Spatial effort allocation: separation of catches in highly mixed fisheries

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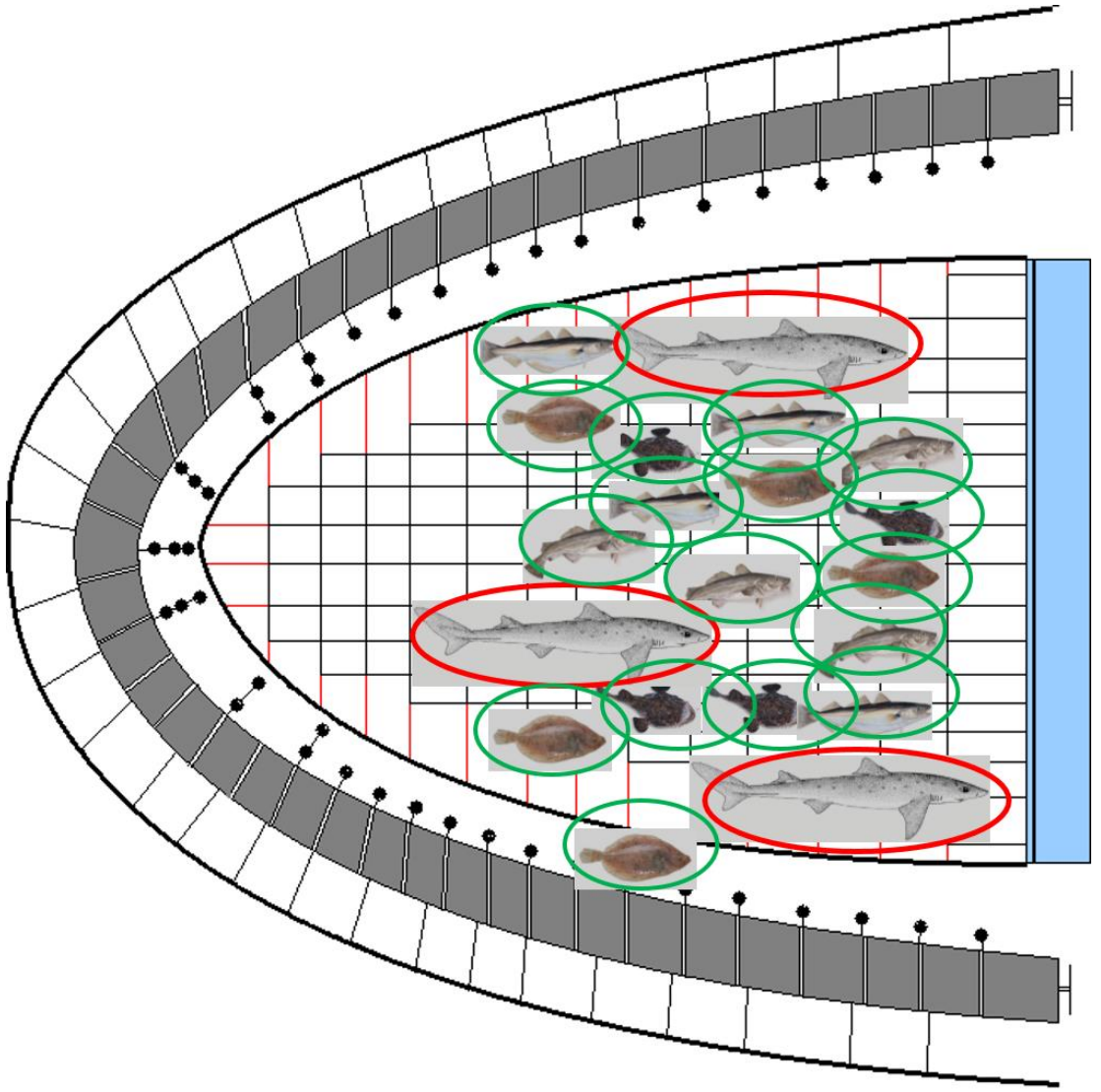
Cefas

Motivation

- Mixed fisheries have highly **complex spatiotemporal dynamics**
- Fishers make decisions about **location choice** in face of uncertainty
- In EU, **‘landing obligation’** makes spatial targeting (and avoidance) key to meeting management goals



Motivation

- Spatial targeting is a mechanism to **decouple exploitation** among species
- Challenge: how far can it practically contribute to **dealing with LO**
- Unknown and anecdotal: need for a **quantifiable framework**

Objectives

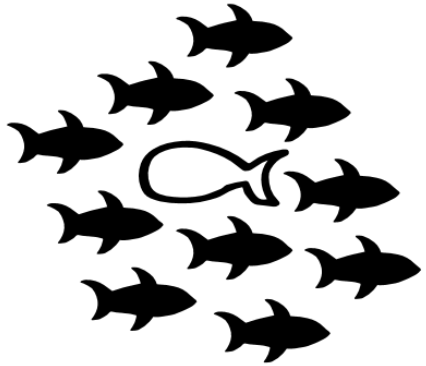
- Goal: Develop a framework for **understanding and simplifying complexities** of spatiotemporal targeting

- Approach:
  - Implement **geostatistical model** to draw inference on fishery-fish community dynamics
  - Identify species assemblages which **co-occur** and are exploited together
  - Tease out potential for (and limitations to) **spatial targeting** in mixed fishery

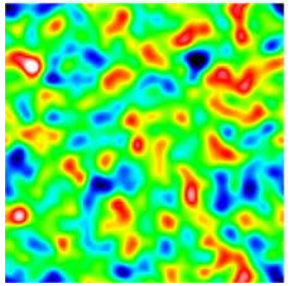
- Applied to **Celtic Sea** case study

Brief methods

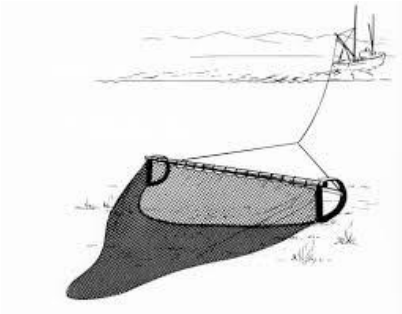
- Spatial Dynamic Factor Analysis (**SDFA**) able to take account of latent (unobserved) drivers which affect species distribution and density for one or more species

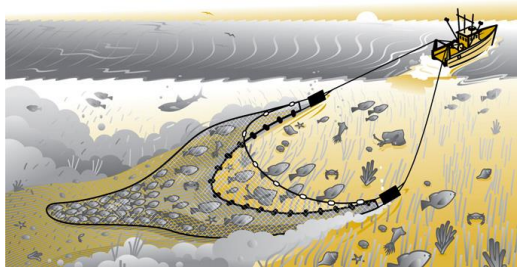


- Gaussian Markov Random Fields (**GMRFs**) to model the variation in probability of occurrence and density (and account for autocorrelation)



- Separate contribution of gear effects, encounter probability and density (**GLMM**).





