

# Low connectivity in a nursery-dependent fish metapopulation revealed by modeling mark-recapture data.

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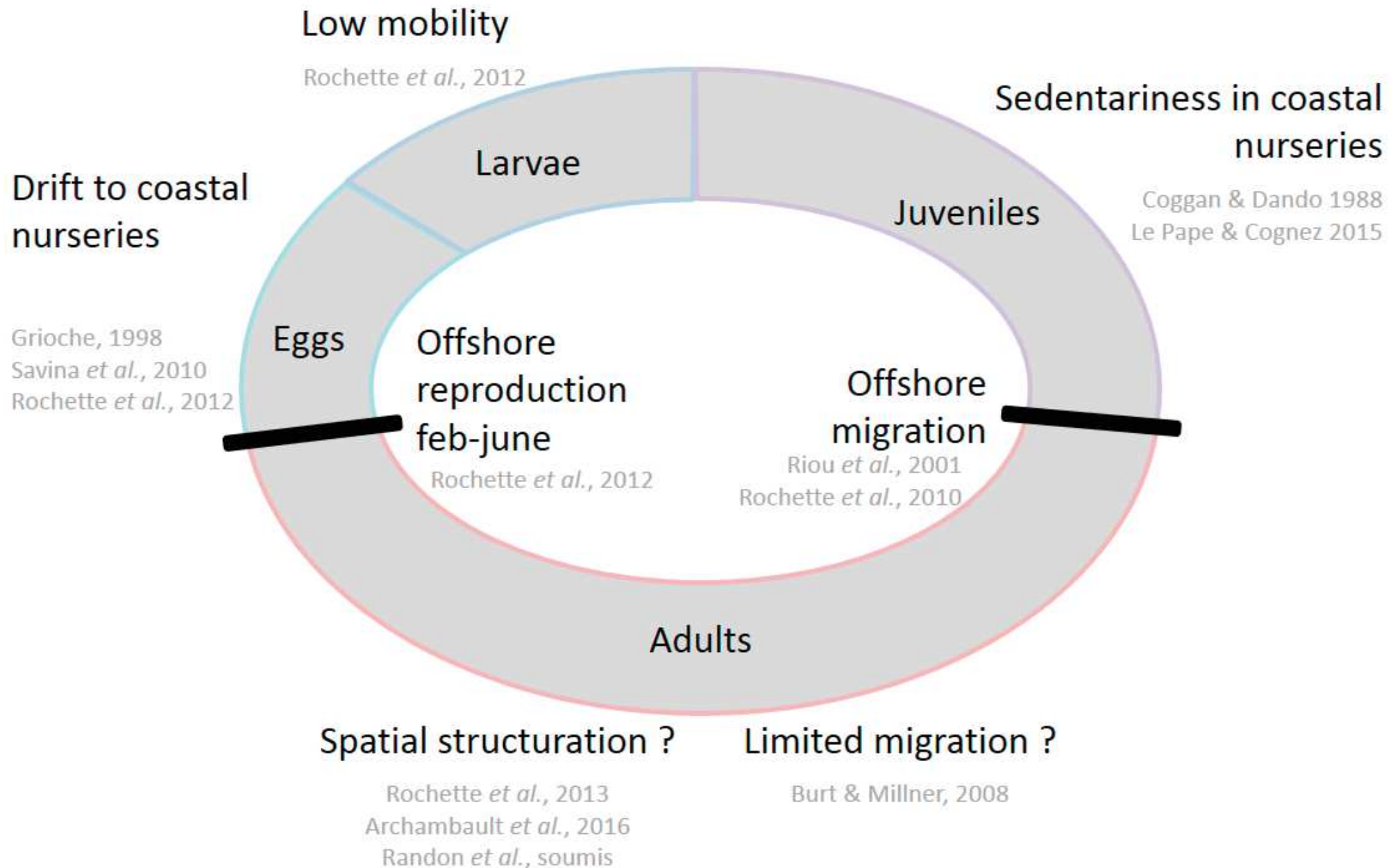
Amédée - July 2018

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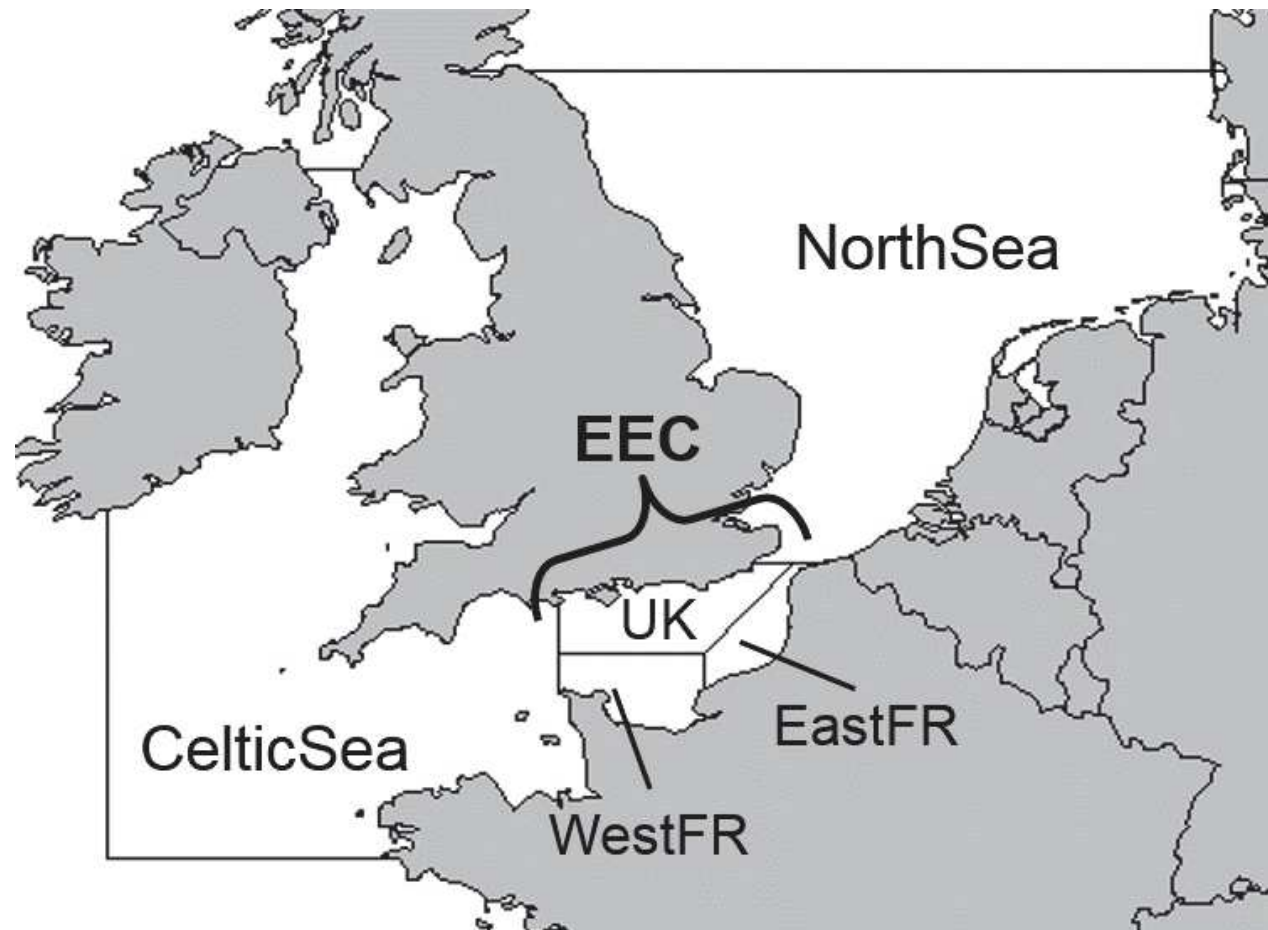
<sup>2</sup>Unit of Fisheries Ecology and Modelling, French Research Institute for Exploitation of the Sea, Nantes, France.

# Introduction



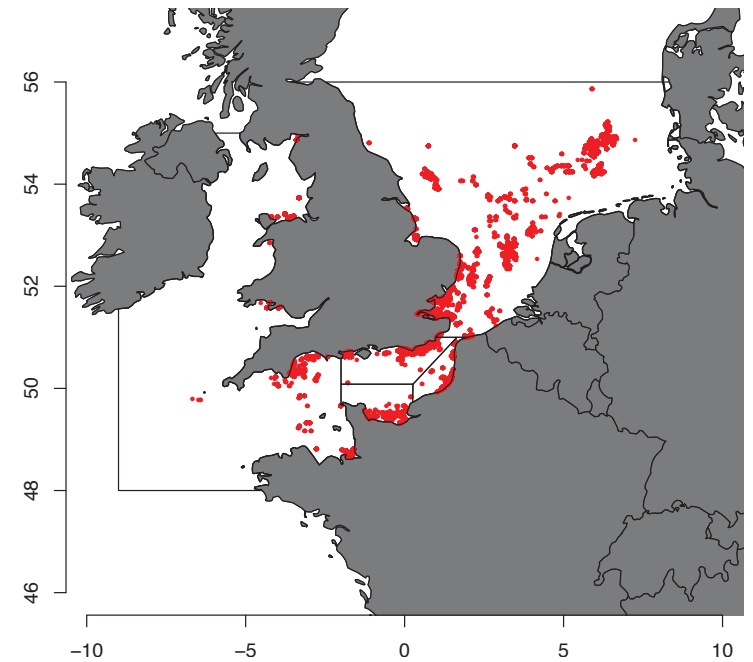
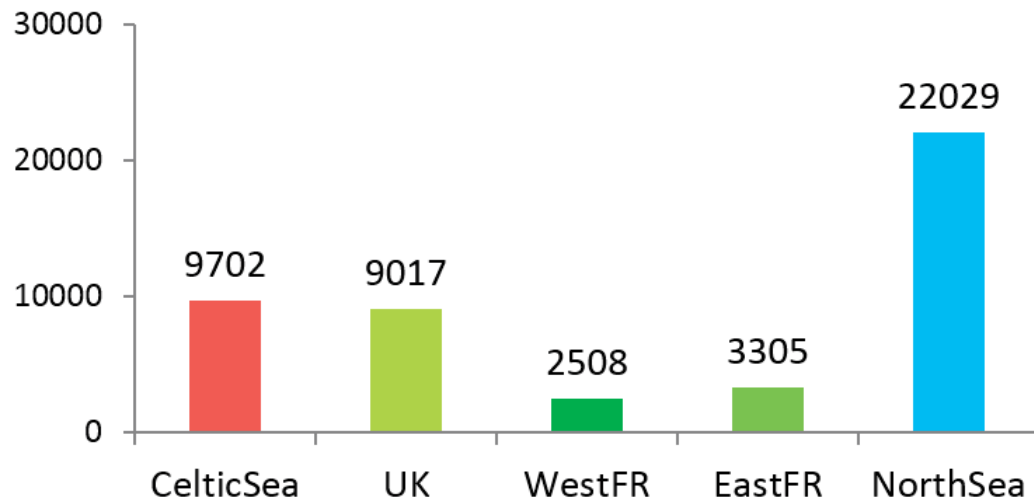
# Introduction

- ▶ Intra East English Channel (EEC) migrations and/or inter English Channel ?
- ▶ Seasonal migrations between these five areas ?



# Data presentation

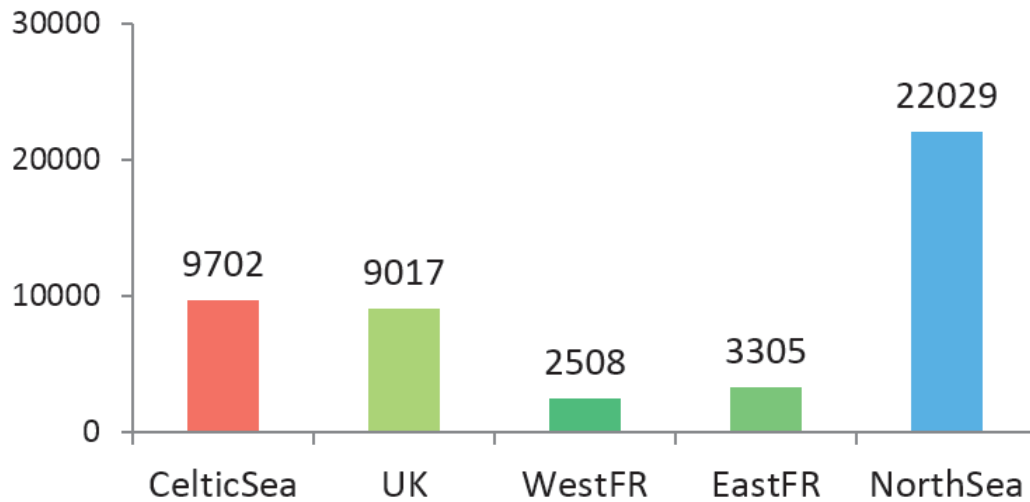
Number of marked sole per area



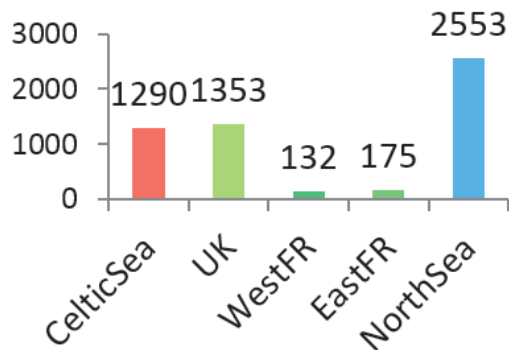


# Data presentation

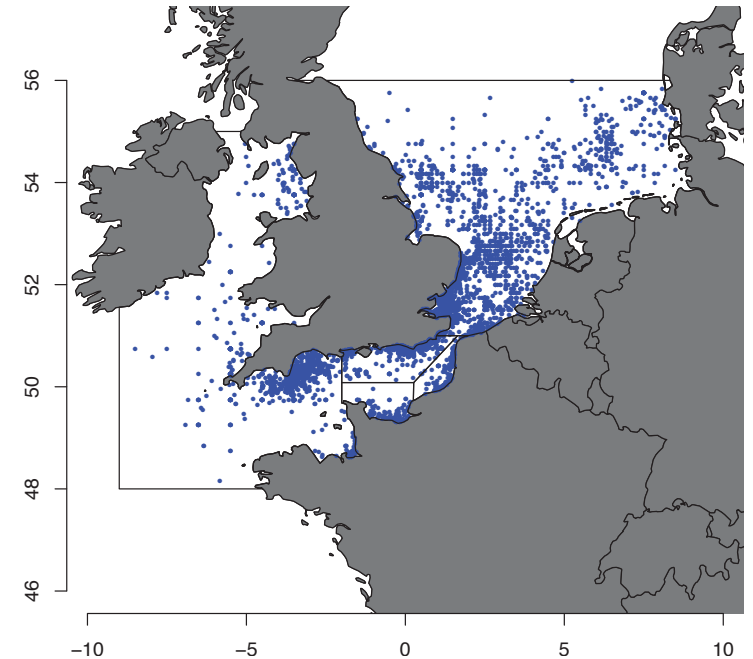
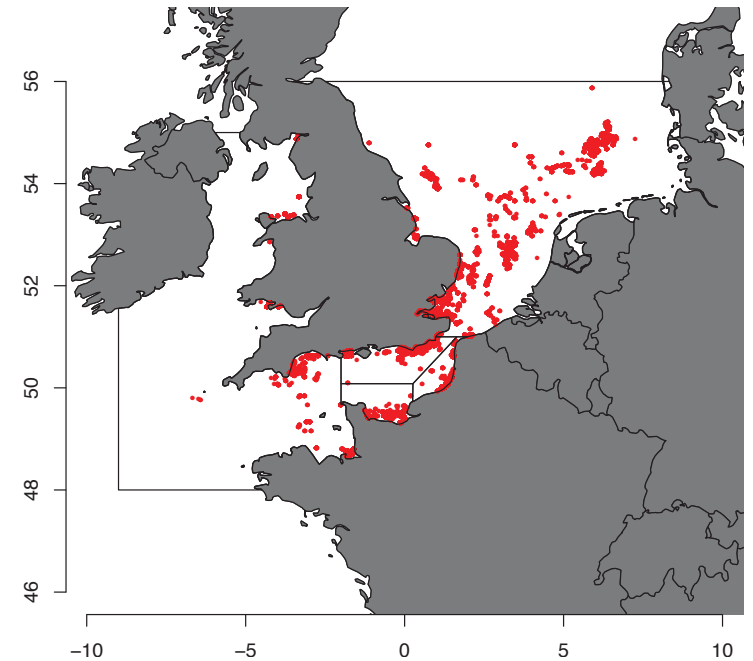
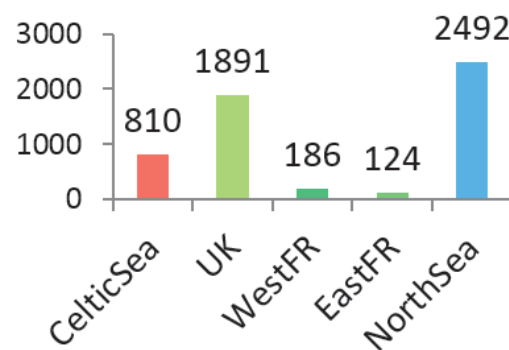
## Number of marked sole per area



## Number of recaptured sole per mark area



## Number of recaptured sole per recapture area



# Models presentation

- ▶ Model Mi.N: without seasonal movements
- ▶ Model Mi.S: with seasonal movements
- ▶ Quasi-AIC: model selection criterion
- ▶ Time step: 3 seasons of four months

Spawning  
February-May

Foraging  
June-September

Overwintering  
October-January

# Models presentation

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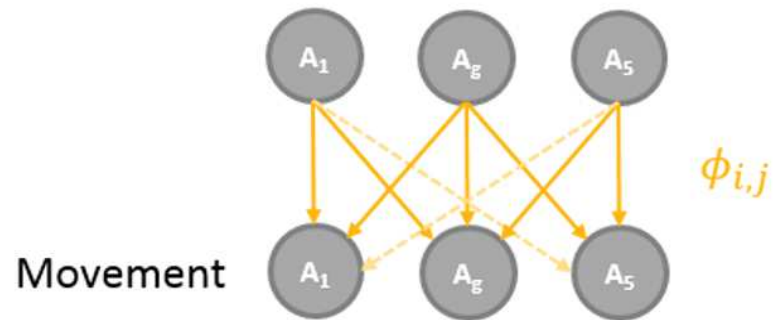
| t | Area            |                |                |                |                |                |
|---|-----------------|----------------|----------------|----------------|----------------|----------------|
|   | CelticSea       | UK             | WestFR         | EastFR         | NorthSea       |                |
|   | Alive           | A <sub>1</sub> | A <sub>2</sub> | A <sub>3</sub> | A <sub>4</sub> | A <sub>5</sub> |
|   | Dead by fishing | F <sub>1</sub> | F <sub>2</sub> | F <sub>3</sub> | F <sub>4</sub> | F <sub>5</sub> |
|   | Natural death   | M <sub>1</sub> | M <sub>2</sub> | M <sub>3</sub> | M <sub>4</sub> | M <sub>5</sub> |

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t+1

# Models presentation

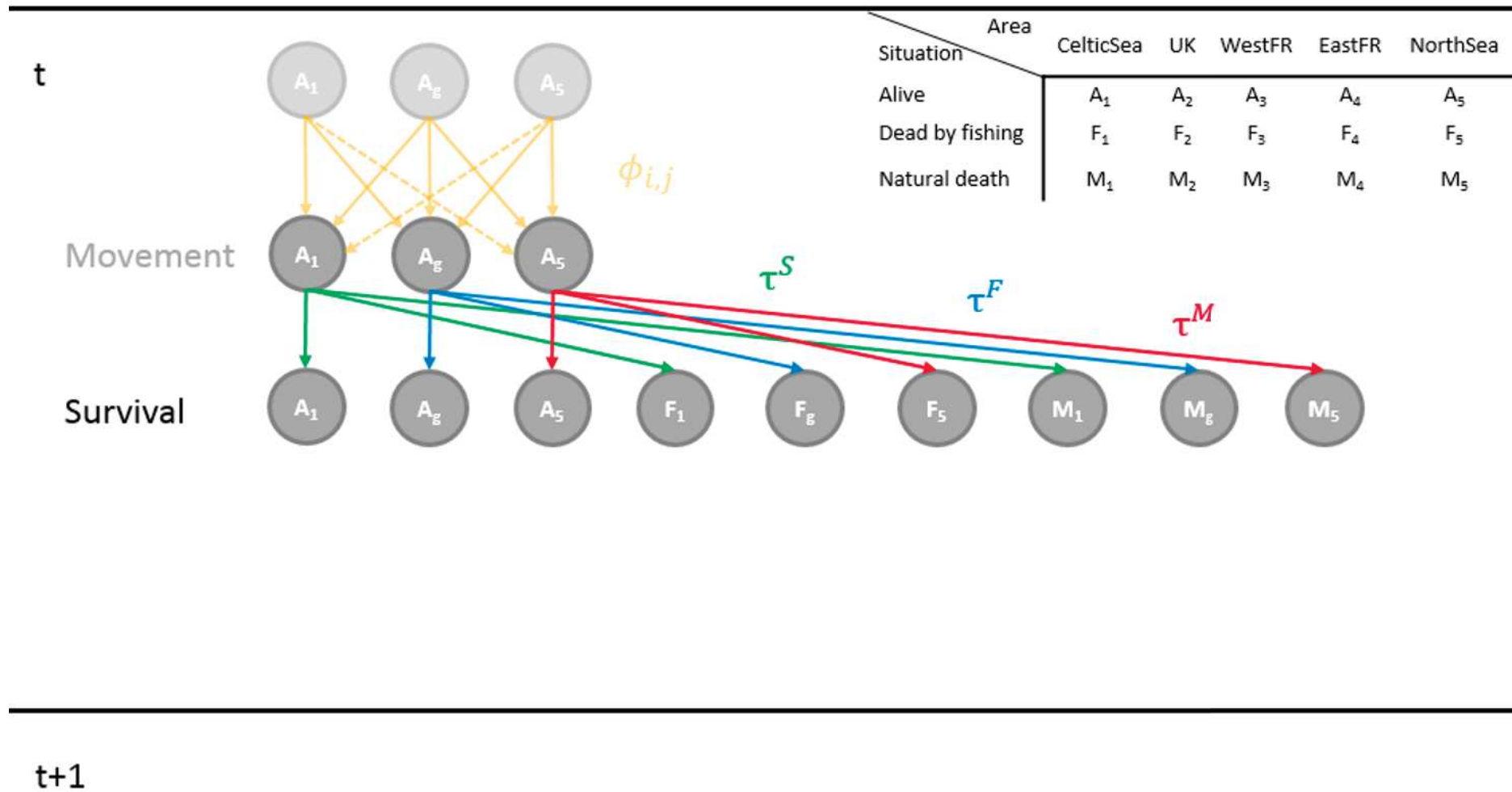
t



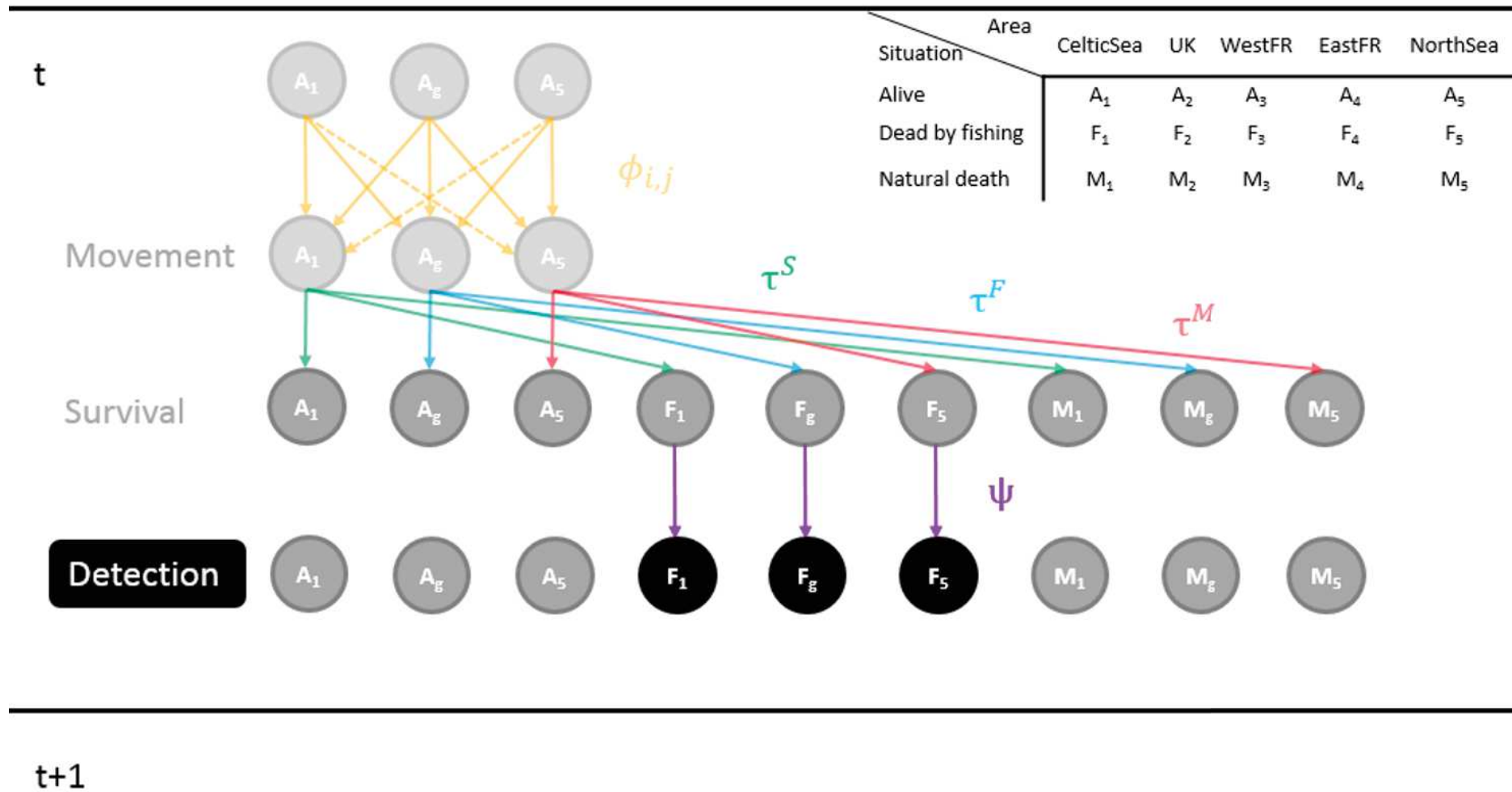
| Situation       | Area      |       |        |        |          |
|-----------------|-----------|-------|--------|--------|----------|
|                 | CelticSea | UK    | WestFR | EastFR | NorthSea |
| Alive           | $A_1$     | $A_2$ | $A_3$  | $A_4$  | $A_5$    |
| Dead by fishing | $F_1$     | $F_2$ | $F_3$  | $F_4$  | $F_5$    |
| Natural death   | $M_1$     | $M_2$ | $M_3$  | $M_4$  | $M_5$    |

