Improving the understanding of diadromous fish at sea for management purposes

Pôle Gestion des MIgrateurs AMphihalins dans leur Environnement (MIAME)

Etienne Rivot & *Sophie Elliott* – Institut Agro
SElliott@gwct.org.uk
Laurent Beaulaton – OFB

Anthony Acou – UAR PatriNat

Elodie Réveillac - LIENSs

***Gaspard Dubost* – UAR PatriNat/Institut Agro**
gaspard.dubost@agrocampus-ouest.fr

LOCAL AND GLOBAL INITIATIVES:
HOW SCIENCE SUPPORTS MANAGEMENT ACTIONS ON DIADROMOUS FISH

Aims

1. Model **distribution** of diadromous species at sea

2. Assess their **vulnerability** to bycatch

3. Evaluate the **relevance** of coastal MPAs

Aims

1. Model **distribution** of diadromous species at sea

2. Assess their **vulnerability** to bycatch

3. Evaluate the **relevance** of coastal MPAs

→ To Meet ***Marine Strategy Framework Directive*** (MSFD) and the ***Habitats Directive*** requirements

Support ***Marine Nature Parks*** & ***Natura 2000 sites*** management measures

Diadromous fish studied

Latin name	EU (2011)	Belgium (2015)	France (2019)	Germany (2003)	Netherlands	UK (2014)
Acipenser sturio	CR	RE	CR	RE	NE	NE
Alosa alosa	LC	RE	CR	RE	NE	NE
Alosa fallax	LC	CR	NT	CR	NE	DD
Alosa agone	LC	NA	NT	NA	NA	NA
Anguilla anguilla	CR	CR	CR	EN	NE	NE
Chelon ramada	LC	VU	LC	NE	NE	NE
Platichthys flesus	LC	LC	DD	DD	NE	NE
Osmerus eperlanus	LC	NT	NT	RE	NE	NE
Lampetra fluviatilis	LC	VU	VU	CR	NE	NE
Petromyzon marinus	LC	CR	EN	CR	NE	NE
Salmo salar	VU	RE	VU	CR	NE	NE
Salmo trutta	LC	VU	LC	CR	NE	NE