Main interactions

Density

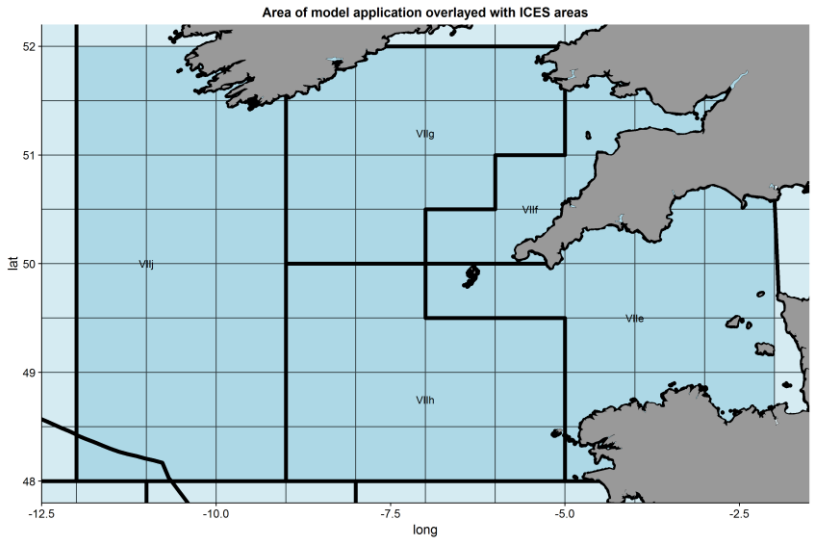
Spp. loading matrix

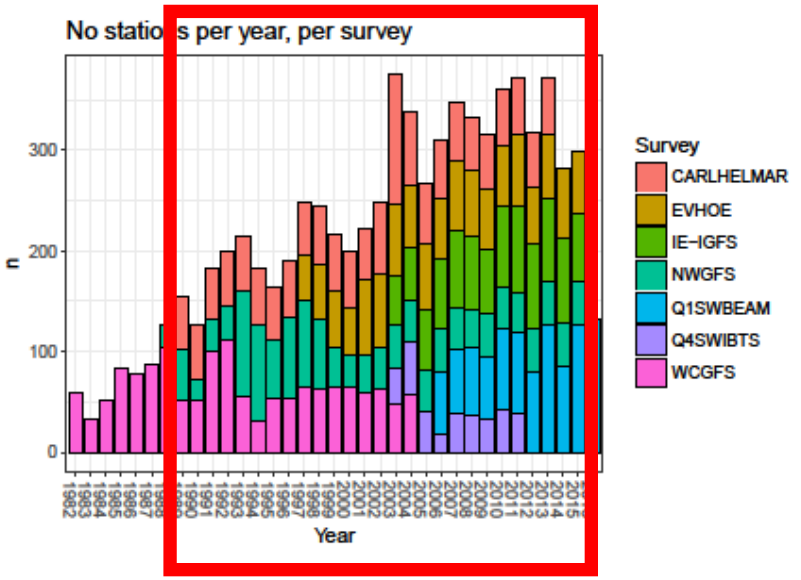
$$\theta_c(s,t) = \sum_{j=1}^{n_j} L_{c,j}\psi_j(s,t) + \sum_{k=1}^{n_k} \gamma_{k,c}\chi_k(s,t)$$

Spatial factor coefficient

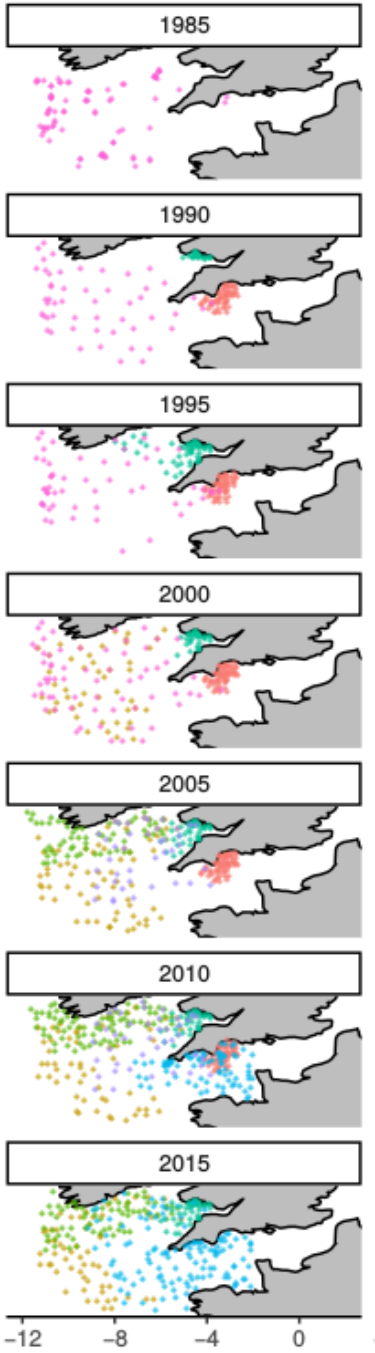
Covariates

Data: Surveys





Survey code	Name	Gear	Temporal extent
CEXP / IE-IGFS	Celtic Explorer (IE)	Otter trawl	2003 - 2015
CARLHELMAR	Carlhelmar (UK)	Commercial beam trawl	1989 - 2013
NWGFS	North West groundfish survey (UK)	Beam trawl	1988 - 2015
Q1SWBEAM	Quarter 1 south-west beam trawl survey (UK)	beam trawl	2006 - 2015
Q4SWIBTS	Quarter 4 south-west international bottom trawl survey (UK)	Otter trawl	2003 - 2010
THA2 / EVHOE	EVHOE survey on Thalasa (FR)	Otter trawl	1997 - 2015
WCGFS	Wstern channel groundfish survey (UK)	Otter trawl (Portuguese high headline)	1982 - 2004