t+1

# Models presentation

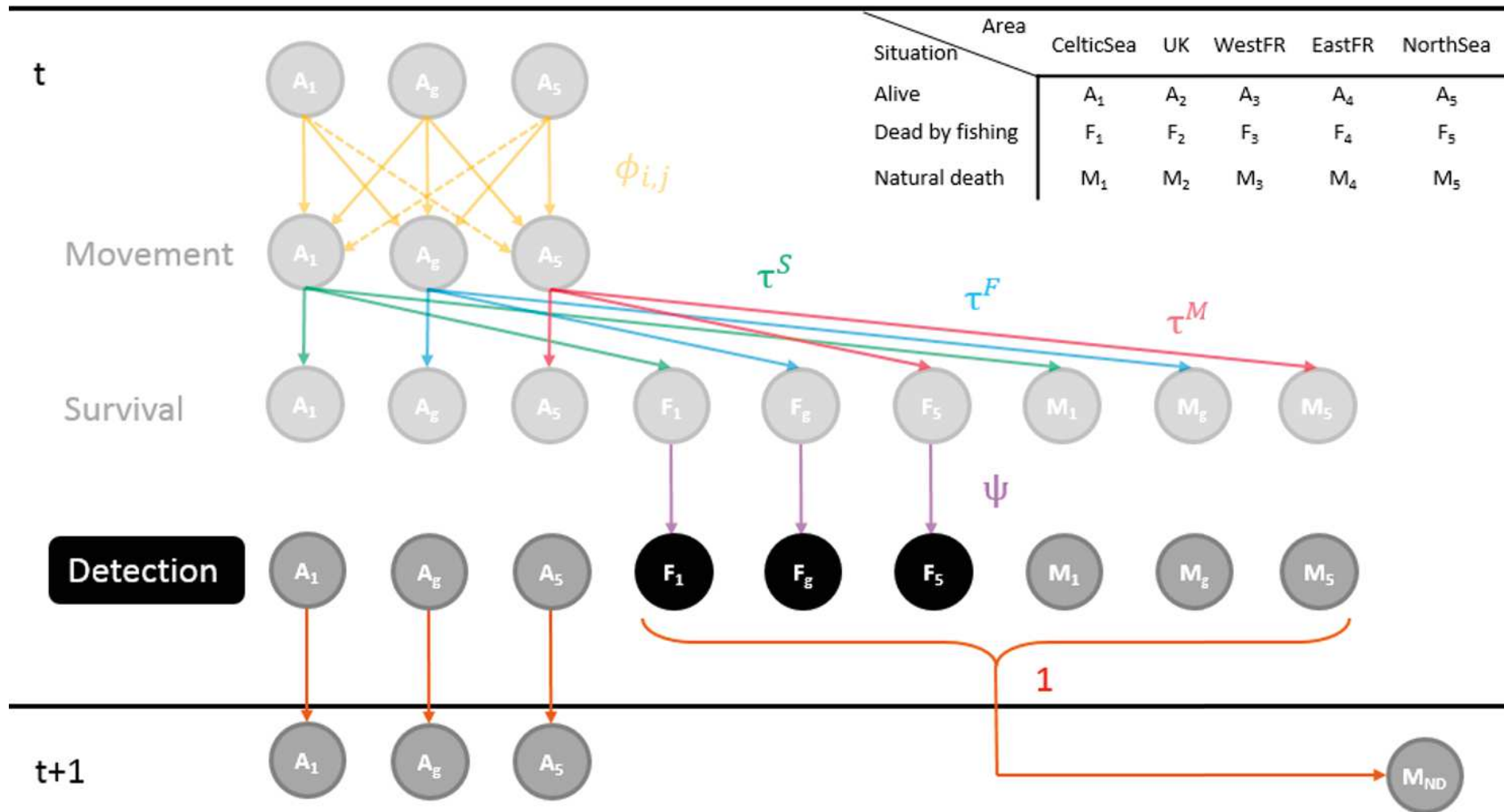


# Models presentation

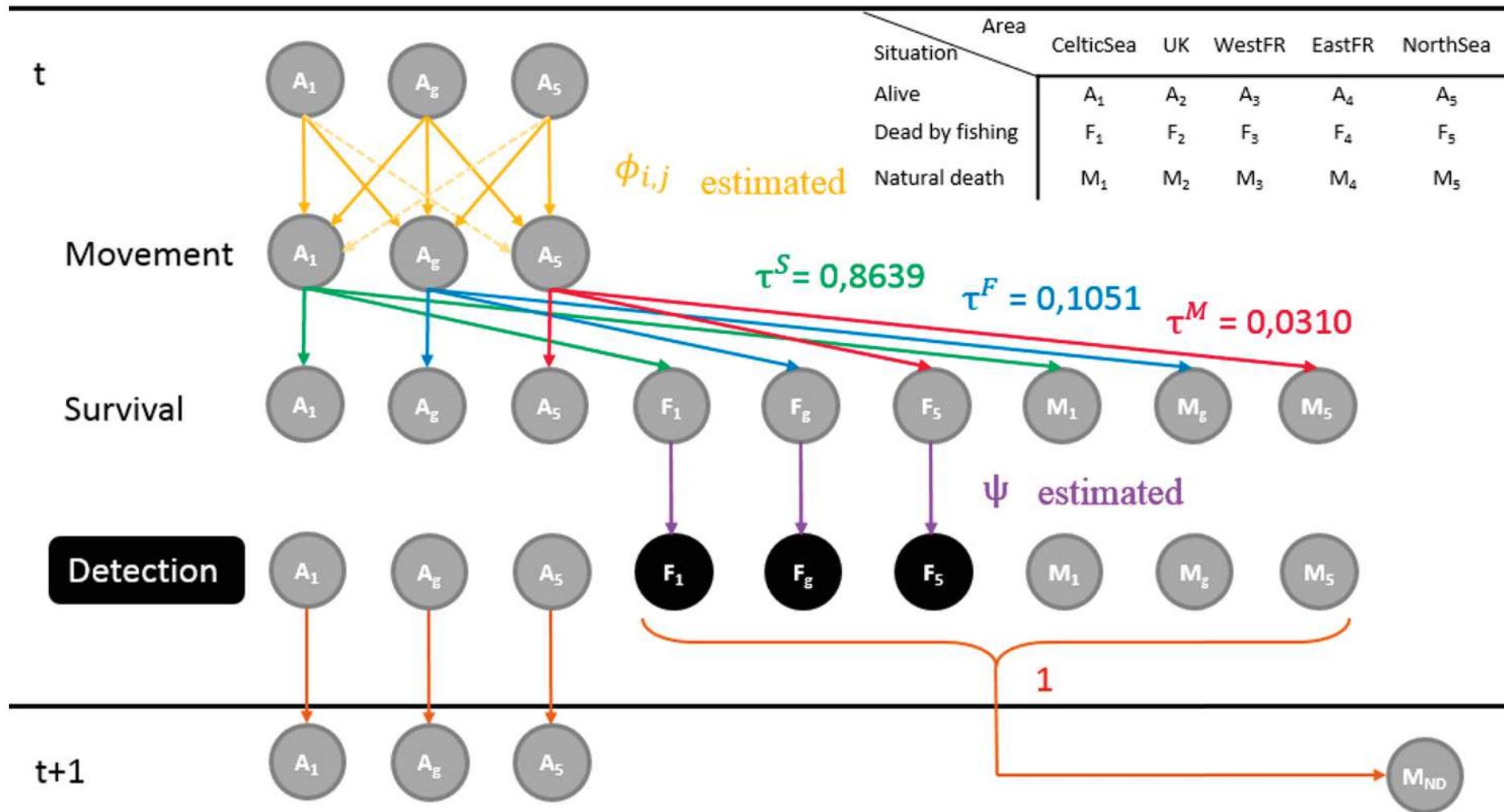




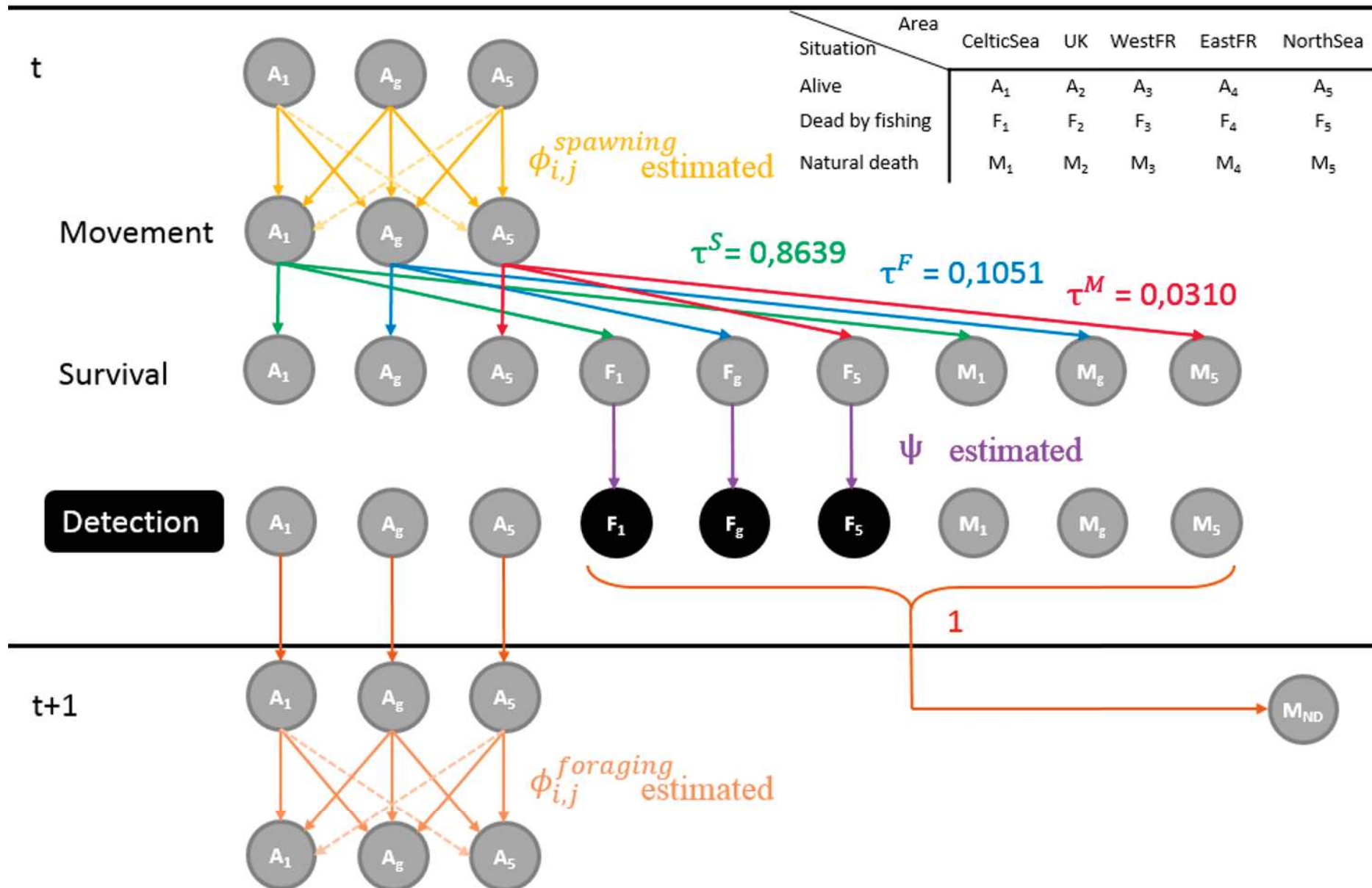
# Models presentation



# Models presentation



# Models presentation



# Simulation study

# Why using a simulation study?

- ① What is the impact of fishing mortality on parameter estimations ?
- ② How the model handles a spatially varying fishing mortality ?
- ③ How the model handles a spatially and temporally varying fishing mortality ?

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# Data simulation

- ▶ 5 zones
- ▶ 15 000 fish
- ▶ 20 years, 60 seasons
- ▶ 6 marking events
- ▶ Probability of recapture:  $\Phi = 0.2$
- ▶ fishing mortality,  $\tau^f = 0.10$
- ▶ natural mortality,  $\tau^m = 0.03$

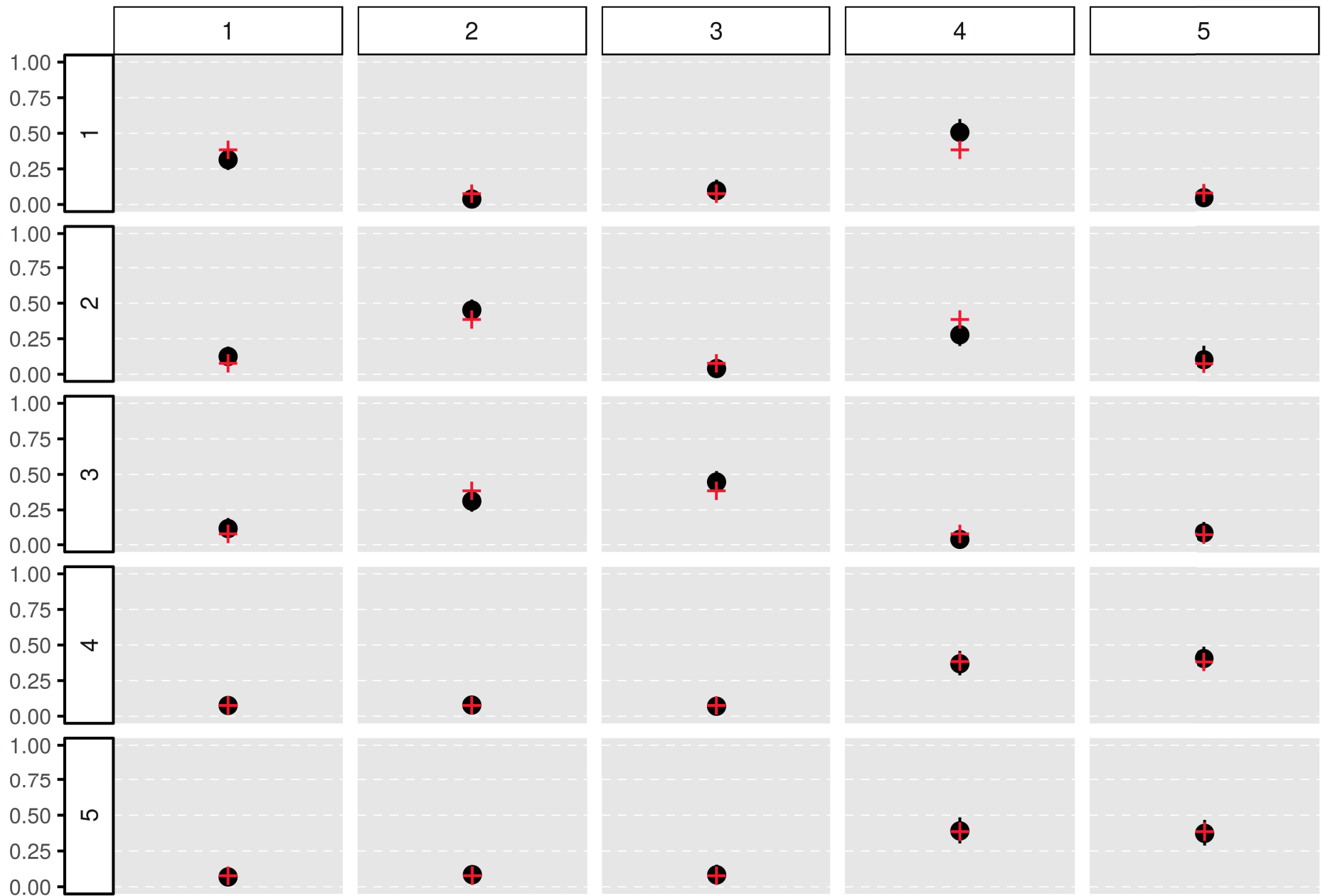
# What is the impact of fishing mortality on parameter estimations ?

Estimation of the models with different  $\tau^f$  as input:

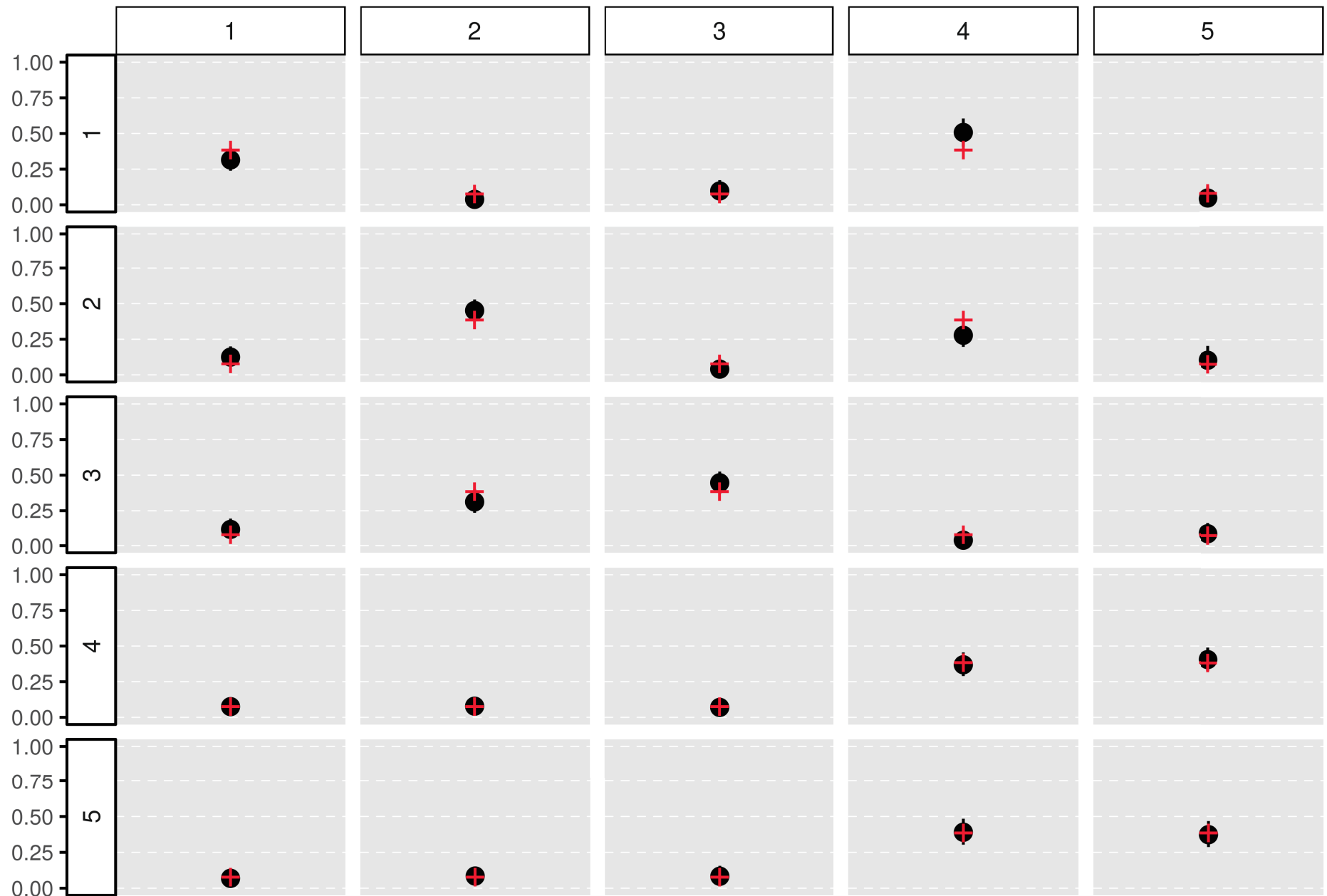
- ① the true fishing mortality,  $\tau^f = 0.10$
- ② the true fishing mortality times 4,  $\tau^f = 0.40$
- ③ the true fishing mortality divided by 4,  $\tau^f = 0.025$

No seasonal effect of the movements.

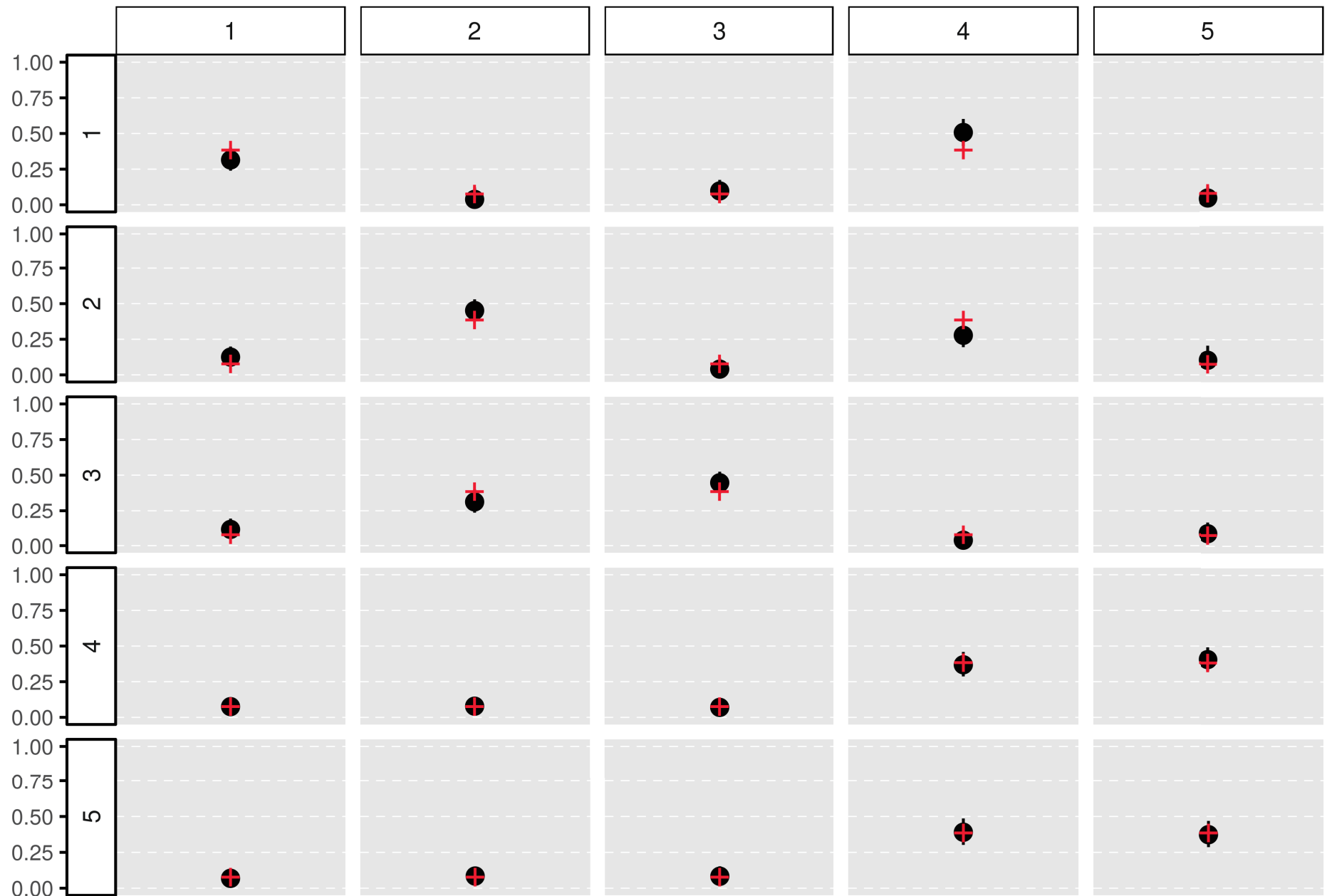
# Estimation with the true $\tau^f = 0.10$



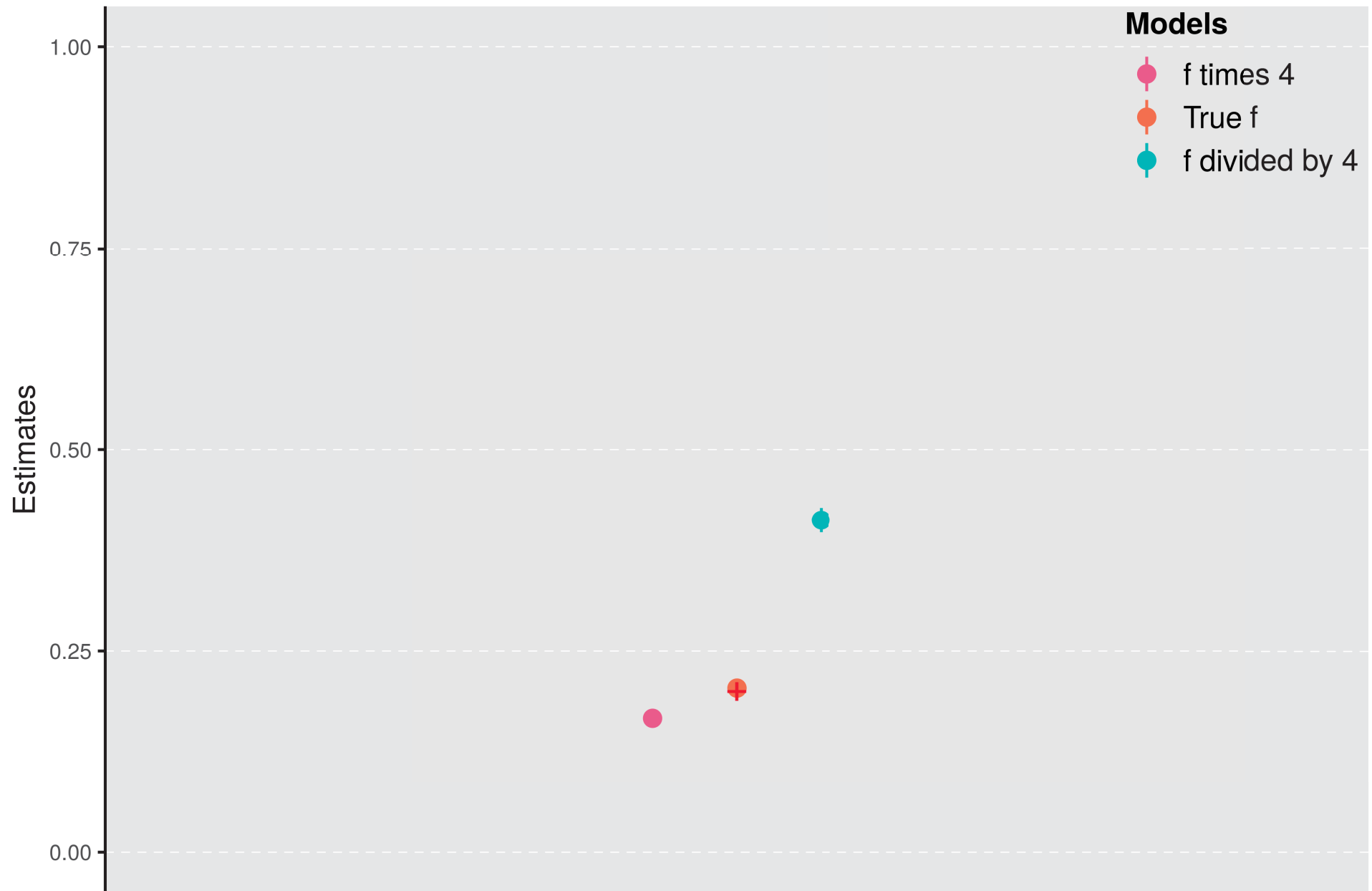
# True fishing mortality times 4, $\tau^f = 0.40$



# True fishing mortality divided by 4, $\tau^f = 0.025$



# Detection rate with variable $\tau^f$





# How the model handles a spatially varying fishing mortality ?

- ▶ Simulation of a dataset with a spatially varying fishing mortality:

$$\tau_{1:4}^f = 0.10$$

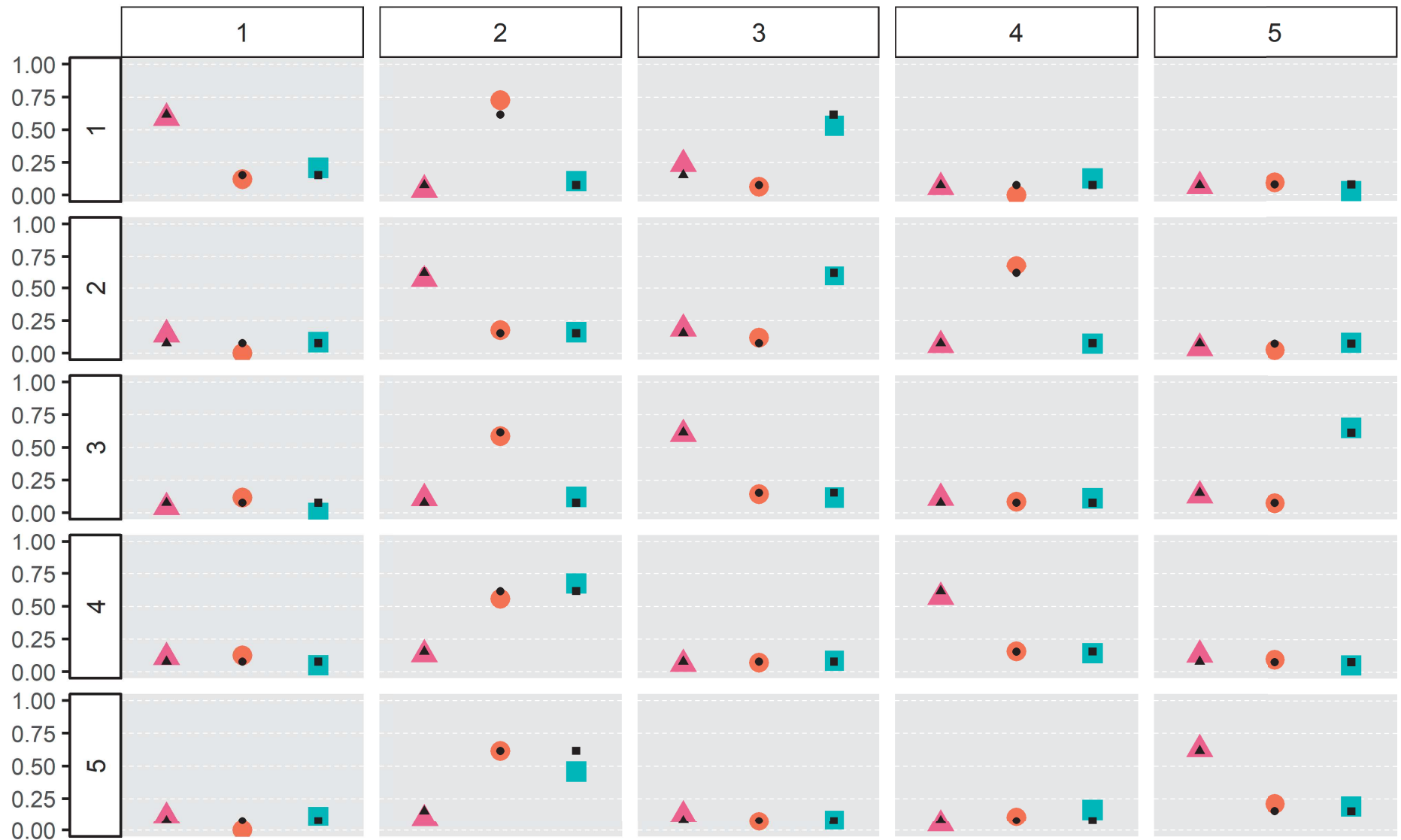
$$\tau_5^f = 0.40$$

- ▶ Fitting two models:

- ① a model accounting for a spatially varying fishing mortality,
- ② a model ignoring spatially varying fishing mortality:  $\tau_{1:5}^f = 0.10$

Seasonal effect of the movements.