Downstream of transitional waters (excluding estuaries and lagoons)*

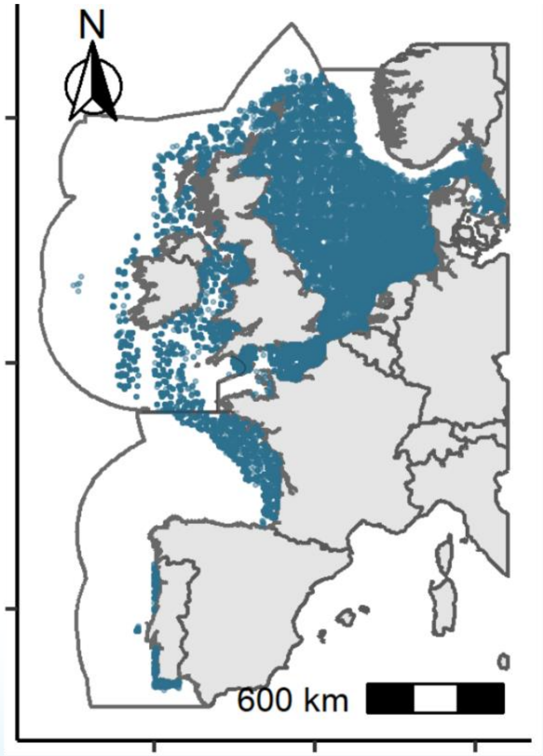
Surveys

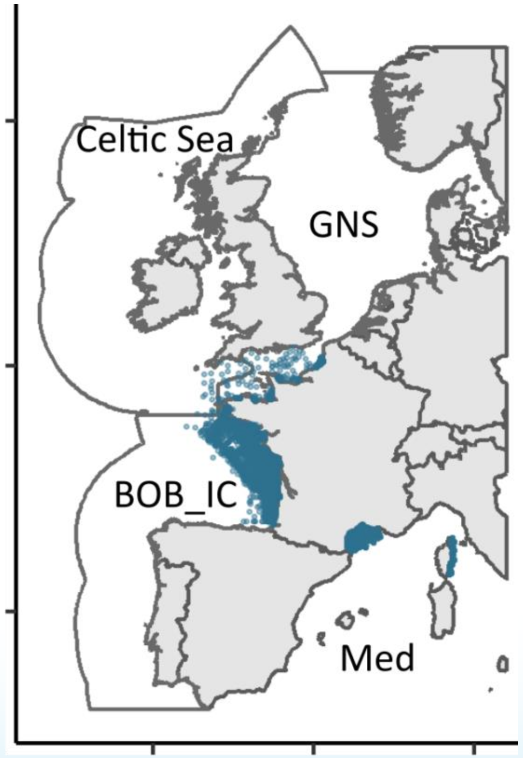
42 surveys, 1965-2019, 168 904 hauls

Scientific surveys

ICES DATRAS
1965 - 2018, 54 865 hauls

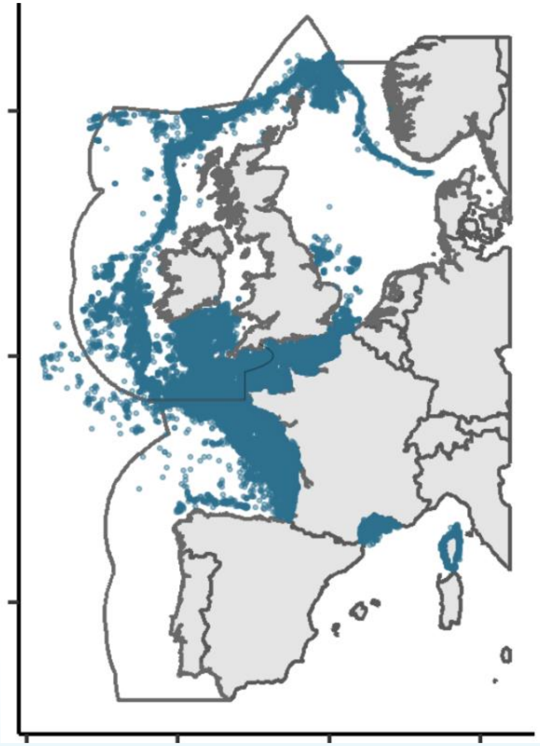
IFREMER
1980 - 2018, 13 422 hauls



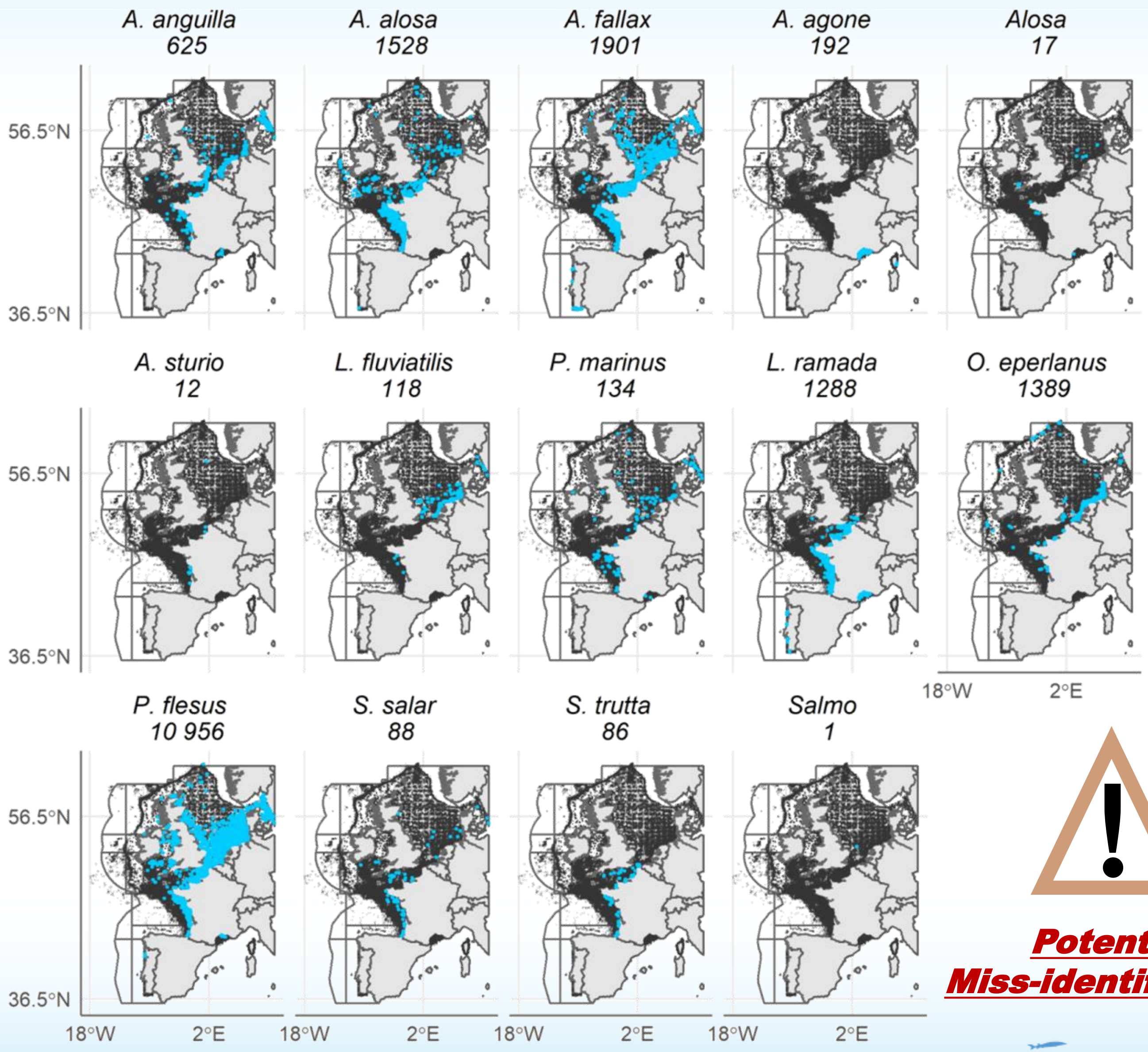


Fisheries dependent data

ObsMer
2003 – 2019, 100 617 hauls



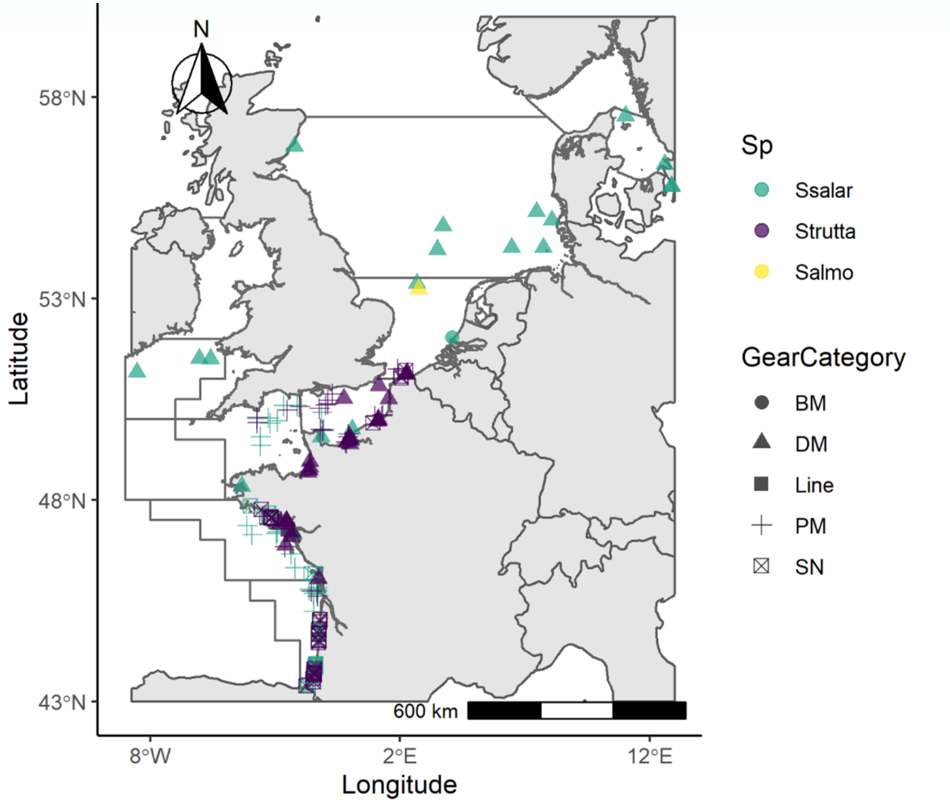
Presence of diadromous fish (1965-2019)