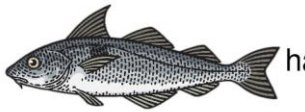


Data: Species

Species code	Common name	Species	MCRS (cm)
juv	Juvenile		
adu	Adult		
bud	Black bellied angler-fish	*Lophius budgessa*	32*
cod	Atlantic cod	*Gadus morhua*	35
had	Atlatic haddock	*Melanogrammus aeglefinus*	30
hke	Atlantic hake	*Merluccius merluccius*	27
meg	Megrim	*Lepidorhombus whiffiagonis*	20
pisc	White bellied angler-fish	*Lophius piscatorius*	32*
ple	European Plaice	*Pleuronectes platessa*	27
sol	Common sole	*Solea solea*	24
whg	Atlantic whiting	*Merlangius merlangus*	27

*Monkfish species estimated based on a 500g minimum marketing weight

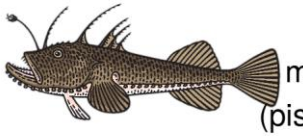

cod


haddock

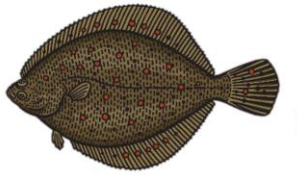

whiting

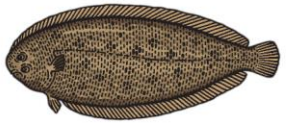

hake

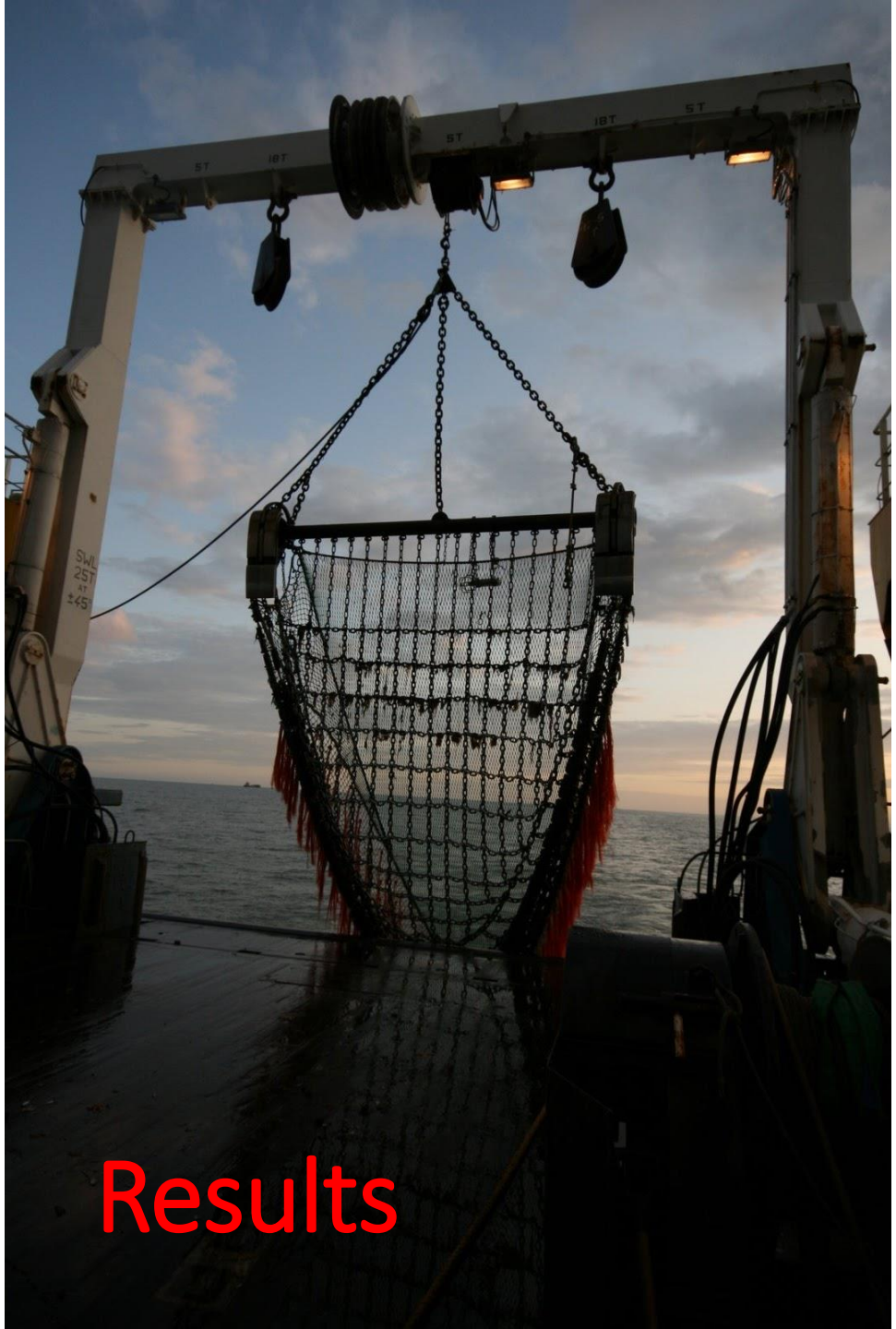

megrim

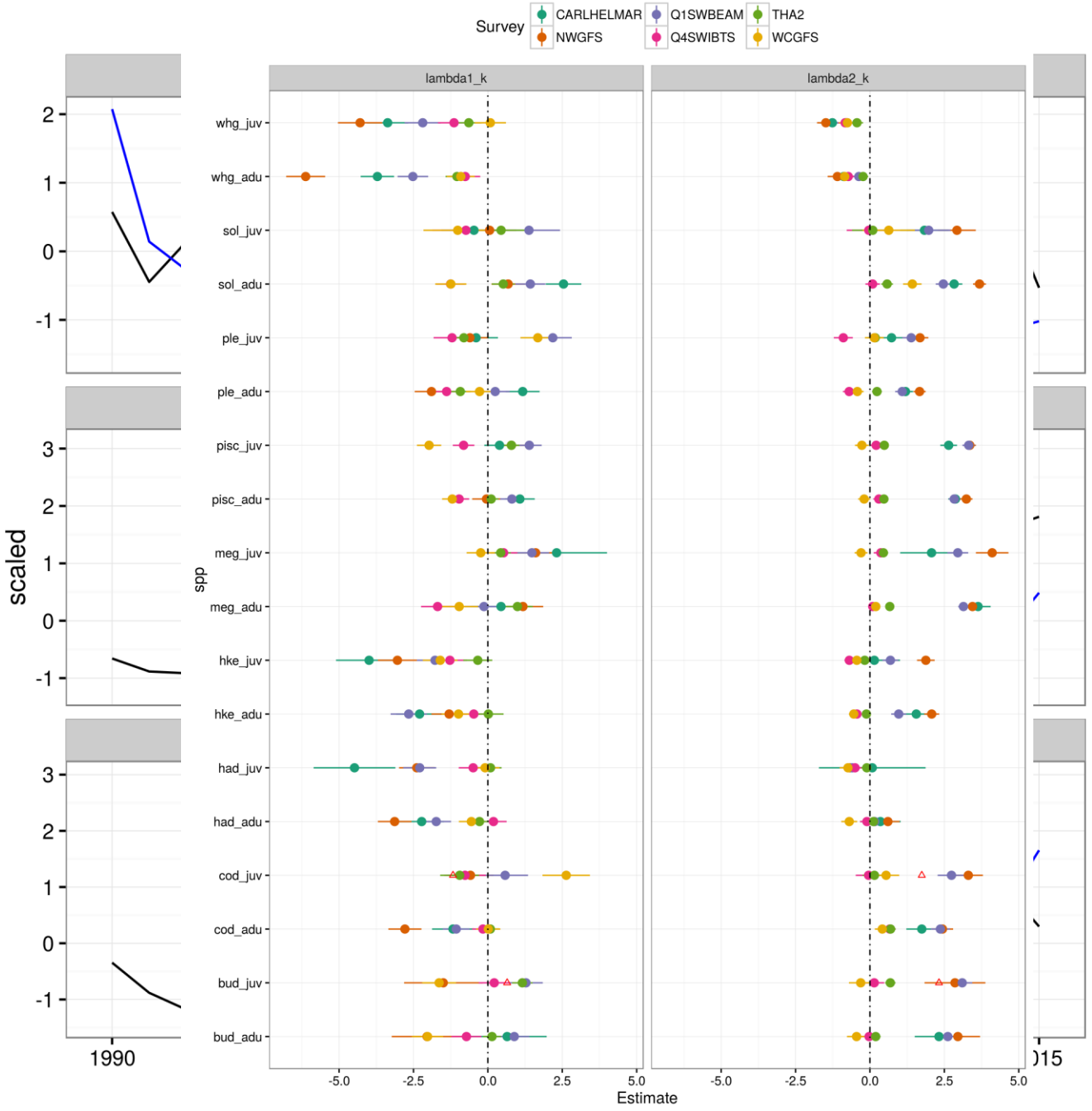

monkfish (piscatorius)


monkfish (budegassa)

