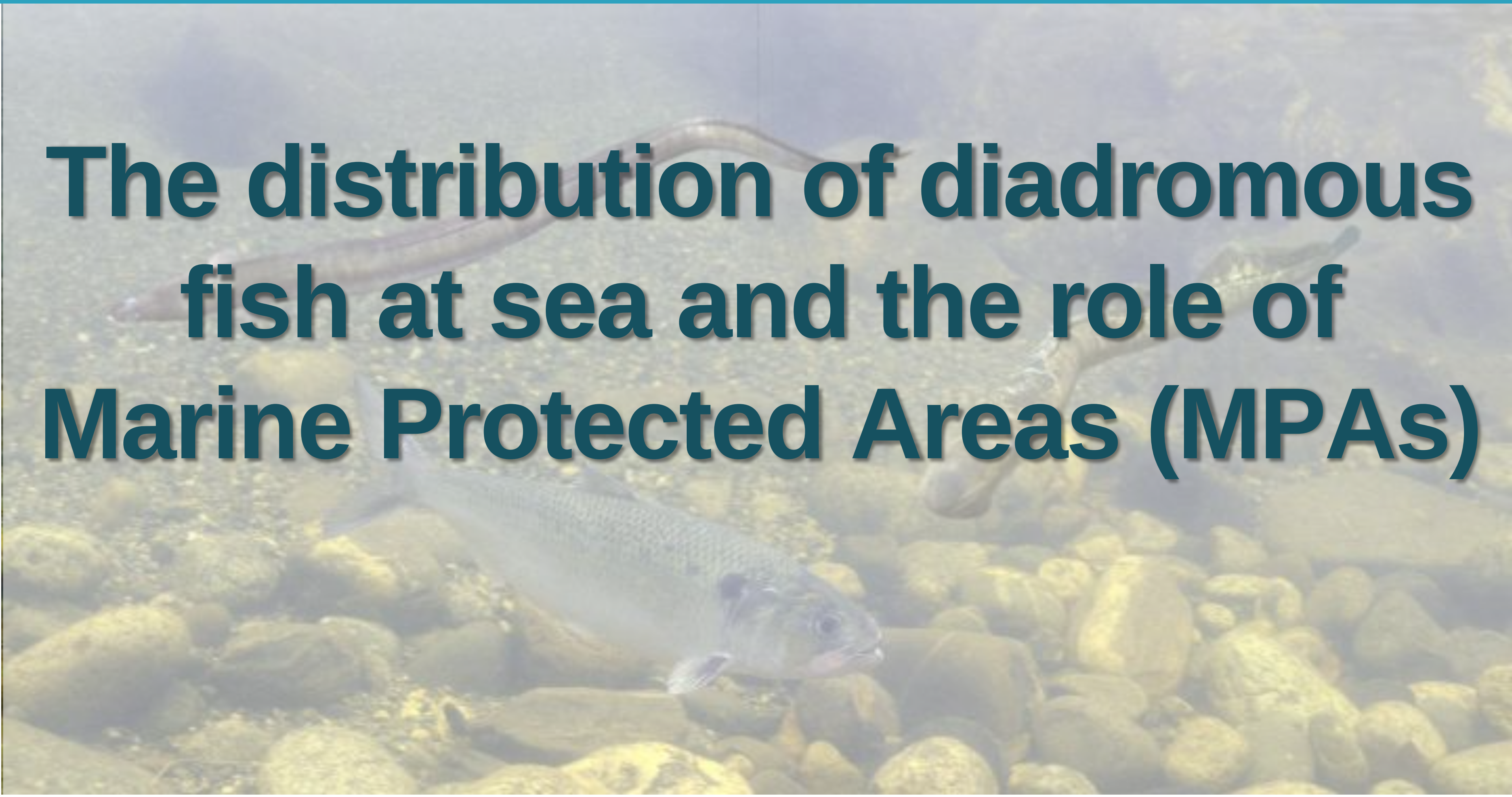
# The distribution of diadromous fish at sea and the role of Marine Protected Areas (MPAs)

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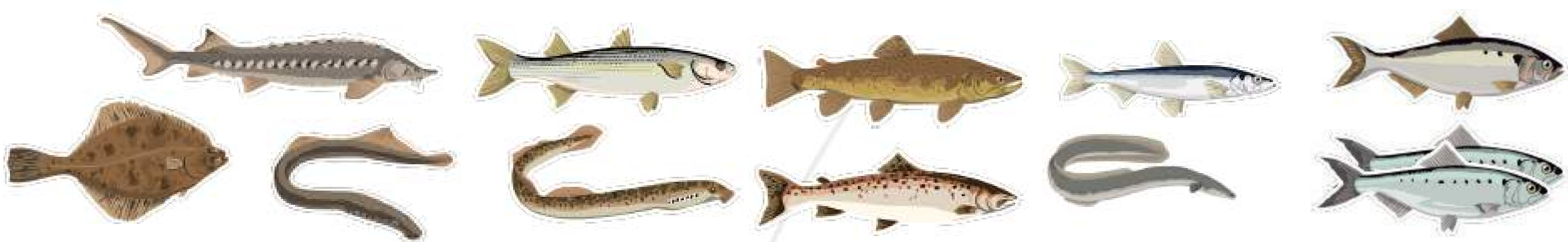
Pôle OFB-INRA-Agrocampus Ouest-UPPA pour la gestion des migrateurs amphihalins dans leur environnement

# Objectives

1. Understand the distribution of diadromous fish at sea.
2. Evaluate the value of MPAs for diadromous fish.
3. Evaluate their sensitivity to bycatch.
4. Connect their freshwater and marine habitats.

→ To respond to the Habitat Directive & Marine Strategy Framework Directive requirements.



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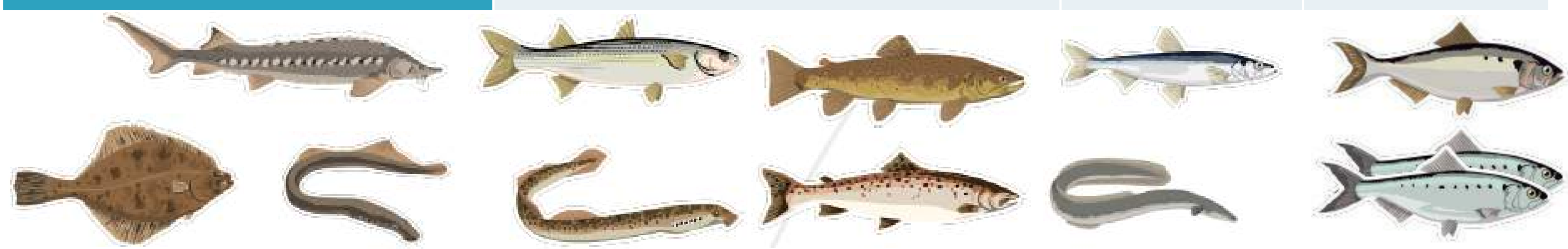
AGRO CAMPUS OUEST
UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR

# Diadromous fish studied

Fr – 2019
EU - 2011

| Latin name | Common name | EU IUCN | Fr IUCN |
|---|---|---|---|
| *Acipenser sturio* | Atlantic sturgeon* | CR | CR |
| *Alosa alosa* | Allis shad* | LC | CR |
| *Alosa fallax* | Twait shad* | LC | NT |
| *Alosa agone* | Mediterranean twaite shad* | LC | NT |
| *Anguilla anguilla* | European eel* | CR | CR |
| *Lampetra fluviatilis* | River lamprey* | LC | VU |
| *Petromyzon marinus* | Sea lamprey* | LC | EN |
| *Chelon ramada** | Thinlip mullet | LC | LC |
| *Osmerus eperlanus* | Smelt | LC | NT |
| *Platichthys flesus* | European flounder | LC | DD |
| *Salmo salar* | Atlantic salmon* | VU | NT |
| *Salmo trutta* | Sea trout | LC | LC |