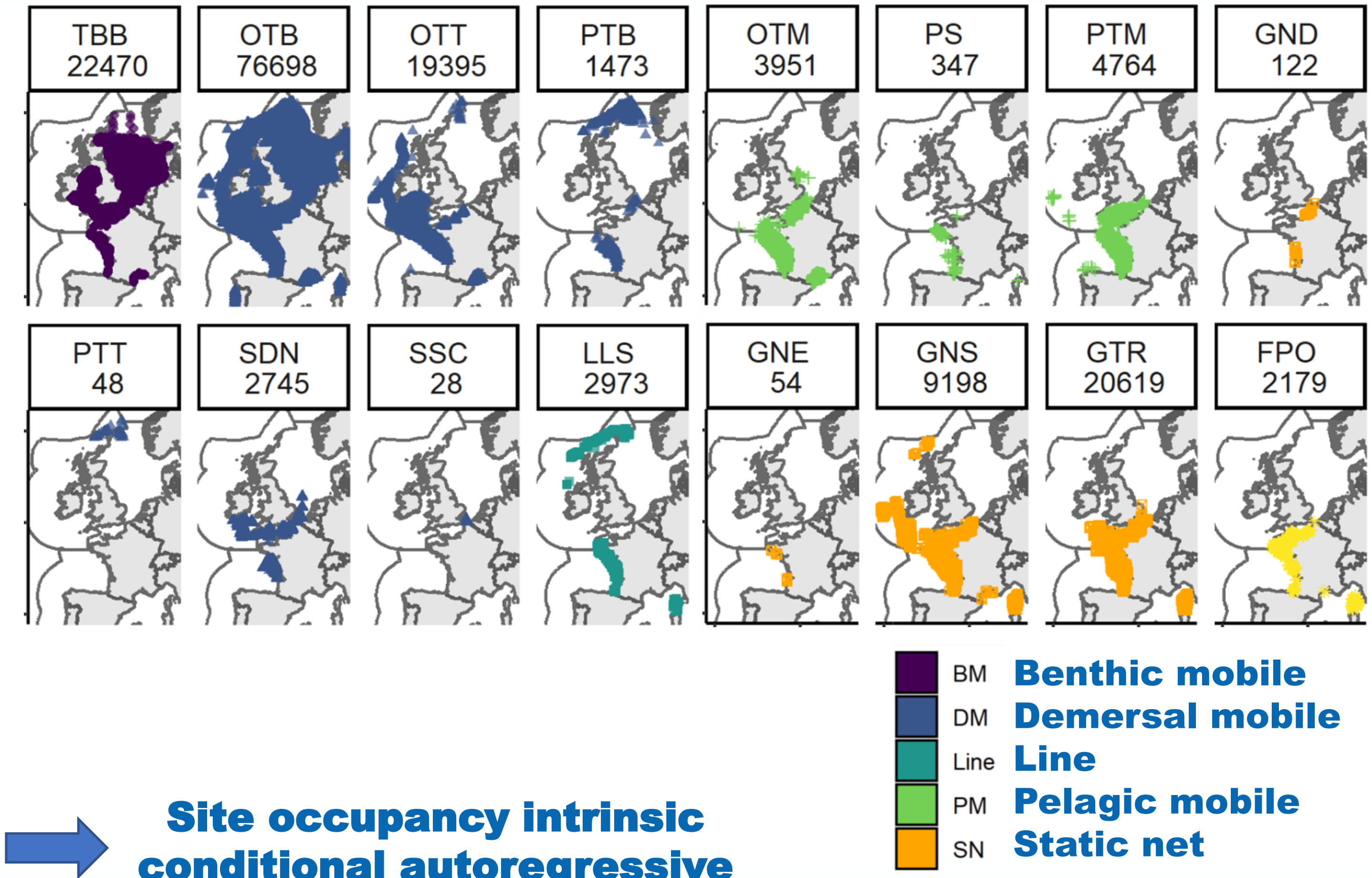


n= number of hauls with presence

Potential Miss-identification

Model the distribution of diadromous fish at sea



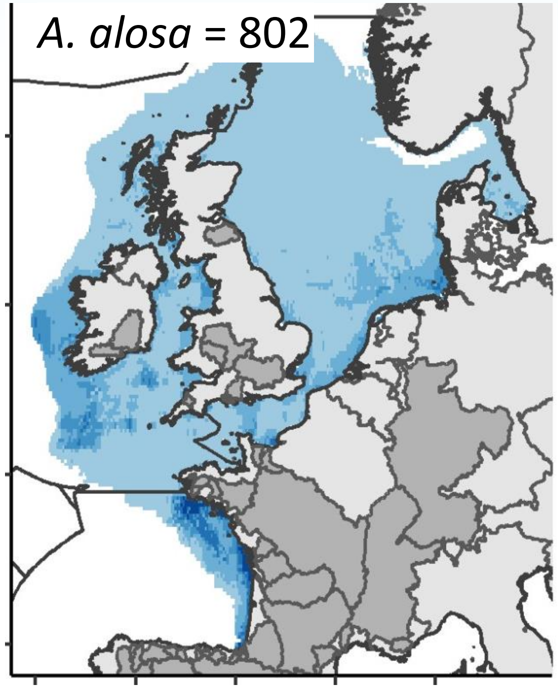


Taking into account imperfect detection gear bias & spatial autocorrelation → **Site occupancy intrinsic conditional autoregressive model (hSDM)**

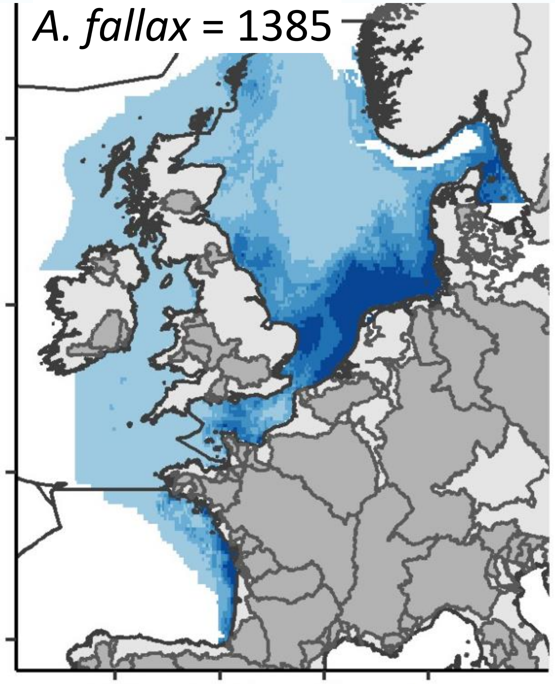
Shad hSDM

Continental presence: EuroDiad v. 4.0

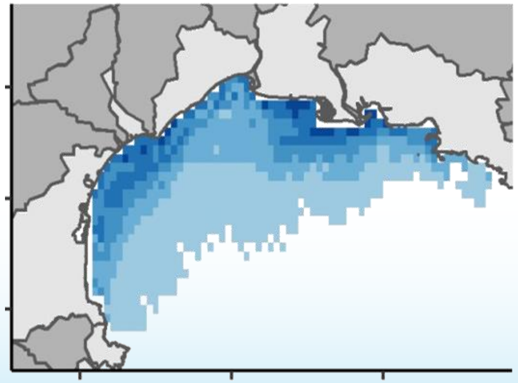
A. alosa = 802



A. fallax = 1385



A. agone = 176

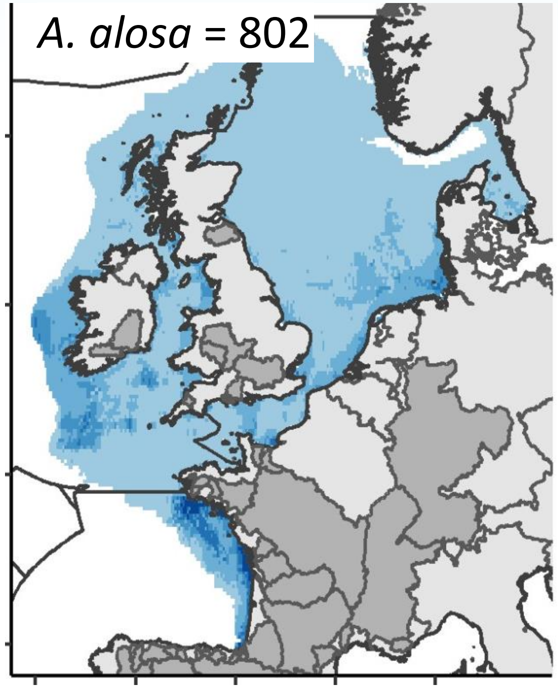


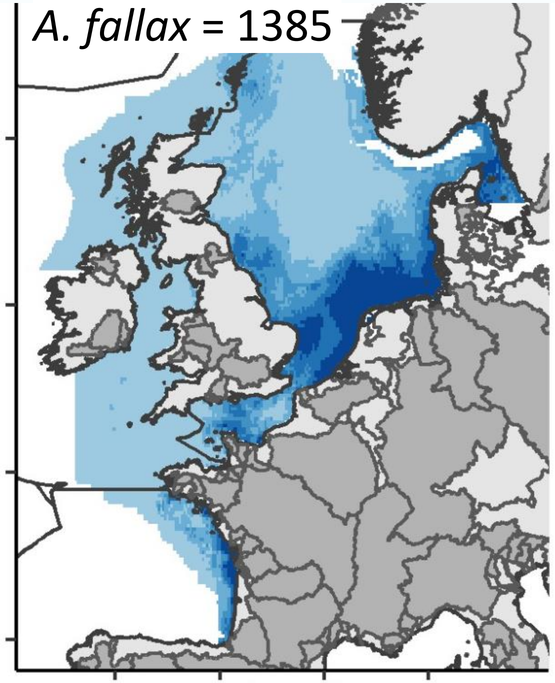
Probability of presence

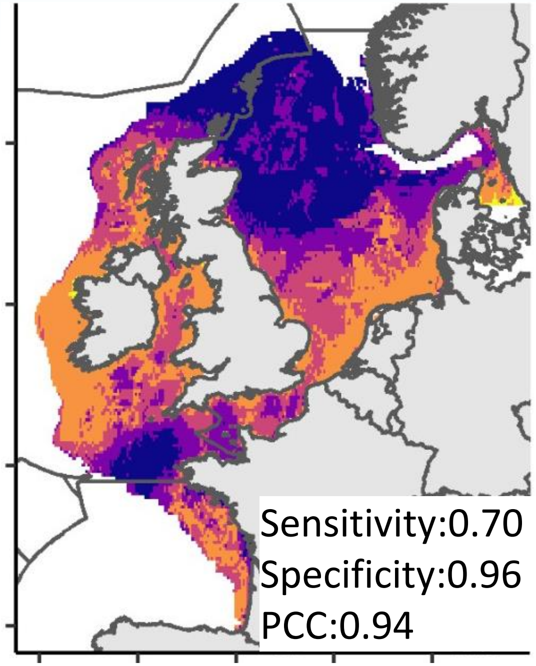
- <0.2
- 0.2-0.4
- 0.4-0.6
- 0.6-0.8
- 0.8-1