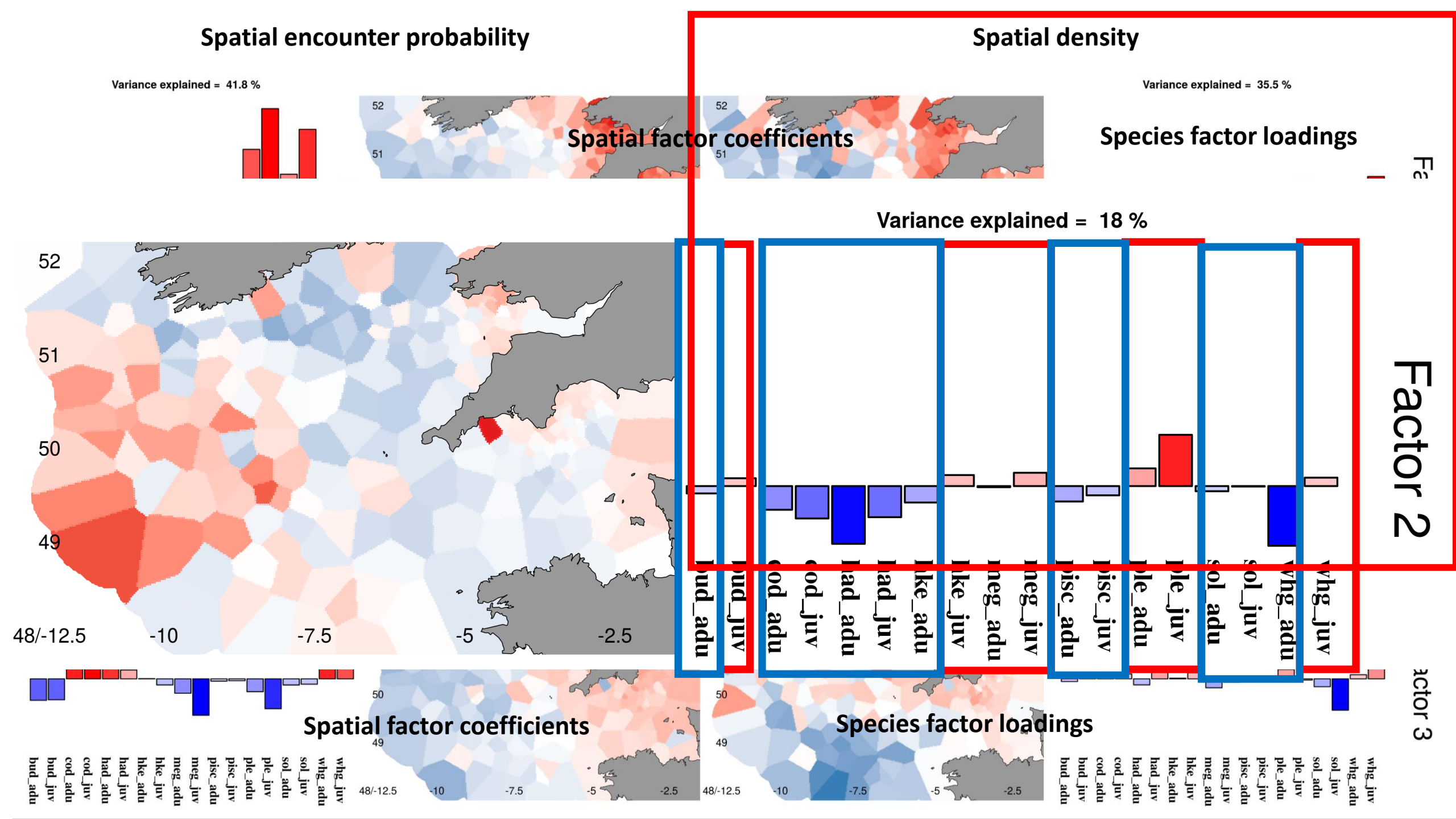

plaice

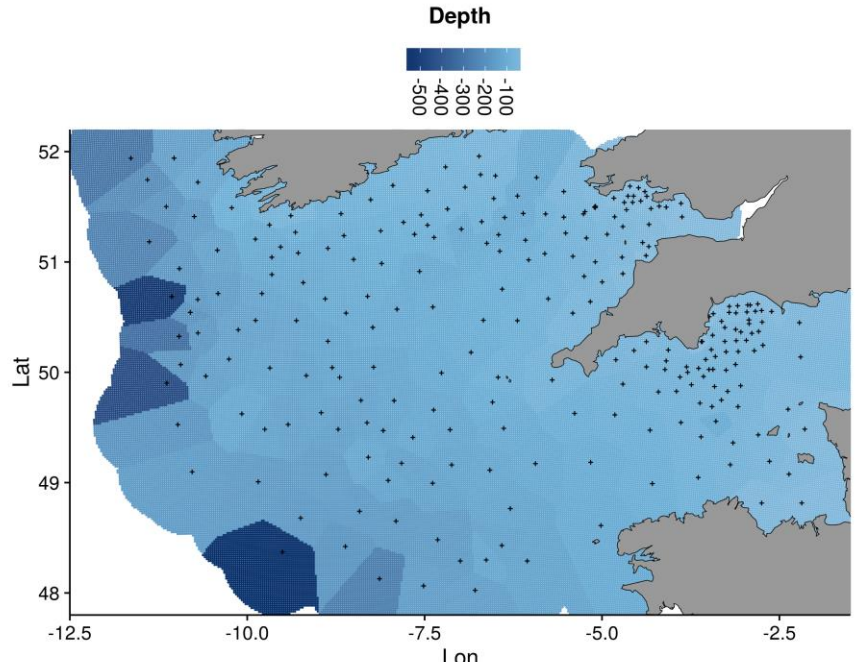

sole

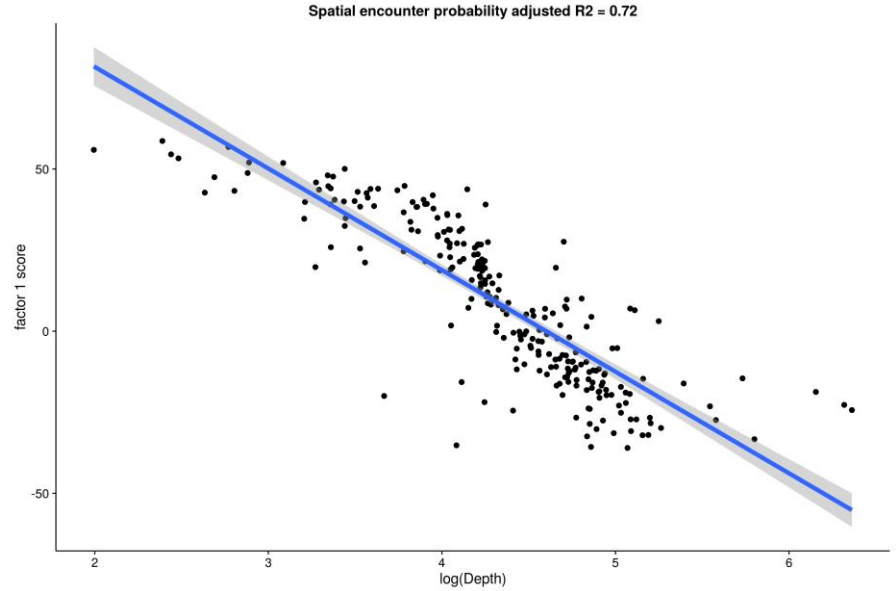

Results

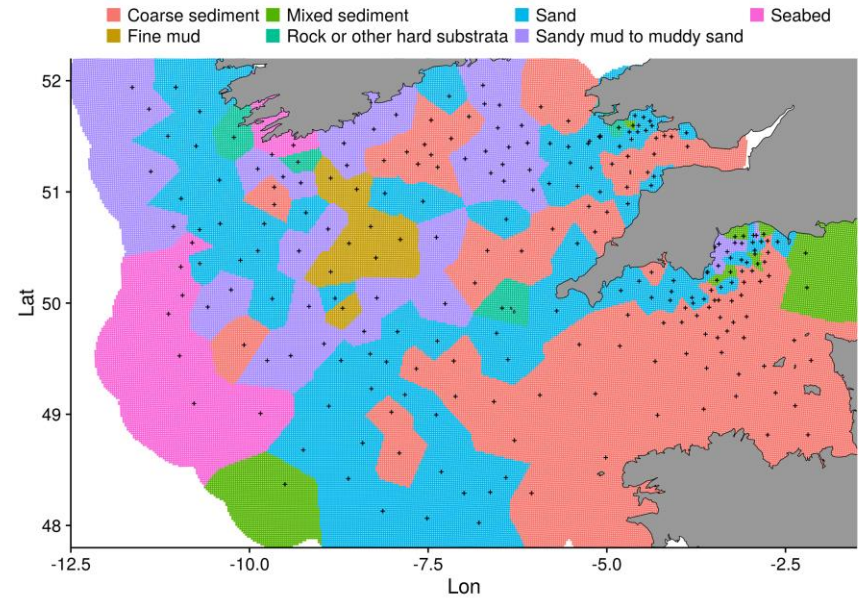

Survey
CARLHELMAR
NWGFS
Q1SWBEAM
Q4SWIBTS
THA2
WCGFS
lambda1_k
lambda2_k
scaled
spp
whg_juv
whg_adu
sol_juv
sol_adu
ple_juv
ple_adu
pisc_juv
pisc_adu
meg_juv
meg_adu
hke_juv
hke_adu
had_juv
had_adu
cod_juv
cod_adu
bud_juv
bud_adu
1990
Estimate