# Surveys

42 surveys, 1965-2019, 168 904 hauls

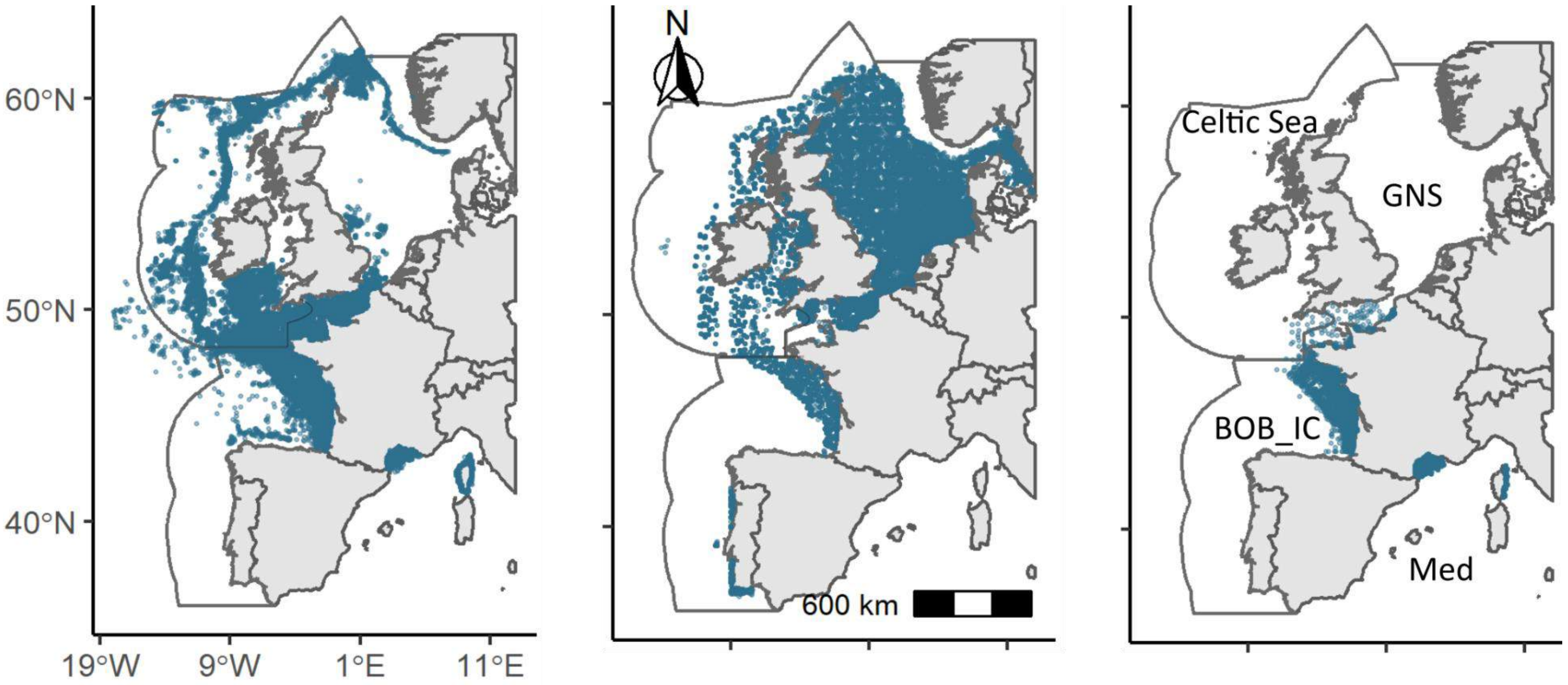
**Fisheries dependent data**

**Scientific surveys**

**OBSMER**
2003 – 2019, 100 617 hauls

**ICES DATRAS**
1965 - 2018, 54 865 hauls

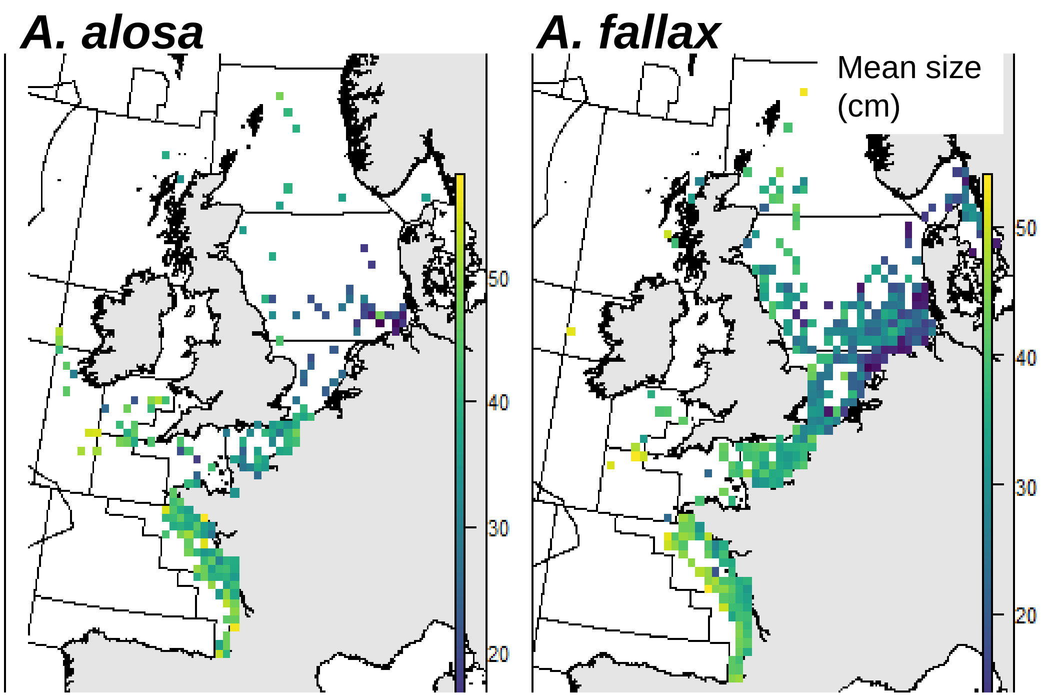
**IFREMER**
1980 - 2018, 13 422 hauls

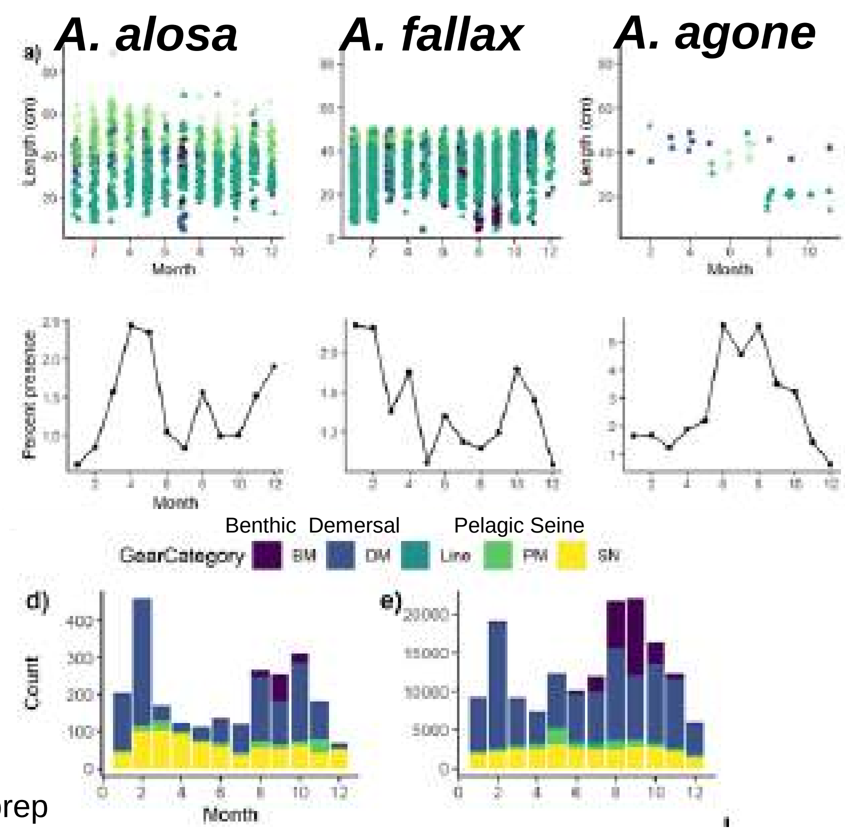


# Data cleaning

- Merging datasets.
- Exploring outliers and NAs (cm/mm, points on land, etc.).
- Data analysis (length, month, distribution, gear effect) & comparison with literature.

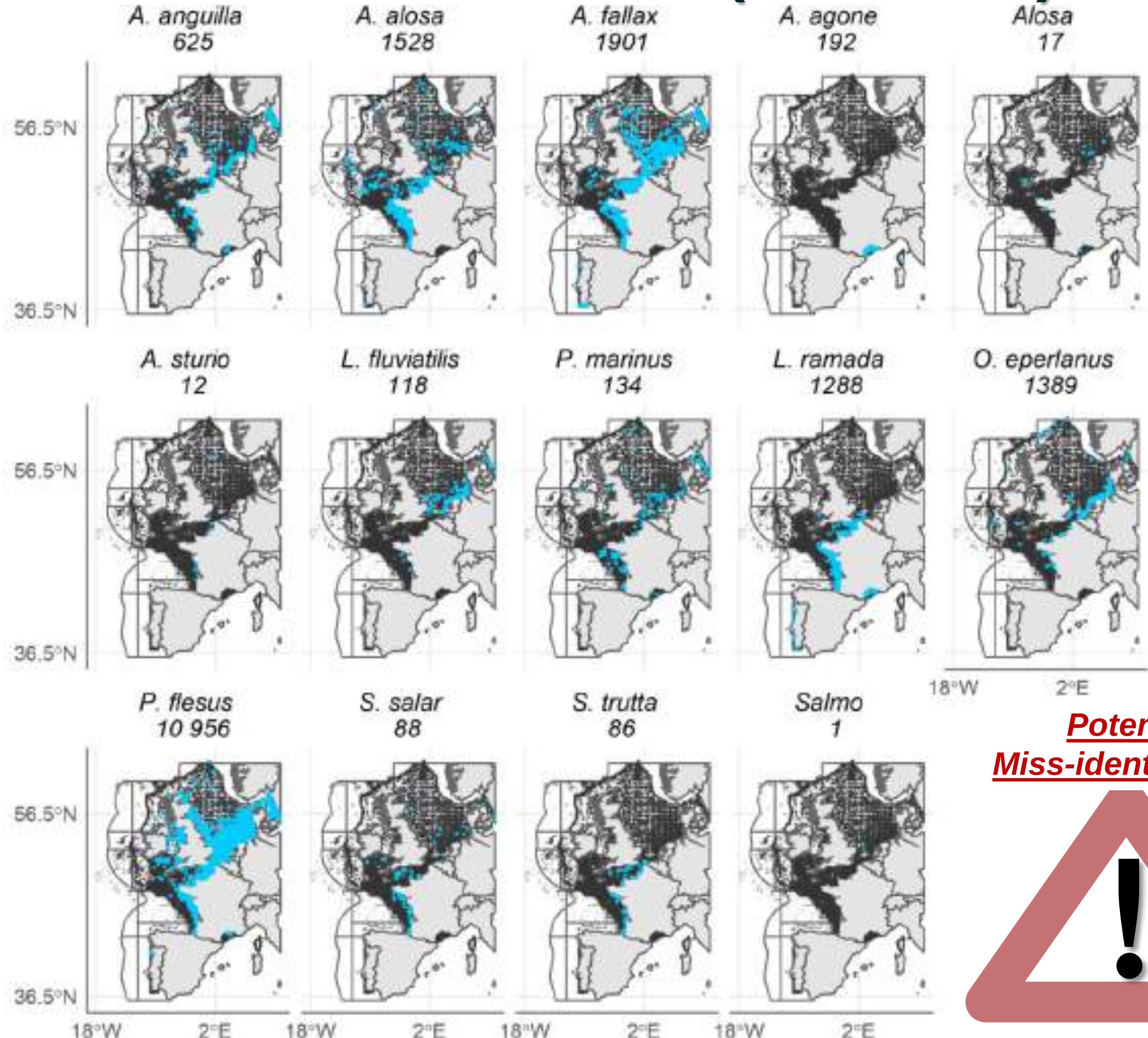
**e.g.**




Taverney & Ellie, 2001; Kukyev & Orlov, 2018 Bianco 2002; Bagliniere in prep

# Presence of diadromous fish (1965-2019)

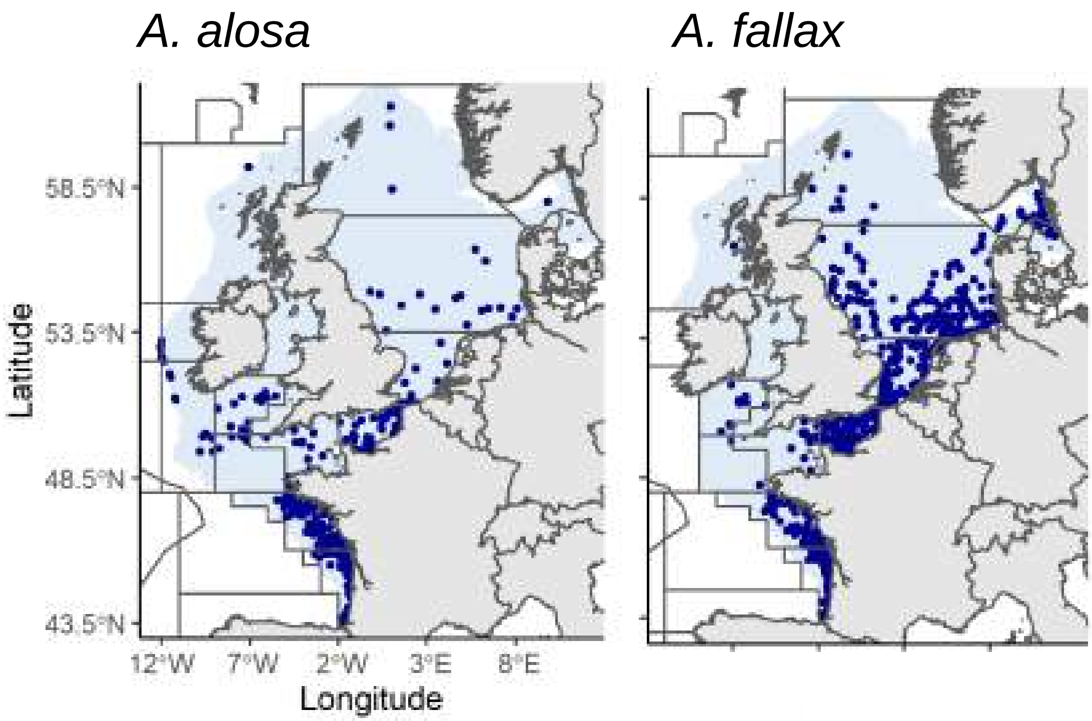


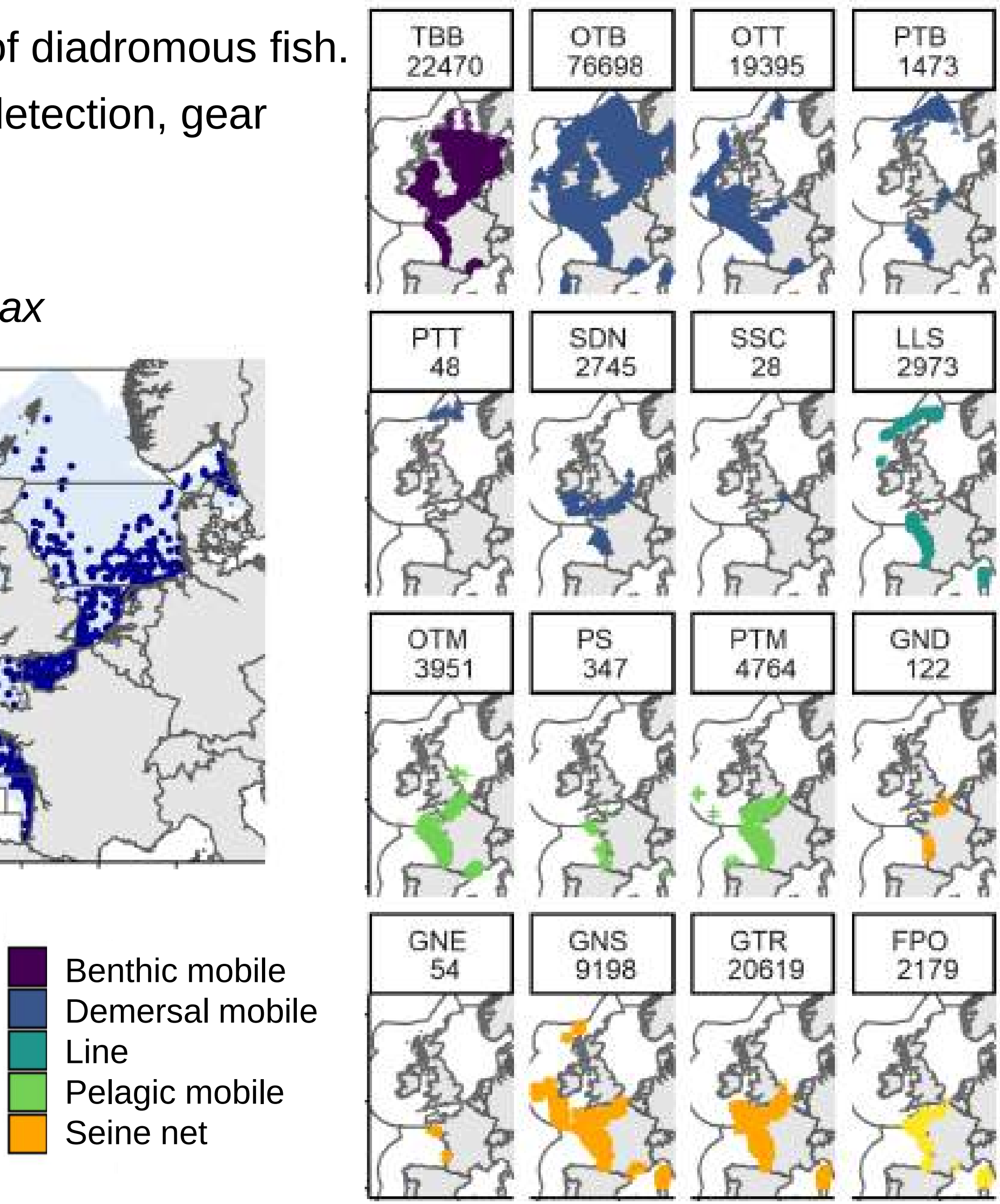

***Potentiel***
***Miss-identification***

# 1) Aim

i. Model the <u>present</u> distribution of diadromous fish.