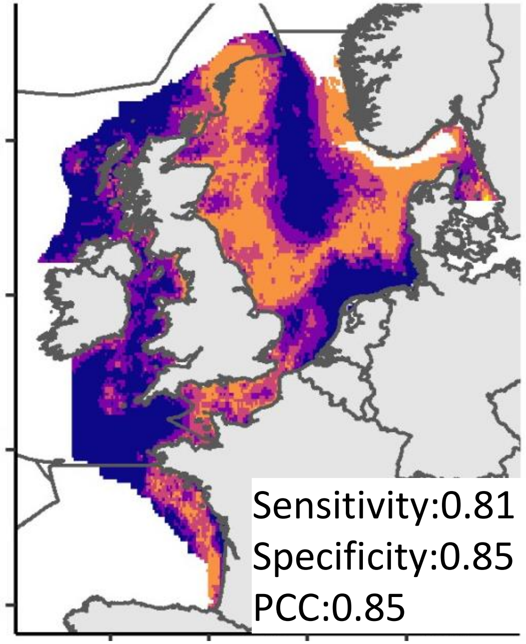
Shad hSDM

Continental presence: EuroDiad v. 4.0

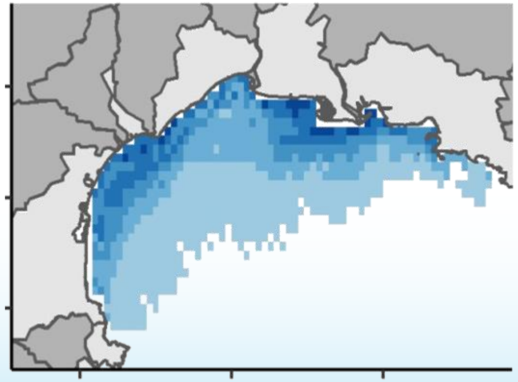






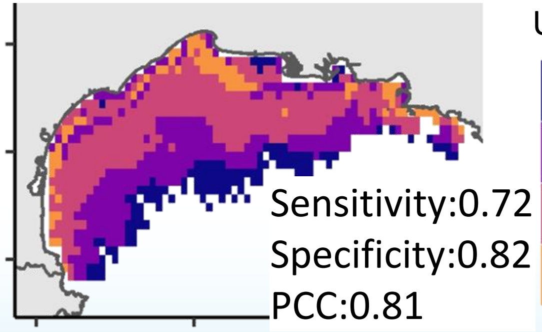


A. agone = 176



Probability of presence

- <0.2
- 0.2-0.4
- 0.4-0.6
- 0.6-0.8
- 0.8-1

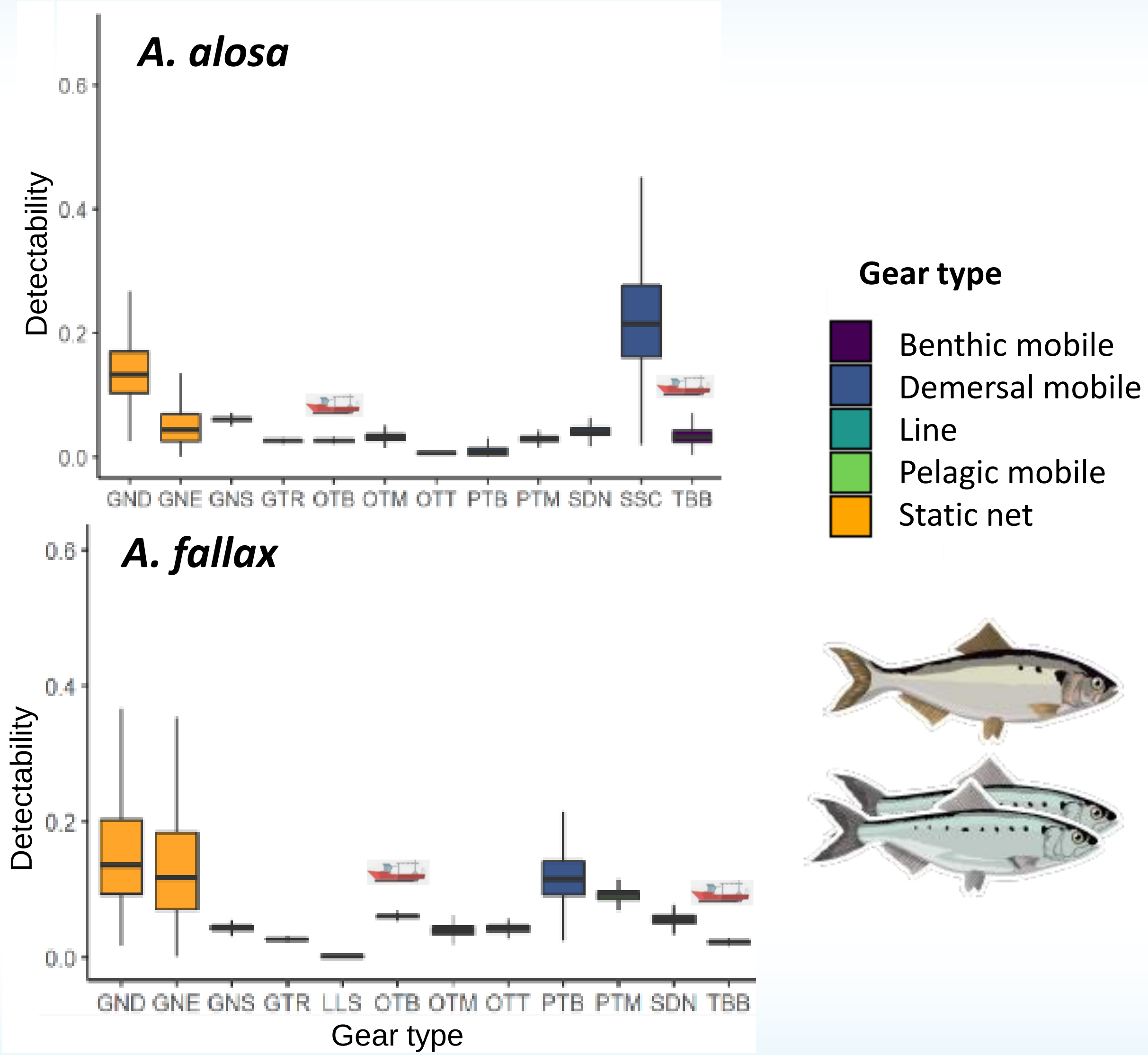


Uncertainty

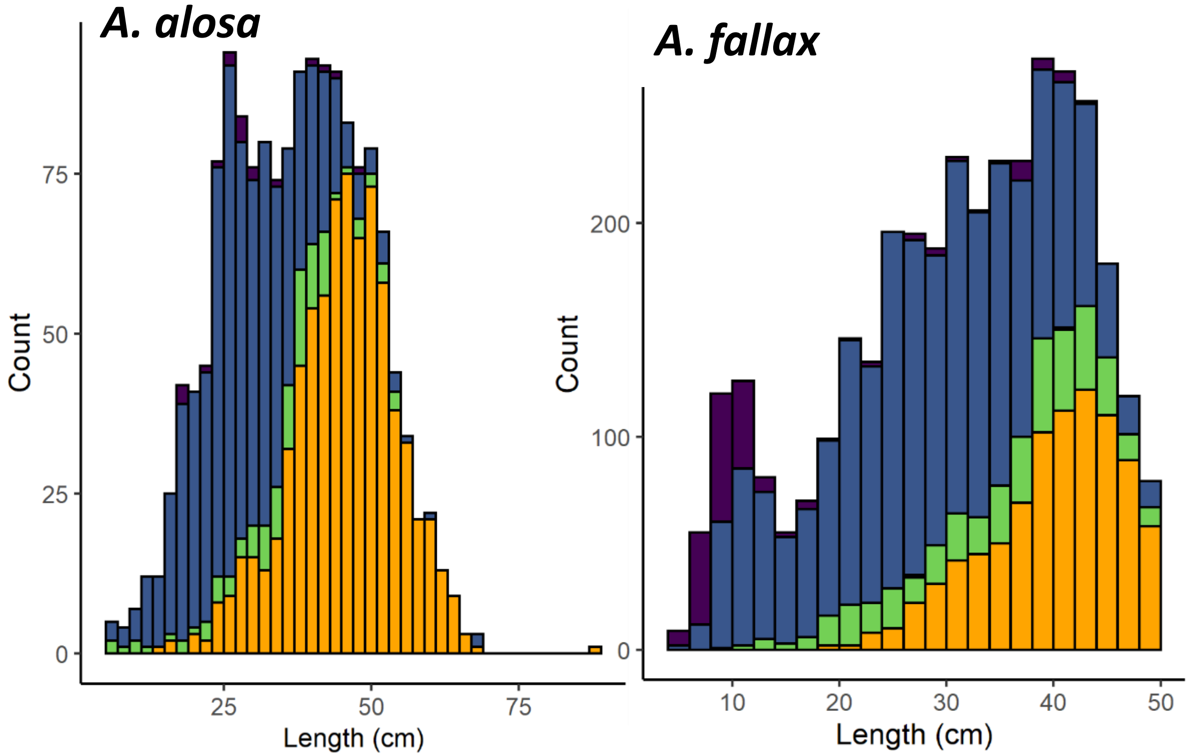
- <0.2
- 0.2-0.4
- 0.4-0.6
- 0.6-0.8

Shad gear capture

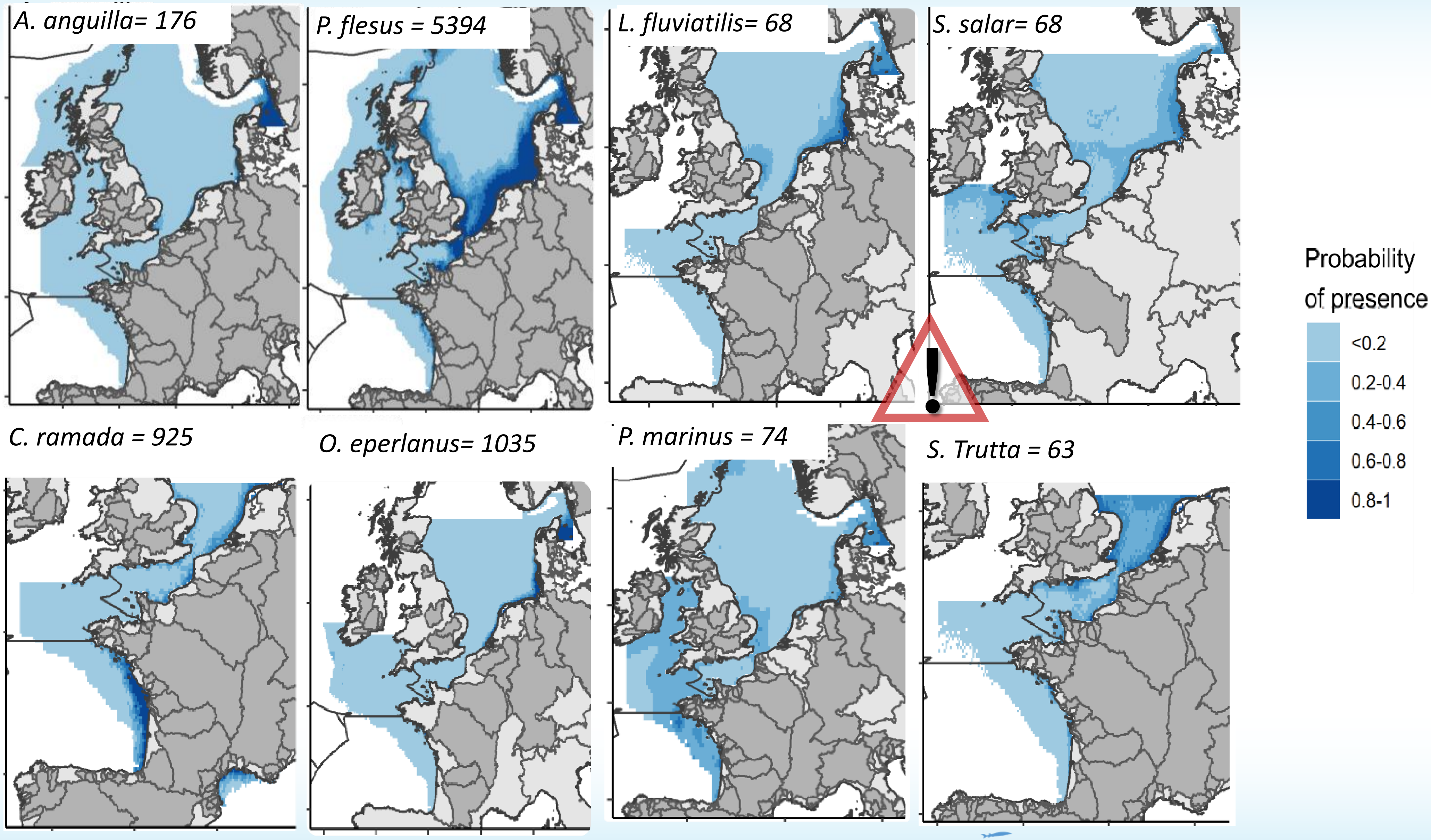
Detectability by gear



Catch by gear



Species hSDM



Bycatch Risk Analysis

Data ObsMer & Publications

Gear category	Fishing gear abbreviations	Lamprey	Shad	Salmonids	*A. anguilla*
Surrounding nets	PS	1	1	1	1
Seines net	SSC, SDN	1	1 / 3#	1	1
Trawls	OTB, OTT, OTM, PTB, PTM, TBB	2	2 / 3#	2 / 3#	2 / 3*#
Dredge	DRB	1	1	1	1
Gillnets	GND, GNC, GNE, GNS, GTR	3* / 2#	3#	3#	1 / 2

Risk: 3 / 2 / 1

* targeted

landed

Acou et al., 2021