# Model in accordance with data



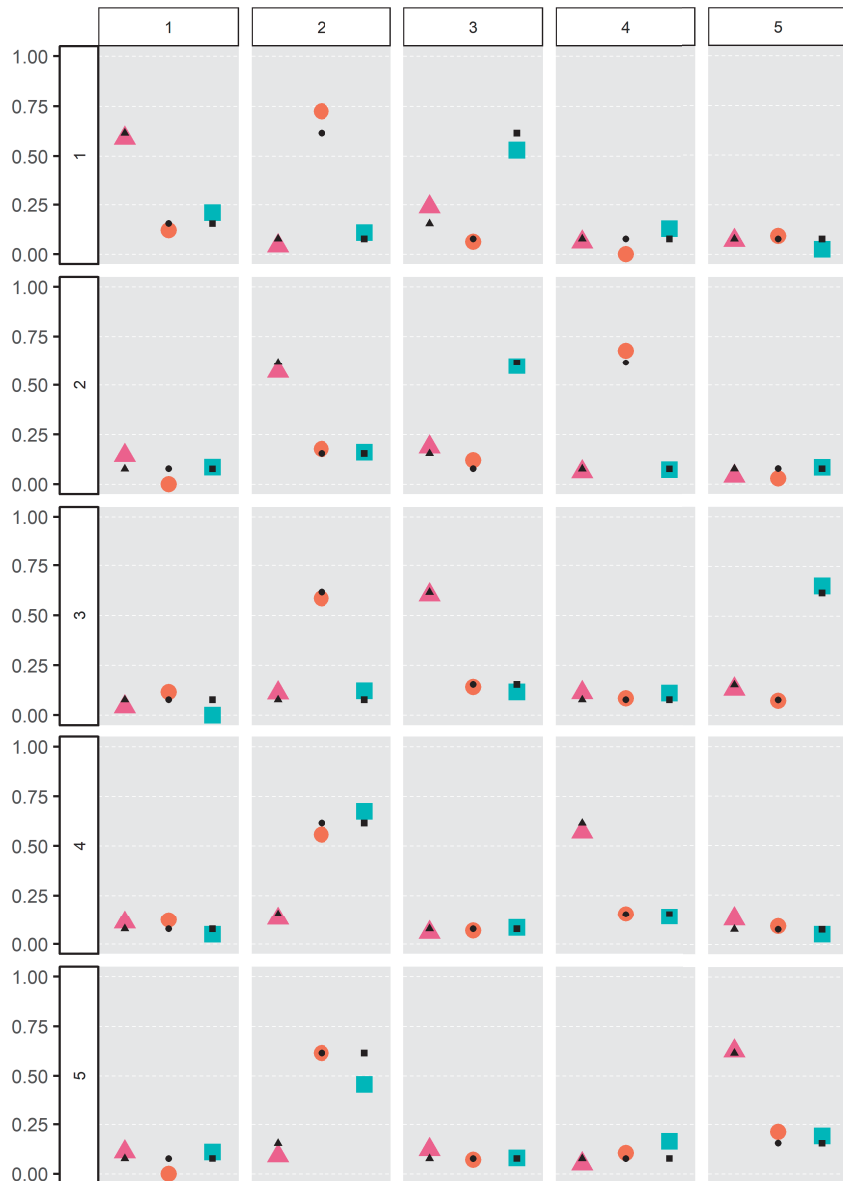
Season ▲ Spring ● Summer ■ Winter

# Model with no spatial variation of $\tau^f$



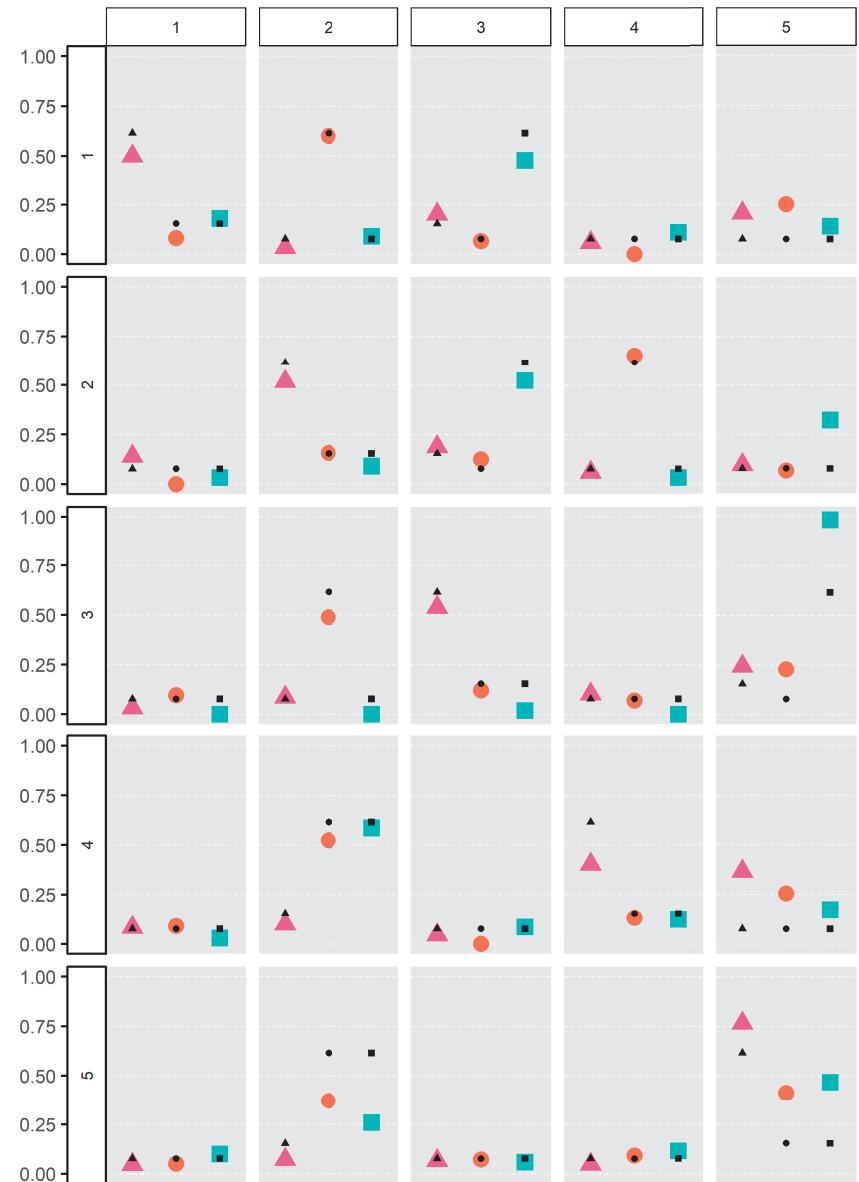
# Model comparison

## Spatial $\tau^f$



Season ▲ Spring ● Summer ■ Winter

## Constant $\tau^f$

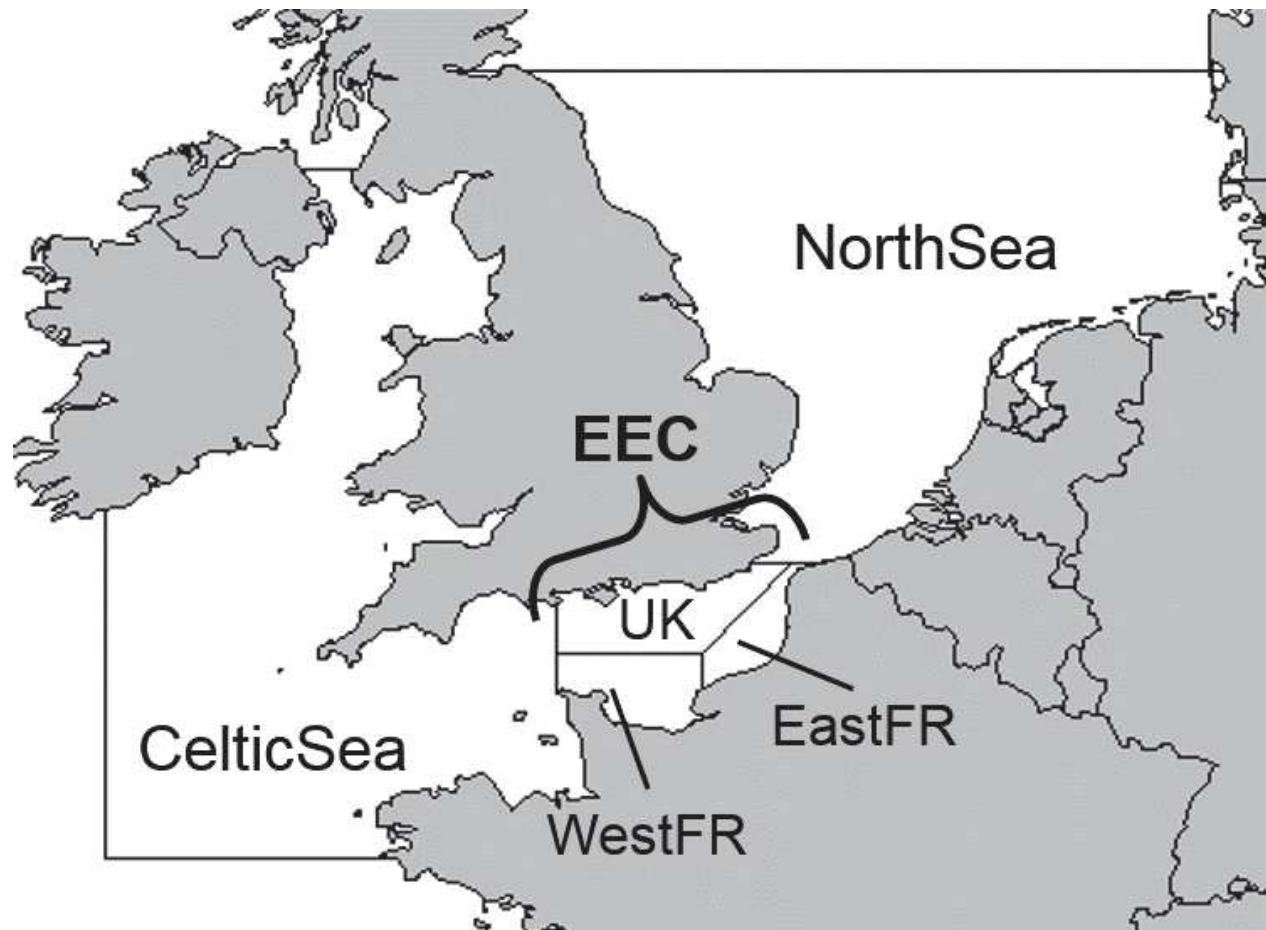


Season ▲ Spring ● Summer ■ Winter

# Data study

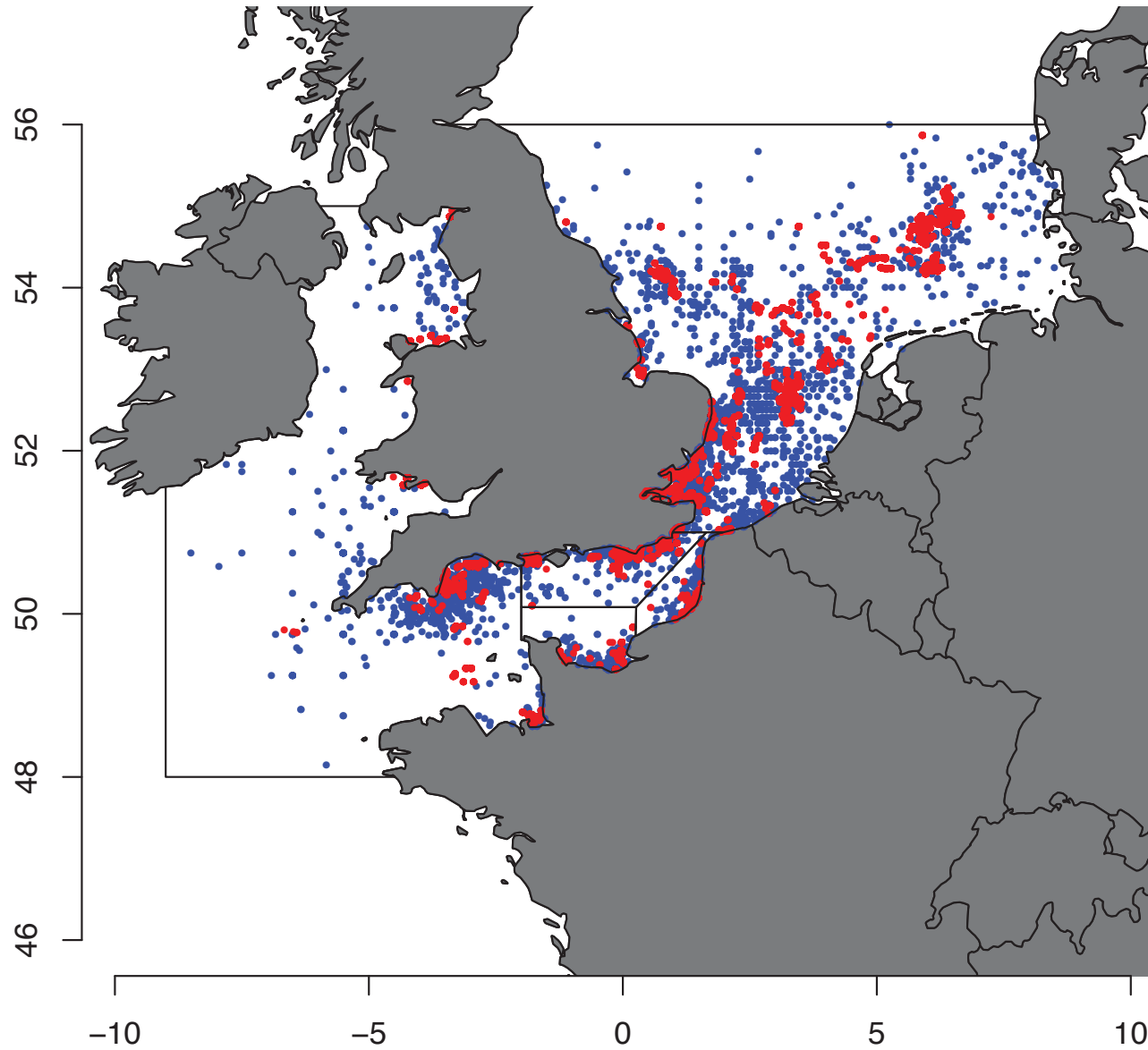
# Questions

- ▶ Intra East English Channel (EEC) migrations and/or inter English Channel ?
- ▶ Seasonal migrations between these five areas ?

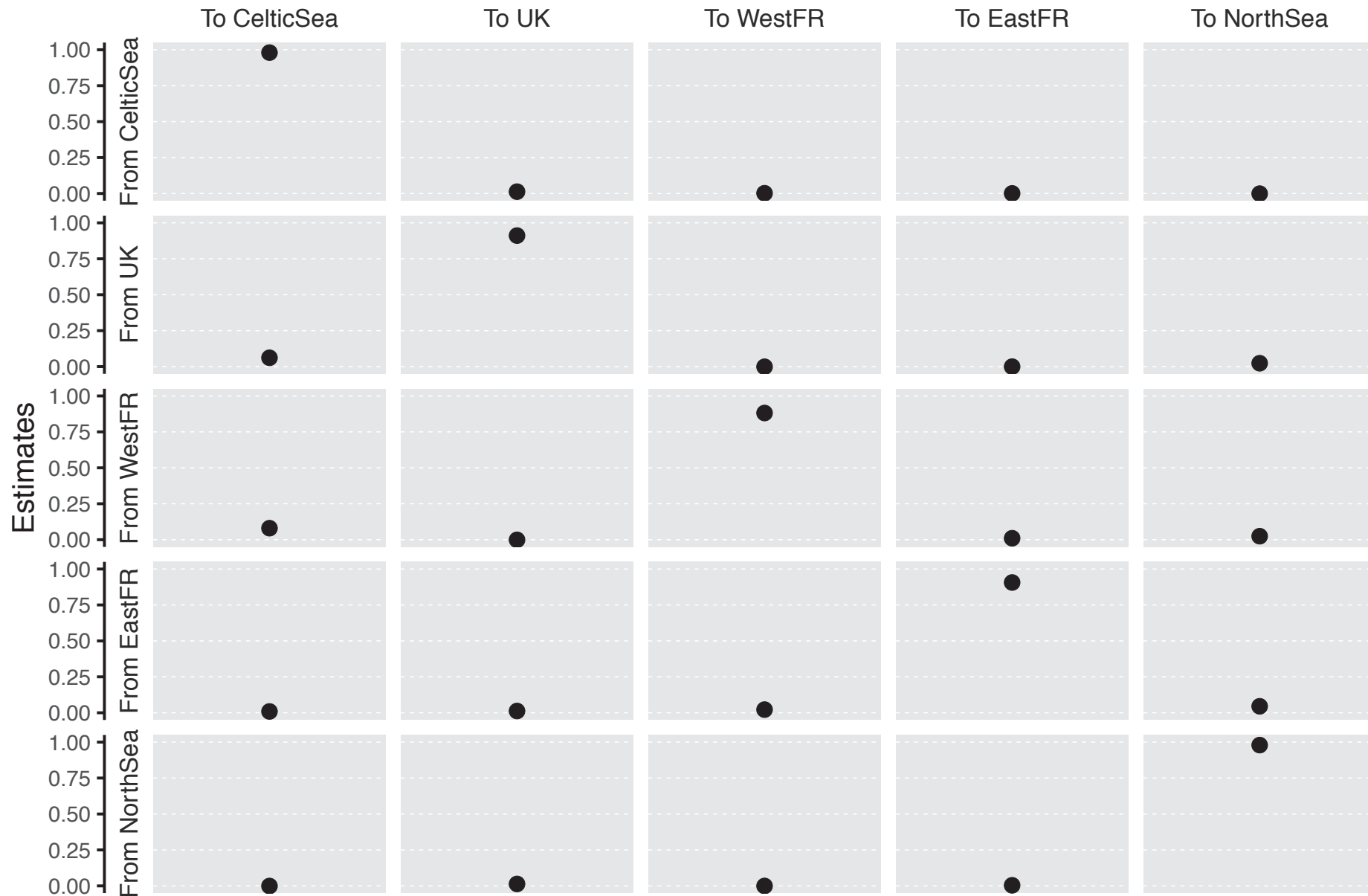




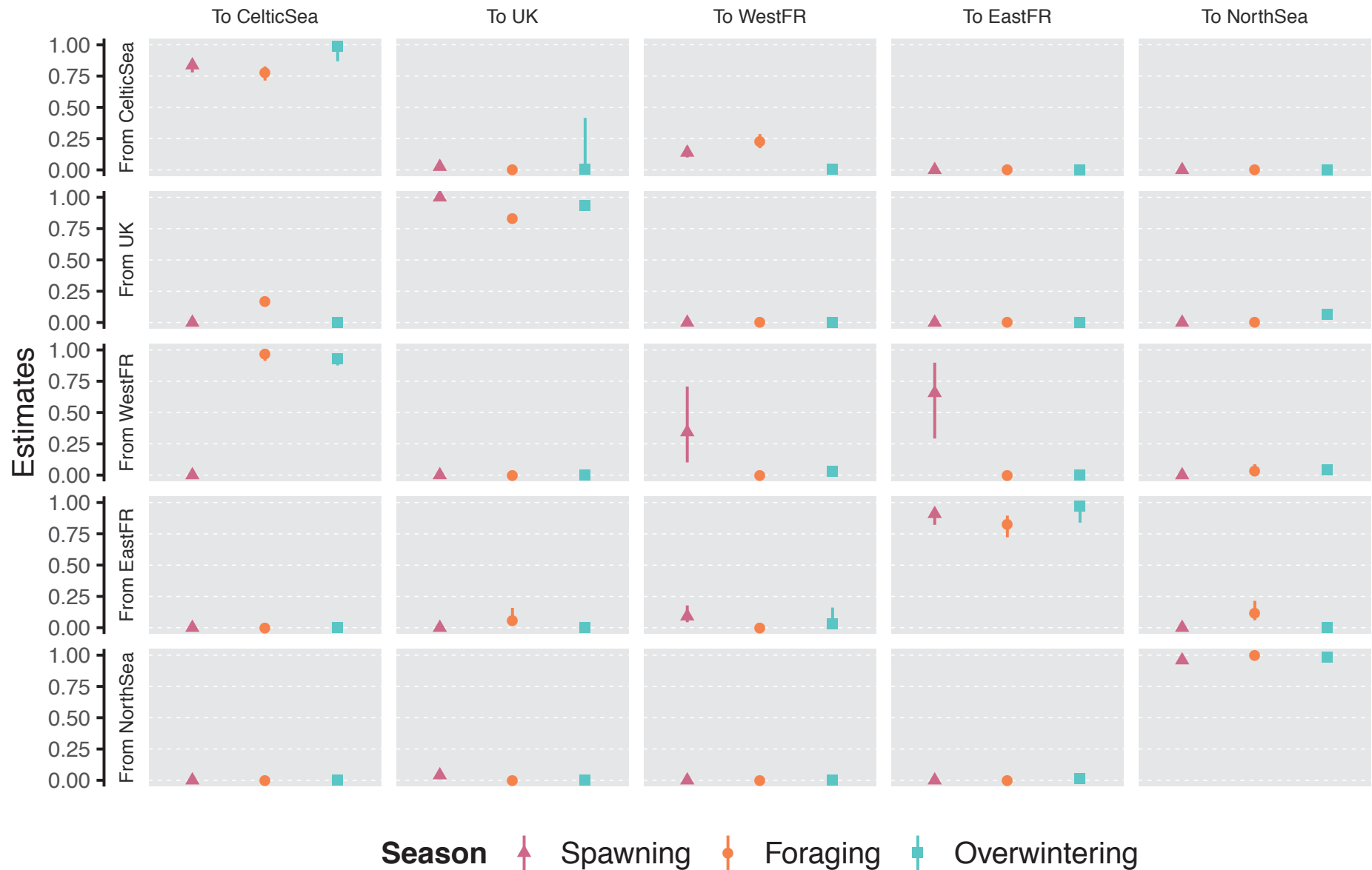
# Model with all campaigns



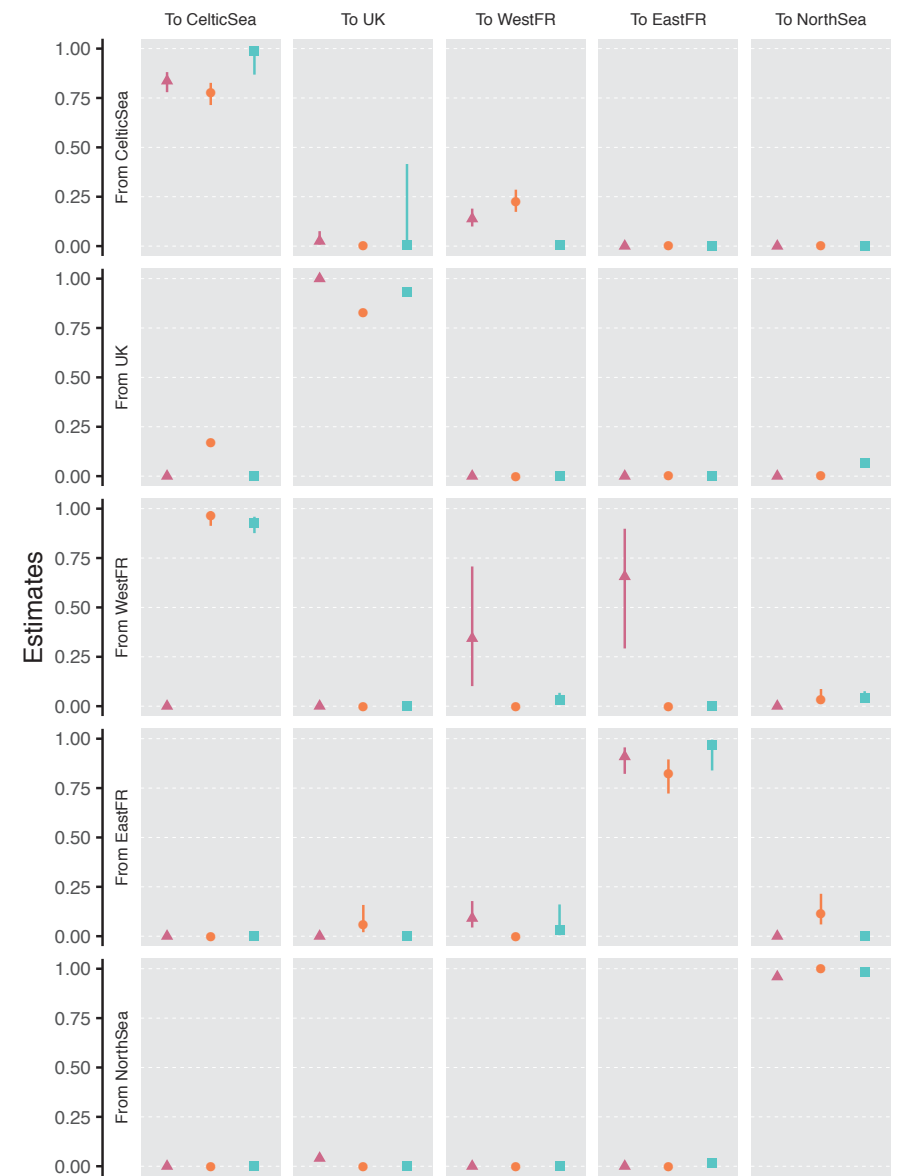
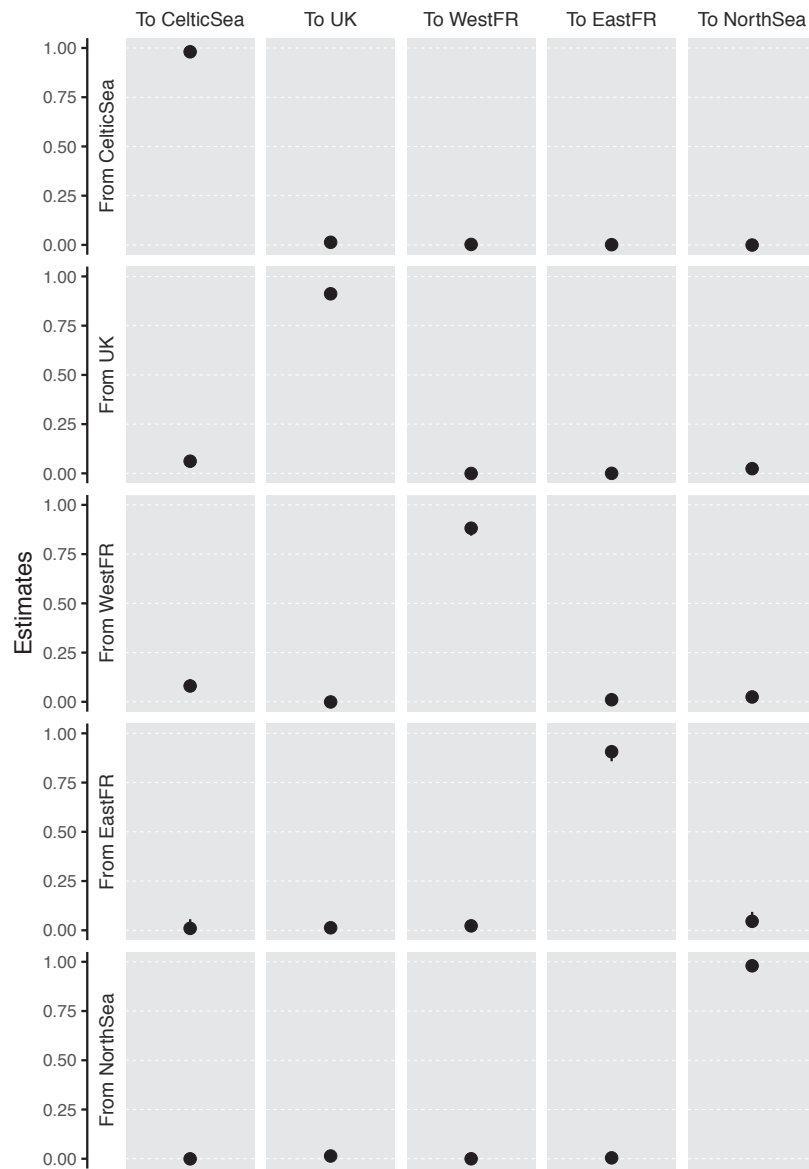
# Movements estimations M1.N: All Campaigns without seasonal movements