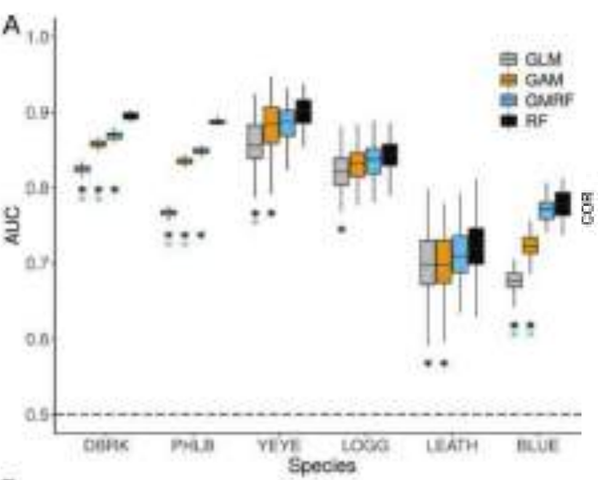
ii. Taking into account imperfect detection, gear bias & spatial autocorrelation.

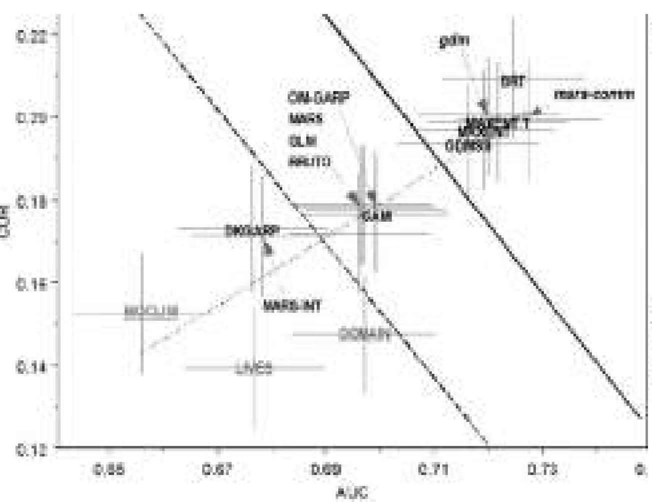


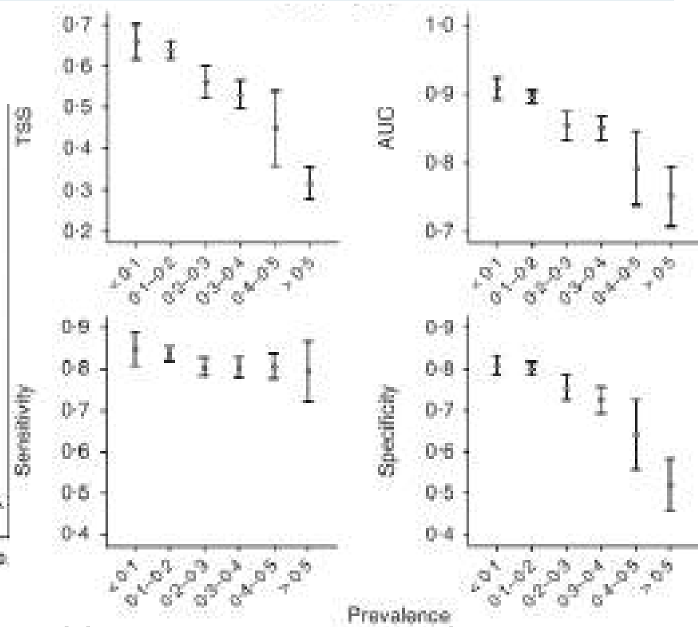



# Classic distribution models

| Model type | Examples | + | - |
|---|---|---|---|
| Multiple regressions | GLM, GAM, MARS | • Existing packages to compare<br>• Commonly used<br>• Computational intensity = lower | • Imperfect detection not considered<br>• Zero imbalance<br>• Doesn’t consider sampling bias of different fear types |
| Regression trees | BRT, RF, CTA | | |
| Discriminate analysis | ANN, FDA | | |
| Presence only | MaxEnt, BIOCLIM, DOMAIN | • Pseudo absences<br>• Reduce zero inflation | • Already have true zeros<br>• Pseudo absences can cause problems |




Stock et al, 2020; Elith et al 2006; Allouche et al 2006

# Hierarchical SDM (Bayesian)

## Site occupancy intrinsic conditional autoregressive model (SO iCAR)

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## Site occupancy intrinsic conditional autoregressive model (SO iCAR)

### Habitat suitability - favourable

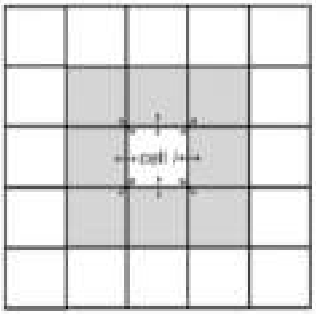
$z_i$ = variable describing presence/absence (PA) at site $i$
$\theta_i$ = probability of presence – habitat suitability
$X_i$= environmental covariates
$\beta$ = how much the environmental variable contribute to the suitability process
$P_j$ = spatial random effect in cell $j$ at observation $i$ (iCAR)

$$z_i \sim Bernoulli\ (\theta_i)$$
$$logit\ (\theta_i) = X_i\beta + P_{j(i)}$$

### iCAR – probability of presence depends on that of the nearest site

$p_j$ = spatial random effect in cell $j$
$\mu_j$ = mean $p$ in the neighbourhood
$V_p$ = variance of the spatial random effect
$P_j$ = spatial random variable
$n_j$ = number of neighbours for cell $j$

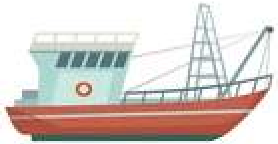
$$P_j \sim Normal\ (\mu_j, \frac{V_p}{n_j})$$



### Observational process

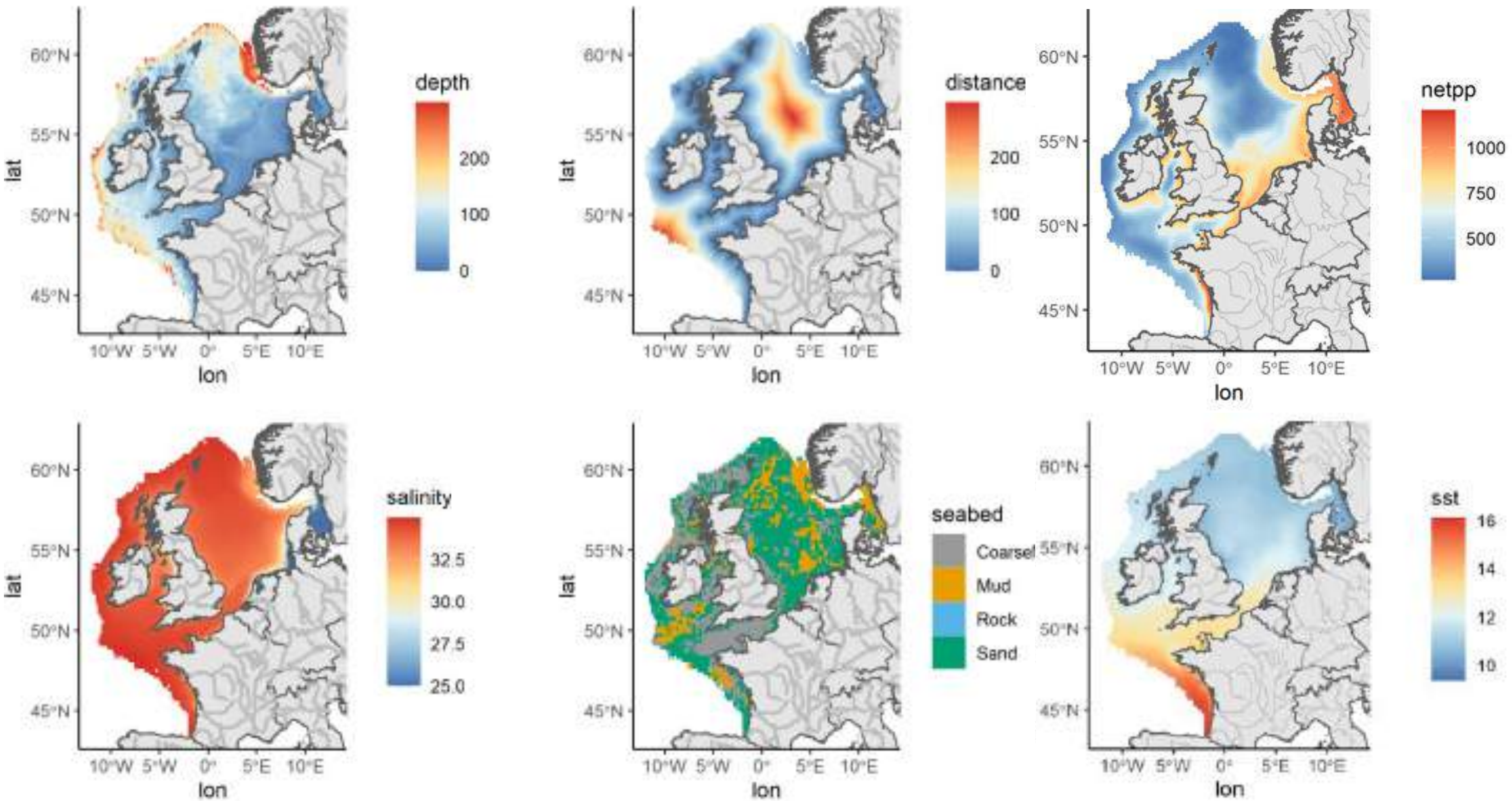
$$y_i \sim Bernoulli\ (z_i\ \delta_i)$$
$$logit\ (\delta_i) = W_i\gamma$$

$y_i$ = PA at site $i$
$z_i$ = habitat suitability for site $i$ + if several visits in 1 cell
$\delta_i$ = probability of detecting species at site i
$W_i$ = observaility covariate (gear)
$\gamma$ = how much the observational variable contribute to the detectability