Bycatch Risk Analysis

Data ObsMer & Publications

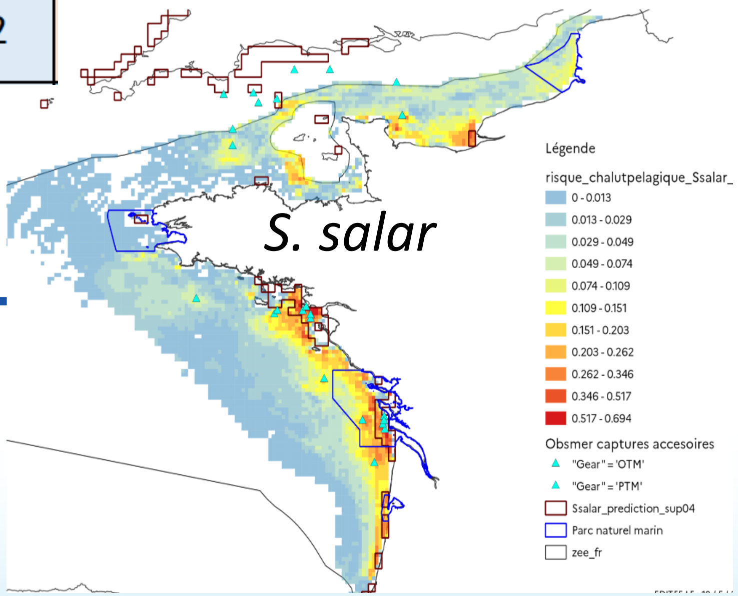
<table>
<tr><th>Gear category</th><th>Fishing gear abbreviations</th><th colspan="2">Lamprey</th><th colspan="2">Shad</th><th colspan="2">Salmonids</th><th colspan="2">A. anguilla</th></tr>
<tr><td>Surrounding nets</td><td>PS</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td></tr>
<tr><td>Seines net</td><td>SSC, SDN</td><td colspan="2">1</td><td>1</td><td>3#</td><td colspan="2">1</td><td colspan="2">1</td></tr>
<tr><td>Trawls</td><td>OTB, OTT, OTM, PTB, PTM, TBB</td><td colspan="2">2</td><td>2</td><td>3#</td><td>2</td><td>3#</td><td>2</td><td>3*#</td></tr>
<tr><td>Dredge</td><td>DRB</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td></tr>
<tr><td>Gillnets</td><td>GND, GNC, GNE, GNS, GTR</td><td>3*</td><td>2#</td><td colspan="2">3#</td><td colspan="2">3#</td><td>1</td><td>2</td></tr>
</table>