# Movements estimations M1.S: All Campaigns with seasonal movements



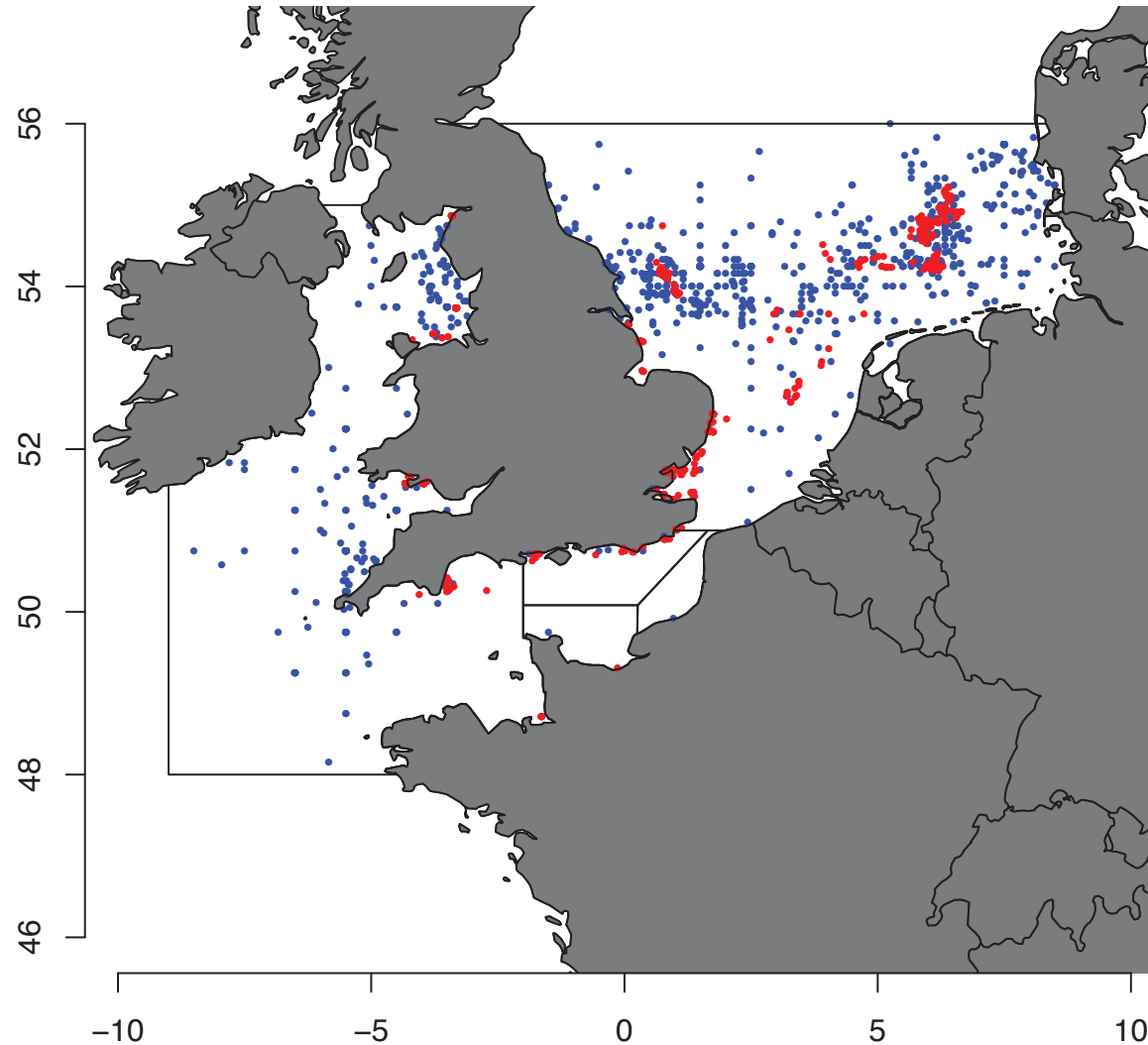
# Movements estimations M1: All Campaigns



Season ▲ Spawning ◆ Foraging ■ Overwintering

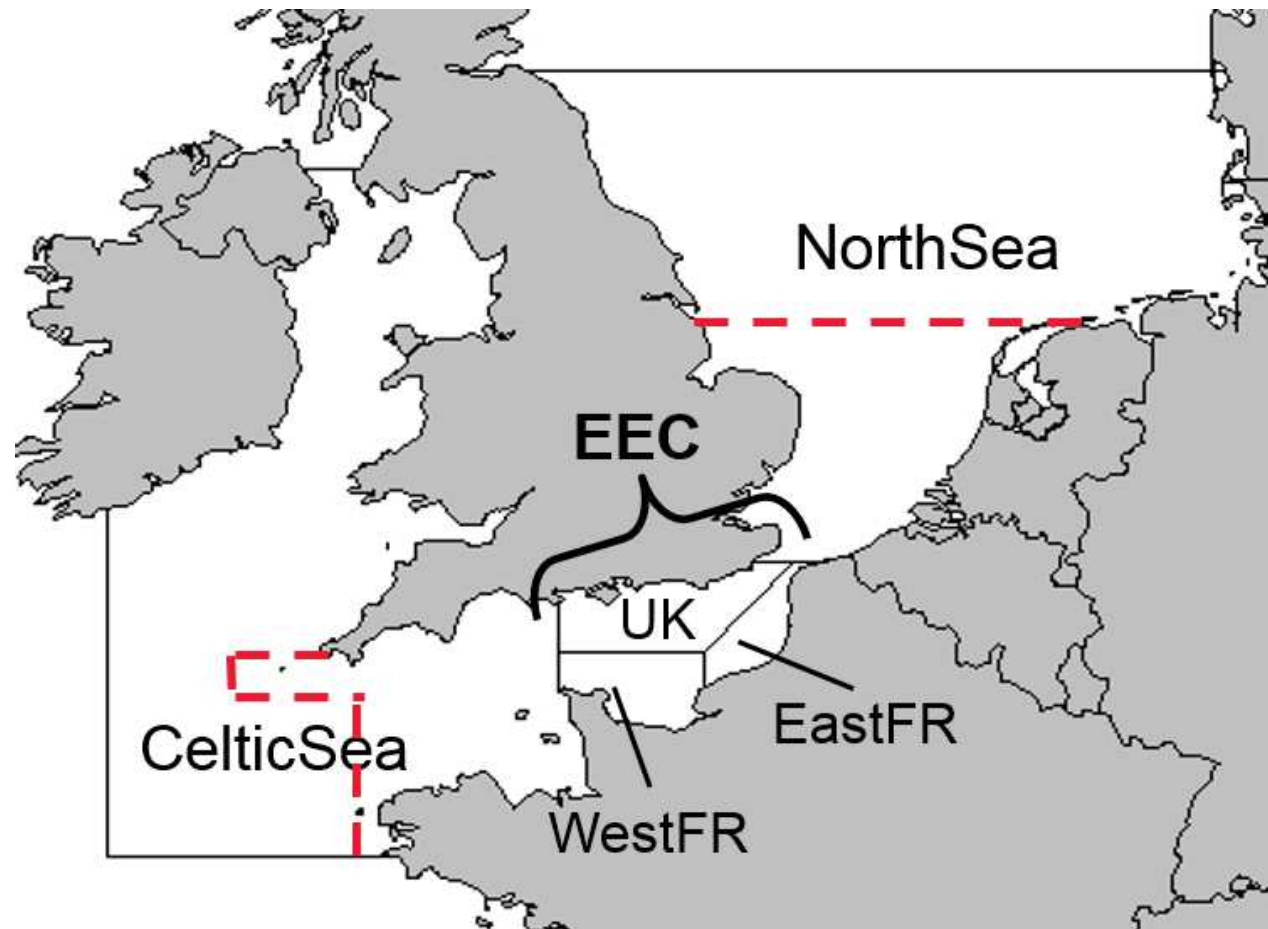
# Questions and hypotheses

- ▶ Reducing the spatial range to focus on migration outside and within the EEC.

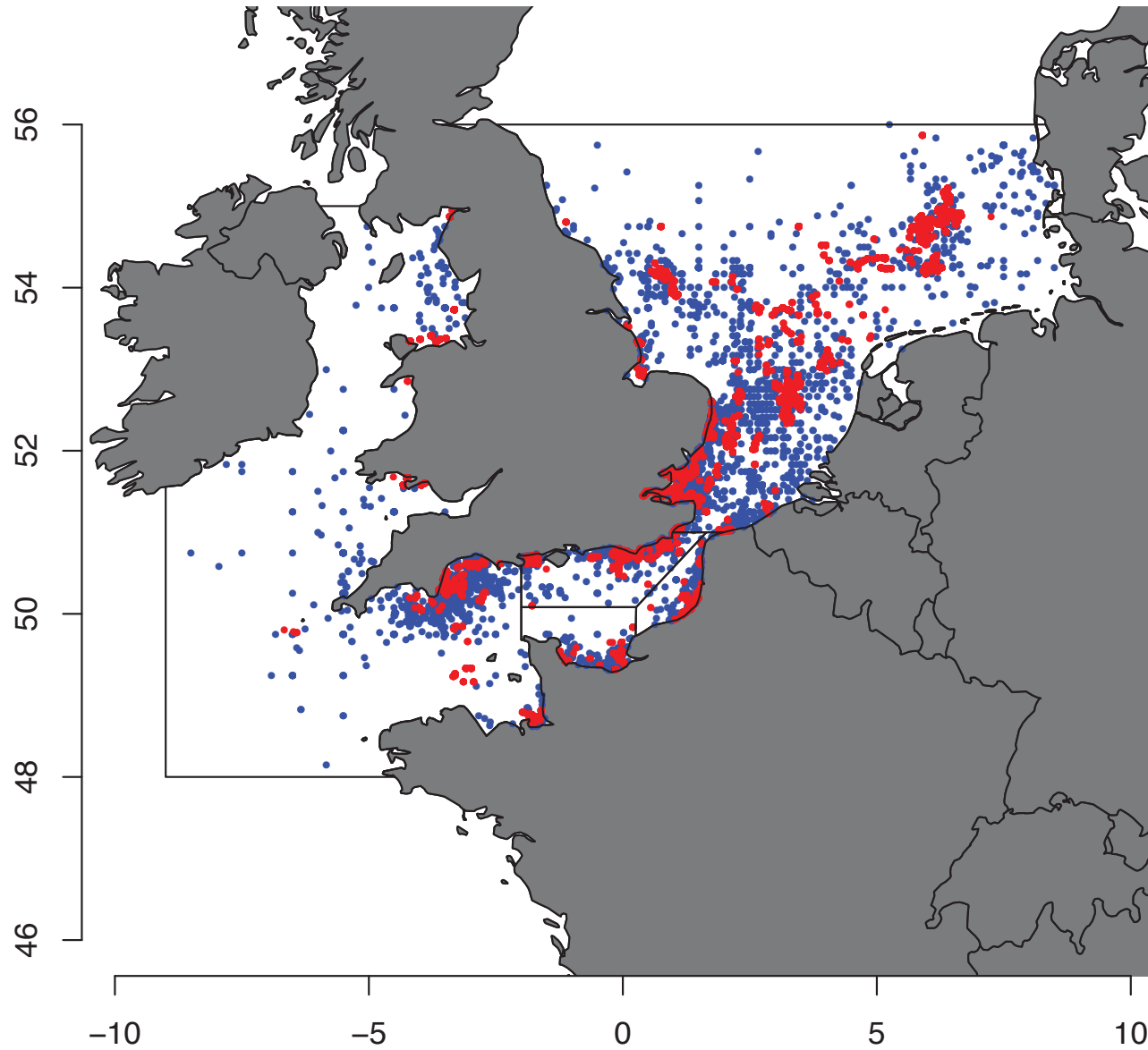


# Questions and hypotheses

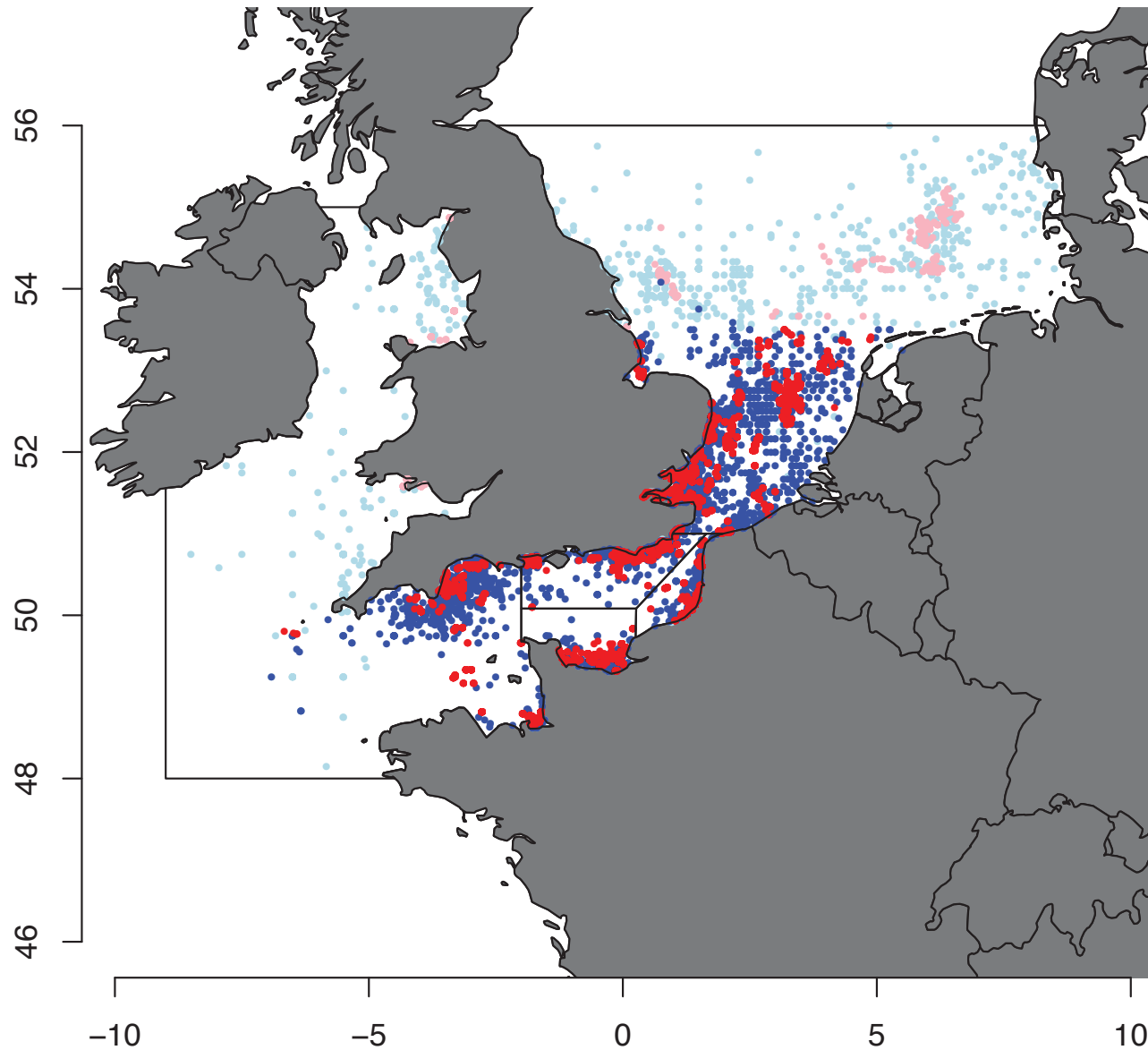
- ▶ Reducing the spatial range to focus on migration outside and within the EEC.



# Model with all campaigns

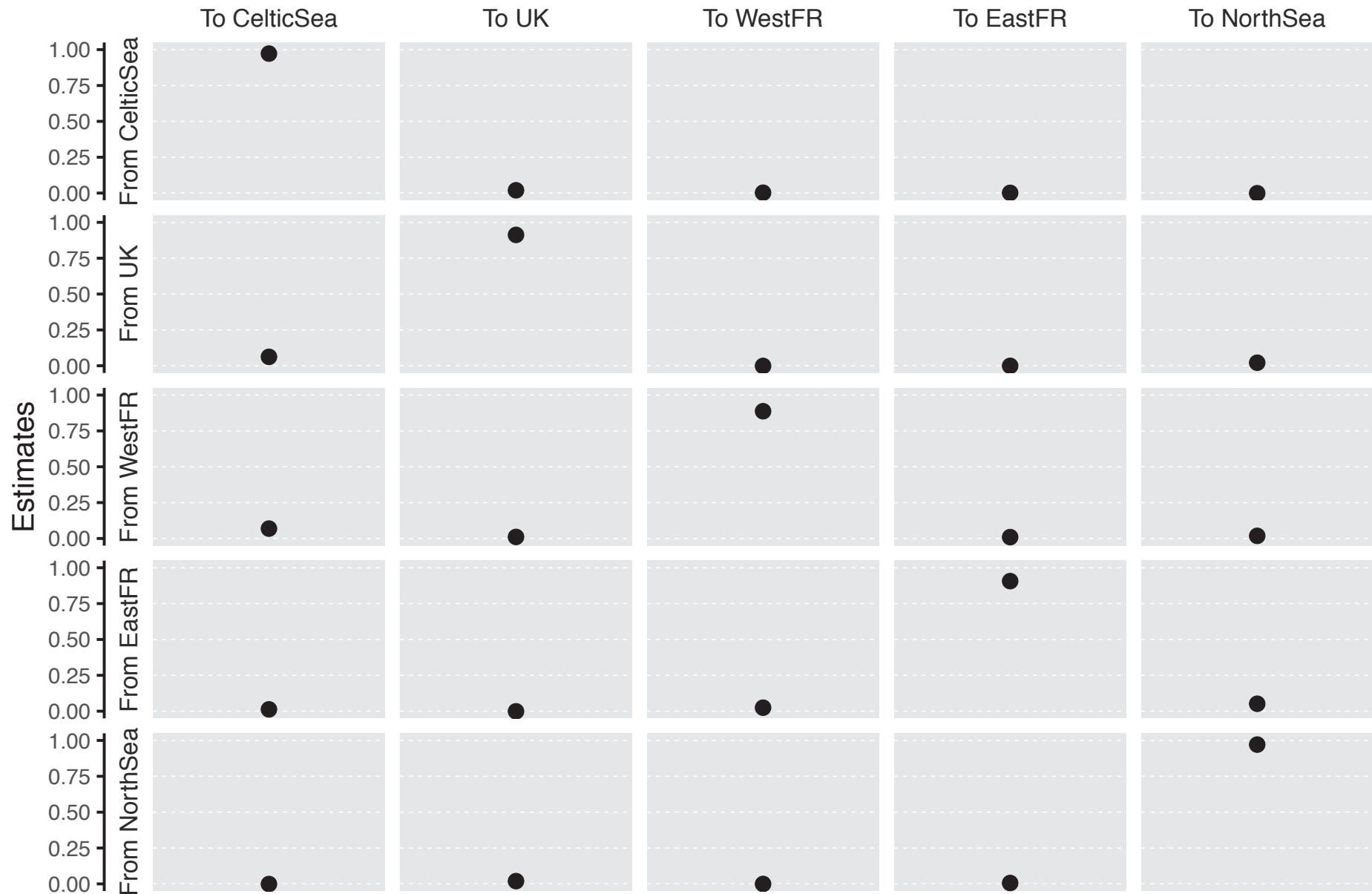


# Model with area reduction VIIe / VIId / IVc

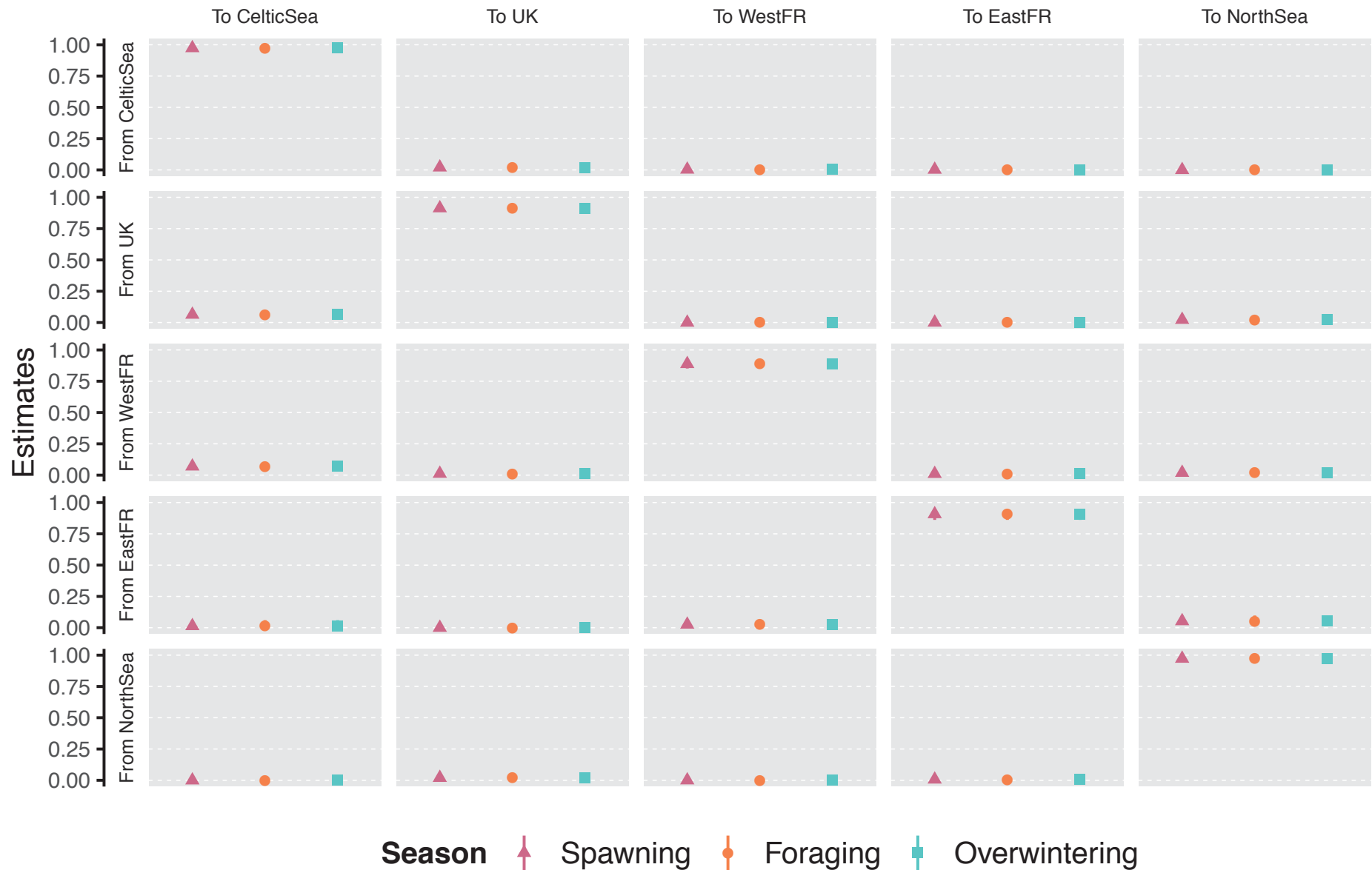




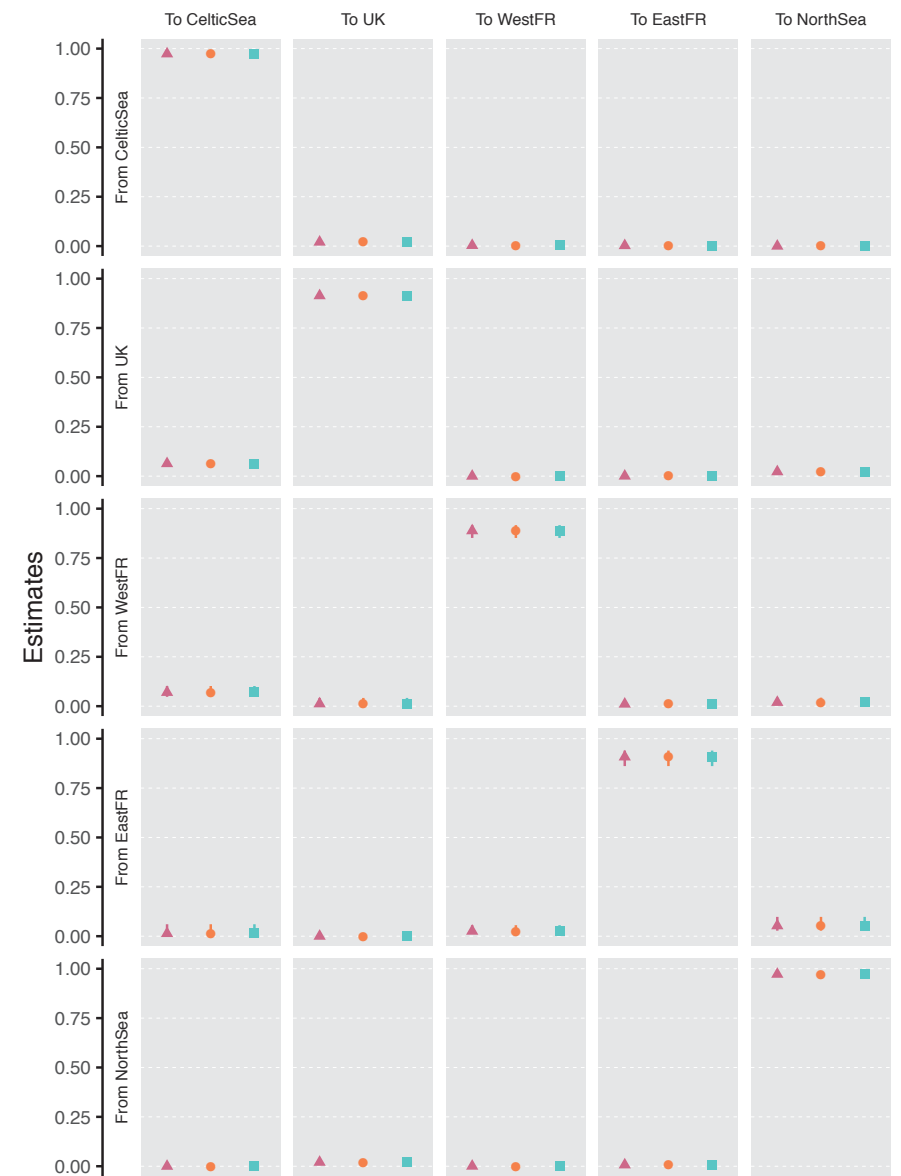
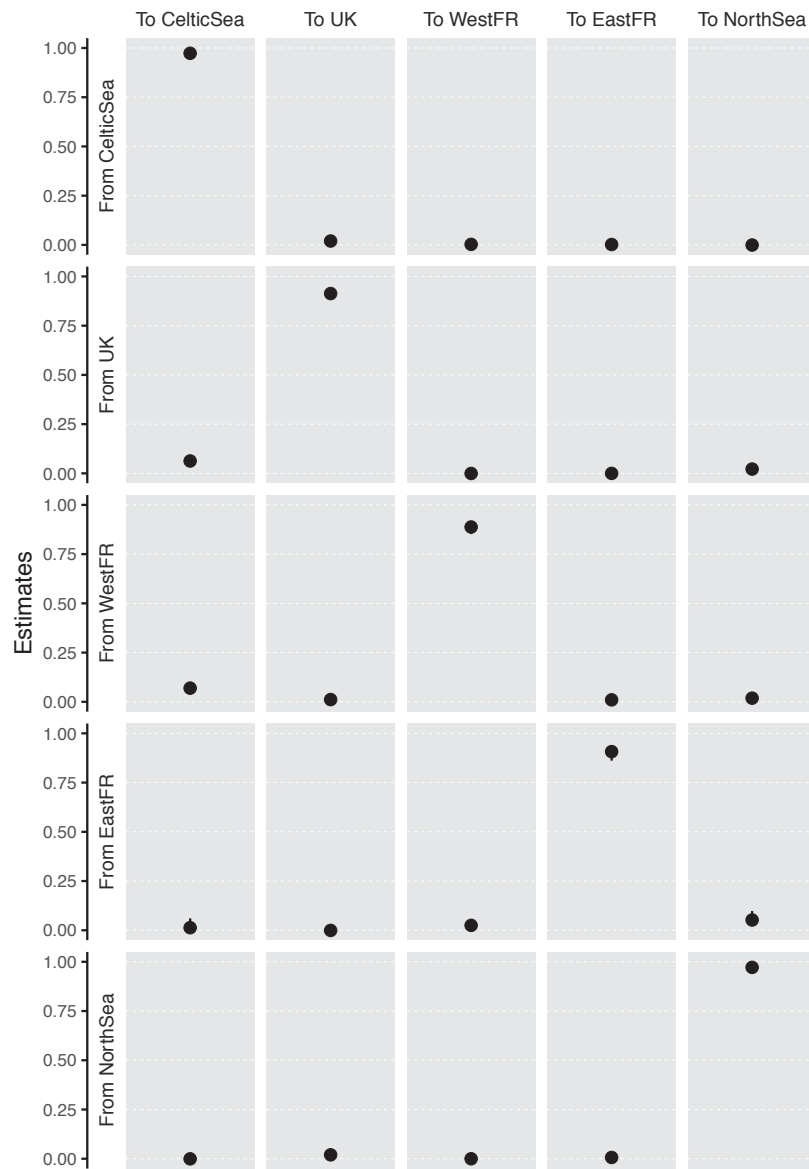
# Movements estimations M2.N: Spatial reduction without seasonal movements