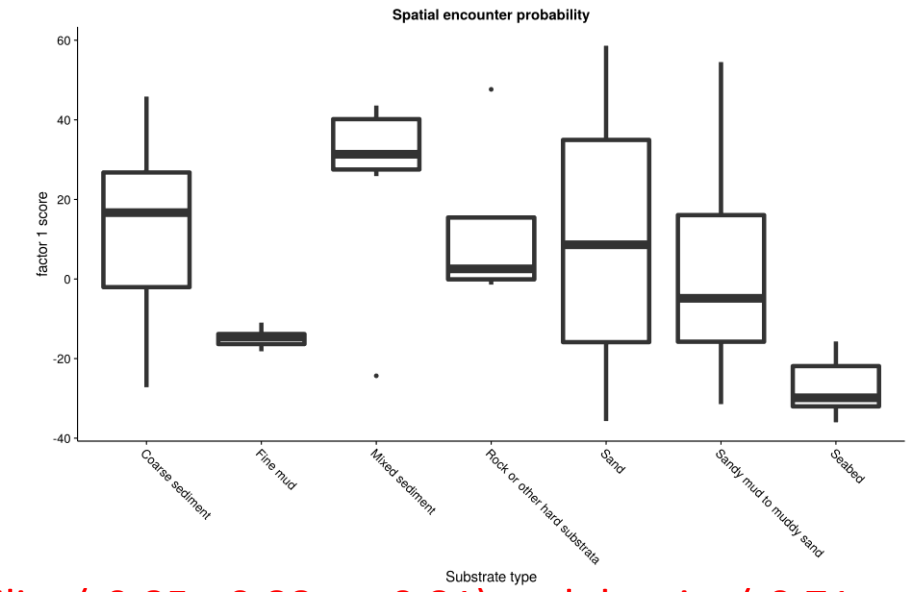
Spatial drivers of species assemblages


Spatial encounter probability
Spatial density
Variance explained = 41.8 %
Variance explained = 35.5 %
Spatial factor coefficients
Species factor loadings
Variance explained = 18 %
Factor 2
52
51
50
49
48/-12.5
-10
-7.5
-5
-2.5
bud_adu
bud_juv
cod_adu
cod_juv
had_adu
had_juv
hke_adu
hke_juv
meg_adu
meg_juv
pisc_adu
pisc_juv
ple_adu
ple_juv
sol_adu
sol_juv
whg_adu
whg_juv
Spatial factor coefficients
Species factor loadings
Factor 3