Risk
3
2
1

Risk

* targeted
# landed

Acou et al., 2021



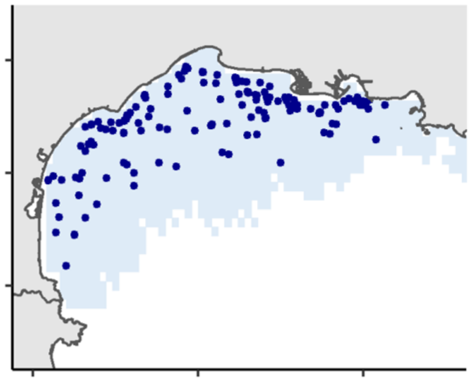
Next Steps:

hSDM model

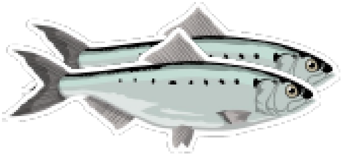
Fishing effort

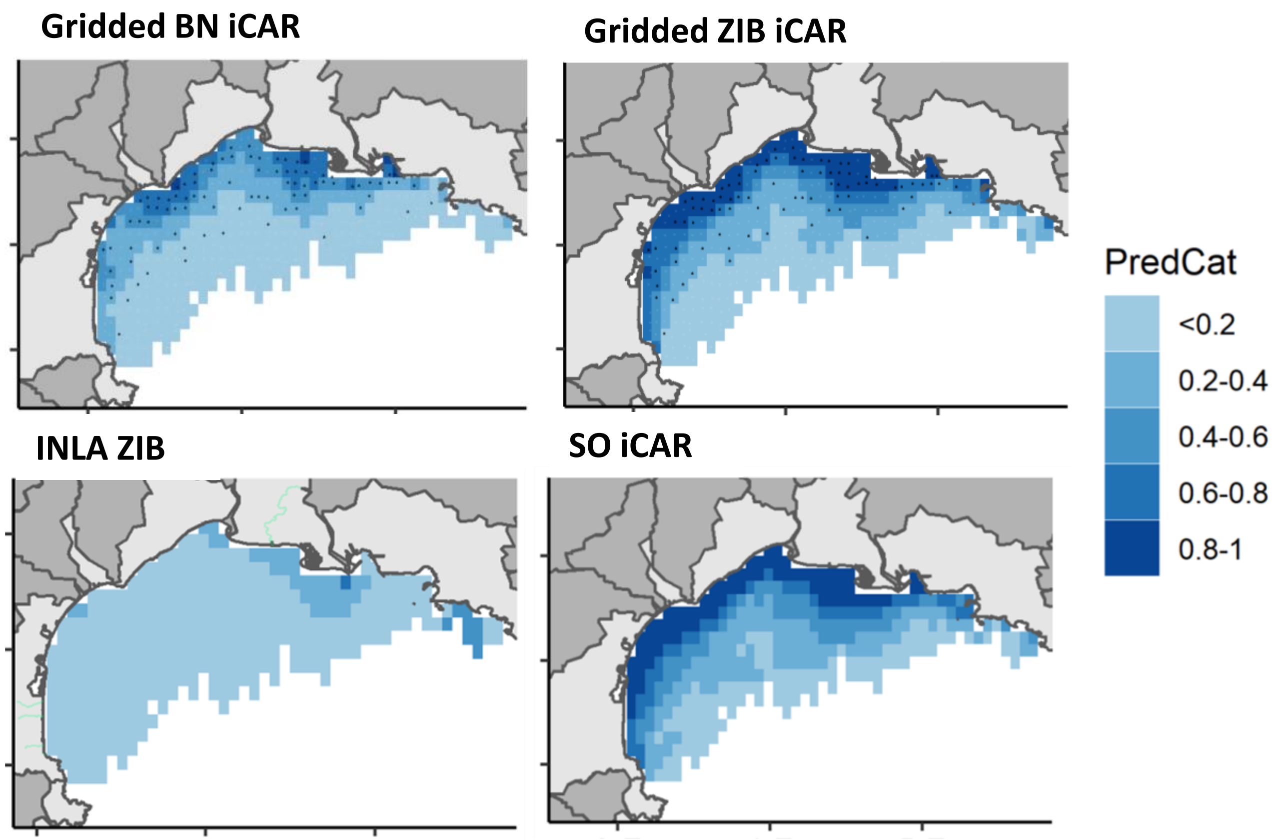
V. Toison et al.,
Evaluating **fishing pressure**

Model the distribution of diadromous fish at a finer scale to evaluate the pertinence of MPAs



Alosa agone



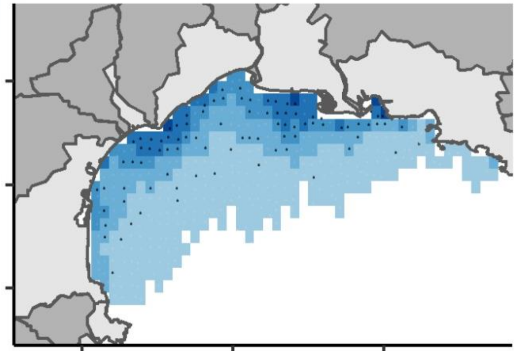


Model comparison & selection :

1. Gridded binomial (BN) iCAR
2. Zero inflated binomial (ZIB) iCAR
3. Site occupancy (SO) iCAR
4. Integrated Nested Laplace Approximation (INLA) ZIB

Combined Model for Accurate Predictions (CMAP)

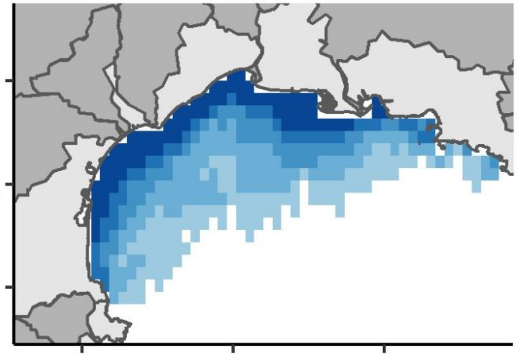
BN iCAR



Different models for separate objectives

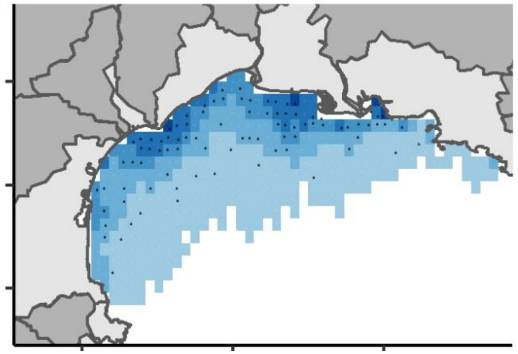
- Core Areas
- Unsuitable areas

SO iCAR

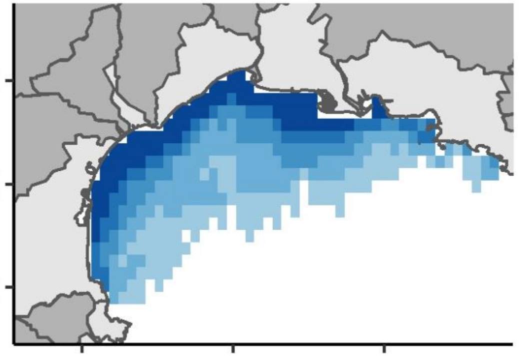


Combined Model for Accurate Predictions (CMAP)