MacKenzie et al, 2002; Latimer et al 2006; Vieilledent et al 2019

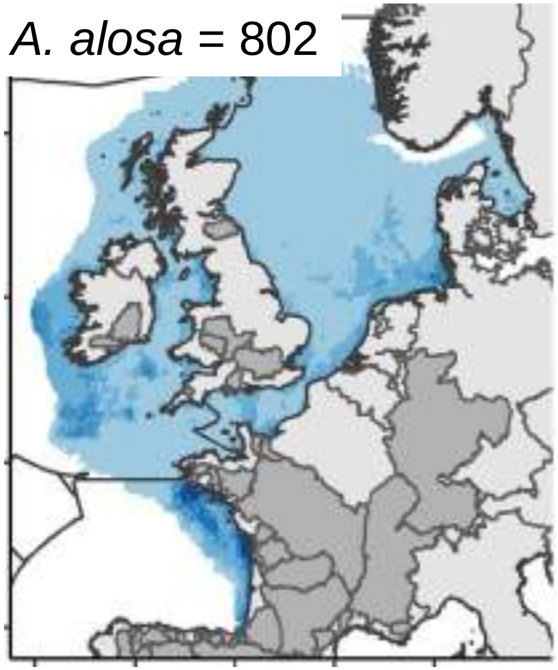
# Environmental variables



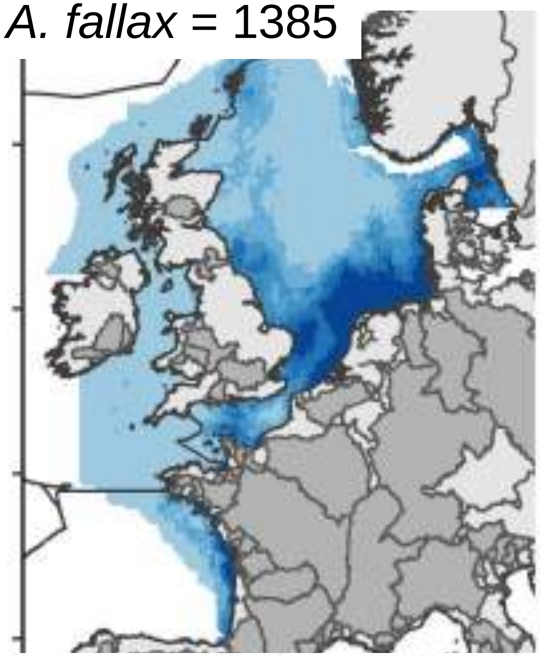
# Shad

**EuroDiad v. 4.0**

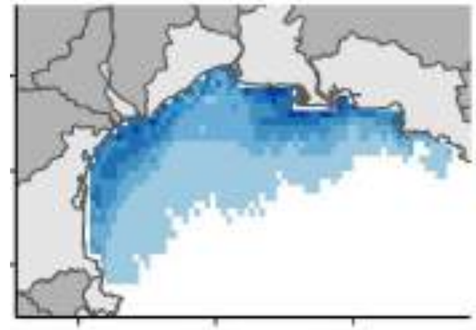
*A. alosa* = 802



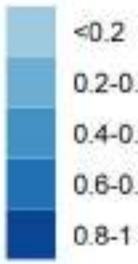
*A. fallax* = 1385

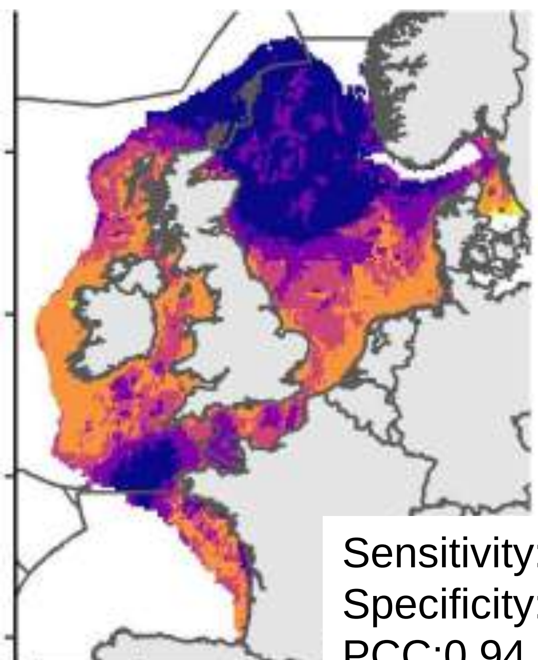


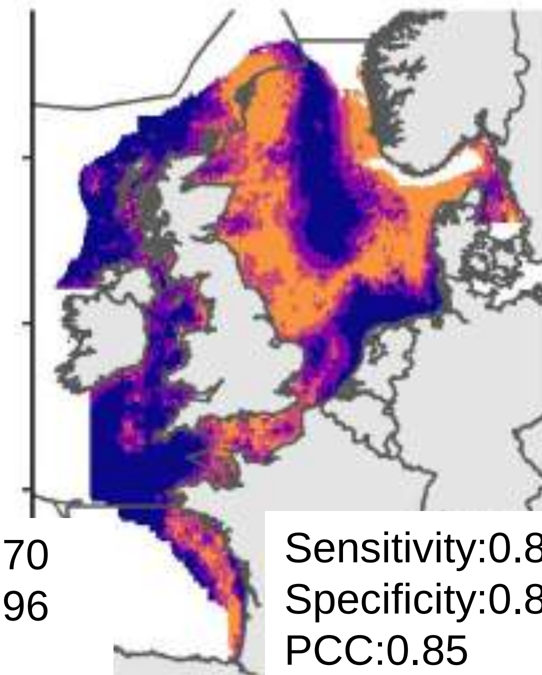
*A. agone* = 176



Probability of presence





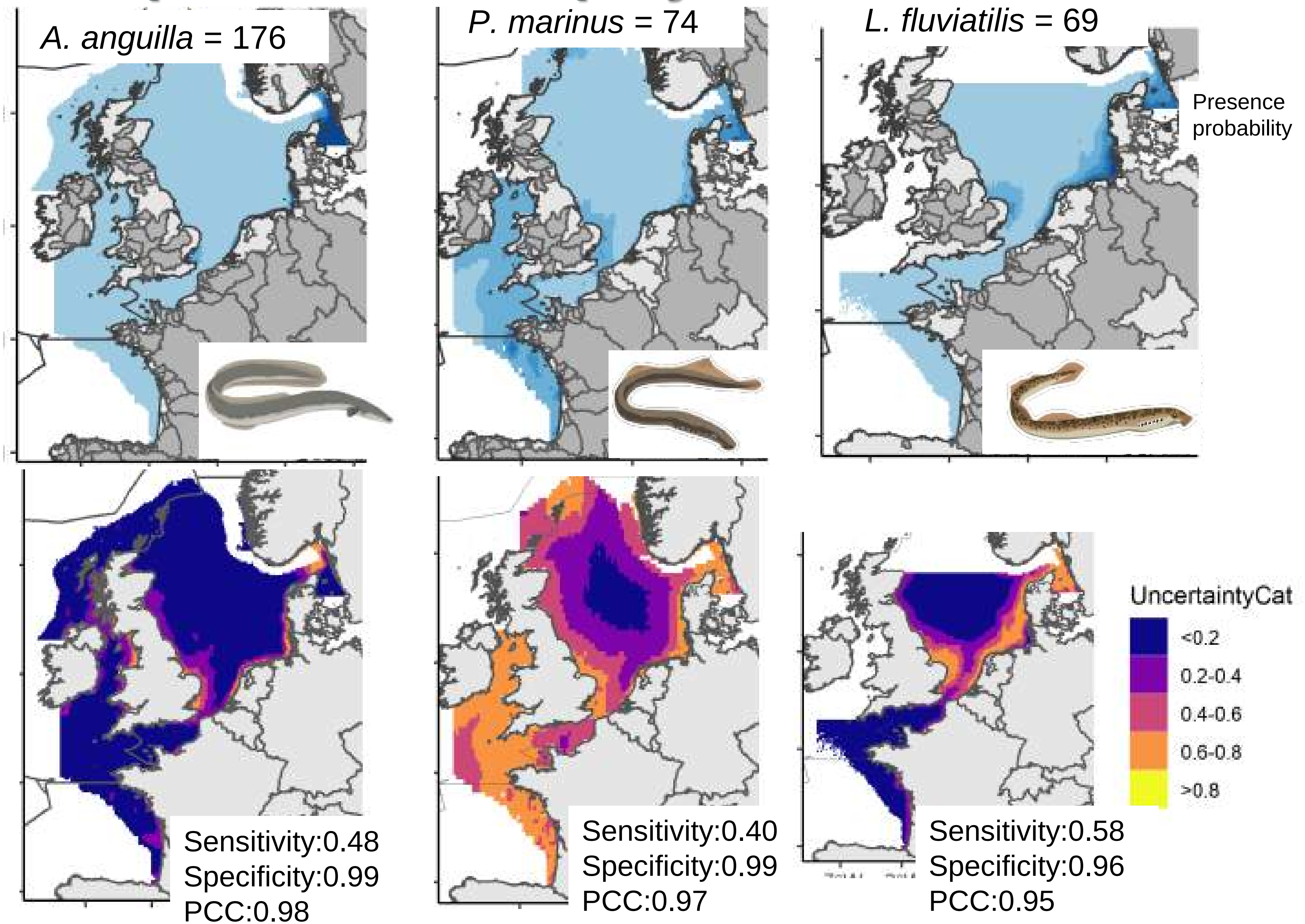
Uncertainty


Sensitivity:0.70
Specificity:0.96
PCC:0.94

Sensitivity:0.81
Specificity:0.85
PCC:0.85

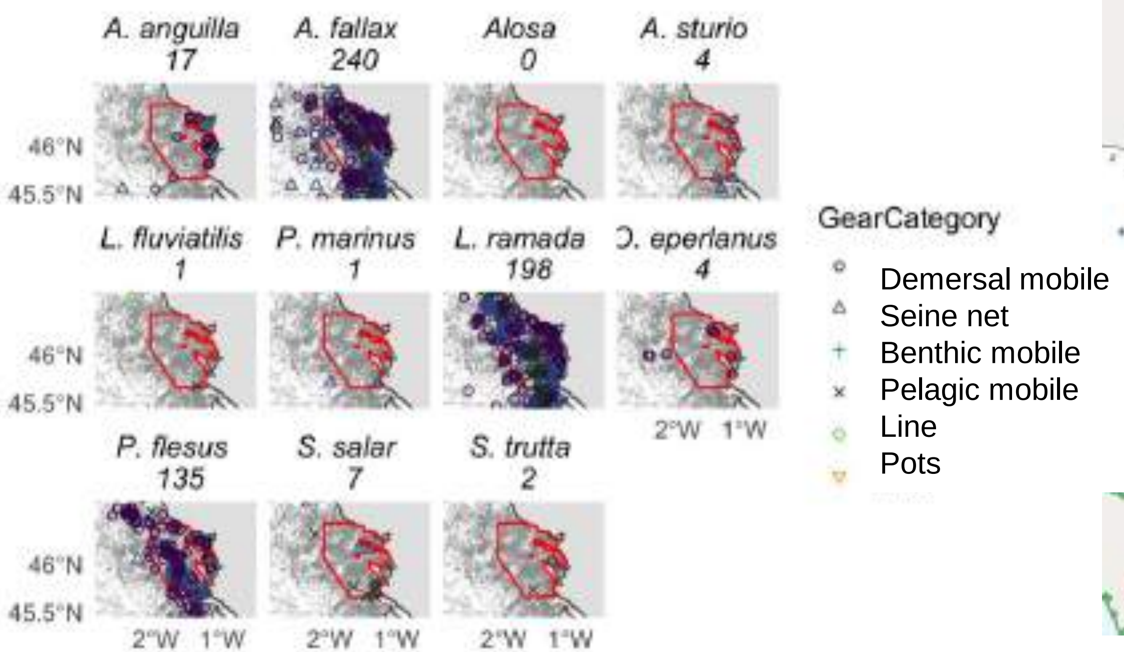
Sensitivity:0.72
Specificity:0.82
PCC:0.81

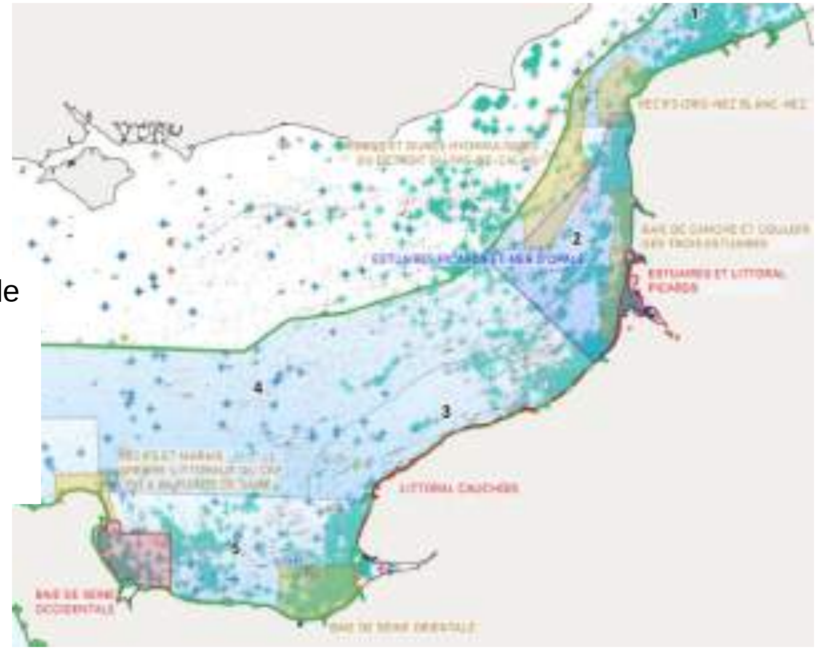
# European eel & Lampreys



# 2) Aim

- Model the present distribution of diadromous fish at a finer resolution to evaluate the pertinence of MPAs.
- Provide information to help with the management of MPAs.