# Movements estimations M2.S: Spatial reduction with seasonal movements



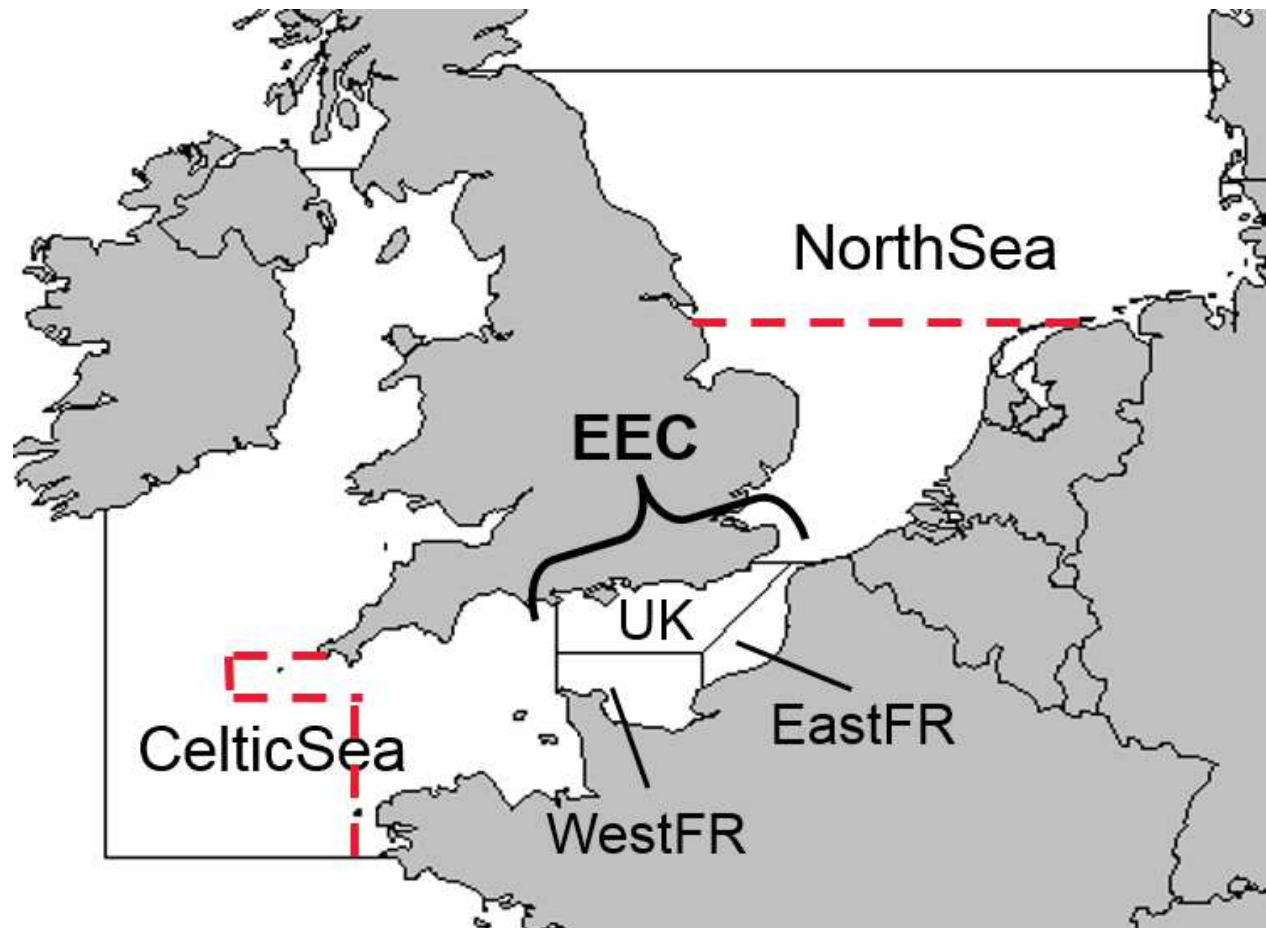
# Movements estimations M2: Spatial reduction



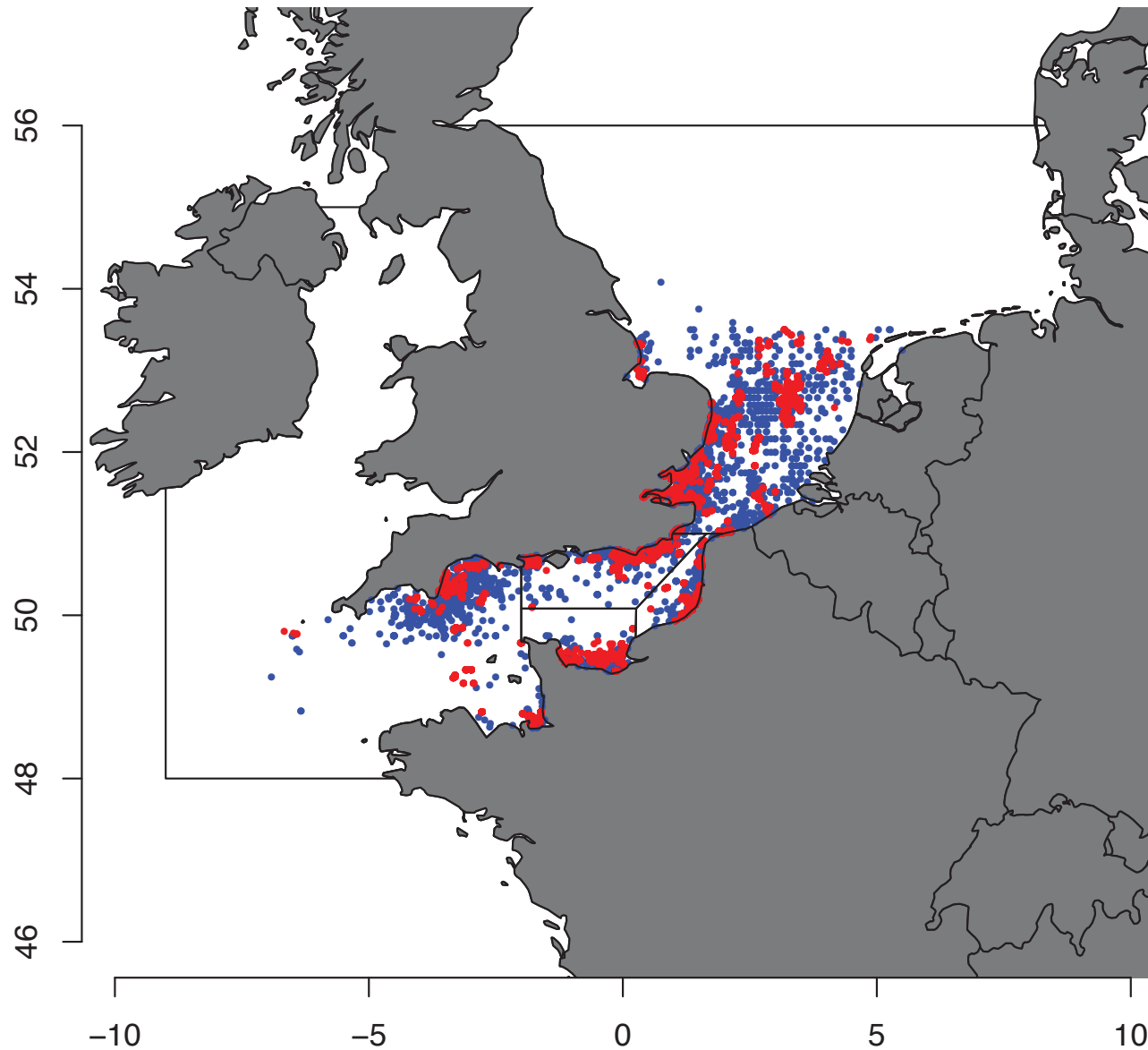
Season ▲ Spawning ● Foraging ■ Overwintering

# Questions and hypotheses

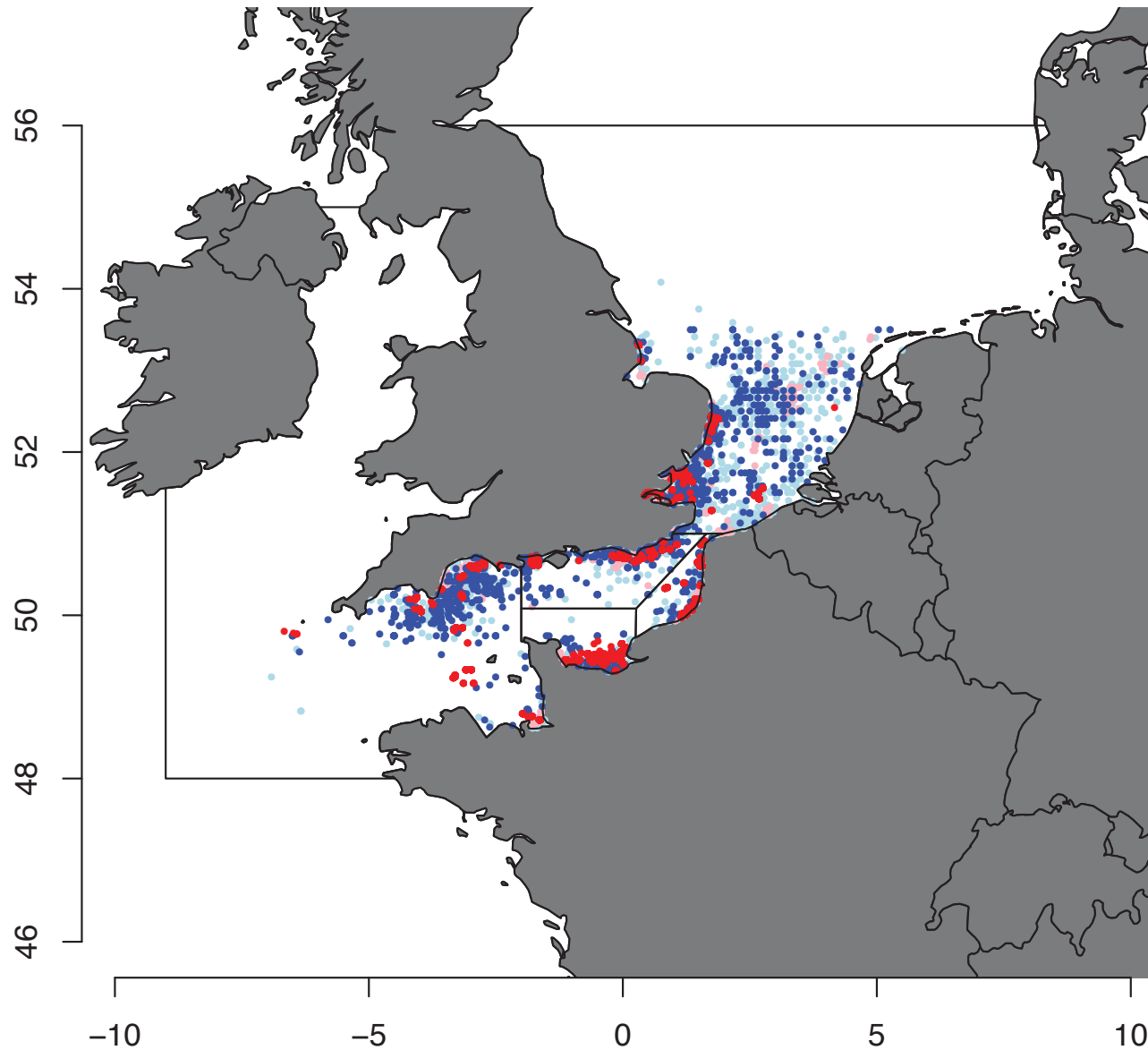
- ▶ Reducing the temporal window to later use a spatially and temporally varying fishing mortality.
- ▶ What is the impact of reducing the time window on previous estimations ?



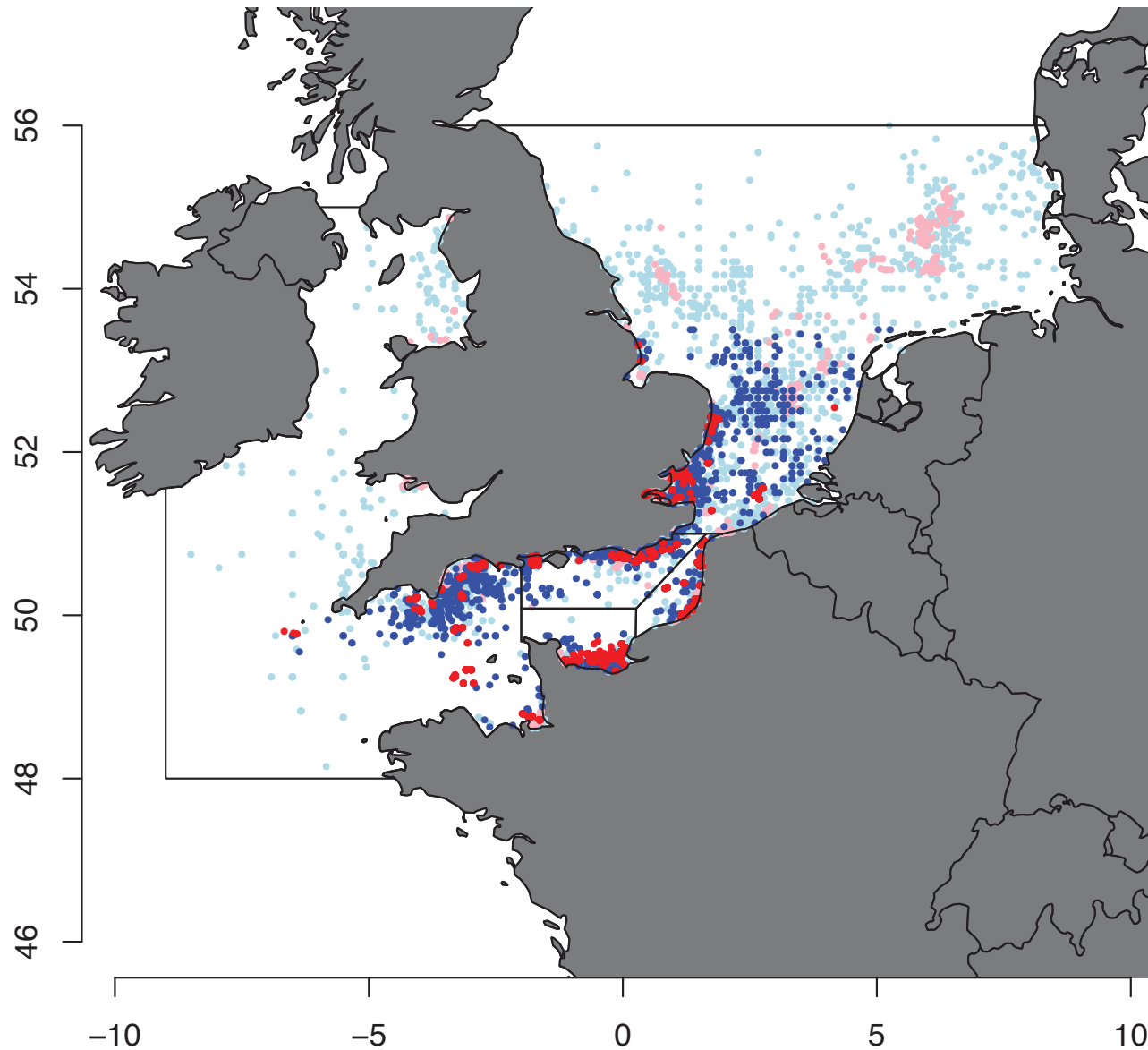
# Model with area reduction VIIe / VIId / IVc