BN iCAR



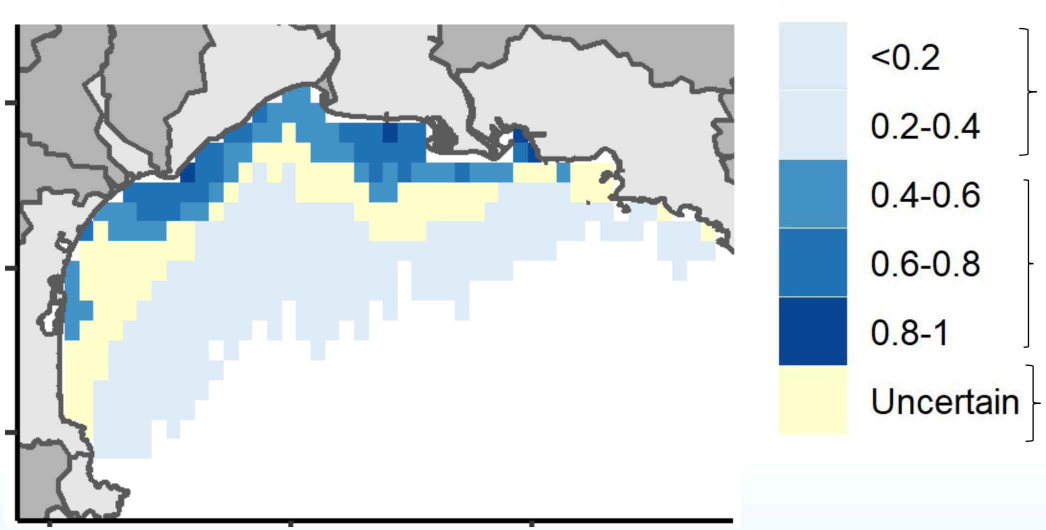
SO iCAR



Different models for separate objectives

Core Areas

Unsuitable areas



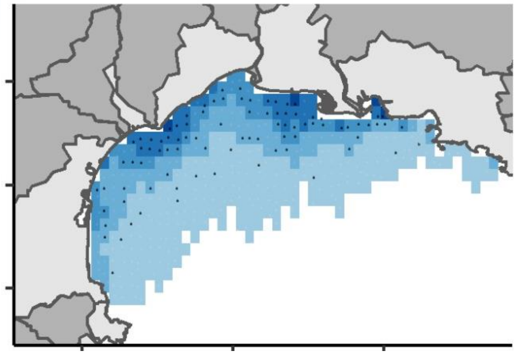
SO iCAR

BN iCAR

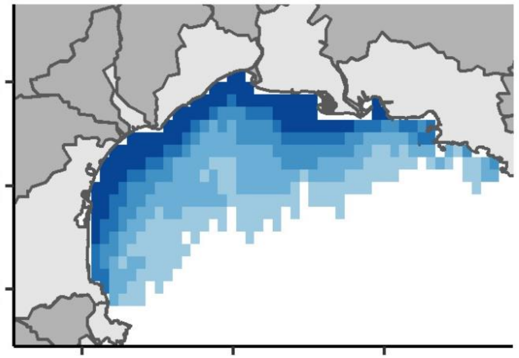
SO iCAR > 0.4 +
BN iCAR <0.4

Combined Model for Accurate Predictions (CMAP)

BN iCAR

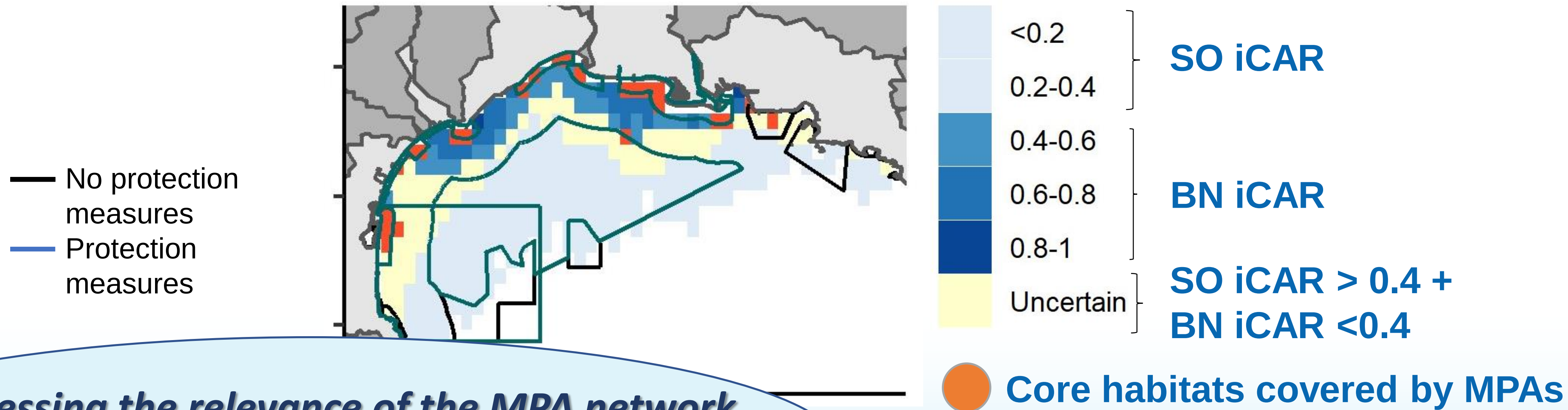


SO iCAR



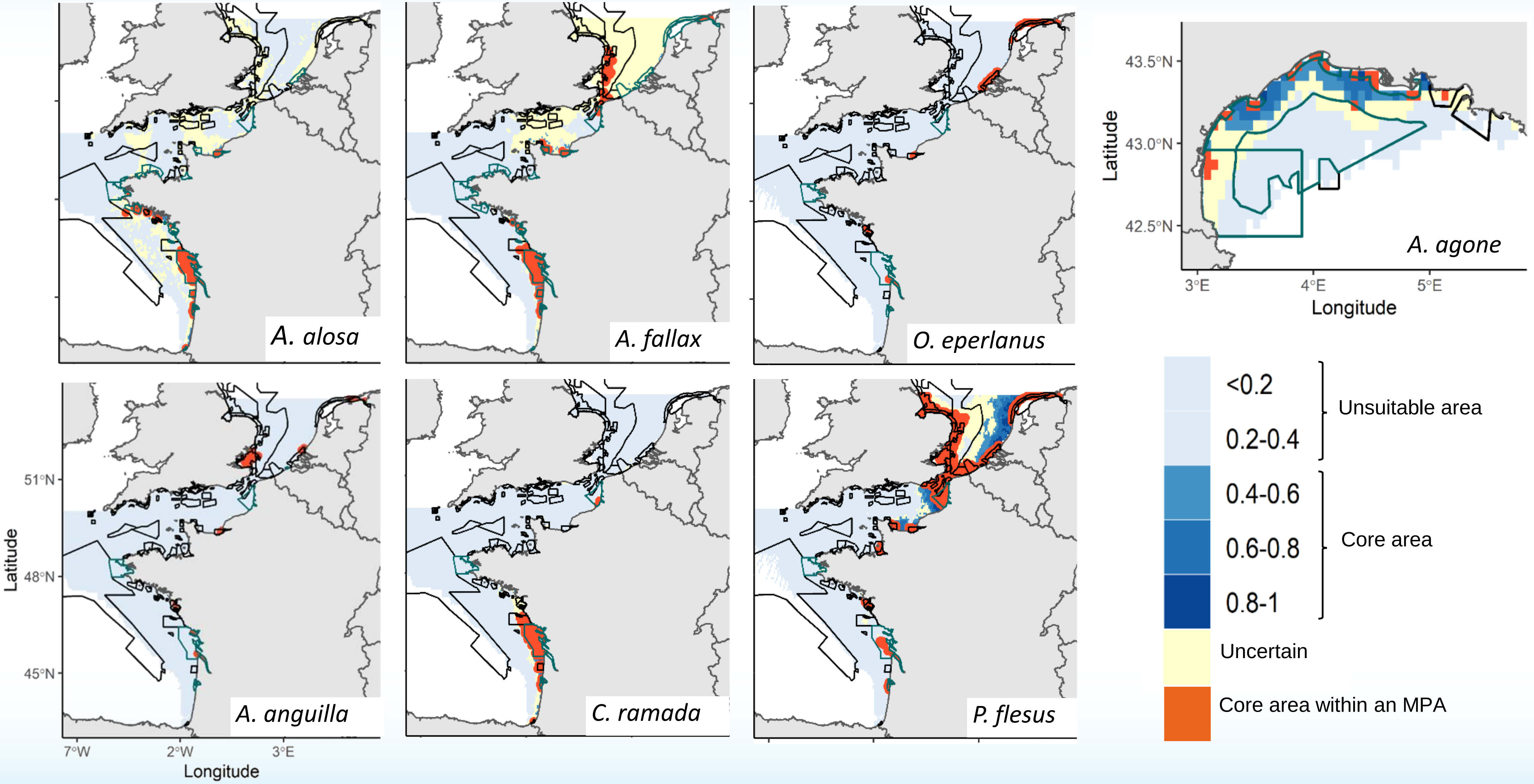
Different models for separate objectives

Core Areas | Unsuitable areas



- ***Assessing the relevance of the MPA network***
- ***Maximise protection by reducing the impact on stakeholders***

Combined Model for Accurate Predictions (CMAP)



Value of MPAs for the protection of diadromous fish

Does the present MPAs network protect DF sufficiently?

Value of MPAs for the protection of diadromous fish

Does the present MPAs network protect DF sufficiently?

60% core area within MPAs

→

43% had specific measures to protect DF

Value of MPAs for the protection of diadromous fish

Does the present MPAs network protect DF sufficiently?