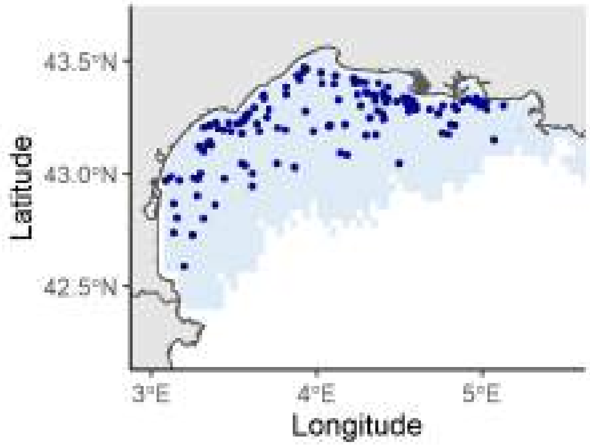


# Combined Model for Accurate Predictions (CMAP)

1. Gridded Binomial (BN) iCAR
2. Gridded Zero Inflated Binomial (ZIB) iCAR
3. Site Occupancy (SO) iCAR

*A. agone*



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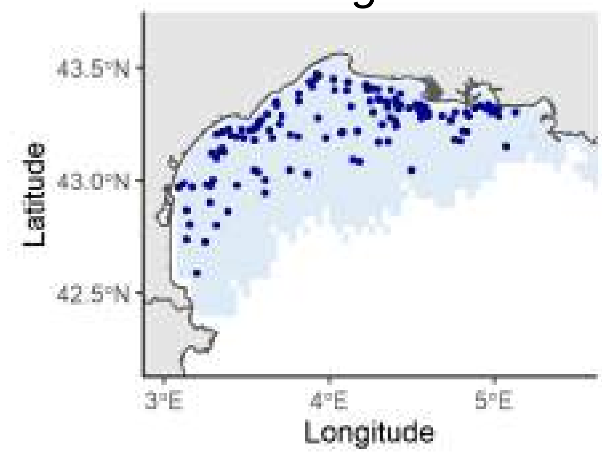
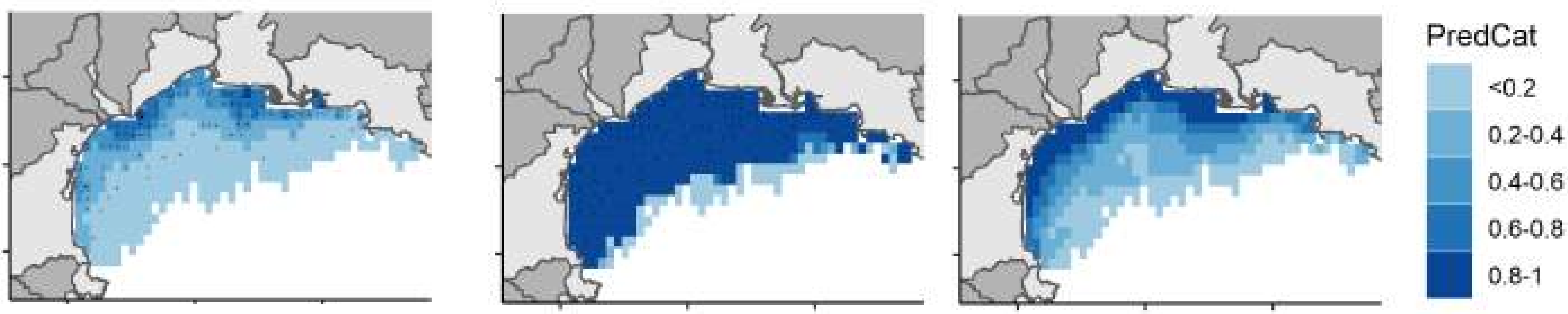



**Gridded BN iCAR** | **Gridded ZIB iCAR** | **SO iCAR**



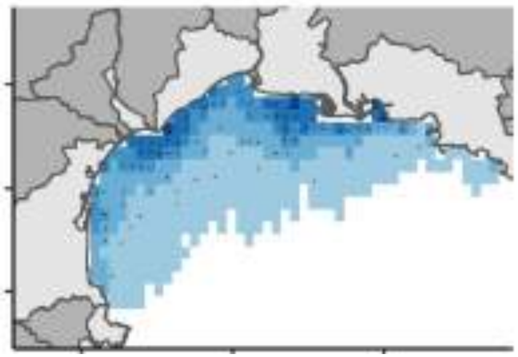

Gridded BN iCAR: PPV:0.72, NPV:0.89

Gridded ZIB iCAR: PPV:0.27, NPV:0.99

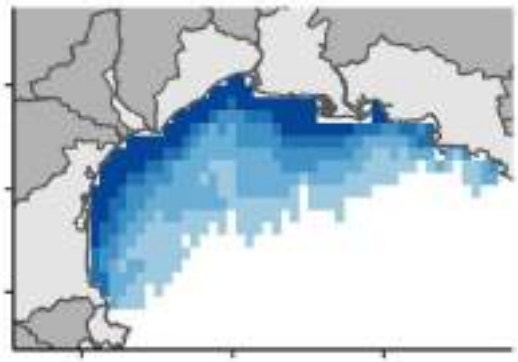
SO iCAR: PPV:0,45, NPV:0.94

# Combined Model for Accurate Predictions

BN iCAR



SO iCAR



**Separate objectives**

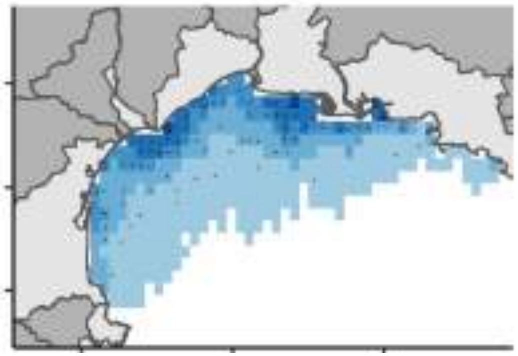
Core habitats

‘Unsuitable’ habitats

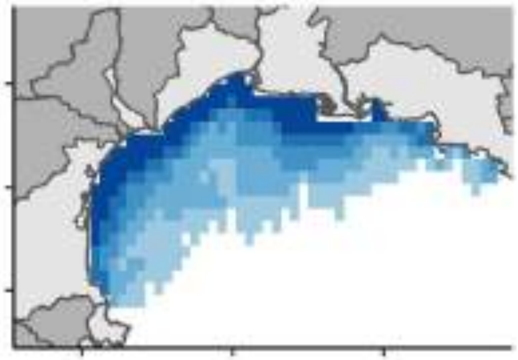
*A. agone*

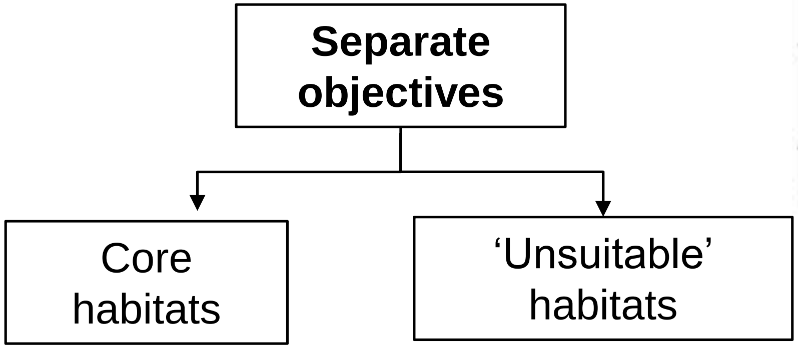
# Combined Model for Accurate Predictions