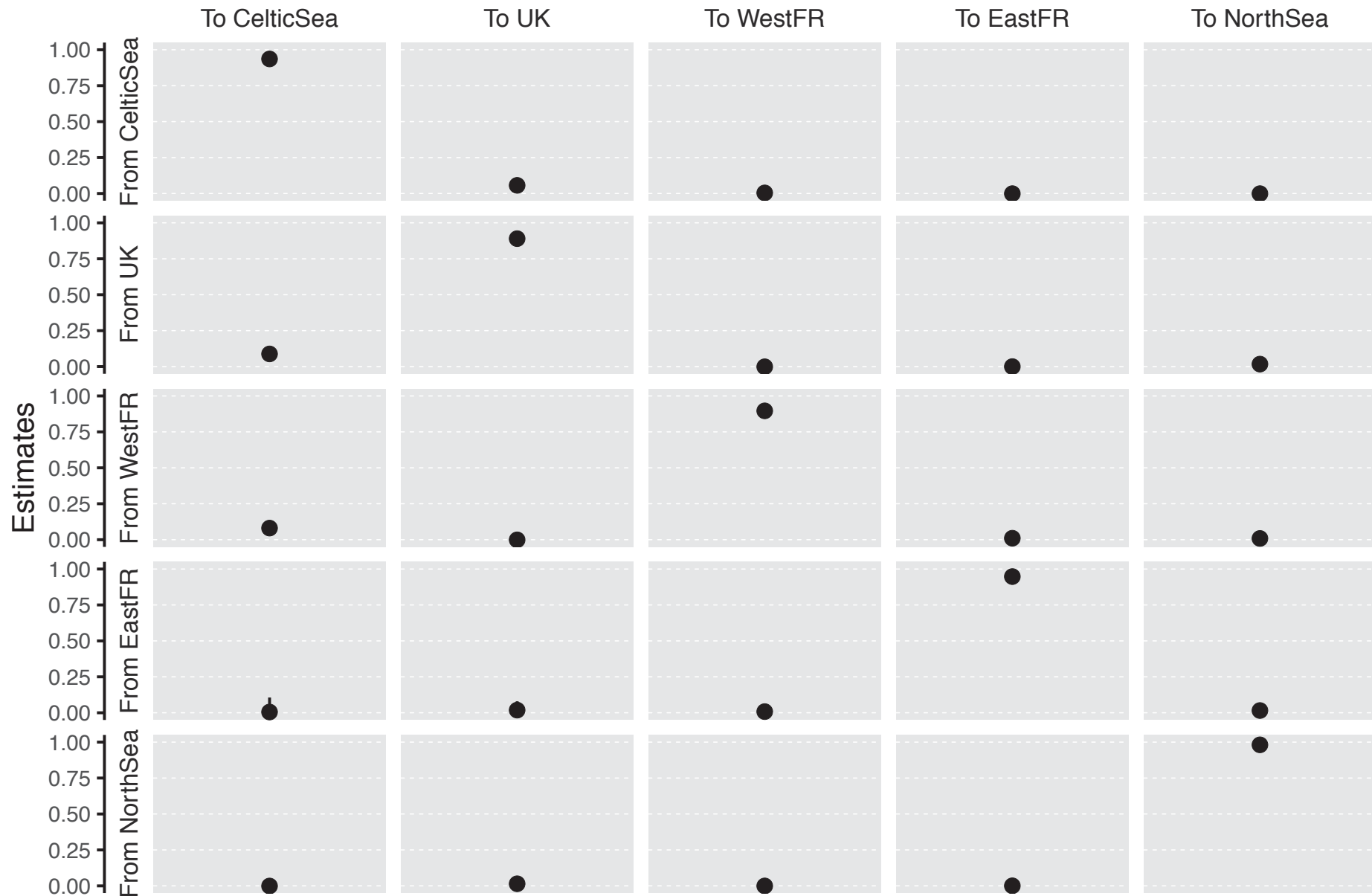
# Model with time reduction: after 1982



# Model with time reduction: after 1982

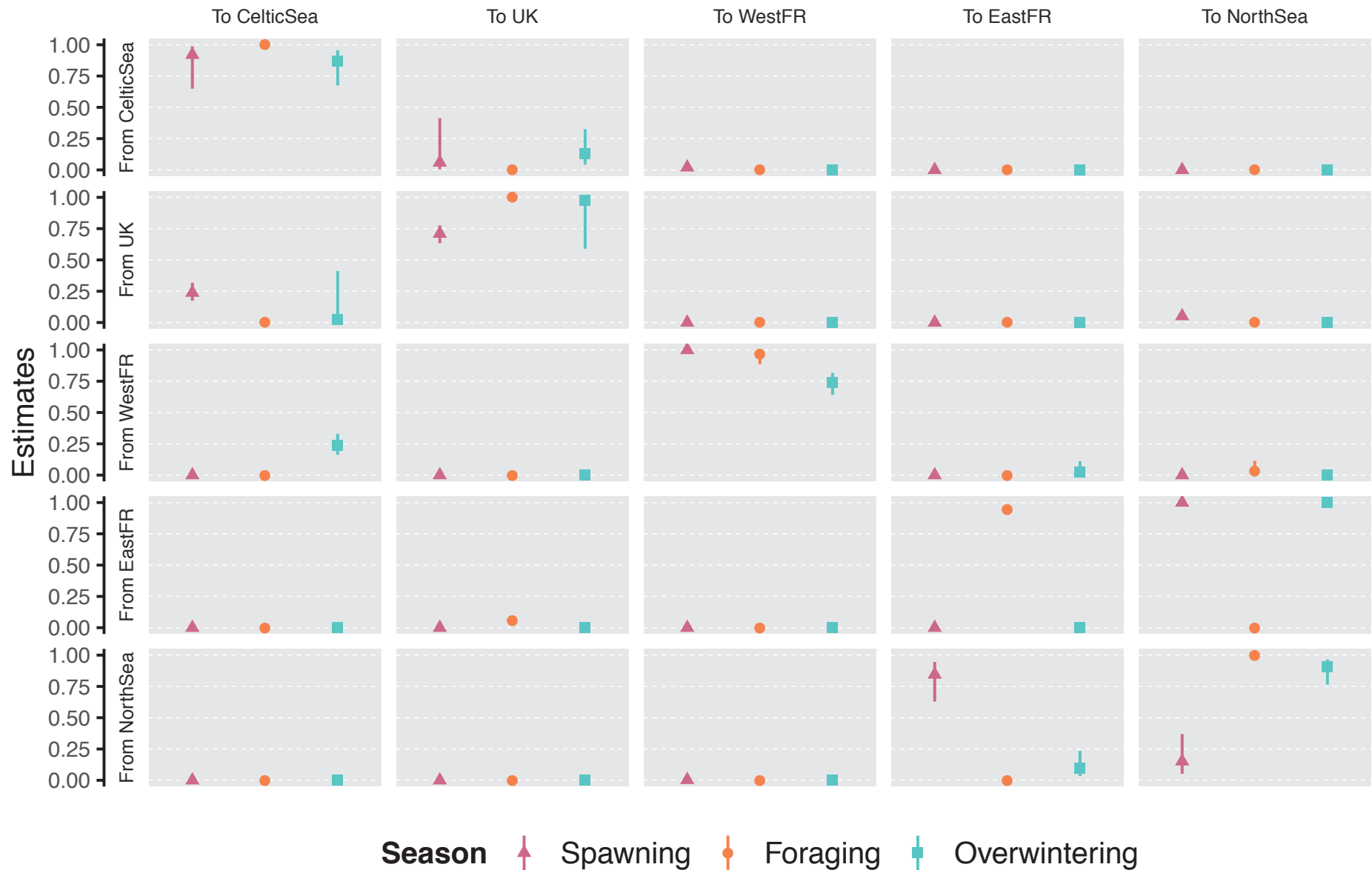


# Movements estimations M3.N: Time reduction without seasonal movements

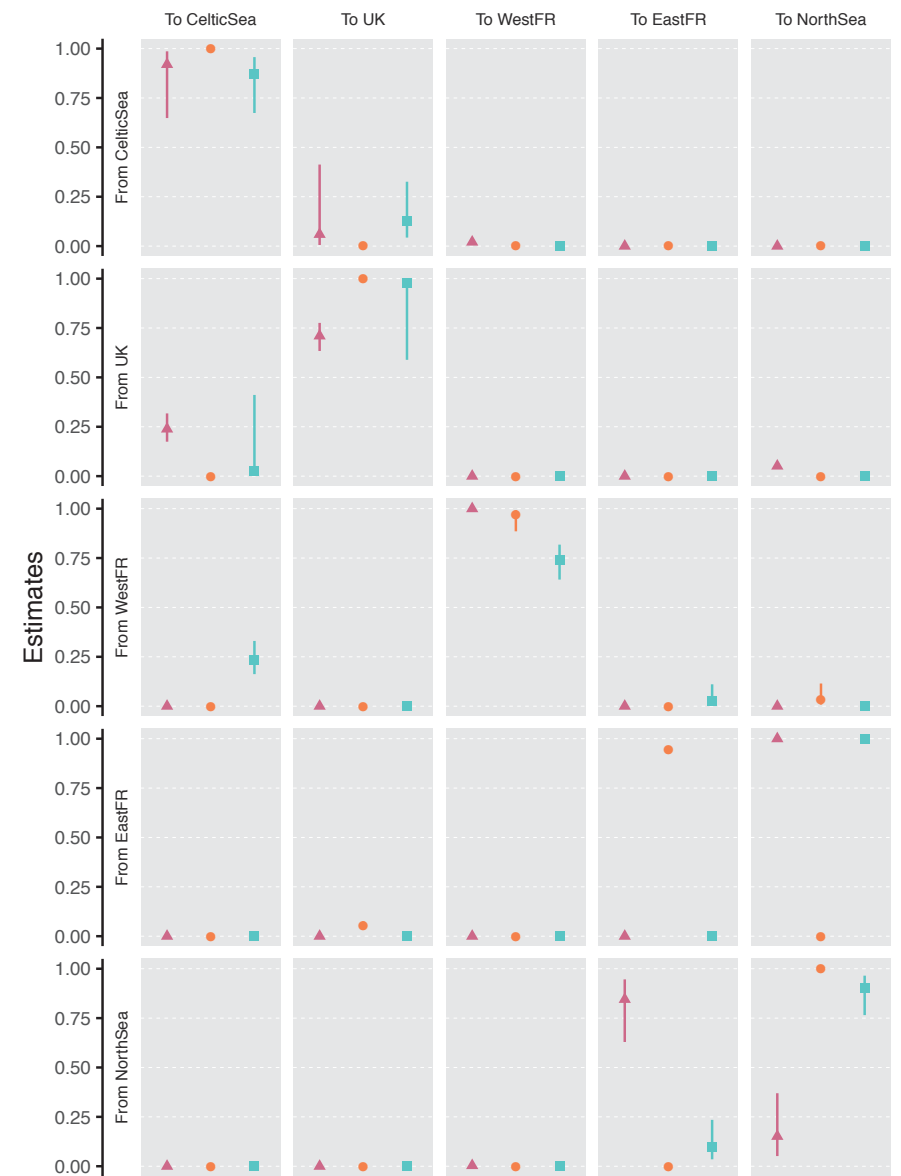
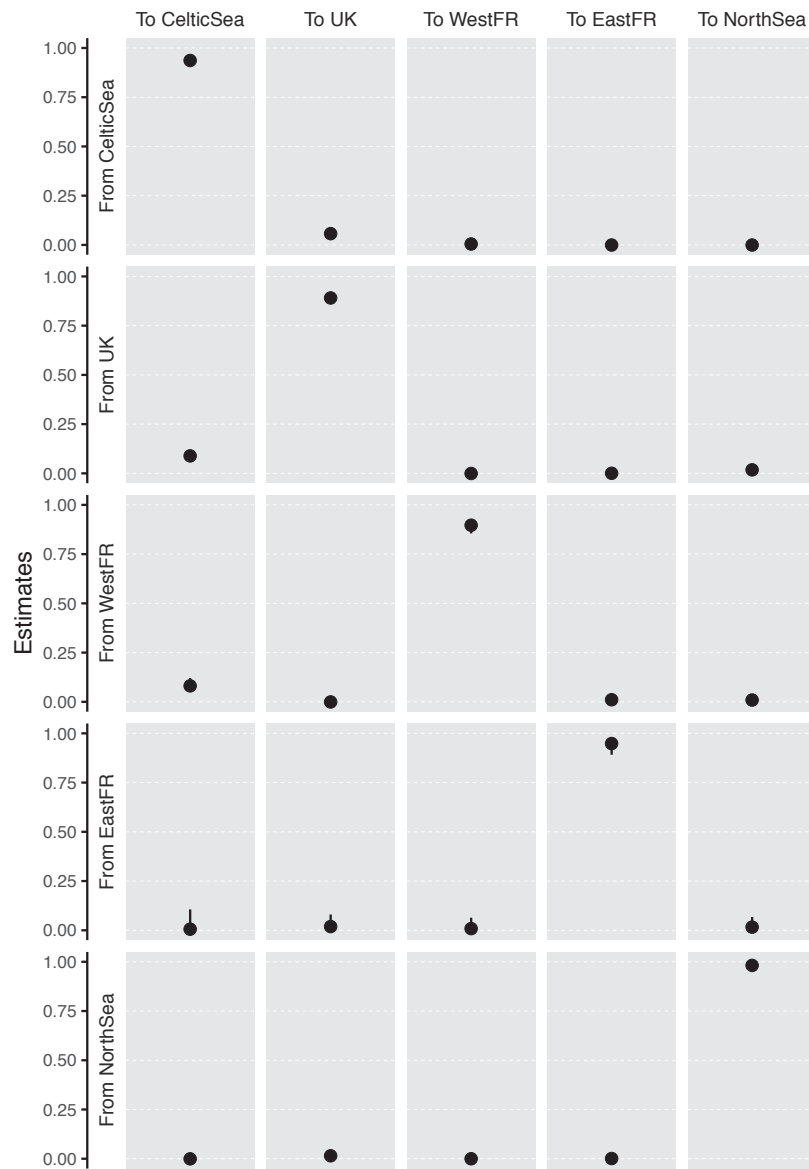




# Movements estimations M3.S: Time reduction with seasonal movements



# Movements estimations M3: Time reduction

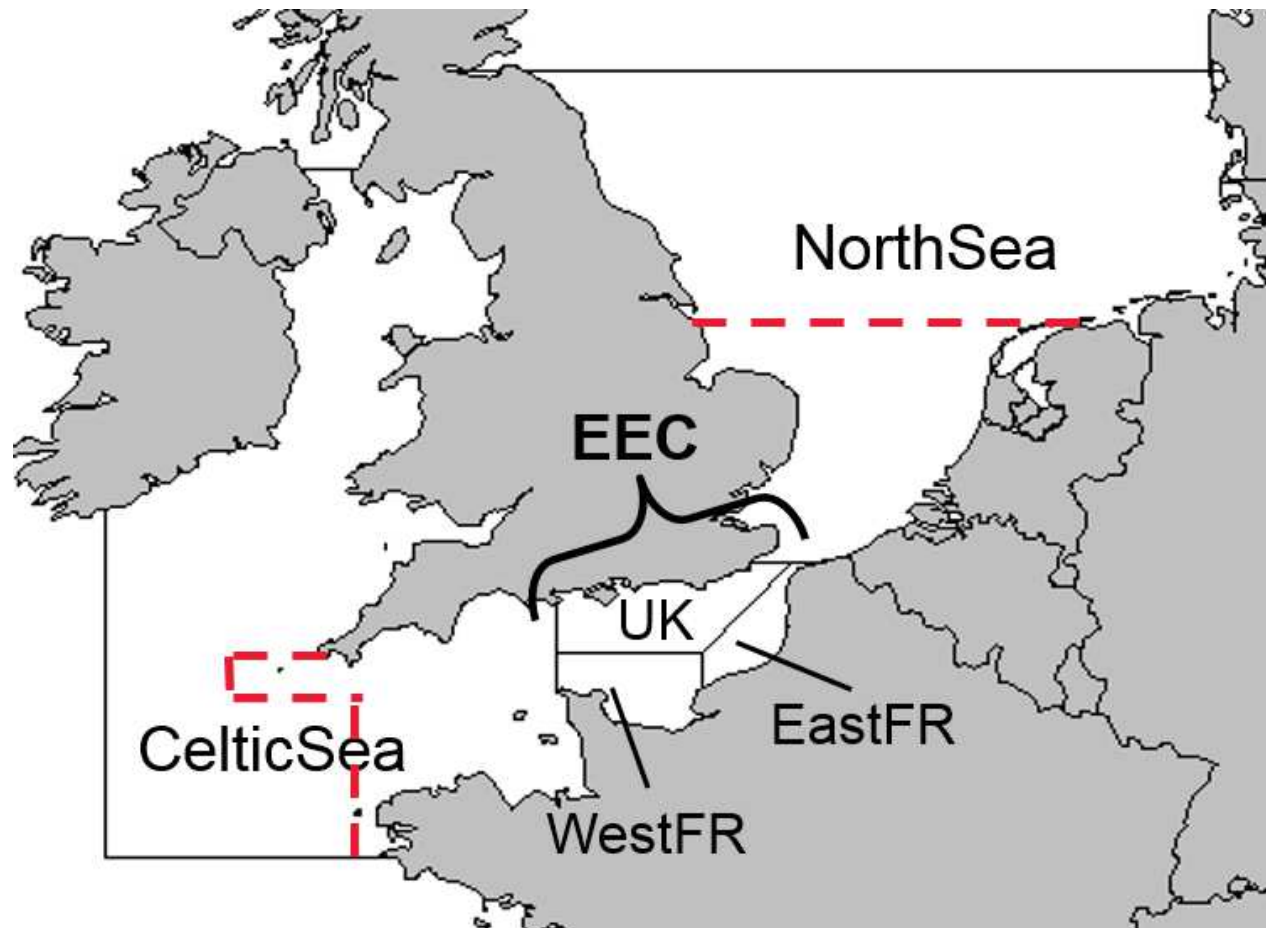


Season ▲ Spawning ● Foraging ■ Overwintering

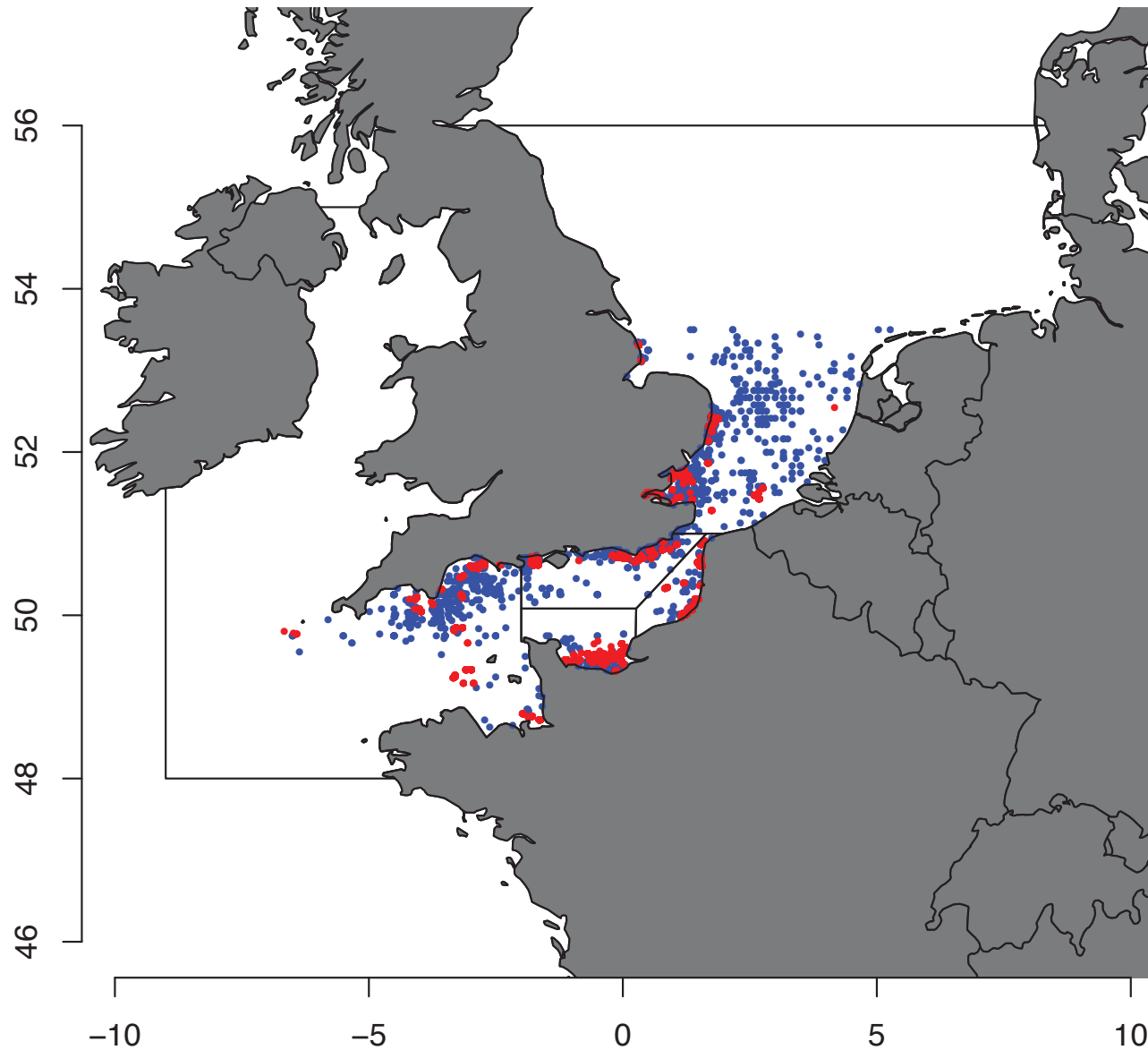
# Questions and hypotheses

Including a spatially varying fishing mortality:

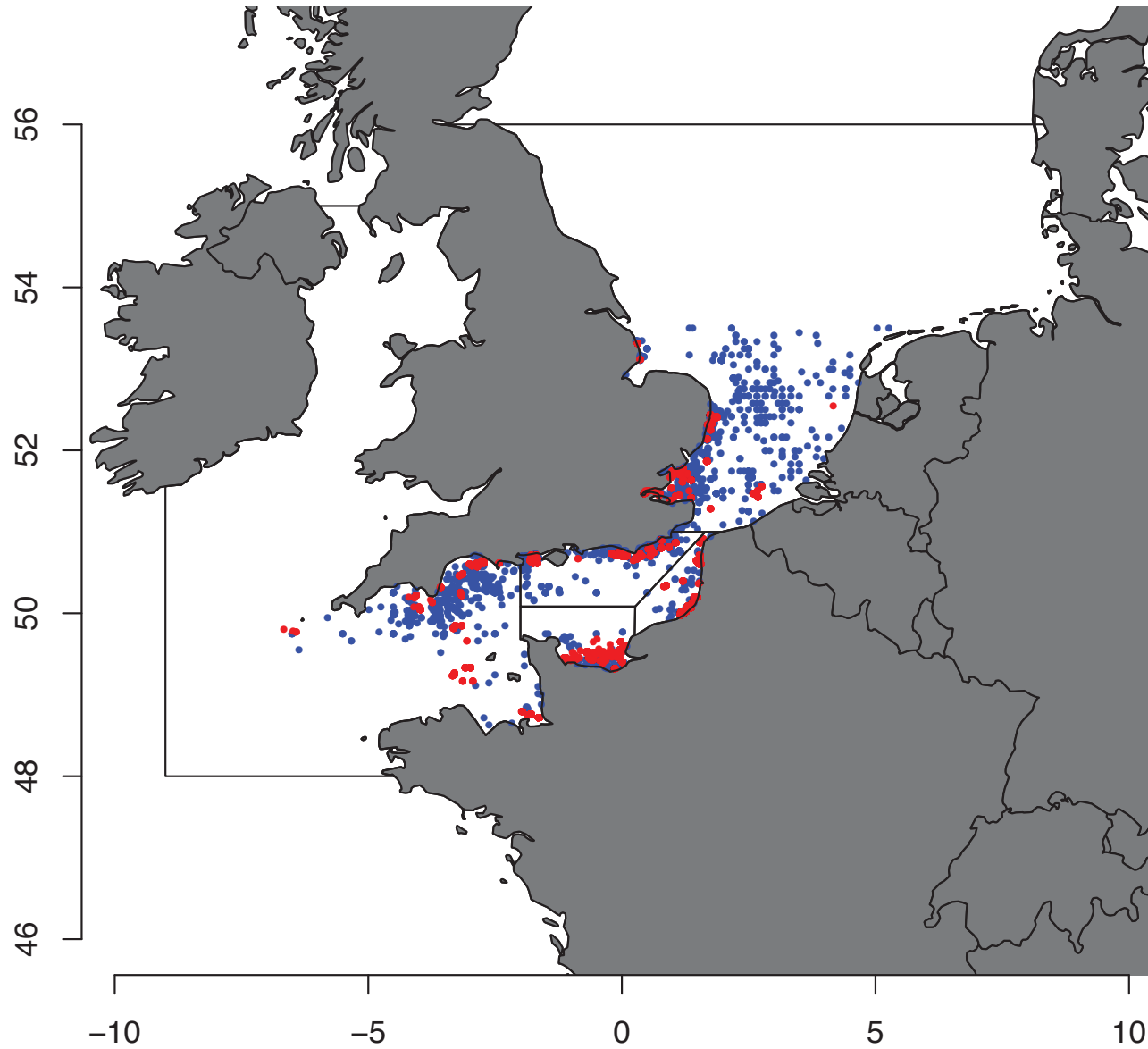
- ▶ Celtic Sea:  $\tau^f = 0.09$
- ▶ EEC:  $\tau^f = 0.10$
- ▶ North Sea:  $\tau^f = 0.15$



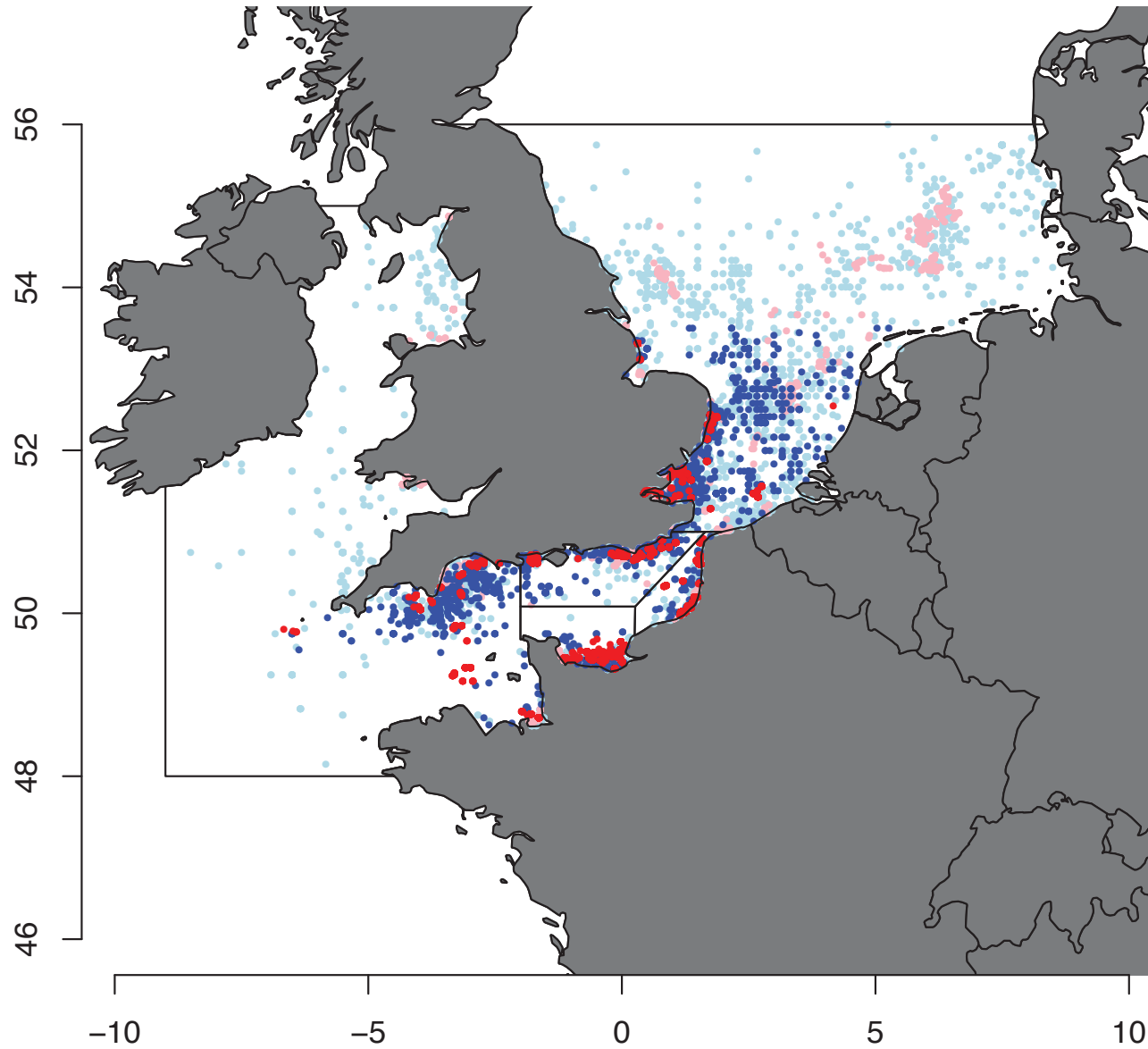
# Model with time reduction: after 1982



# Model with $\tau^f$ per area

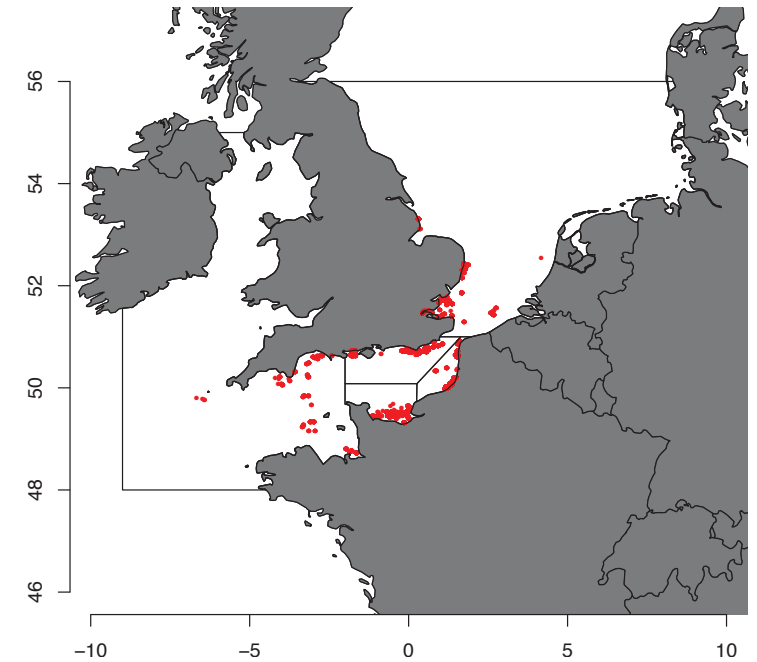
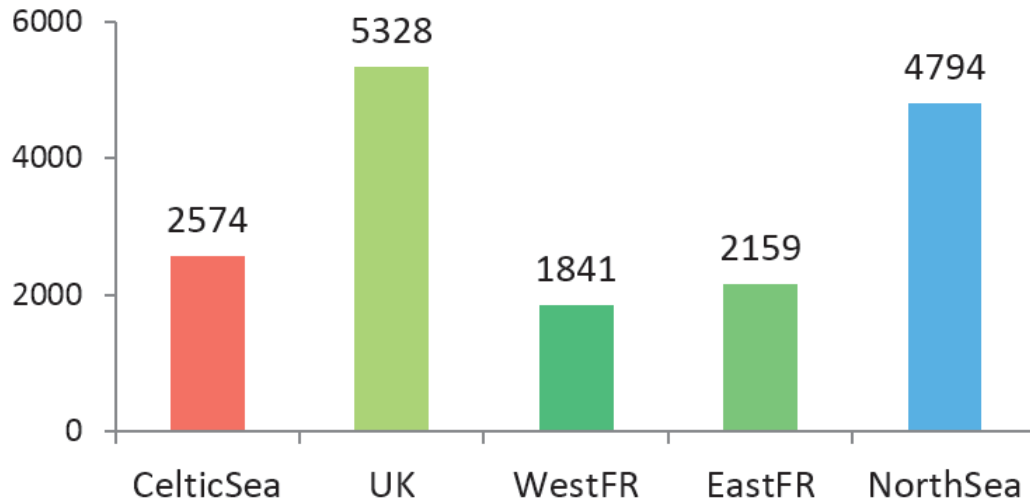


# Model with $\tau^f$ per area

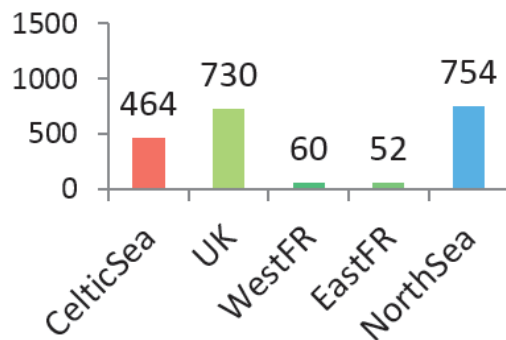


# Data reminder for model with $\tau^f$ per area

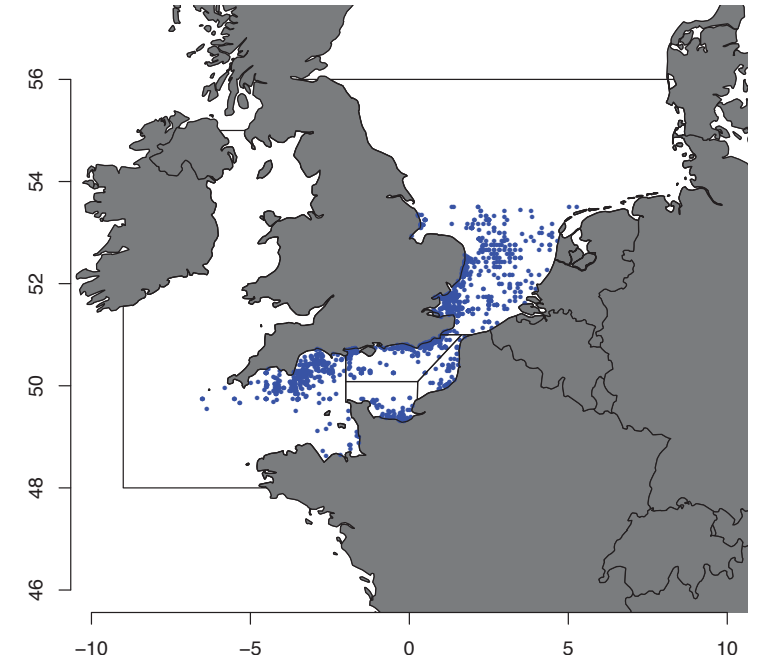
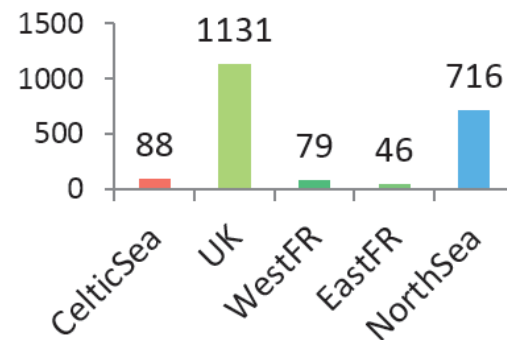
## Number of marked sole per area