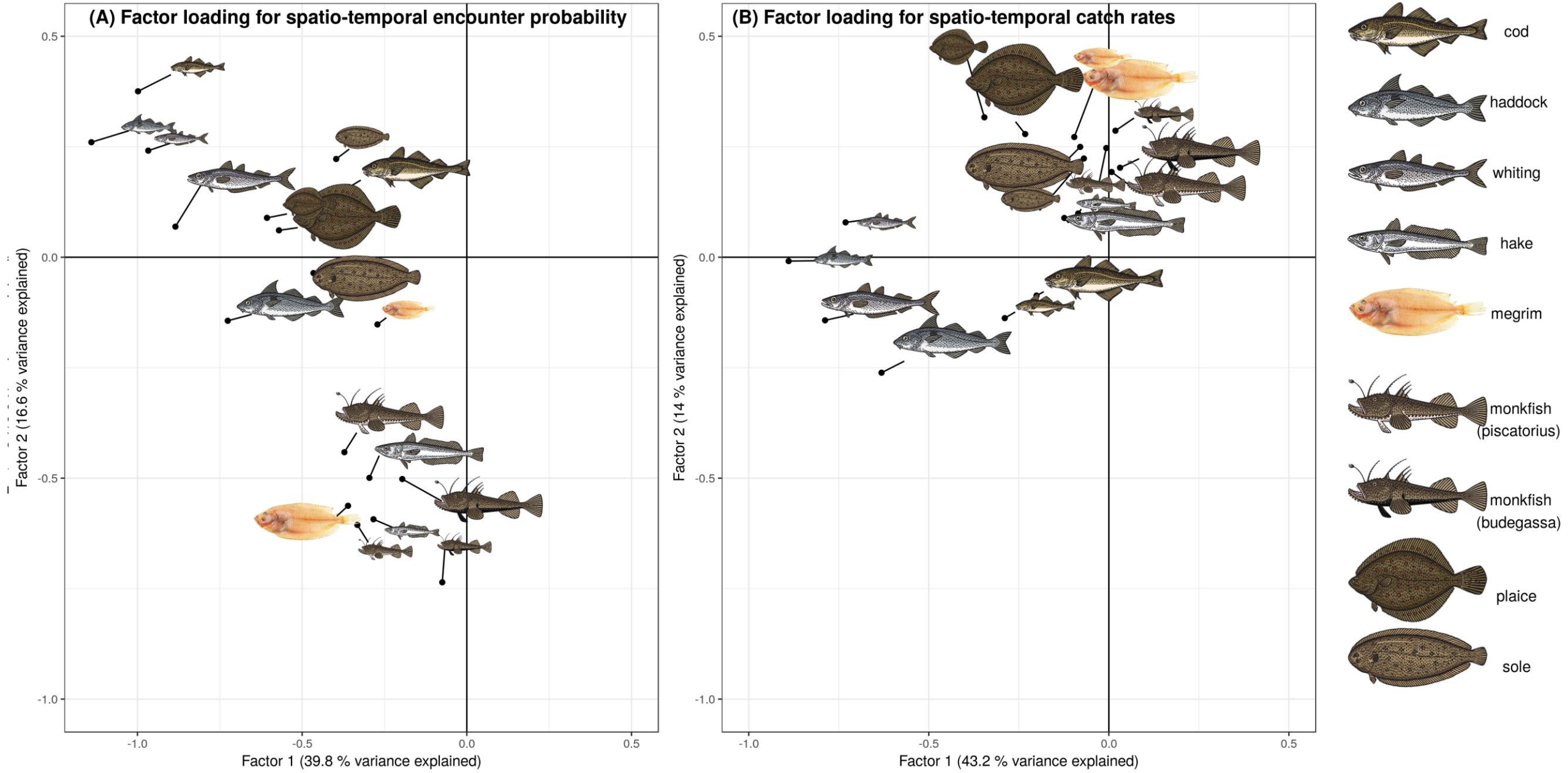




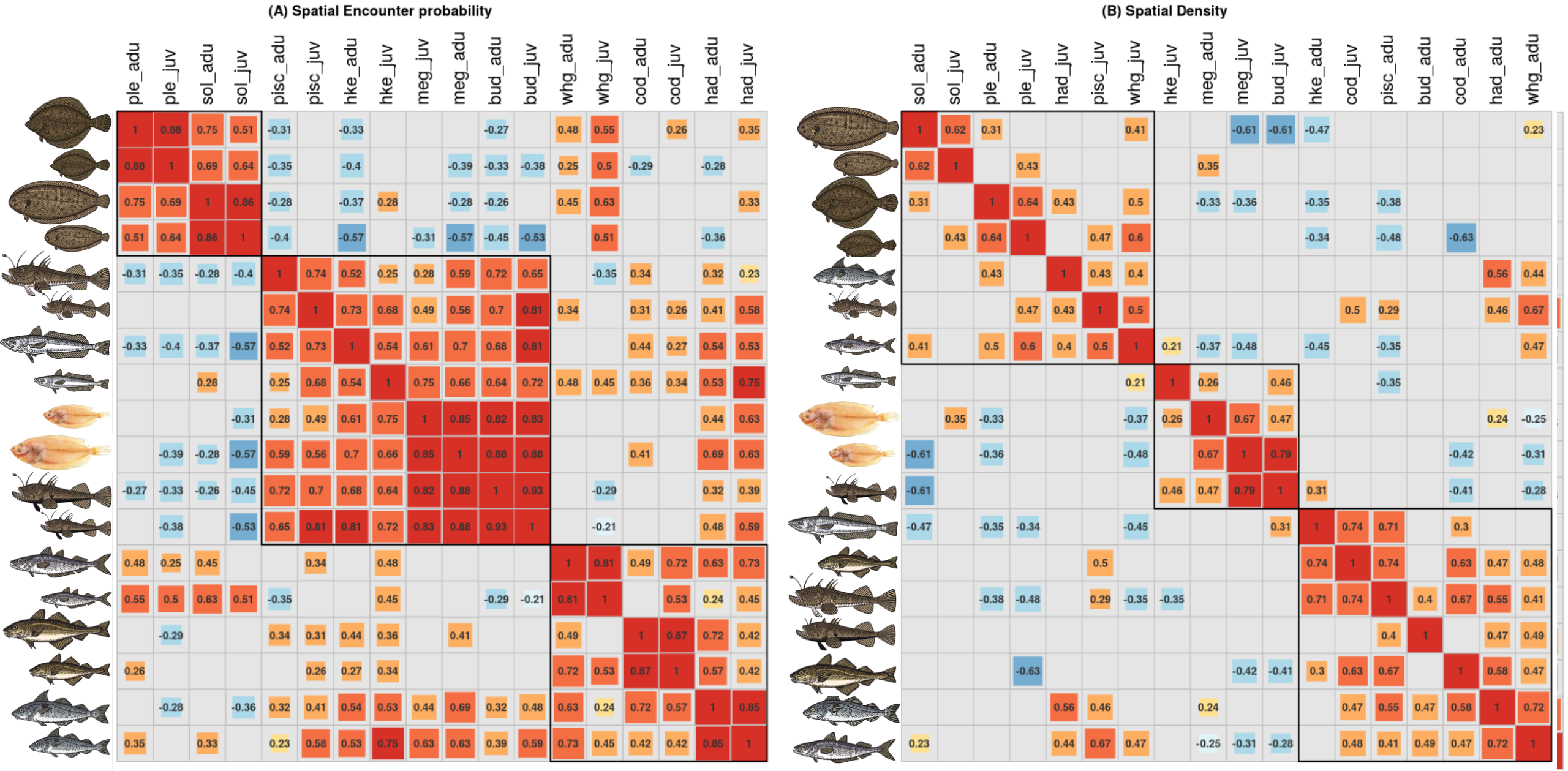


First factor shows strong correlation with depth for encounter probability (-0.85, -0.88 to -0.81) and density (-0.71, -0.77 to -0.65). 