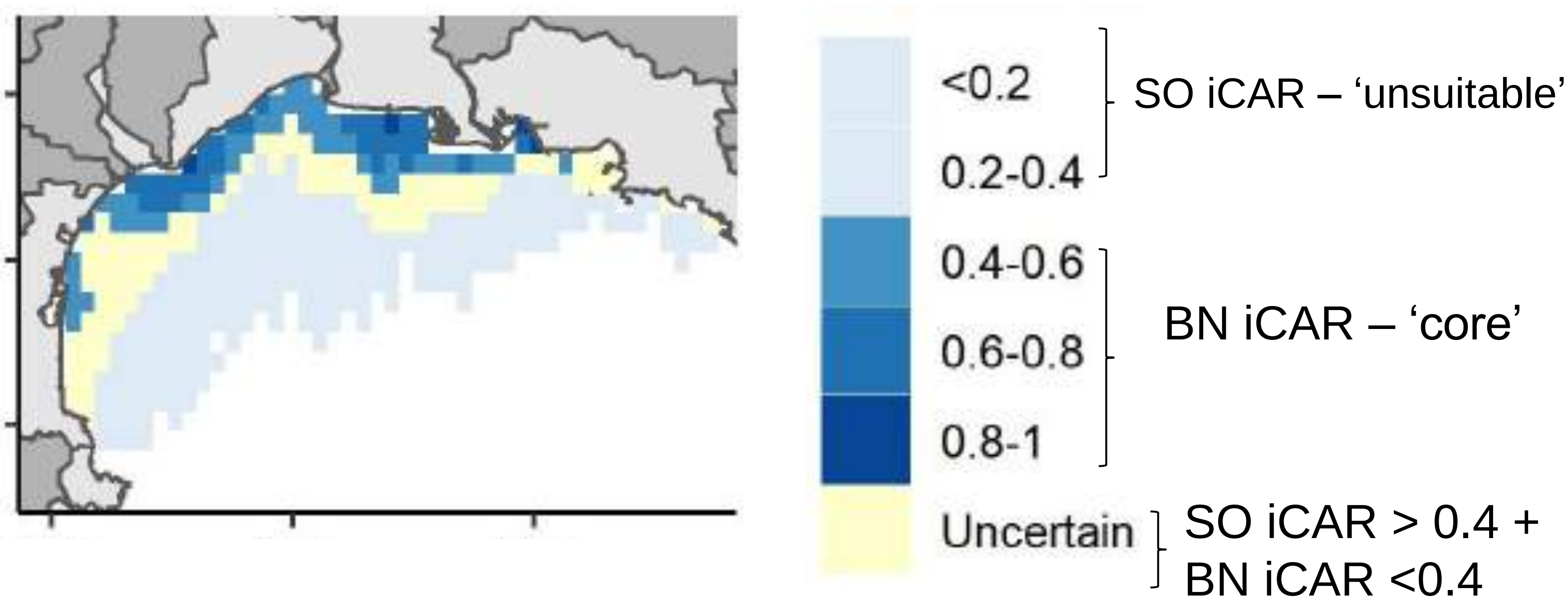
BN iCAR



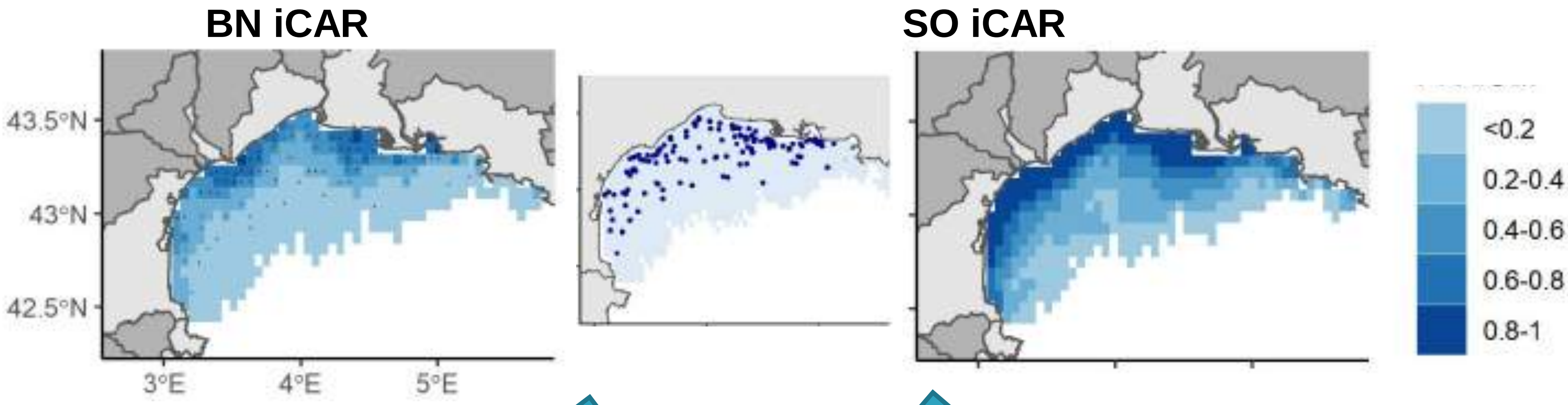
SO iCAR

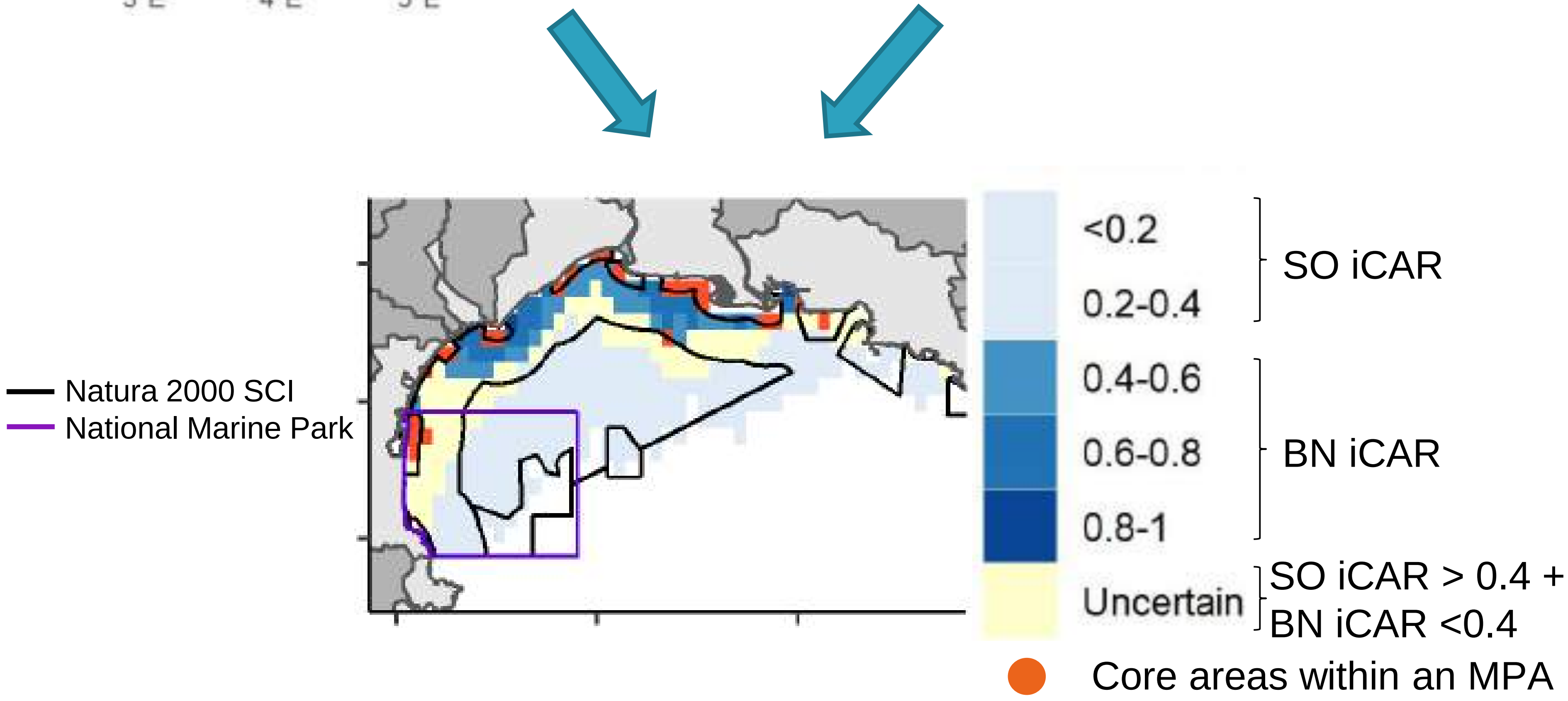




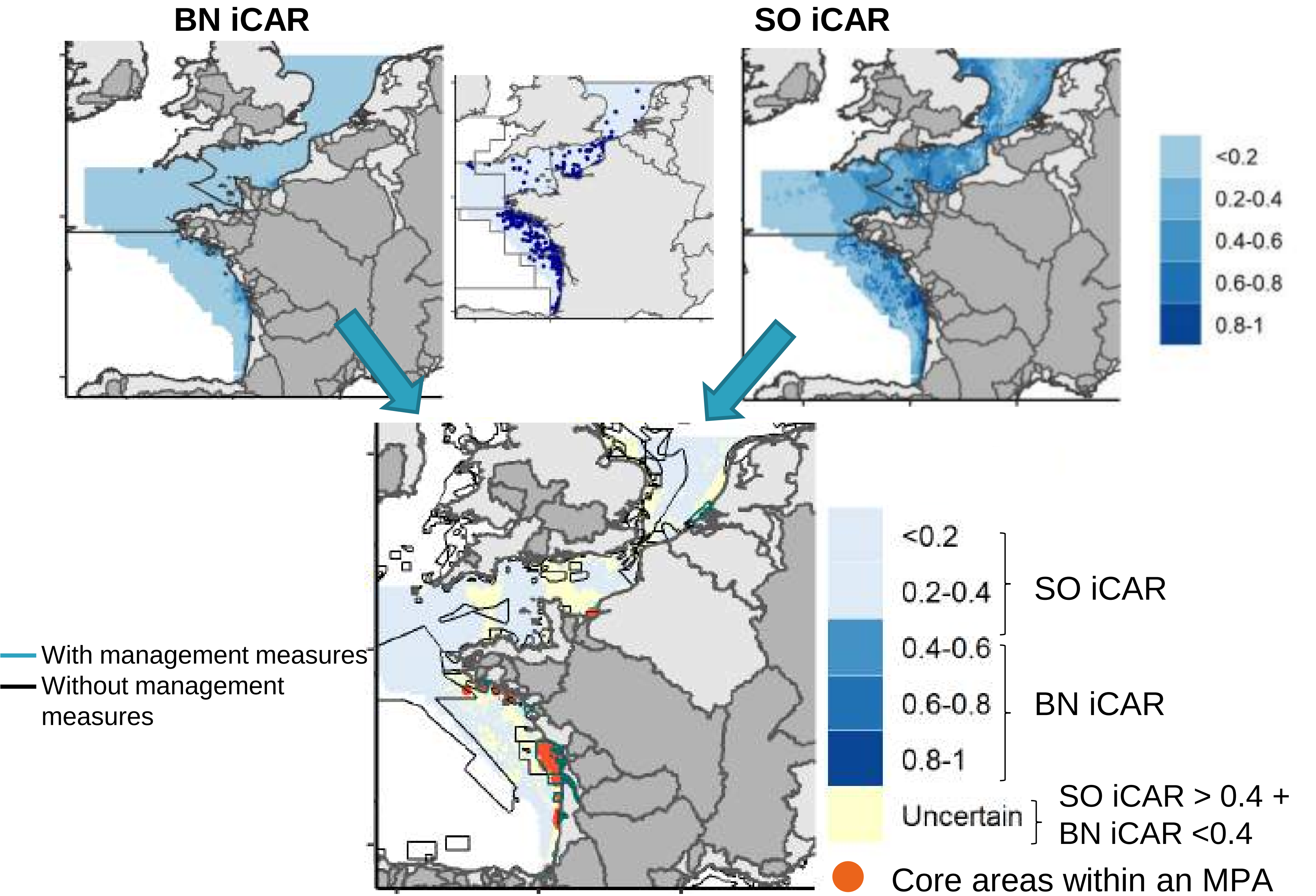



# CMAP for Marine Protected Areas (MPA) management



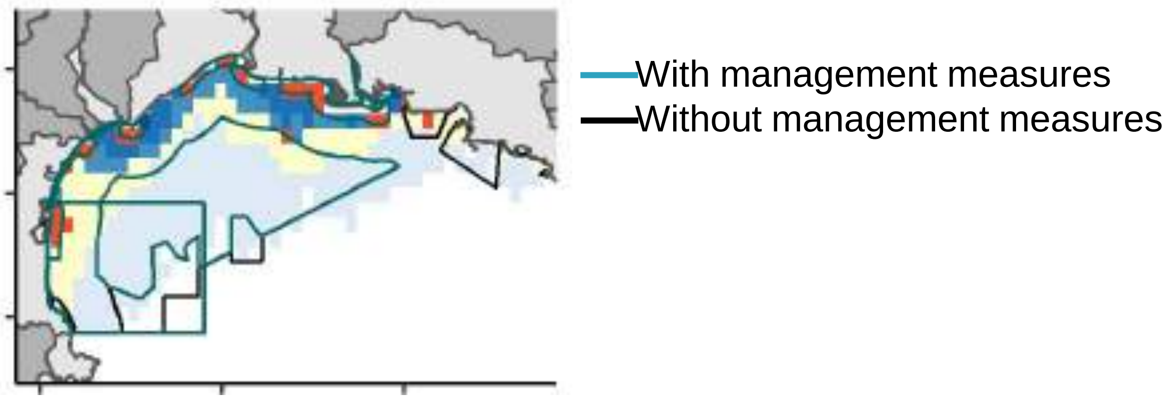
# *A. alosa*

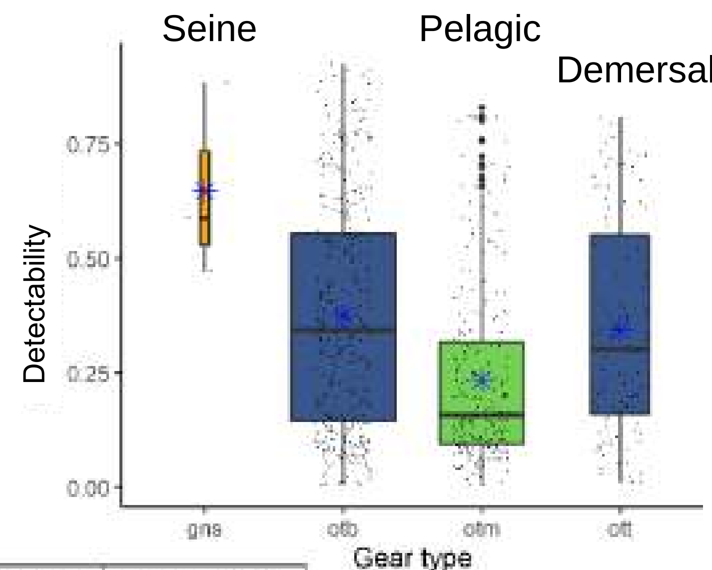


BN iCAR
SO iCAR
<0.2
0.2-0.4
0.4-0.6
0.6-0.8
0.8-1
With management measures
Without management measures
<0.2
0.2-0.4
SO iCAR
0.4-0.6
0.6-0.8
BN iCAR
0.8-1
Uncertain
SO iCAR > 0.4 +
BN iCAR <0.4
Core areas within an MPA

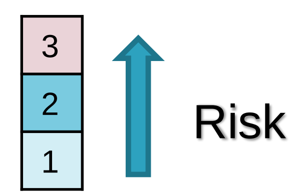
# Value of MPAs for the protection of diadromous fish

1) Are their MPAs which don't protect diadromous fish and which may be of benefit?
2) Do the present management measures protect them sufficiently?
3) What factors affect the present of diadromous fish within MPAs?



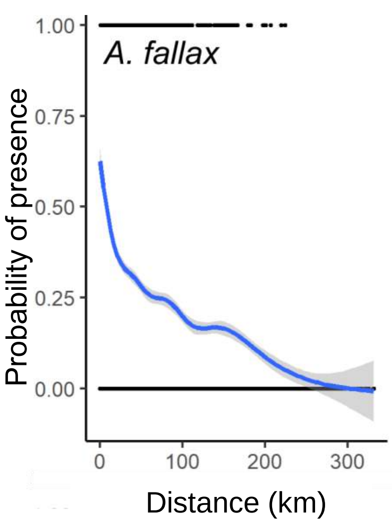

| Gear category | Standard abbreviations | Shad | Eel | Lamprey | Sturgeon | Salmonids |
|---|---|---|---|---|---|---|
| Purse Seine | PS | 1 | 1 | 1 | 1 | 1 |
| Seines | SPR, SSC | 1 3 | 1 | 2 | 1 | 1 |
| Trawls | OTB, OTT, PTB, PTM, TBB | 2 3 | 2 3 | 2 | 3 | 2 3 |
| Dredge | DRB | 1 | 1 | 1 | 1 | 1 |

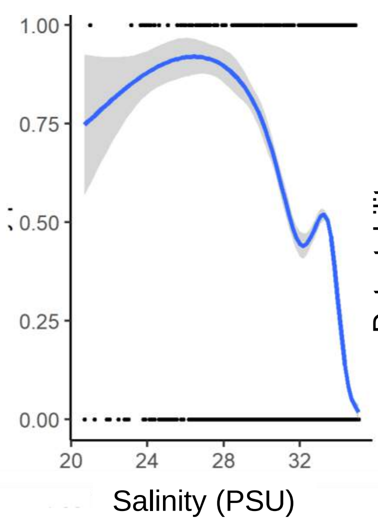


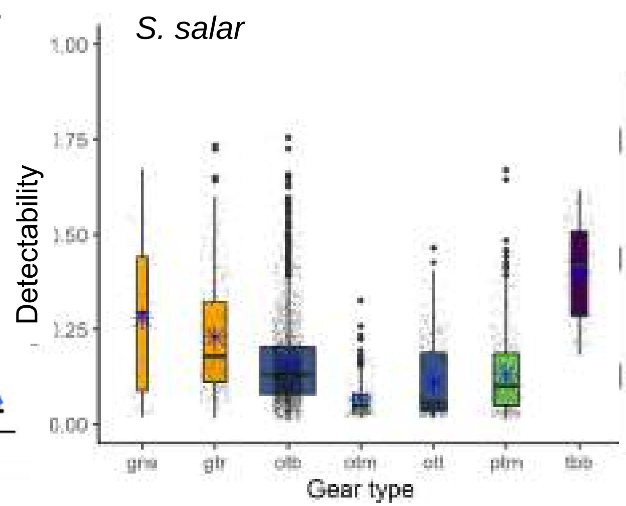
# Conclusion

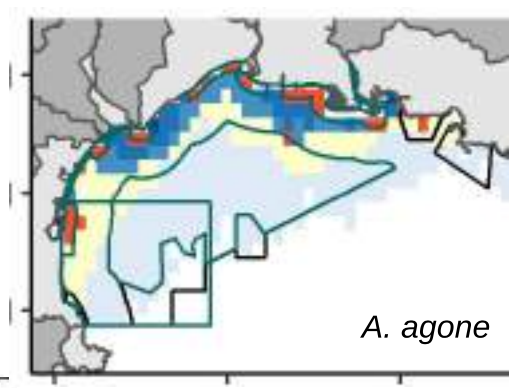
- All species have a coastal distribution.
- All species caught by a variety of gear types.
- Relatively little bycatch BUT even a small amount may have a large impact on the population…
- Limiting access to certain gear types with higher probability of capture may help protect diadromous fish.
- Need for targeted data collection on diadromous fish to better understand their marine life history stages.

e.g.