60% core area within MPAs → 43% had specific measures to protect DF

Habitat Directive Species of Community Interest

- *A. Alosa* & *A. fallax*: 61% & 65%
- *A. Agone: 30%*

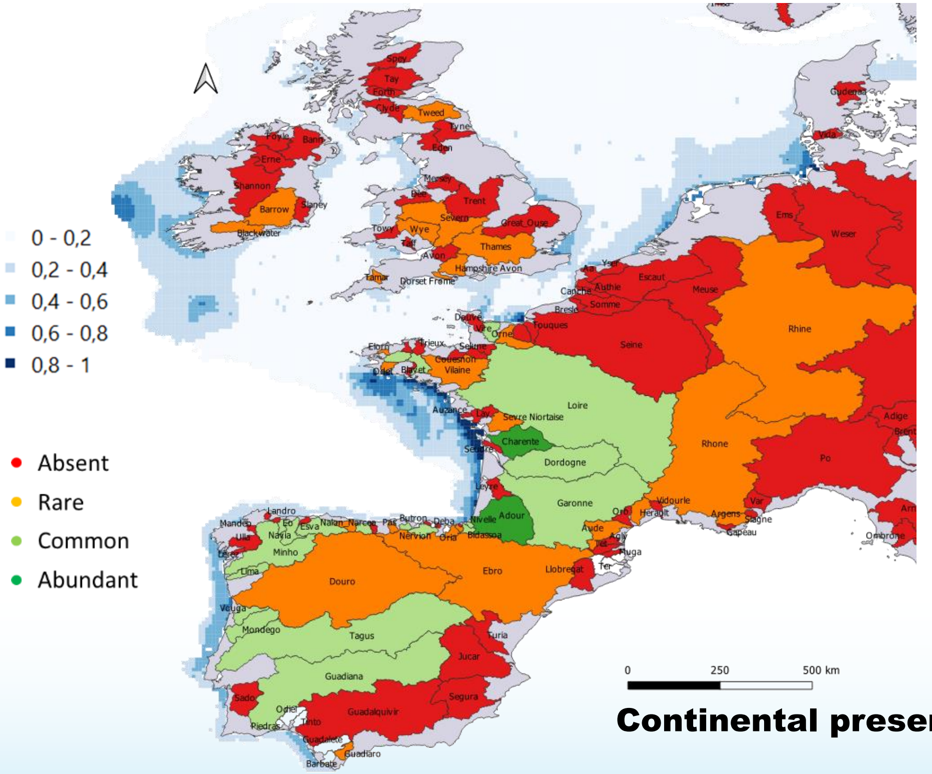
Other species

- >**66%** of core areas within MPAs
- **80%** of eels within MPAs, only **10%** protected

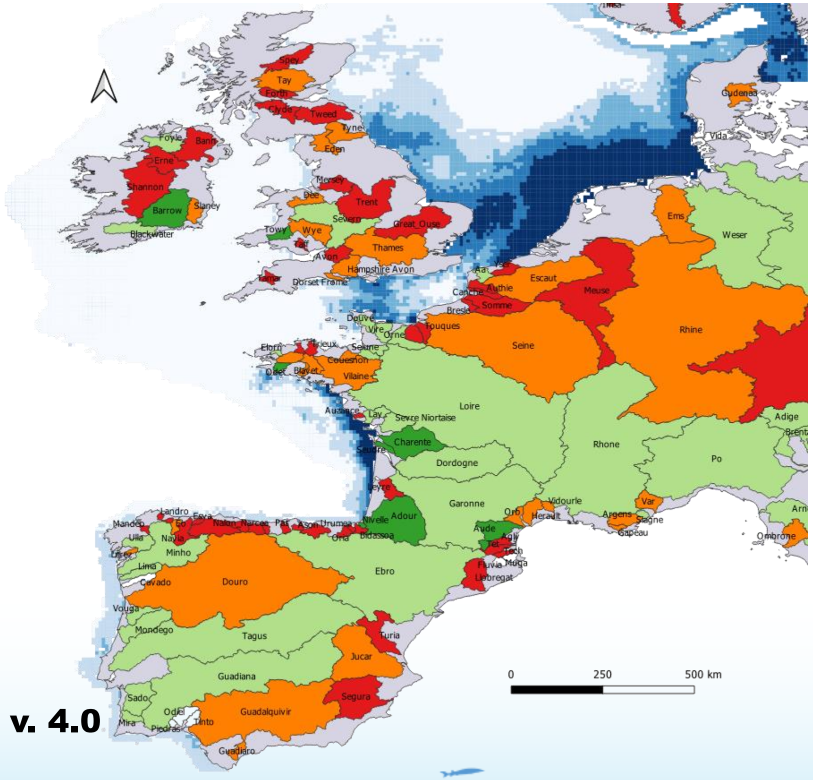
Connectivity between marine & continental habitats for management purposes

Input	Terrain	Reference
EuroDiad 4.0	Observed population functionality in present time	Barber-O'Malley et al, 2022a
HyDiad	Simulated continental habitat suitability in present and future time	Barber-O'Malley et al, 2022b
hSDM	Simulated marine habitat suitability in present time	Elliott et al, In review

A. alosa



A. fallax



Continental presence: EuroDiad v. 4.0

Chloé Dambrine

Conclusion

- ***hSDM model*** - suitable for ***excess of zeros***

Captured mainly by ***trawls & static nets***

DF at sea remain in ***coastal areas***

- CMAP - ***accurate*** for ***spatial management***

Use to identify MPAs requiring ***fisheries management measures*** to protect DF

- ***MPAs connecting with freshwater river*** with DF presence are of ***greater benefit***

Conclusion

- ***hSDM model*** - suitable for ***excess of zeros***

Captured mainly by ***trawls & static nets***

DF at sea remain in ***coastal areas***

- CMAP - ***accurate*** for ***spatial management***

Use to identify MPAs requiring ***fisheries management measures*** to protect DF

- ***MPAs connecting with freshwater river*** with DF presence are of ***greater benefit***

Perspectives

- Need to quantify gear-specific mortality
- Understand abundance trends in time for the more abundant species

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 rare and data-poor diadromous fish at sea for protected area management. Progress in Oceanography.

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

4. Elliott et al, In prep. Accurately predicting data-limited species distribution for spatial protection.

5. Acou et al, 2021. Matrice d'interaction entre espèces amphihalines et activité de pêche dans le milieu marin. OFB.

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

7. Barber-O'Malley et al, 2022. Dataset on European diadromous species distributions from 1750 to present time in Europe, North Africa and the Middle East.

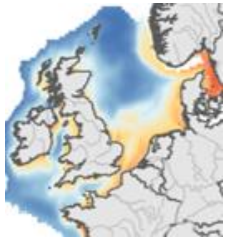
8. Barber-O'Malley et al, 2022. HyDiaD: A hybrid species distribution model combining dispersal, multi-habitat suitability, and population dynamics for diadromous species under climate change scenarios.

Thank you for your attention !

Any questions ?

Hierarchical SDM (Bayesian)

Site occupancy intrinsic conditional autoregressive model (SO iCAR)



Latent ecological process (habitat suitability)

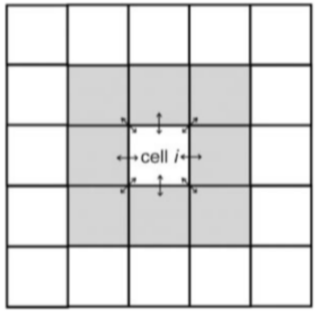
$z_{j,i}$ = variable describing presence/absence (PA) at site i located within the grid cell j
θ_j = probability of presence – habitat suitability within cell j
X_j= environmental predictors
β = how much the environmental variable contribute to the suitability process
P_j = spatial random effect in cell j at observation i (iCAR)

$$z_{j,i} \sim Bernoulli\,(\theta_j)$$
$$logit\,(\theta_j) = X_j\beta + P_j$$

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

p_j = spatial random effect in cell j
μ_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

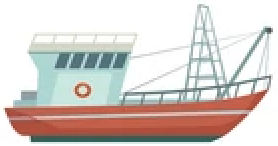
$$P_j \sim Normal\,(\mu_j, \frac{V_p}{n_j})$$



Observational process (detection)

$$y_{j,i} \sim Bernoulli\,(z_{j,i}\,\delta_{j,i})$$
$$logit\,(\delta_{j,i}) = W_{j,i}\gamma$$

$y_{j,i}$ = PA at site i within the gred cell j
$z_{j,i}$ = probability of detecting the species at site i within cell j
$\delta_{j,i}$ = probability of detecting species at site i
$W_{j,i}$ = gear affect associated with observation at site i
γ = vector of the gear effects



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