES stock assessments
- The fishing mortality trends are different, mainly due to North Iberia

Discussion

- Trends in abundance do not support strong connectivity between sardine populations in European and Morocco Atlantic waters at the adult stage; however, the relationship with the Gulf of Cadiz deserves further attention.
- Asynchronous recruitment, age structure typical of “source areas” and a major difference in mean length supports the existence of self sustained Alboran and Catalan populations, as currently considered in stock assessment;
- Indications of synchronous recruitments and population abundance and age structure typical of source-sink dynamics suggest connectivity between Central and (part of ?) South Morocco

Discussion

- Our spatial models included (over-) simplified spatial structure and movement scenarios
- They provided comparable perceptions of regional population dynamics, apart in the Bay of Biscay and comparable fishing mortality trends except in North Iberia;

- The similar perception of SSB and Recruitment provided by spatial models and ICES stock assessments for the whole area seems re-assuring
- Data and model assumptions to be re-visited e.g. assignment of Galicia to the southern region, re-evaluation of autumn acoustic surveys, split of east from west Cantabrian Sea data, higher spatial disaggregation, movement hypothesis
- Growth differences need to be accounted for to get correct SSB trends (BoBiscay)
- The current-like stock structure was more likely than the genetic-like, with some improvement of fitting to data from northern areas
- Low movement rates increasing with age contradict previous results although being consistent with the difference in abundance among regions


THANKS FOR YOUR ATTENTION
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Acknowledgements

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