# Outputs

1. Elliott et al, 2021. Shedding light on the river and sea lamprey within western European waters. Endangered species research. DOI:10.3354/esr01113.

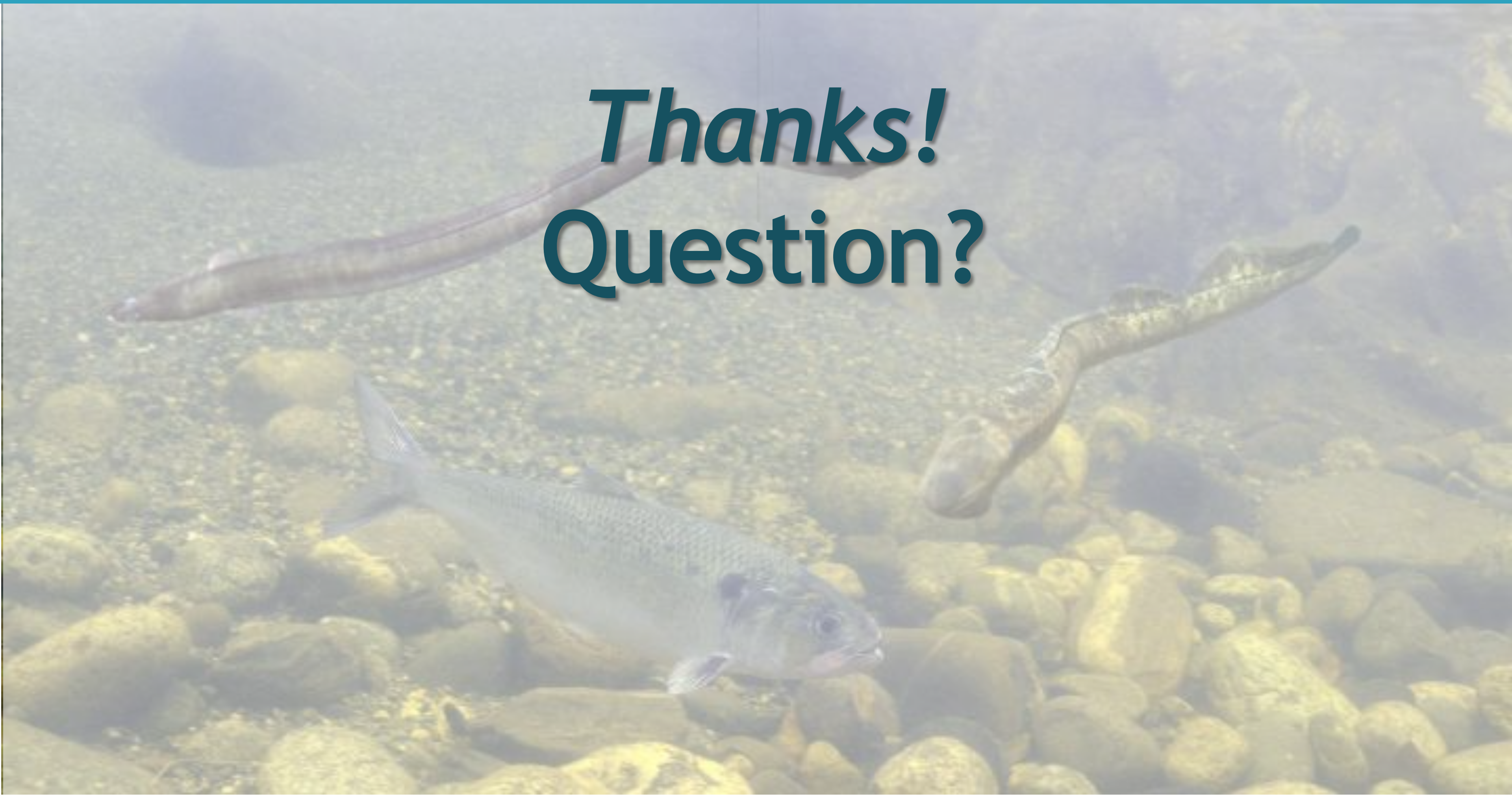
2. Elliott et al, In review. Modelling the distribution of low occurring diadromous fish at sea from fisheries dependent and independent data. Biological Conservation.

3. Elliott et al, In review. Data paper: Fisheries dependent and independent data used to model the distribution of diadromous fish. Biological Conservation.

4. Elliott et al, In prep. Could MPAs do more for diadromous fish at sea?

5. Dambrine et al, In prep. Connecting diadromous fish freshwater and marine habitats to assess climate change vulnerability.

# *Thanks!*
# Question?



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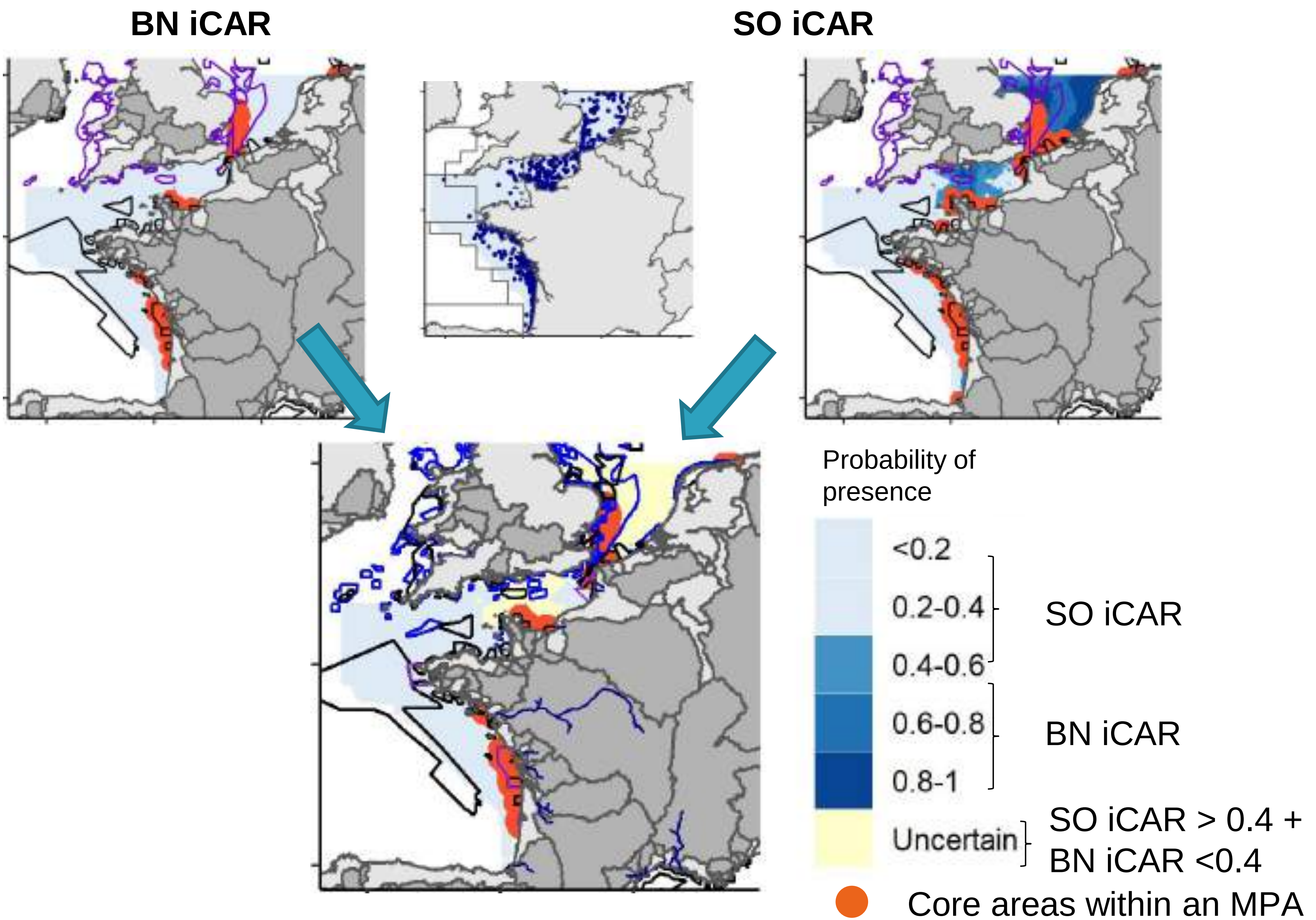
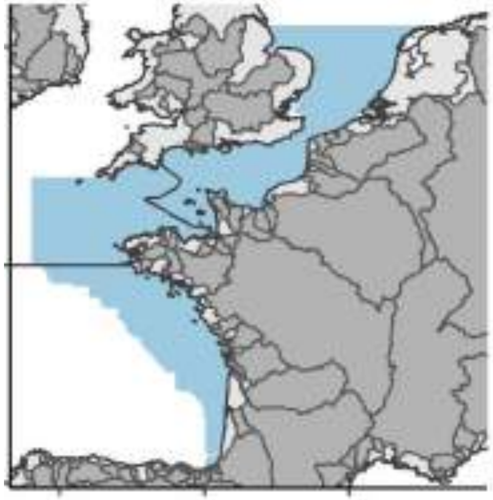
Pôle AFB-INRA-Agrocampus Ouest-UPPA
pour la gestion des migrateurs amphihalins
dans leur environnement

# CMAP for MPA management - *A. fallax*



# CMAP for MPA management - *A. anguilla*

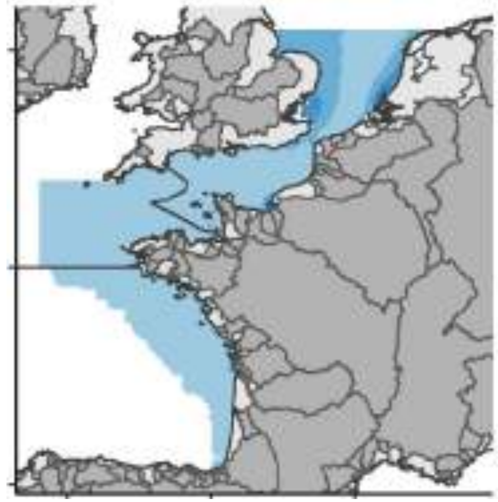
**BN iCAR**



| | | |
|---|---|---|
| | 1 | 0 |
| 1 | 4 | 1 |
| 0 | 56 | 4451 |

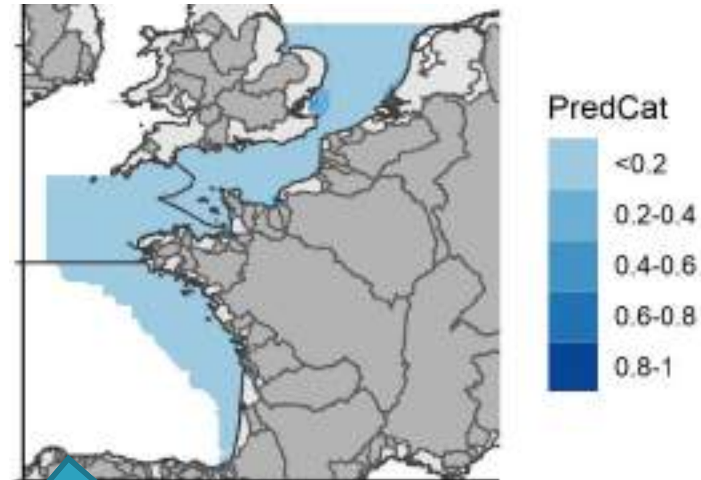
Sens:0.03
Spec:0.99
PPV:0.80
NPV:0.99

**ZIB iCAR**



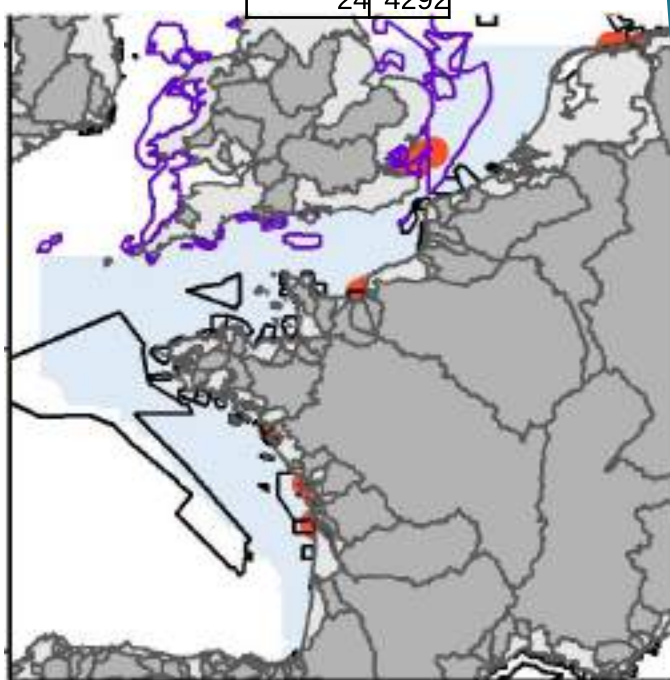
| | |
|---|---|
| 36 | 160 |
| 24 | 4292 |