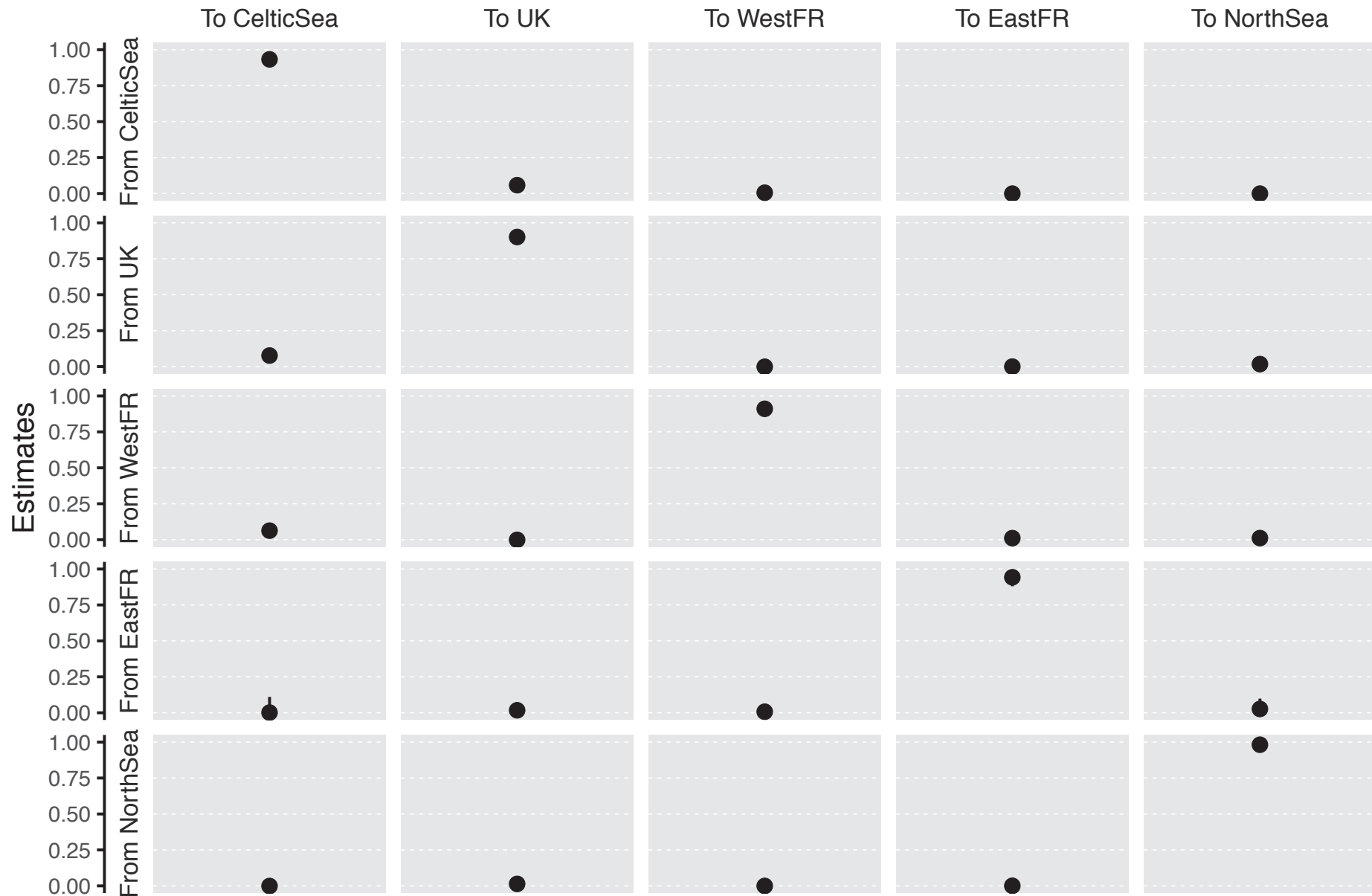
## Number of recaptured sole per mark area



## Number of recaptured sole per recapture area

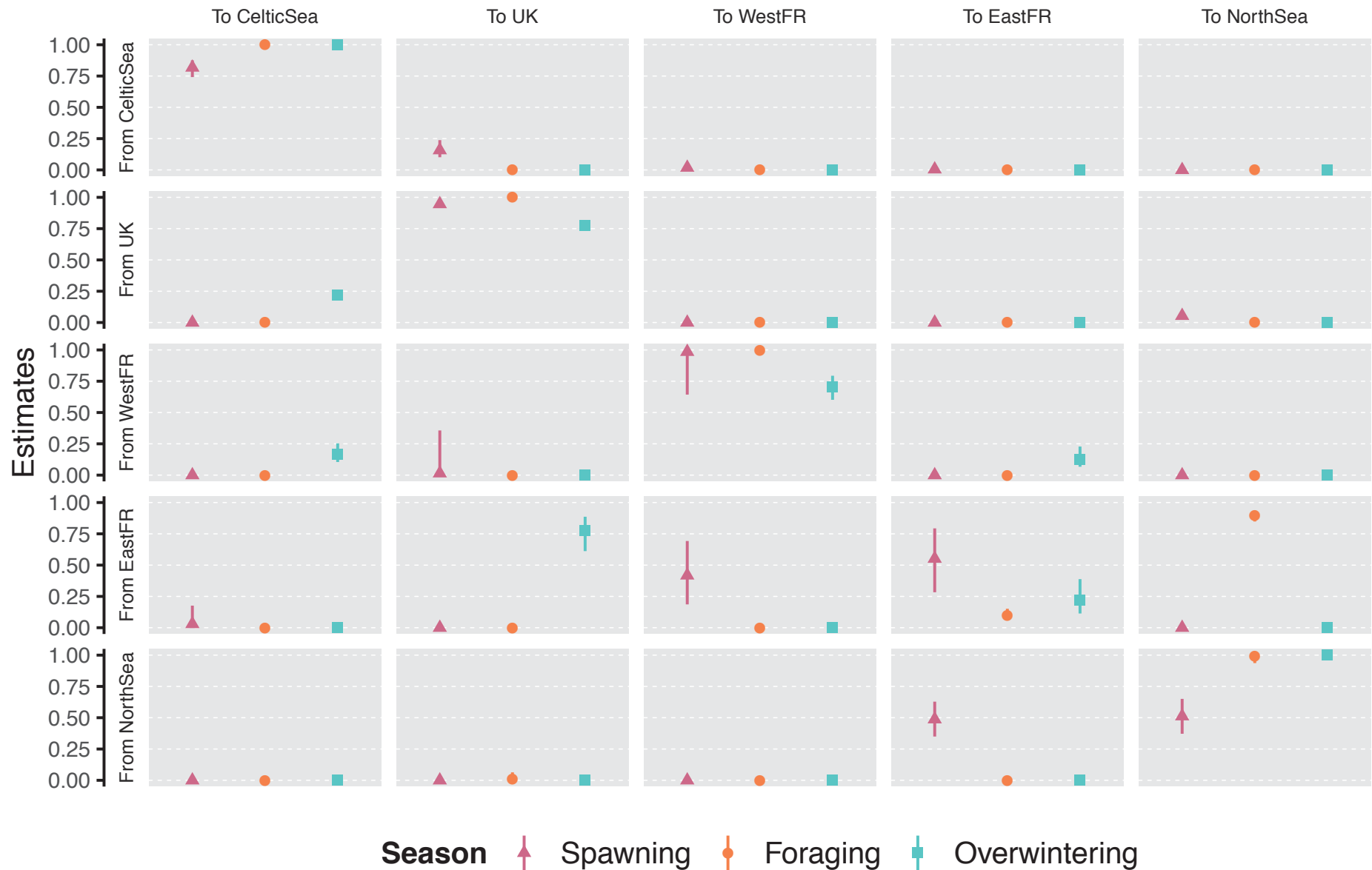


# Movements estimations M4.N: $\tau^f$ per area without seasonal movements

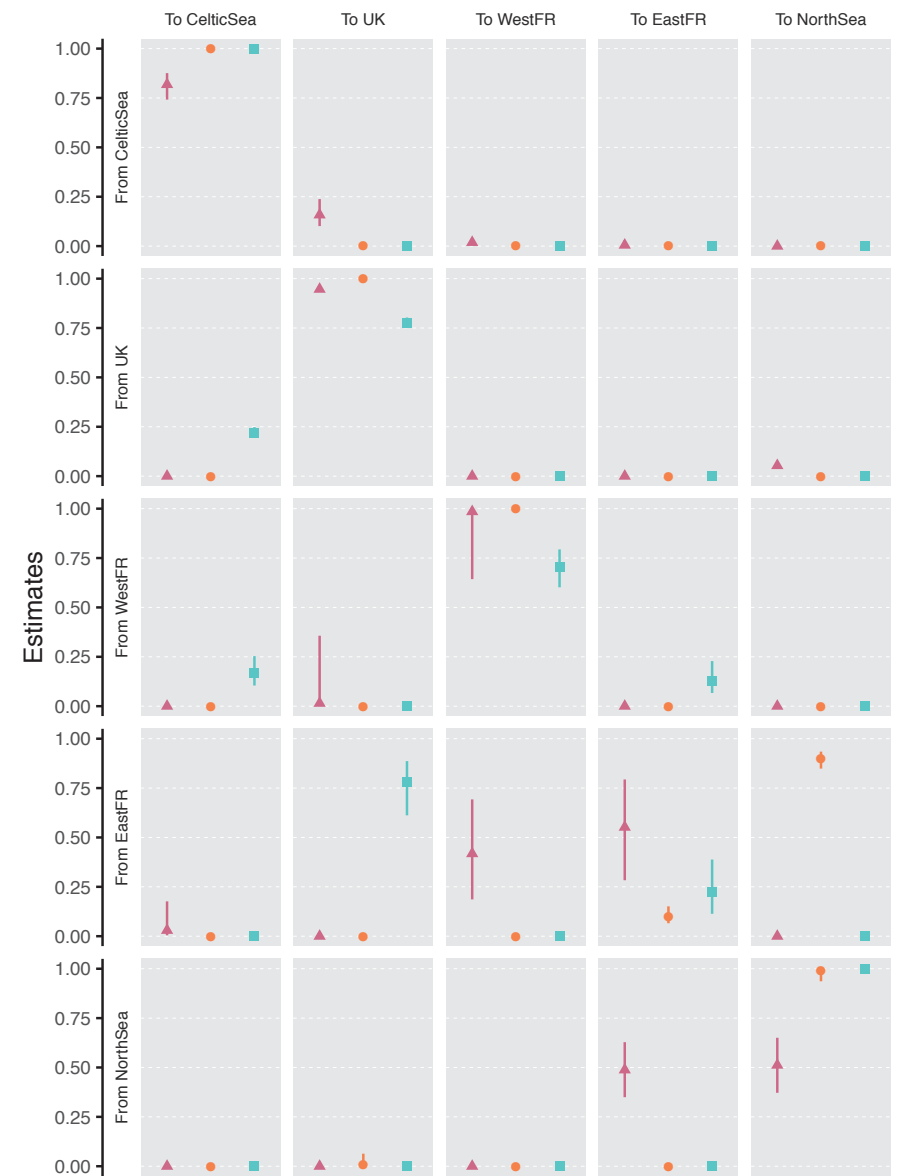
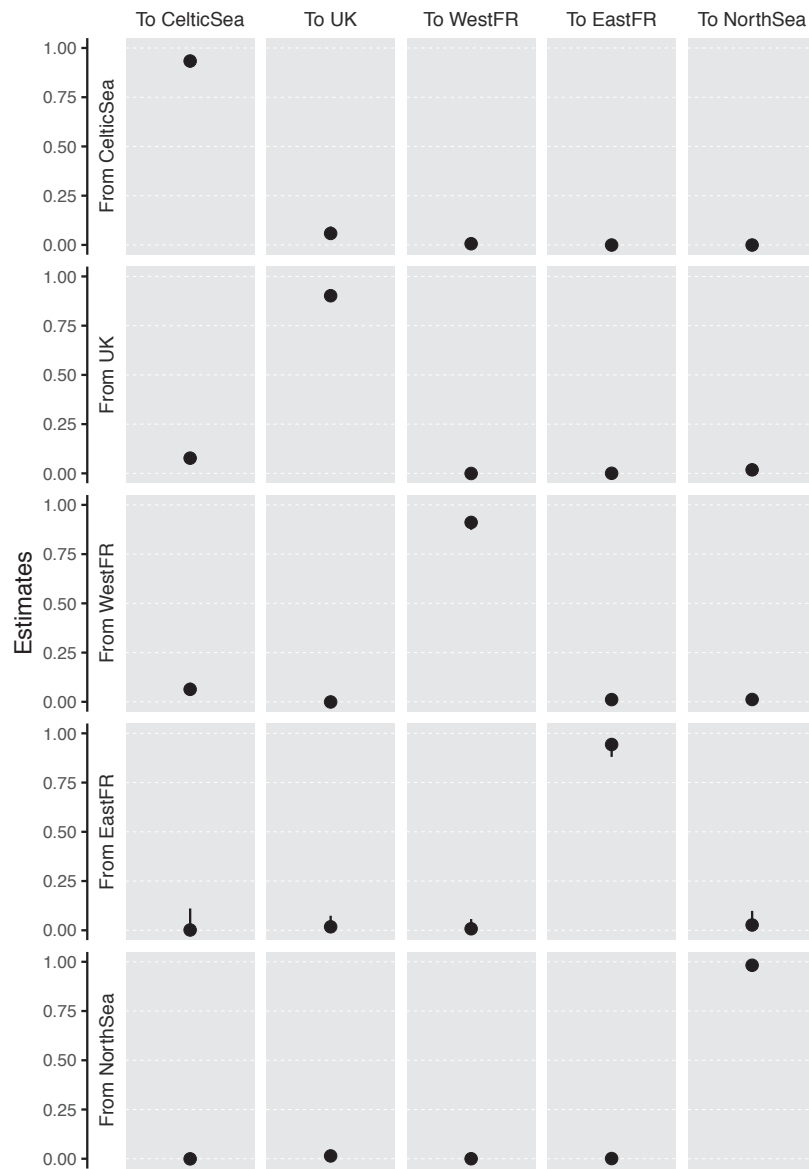




# Movements estimations M4.S: $\tau^f$ per area with seasonal movements



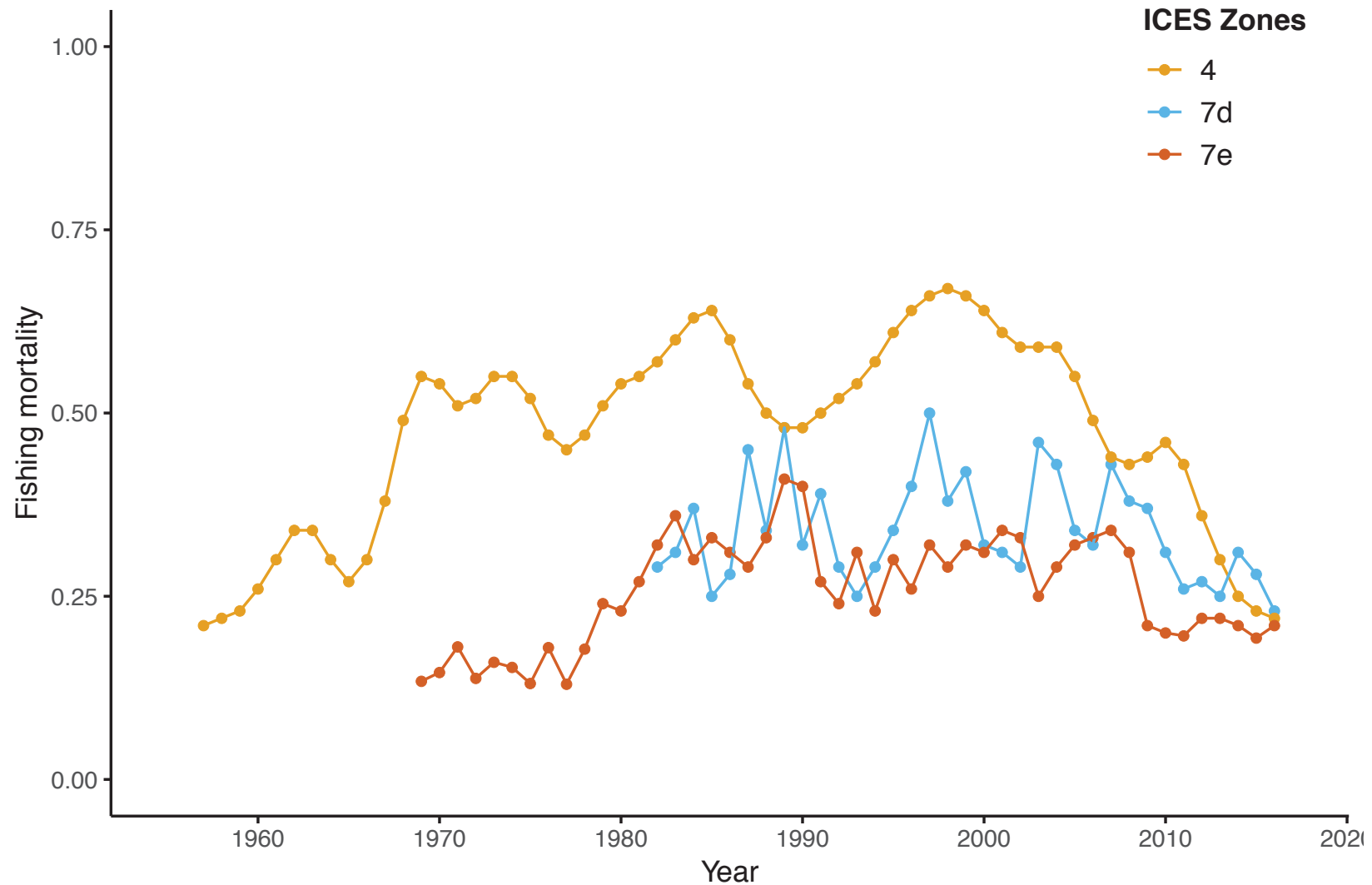
# Movements estimations M4: $\tau^f$ per area



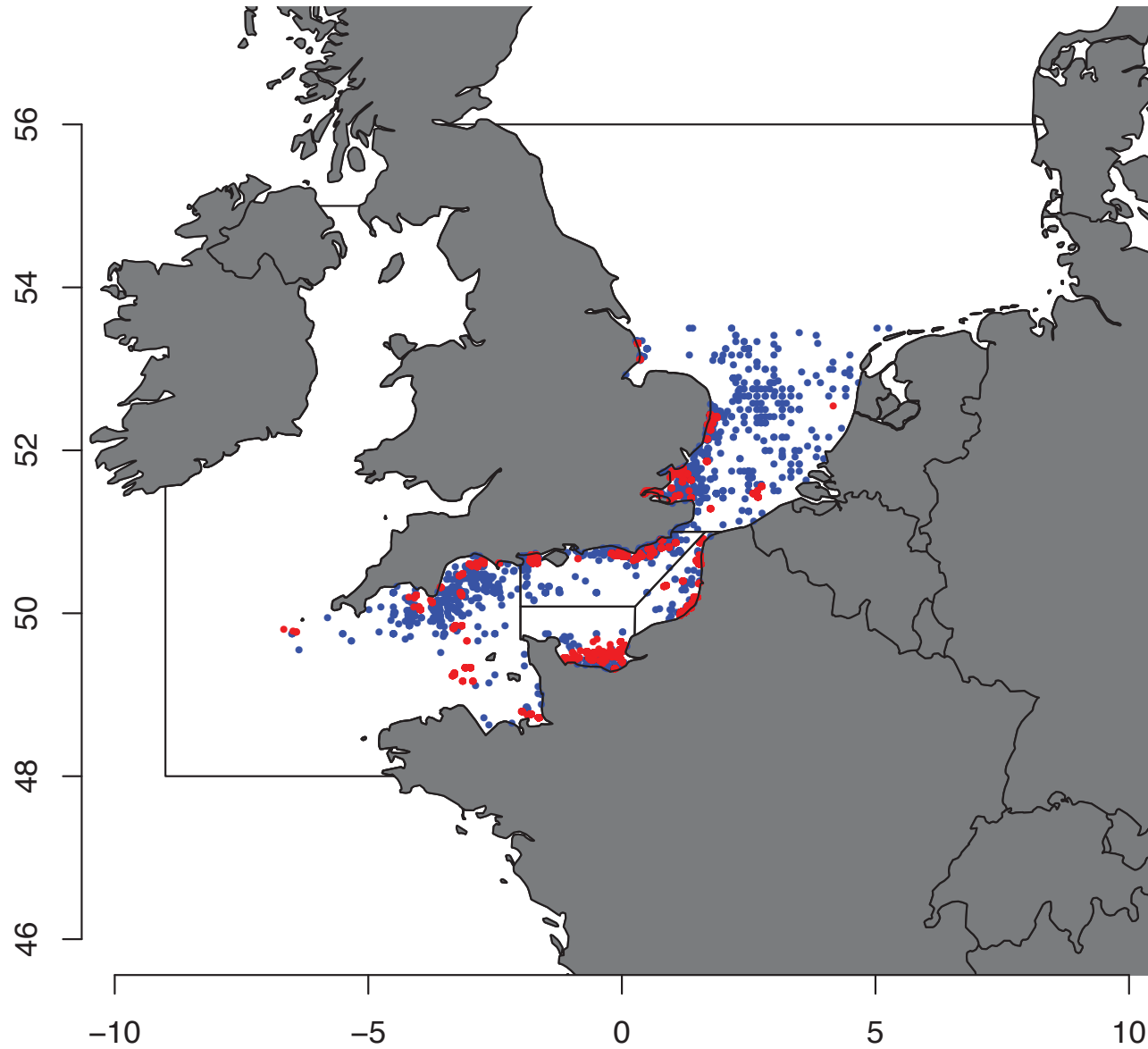
Season ▲ Spawning ◆ Foraging ■ Overwintering

# Questions and hypotheses

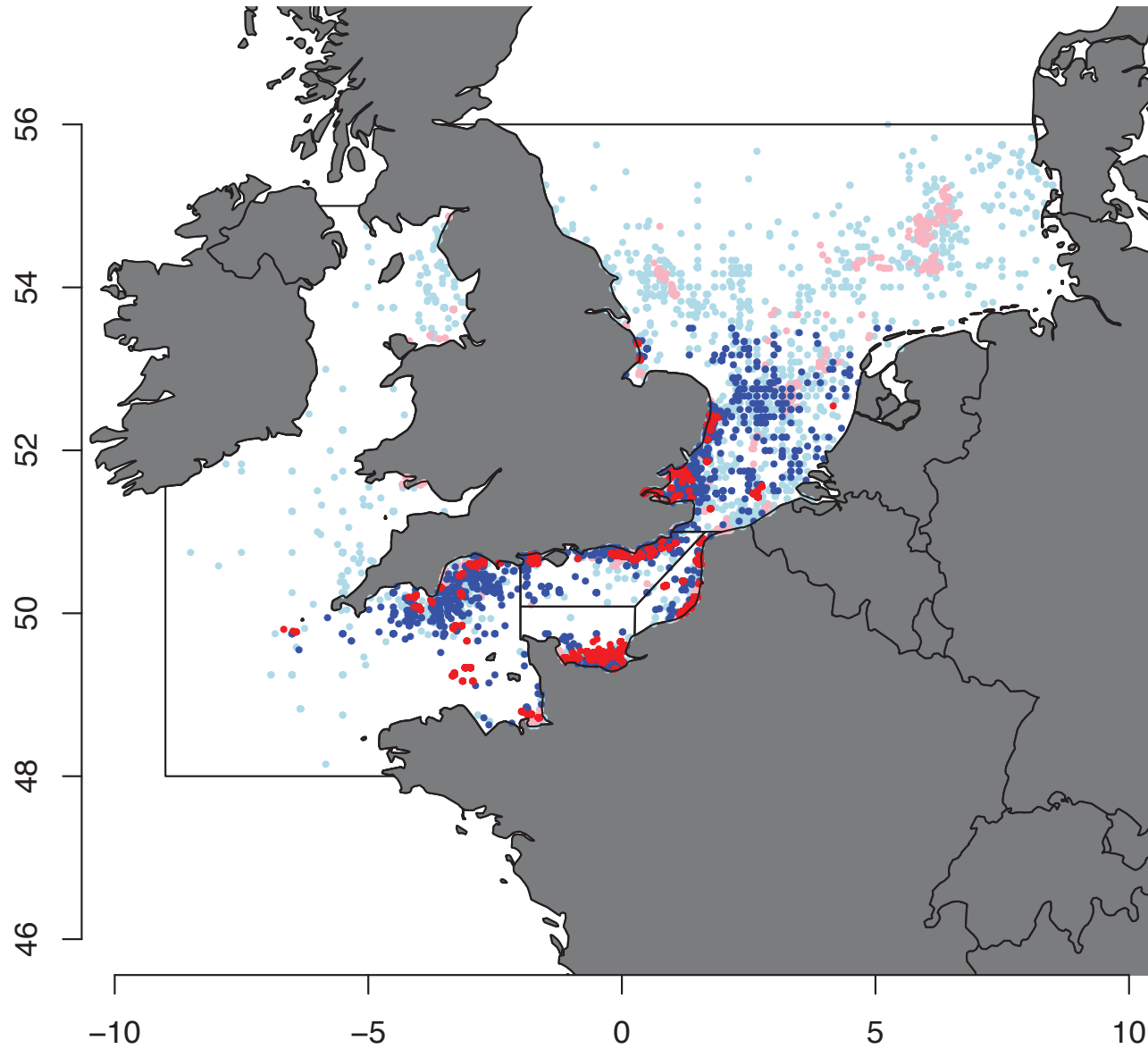
Including a spatially and temporally varying fishing mortality.