80 % of variance explained by depth and habitat: 9/10 of that by depth.

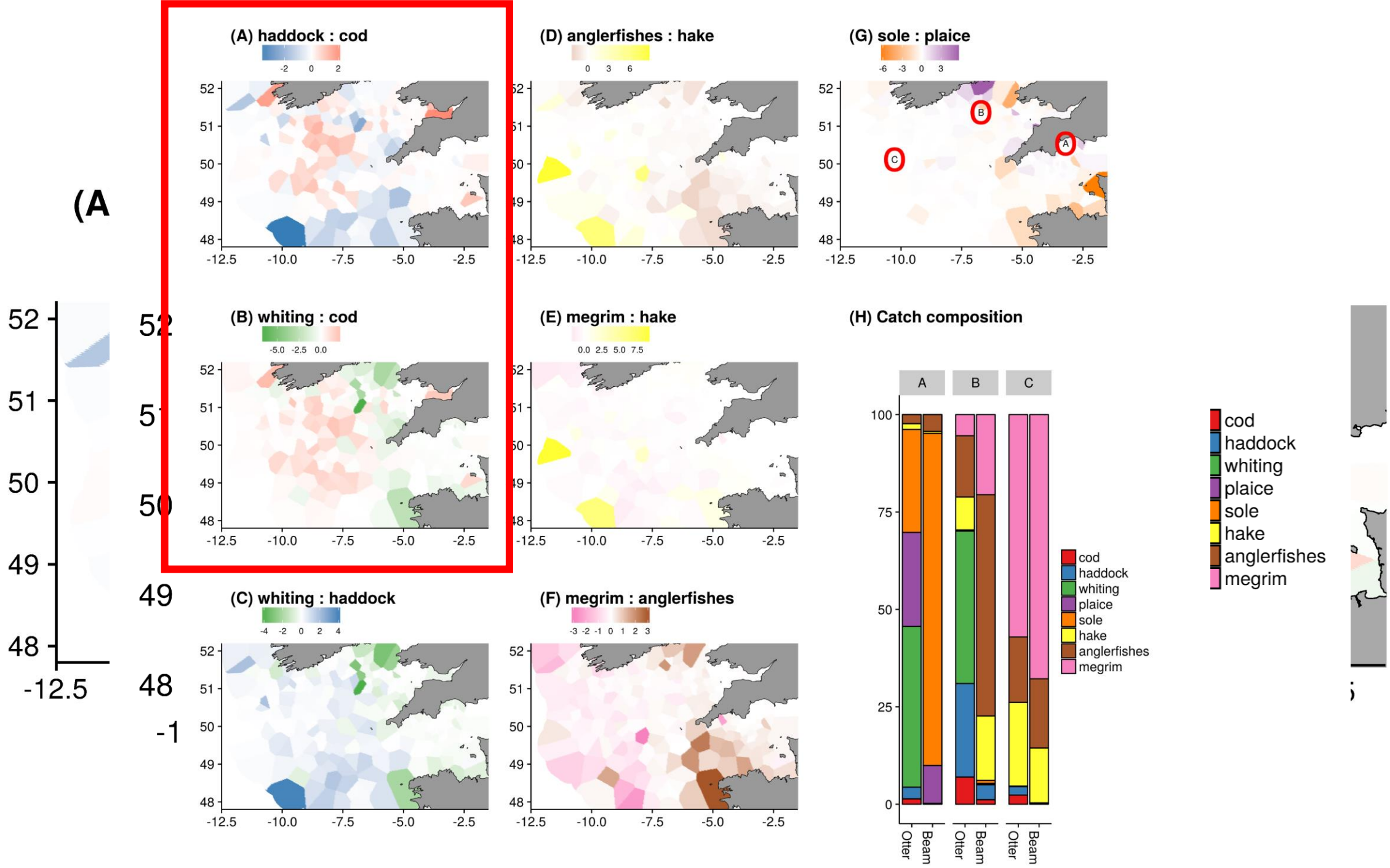
Spatiotemporal changes in assemblages distributions