**SO iCAR**



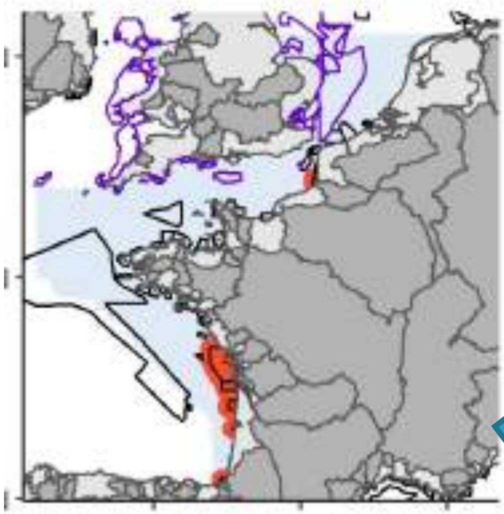

| | |
|---|---|
| 26 | 32 |
| 34 | 4420 |

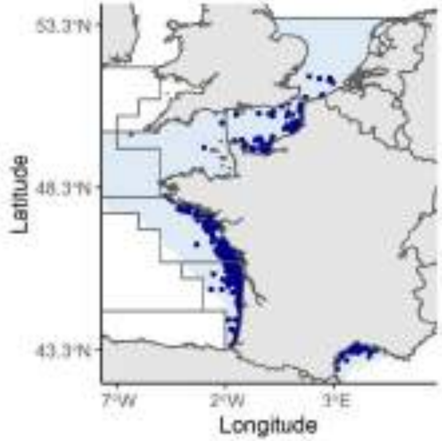
Sens:0.23
Spec:0.99
PPV:0.45
NPV:0.94



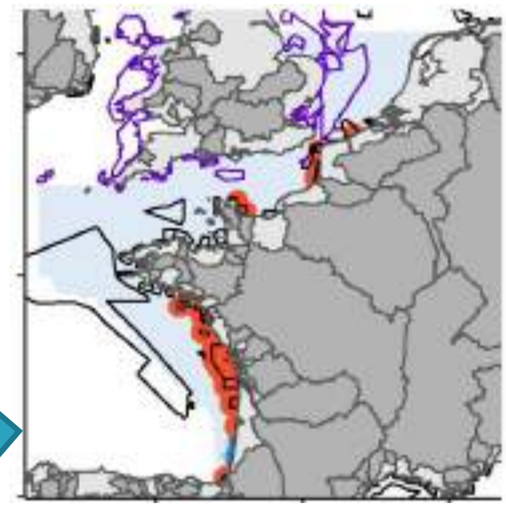
# CMAP for MPA management - *C. ramada*

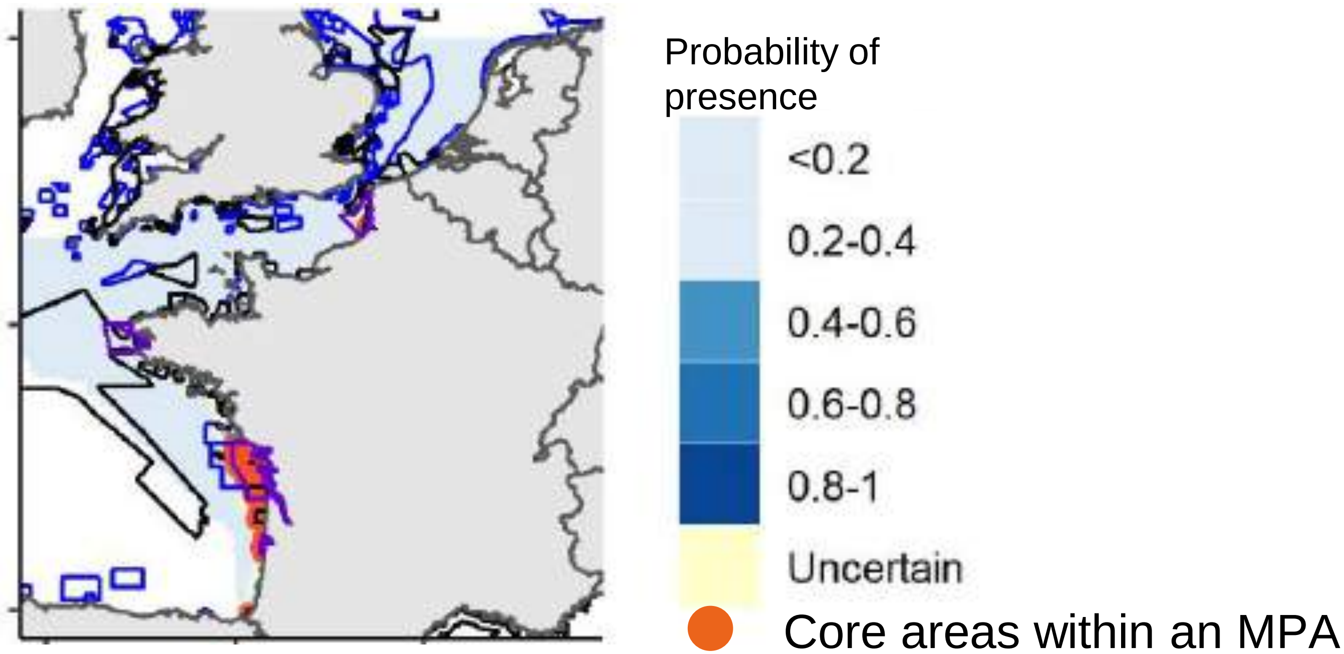
**BN iCAR**



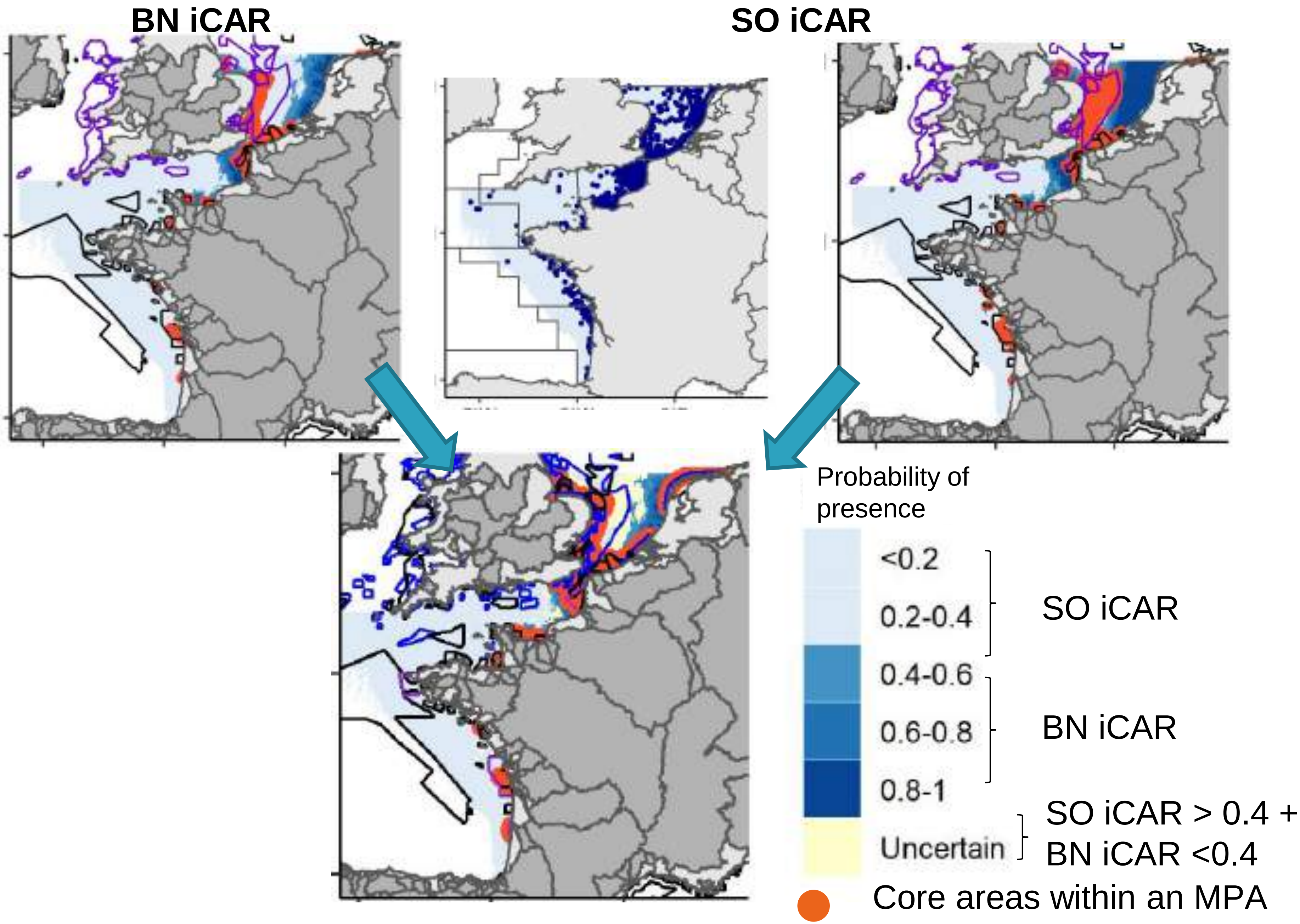



**SO iCAR**

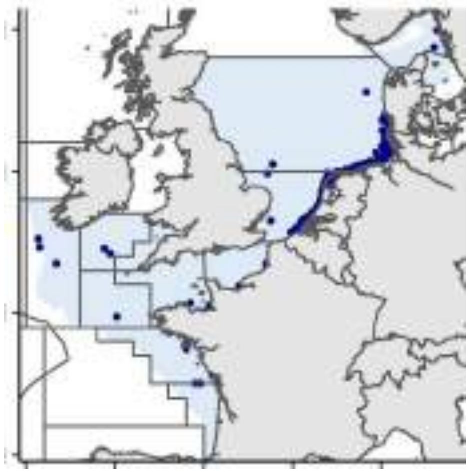




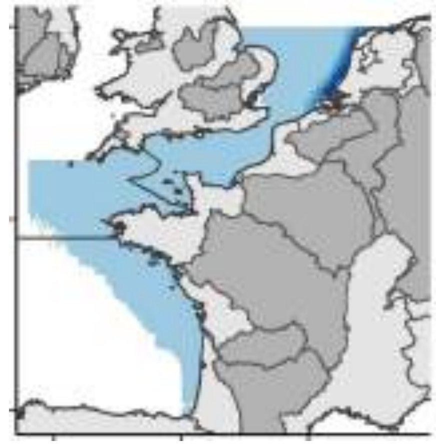
# ‘CMAP for MPA management – *P. flesus*



# CMAP for MPA management – *O. eperlanus*



**ZIB iCAR**



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Spec:0.98
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NPV:1

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|---|---|---|
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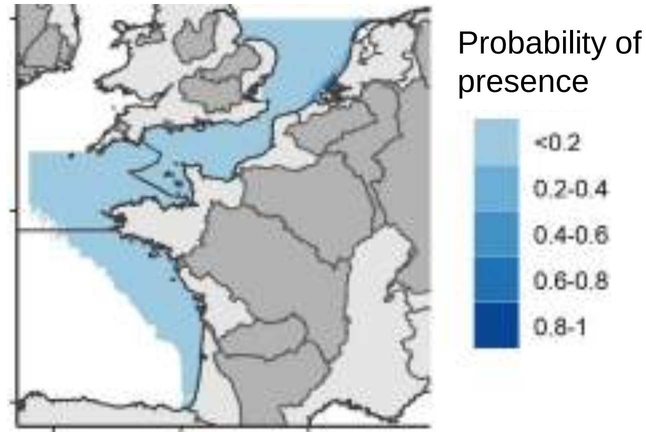
| 0 | 19 | 5199 |

**SO iCAR**




| | |
|---|---|
| 58 | 32 |
| 21 | 5293 |

Sens:0.66
Spec:0.99
PPV:0.64
NPV:1