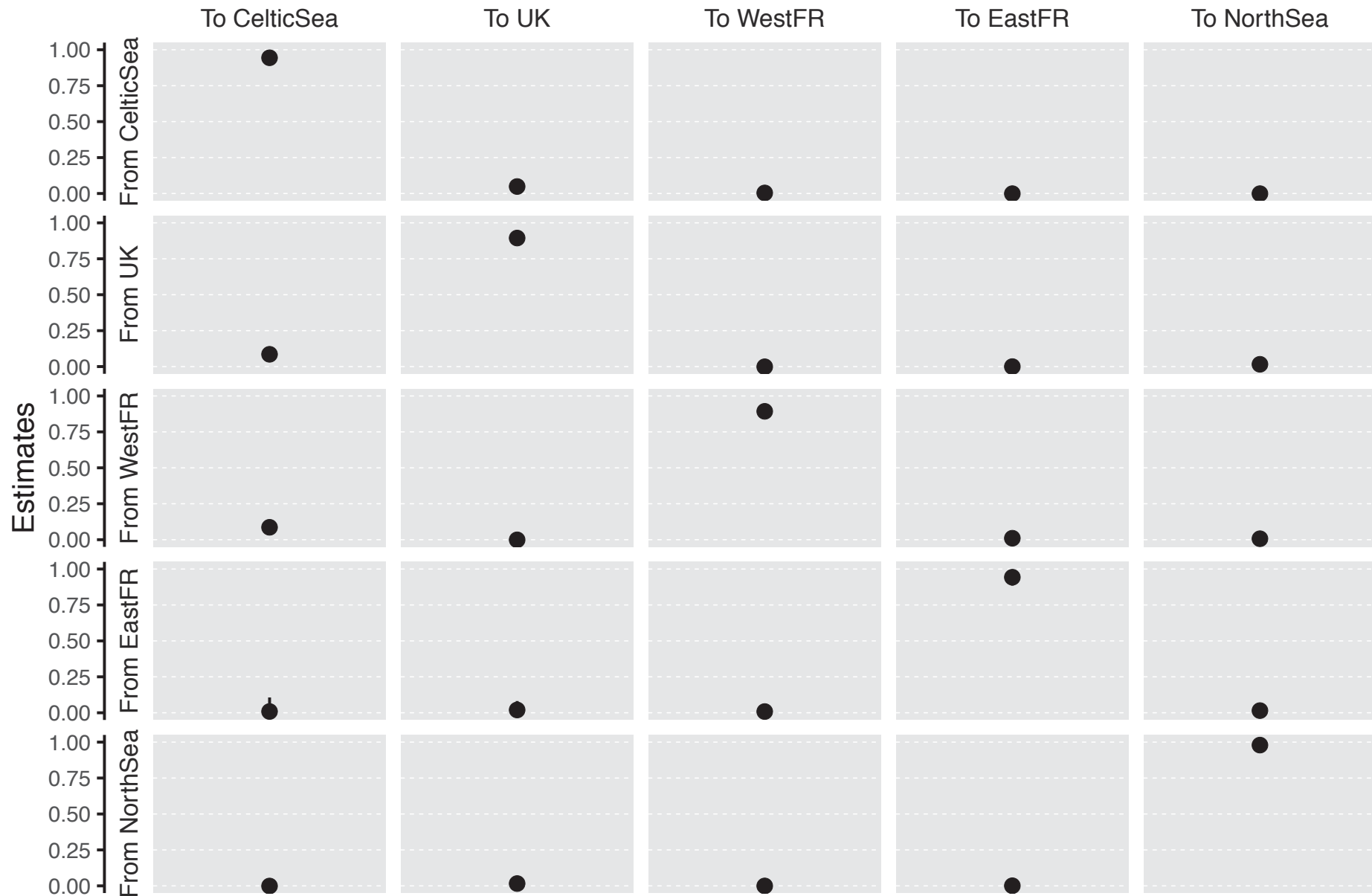
# Model with $\tau^f$ per area and year



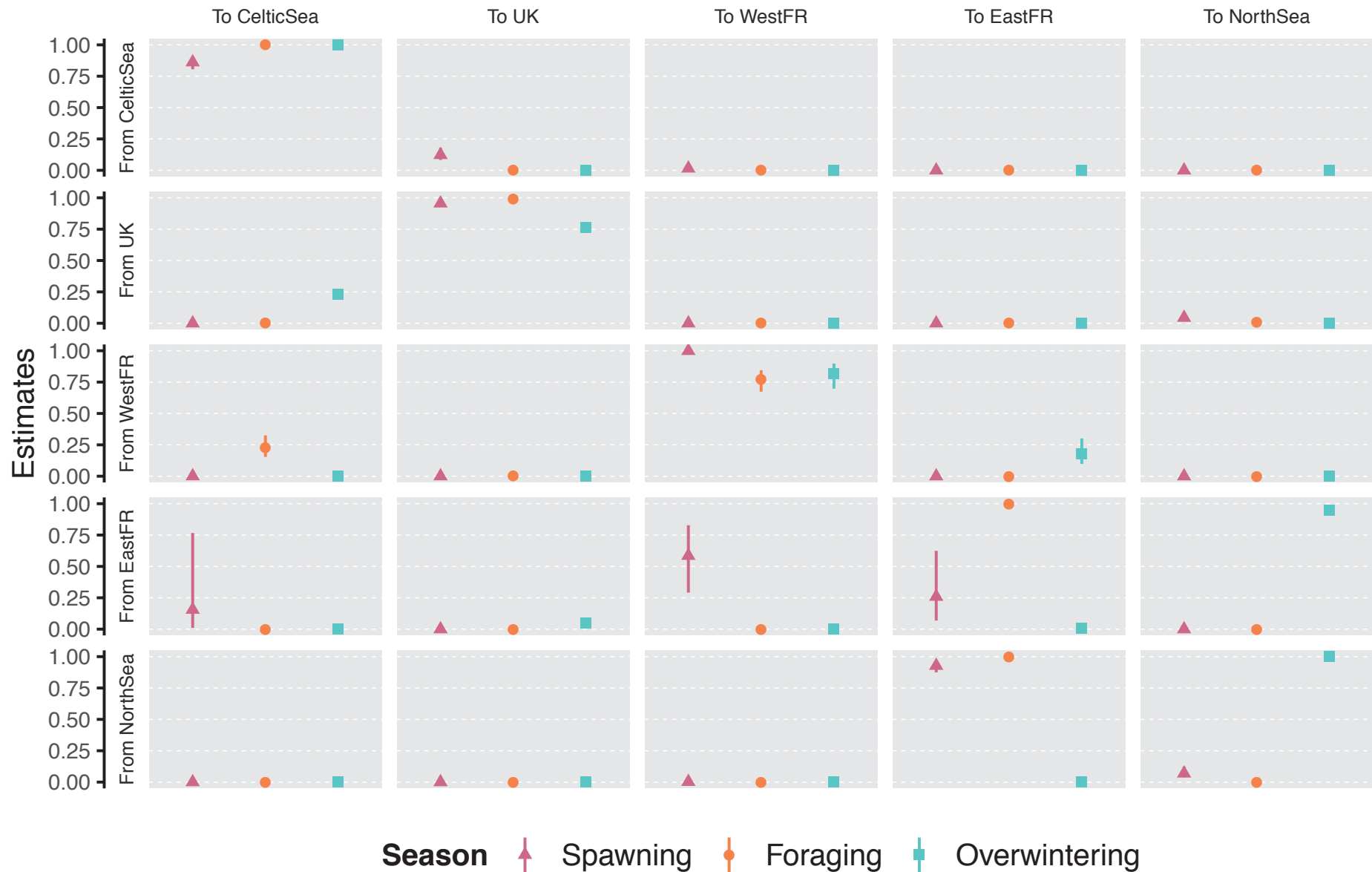
# Model with $\tau^f$ per area and year



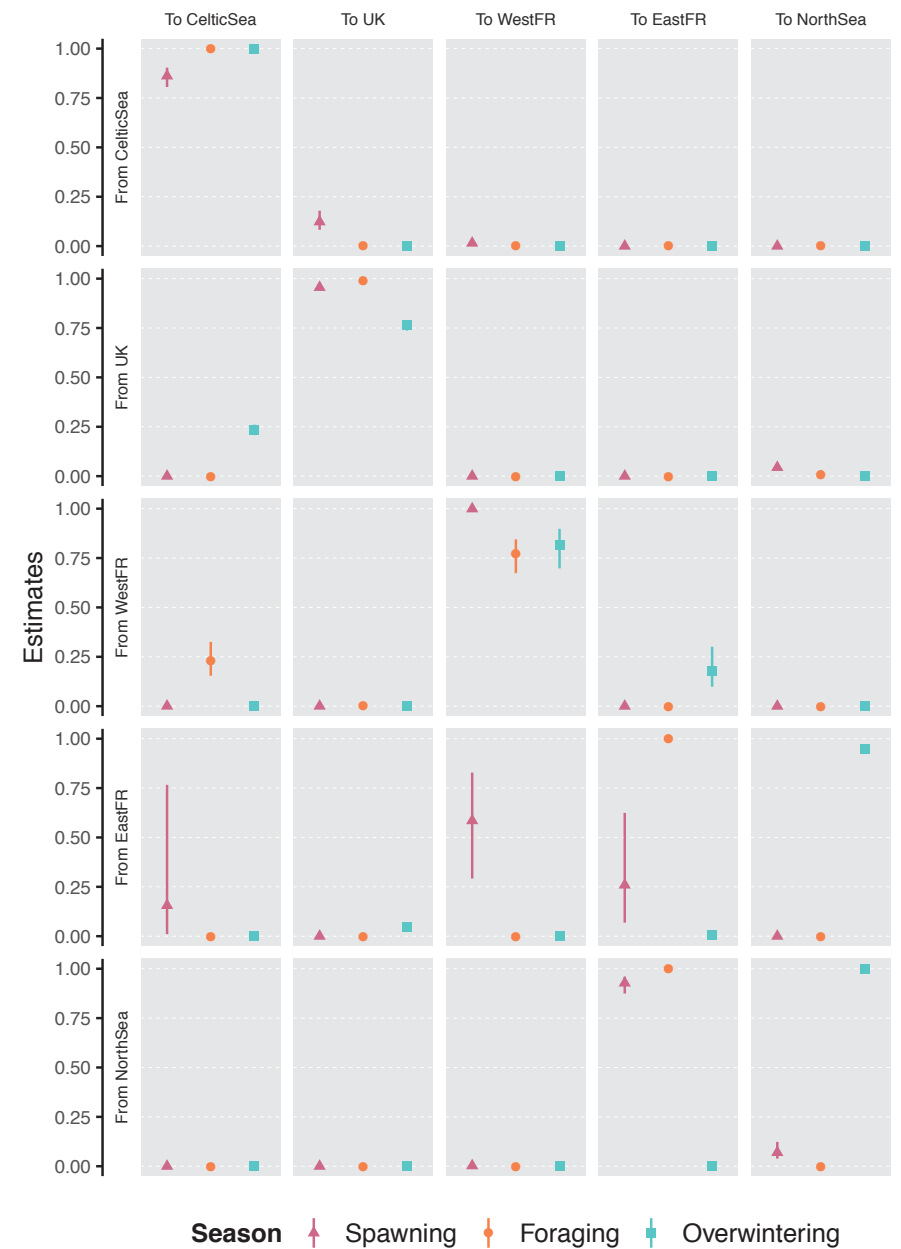
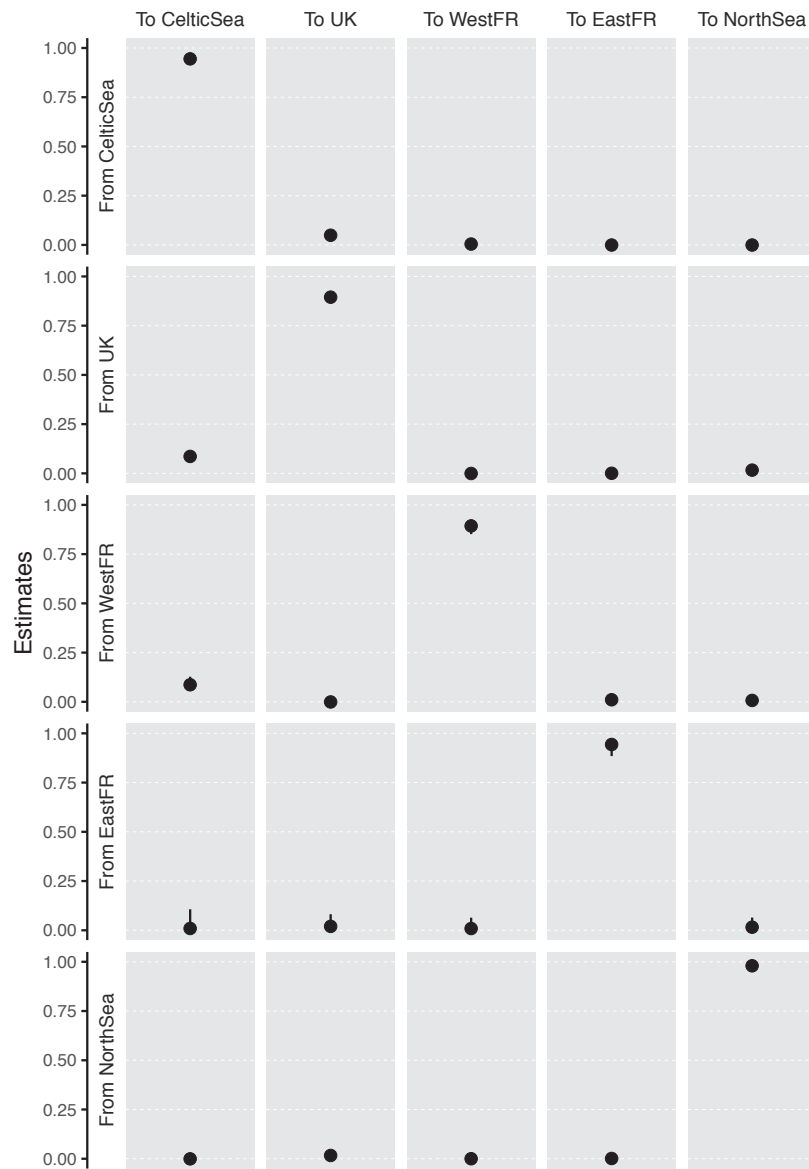
# Movements estimations M5.N: $\tau^f$ per area and year without seasonal movements



# Movements estimations M5.S: $\tau^f$ per area and year with seasonal movements



# Movements estimations M5: $\tau^f$ per area and year





# Models overview

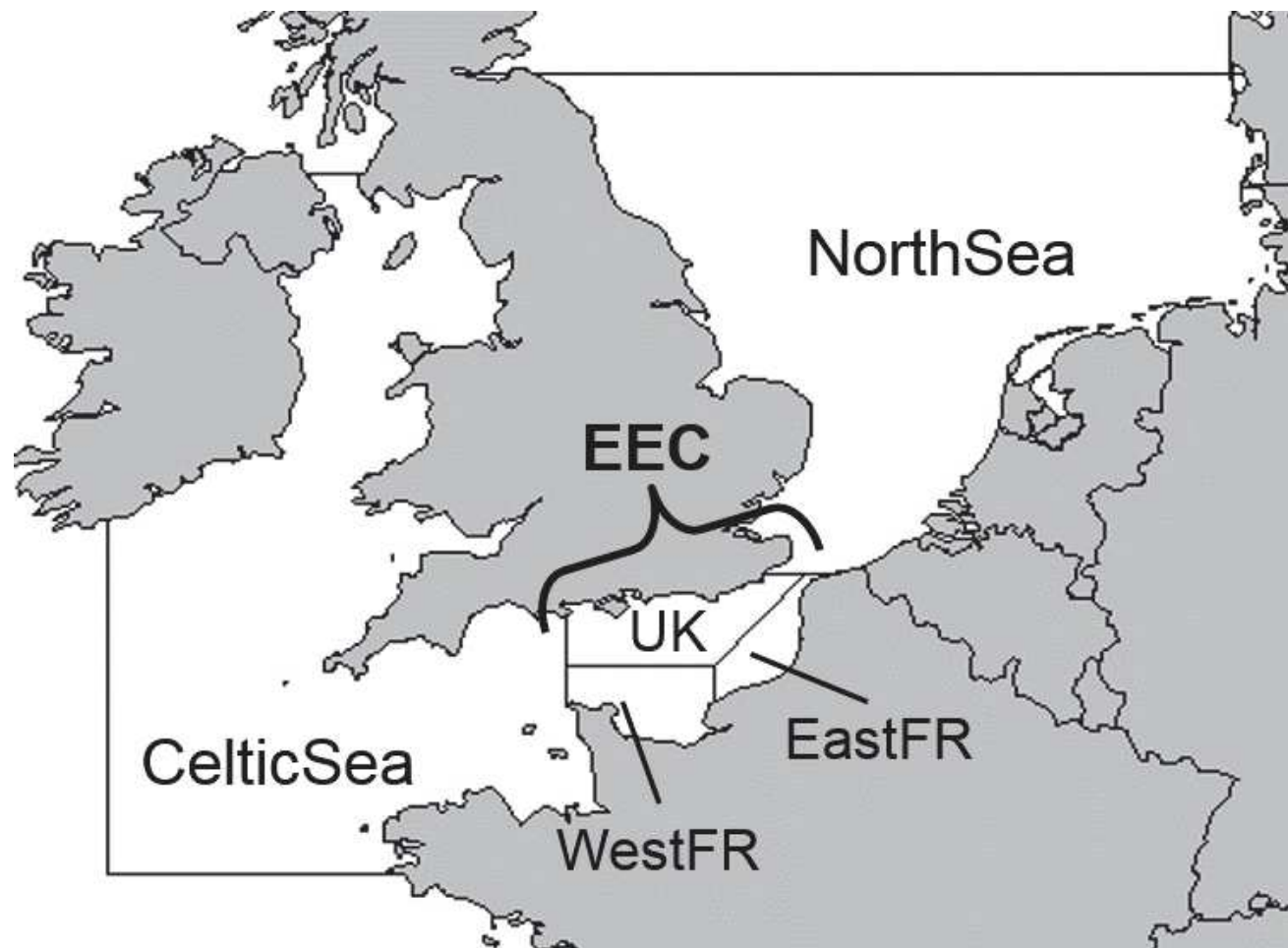
| Model | Area            | Dates        | Movements estimated        | Survival fixed            | Declaration estimated | Quasi-AIC |
|-------|-----------------|--------------|----------------------------|---------------------------|-----------------------|-----------|
| M1.N  | All             | 55-18        | Constant in time           | Constant space & time     | 0,15                  | 193039    |
| M1.S  | "               | "            | Seasonal, constant in year | "                         | "                     | 193274    |
| M2.N  | Ville/VIIId/IVc | "            | Constant in time           | "                         | 0,16                  | 156392    |
| M2.S  | "               | "            | Seasonal, constant in year | "                         | "                     | 156407    |
| M3.N  | "               | <b>82-18</b> | Constant in time           | "                         | 0,17                  | 78060     |
| M3.S  | "               | "            | Seasonal, constant in year | "                         | "                     | 78153     |
| M4.N  | "               | "            | Constant in time           | <b>≠ space, csts time</b> | "                     | 78108     |
| M4.S  | "               | "            | Seasonal, constant in year | "                         | "                     | 78227     |
| M5.N  | "               | "            | Constant in time           | <b>≠ space, ≠ time</b>    | "                     | 77897     |
| M5.S  | "               | "            | Seasonal, constant in year | "                         | 0,18                  | 77533     |

# Discussion

- ▶ Models with no seasonal movements show no migration patterns
- ▶ Models with seasonal movements show migration patterns for North Sea and East FR area
- ▶ Models with no seasonal have best quasi-AIC scores, excepts when fishing mortality varies in space and time.

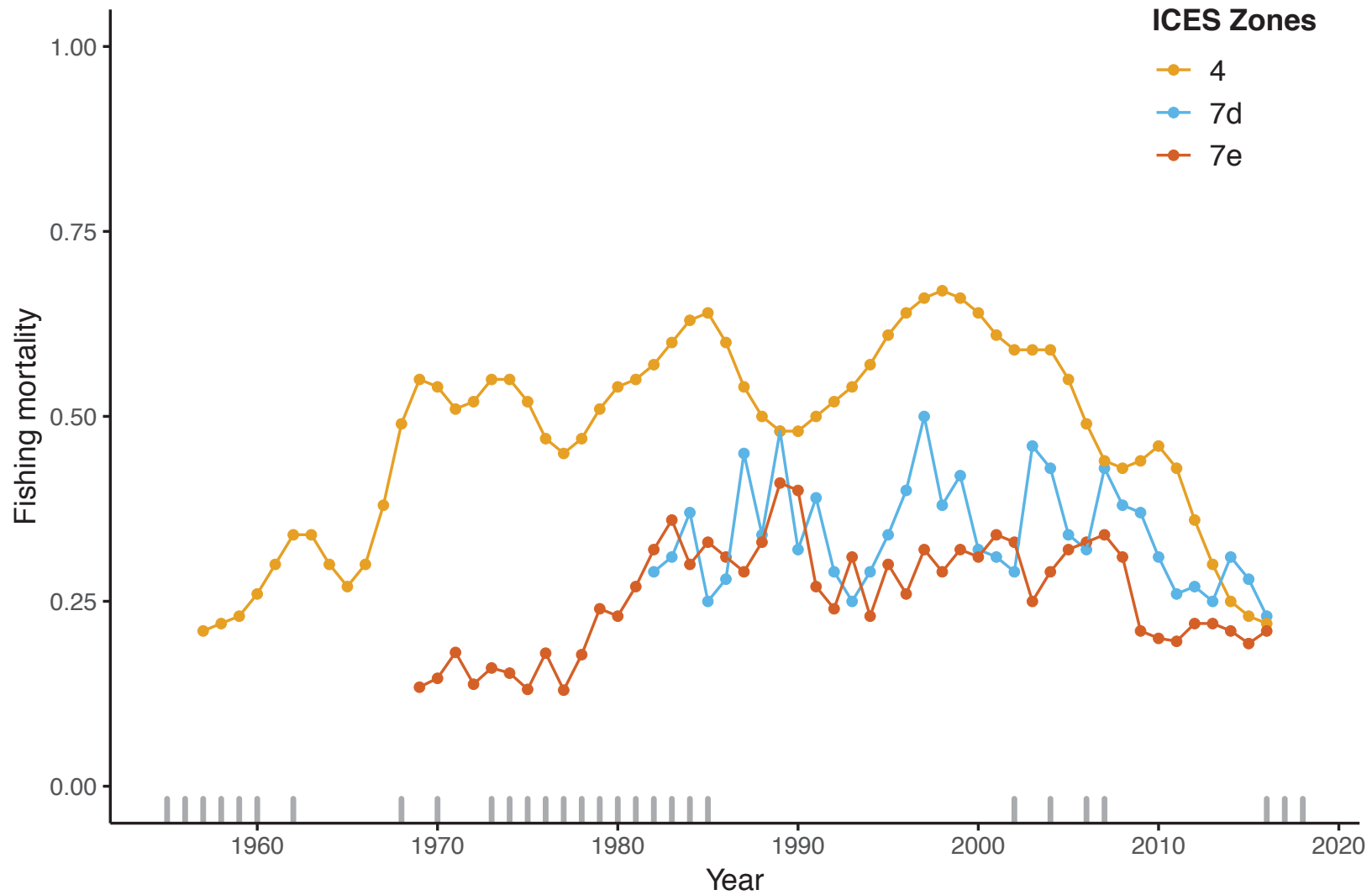
# Limits

- ▶ Area definitions



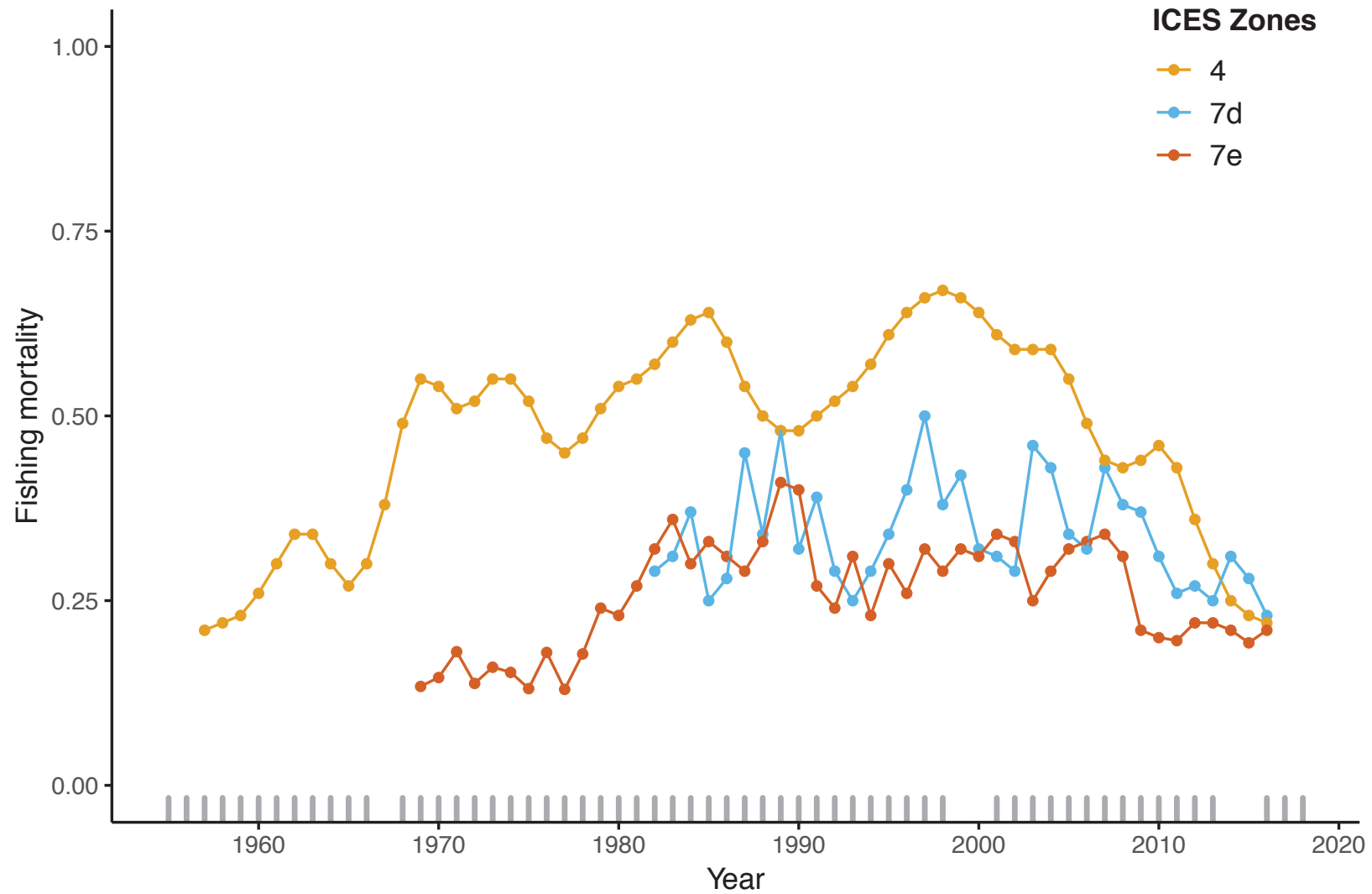
# Limits

- ▶ Area definitions
- ▶ A marking campaign not homogeneous in time



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- ▶ Area definitions
- ▶ A marking campaign not homogeneous in time
- ▶ A declaration rate constant in space and time
- ▶ A yearly fishing mortality equal among seasons

# On going and future work

- ▶ Testing limits area, in particular North Sea, East FR and UK
- ▶ Spreading the fishing mortality in accordance with fishing seasons
- ▶ Testing a model with a different fishing mortality among EEC subzones
- ▶ Integration of these results to a life cycle model



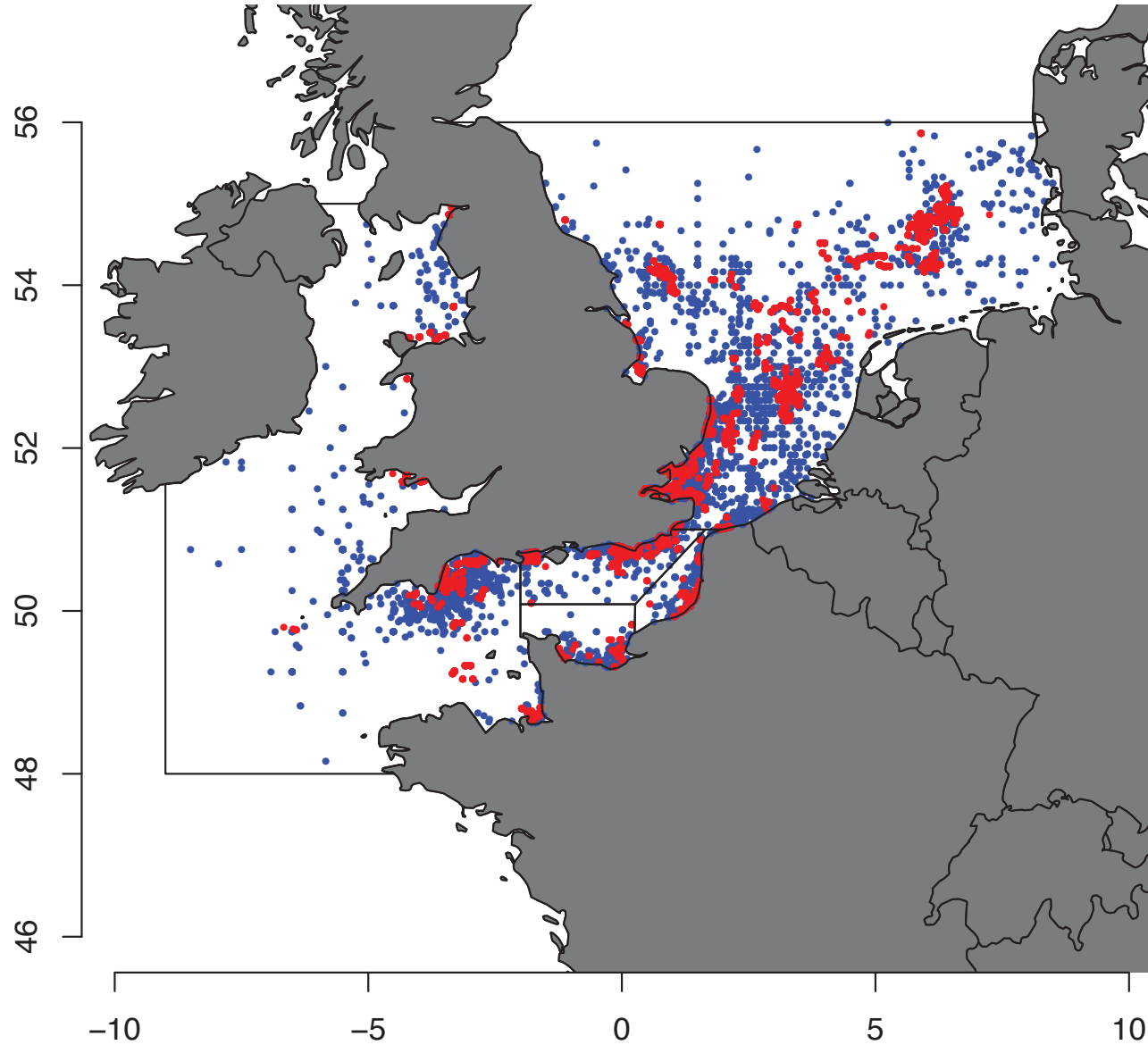
The End



for your attention

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Ensemble des points M1



# Fishing and natural mortality rate

Computation of fishing and natural mortality rate from ICES reports.

$$\tau^f = \frac{f}{f + m} (1 - \exp(-(f + m)))$$

$$\tau^m = \frac{m}{f + m} (1 - \exp(-(f + m)))$$