(A) Factor loading for spatio-temporal encounter probability
(B) Factor loading for spatio-temporal catch rates
Factor 2 (16.6 % variance explained)
Factor 1 (39.8 % variance explained)
Factor 2 (14 % variance explained)
Factor 1 (43.2 % variance explained)
0.5
0.0
-0.5
-1.0
cod
haddock
whiting
hake
megrim
monkfish (piscatorius)
monkfish (budegassa)
plaice
sole

Correlation between species


(A) Spatial Encounter probability
ple_adu ple_juv sol_adu sol_juv pisc_adu pisc_juv hke_adu hke_juv meg_juv meg_adu bud_adu bud_juv whg_adu whg_juv cod_adu cod_juv had_adu had_juv
1 0.88 0.75 0.51 -0.31 -0.33 -0.27 0.48 0.55 0.26 0.35
0.88 1 0.69 0.64 -0.35 -0.4 -0.39 -0.33 -0.38 0.25 0.5 -0.29 -0.28
0.75 0.69 1 0.86 -0.28 -0.37 0.28 -0.28 -0.26 0.45 0.63 0.33
0.51 0.64 0.86 1 -0.4 -0.57 -0.31 -0.57 -0.45 -0.53 0.51 -0.36
-0.31 -0.35 -0.28 -0.4 1 0.74 0.52 0.25 0.28 0.59 0.72 0.65 -0.35 0.34 0.23
0.74 1 0.73 0.68 0.49 0.56 0.7 0.81 0.34 0.31 0.26 0.41 0.58
-0.33 -0.4 -0.37 -0.57 0.52 0.73 1 0.54 0.61 0.7 0.68 0.81 0.44 0.27 0.54 0.53
0.28 0.25 0.68 0.54 1 0.75 0.66 0.64 0.72 0.48 0.45 0.36 0.34 0.53 0.75
-0.31 0.28 0.49 0.61 0.75 1 0.85 0.82 0.83 0.44 0.63
-0.39 -0.28 -0.57 0.59 0.56 0.7 0.66 0.85 1 0.88 0.88 0.41 0.69 0.63
-0.27 -0.33 -0.26 -0.45 0.72 0.7 0.68 0.64 0.82 0.88 1 0.93 -0.29 0.32 0.39
-0.38 -0.53 0.65 0.81 0.81 0.72 0.83 0.88 0.93 1 -0.21 0.48 0.59
0.48 0.25 0.45 0.34 0.48 1 0.81 0.49 0.72 0.63 0.73
0.55 0.5 0.63 0.51 -0.35 0.45 -0.29 -0.21 0.81 1 0.53 0.24 0.45
-0.29 0.34 0.31 0.44 0.36 0.41 0.49 1 0.87 0.72 0.42
0.26 0.26 0.27 0.34 0.72 0.53 0.87 1 0.57 0.42
-0.28 -0.36 0.32 0.41 0.54 0.53 0.44 0.69 0.32 0.48 0.63 0.24 0.72 0.57 1 0.85
0.35 0.33 0.23 0.58 0.53 0.75 0.63 0.63 0.39 0.59 0.73 0.45 0.42 0.42 0.85 1
(B) Spatial Density
sol_adu sol_juv ple_adu ple_juv had_juv pisc_juv whg_juv hke_juv meg_adu meg_juv bud_juv hke_adu cod_juv pisc_adu bud_adu cod_adu had_adu whg_adu
1 0.62 0.31 0.41 -0.61 -0.61 -0.47 0.23
0.62 1 0.43 0.35
0.31 1 0.64 0.43 0.5 -0.33 -0.36 -0.35 -0.38
0.43 0.64 1 0.47 0.6 -0.34 -0.48 -0.63
0.43 1 0.43 0.4 0.56 0.44
0.47 0.43 1 0.5 0.5 0.29 0.46 0.67
0.41 0.5 0.6 0.4 0.5 1 0.21 -0.37 -0.48 -0.45 -0.35 0.47
0.21 1 0.26 0.46 -0.35
0.35 -0.33 -0.37 0.26 1 0.67 0.47 0.24 -0.25
-0.61 -0.36 -0.48 0.67 1 0.79 -0.42 -0.31
-0.61 0.46 0.47 0.79 1 0.31 -0.41 -0.28
-0.47 -0.35 -0.34 -0.45 0.31 1 0.74 0.71 0.3
0.5 0.74 1 0.74 0.63 0.47 0.48
-0.38 -0.48 0.29 -0.35 -0.35 0.71 0.74 1 0.4 0.67 0.55 0.41
0.4 1 0.47 0.49
-0.63 -0.42 -0.41 0.3 0.63 0.67 1 0.58 0.47
0.56 0.46 0.24 0.47 0.55 0.47 0.58 1 0.72
0.23 0.44 0.67 0.47 -0.25 -0.31 -0.28 0.48 0.41 0.49 0.47 0.72 1

Potential for spatial targeting


(A) haddock : cod
(B) whiting : cod
(C) whiting : haddock
(D) anglerfishes : hake
(E) megrim : hake
(F) megrim : anglerfishes
(G) sole : plaice
(H) Catch composition
A
B
C
Otter
Beam
cod
haddock
whiting
plaice
sole
hake
anglerfishes
megrim

Conclusions

- Provides **a dimension-reduction framework** to understand how spatial community and fishery dynamics interact to determine species and size composition

- Applied to the highly mixed fisheries of the Celtic Sea: clear common spatial patterns emerge for **three distinct assemblages**

- Importance to focus management on **axes of maximal separation** and identify how spatial targeting can help support catch balancing

(modelling priority)

BUT

- Wasn’t what I came here initially to talk about….
- Developing comparison of spatial effort allocation methods: RUMs, Markov, Dynamic state. Welcome a chat about your experiences
- Also talk this afternoon on spatial simulation model: Spatial management and MPAs 3.30 PM – 5.00 PM

Thank you for listening!

Questions?

Contact: paul.dolder@gmit.ie

Spatial separation of catches in highly mixed fisheries. Scientific Reports (*in review*)

Acknowledgements:

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Cefas Seedcorn

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