HyDiaD model: A tool to explore the effect of climate change on diadromous species assemblage in Western Europe

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A tool to explore the effect of climate change on diadromous species assemblage in Western Europe

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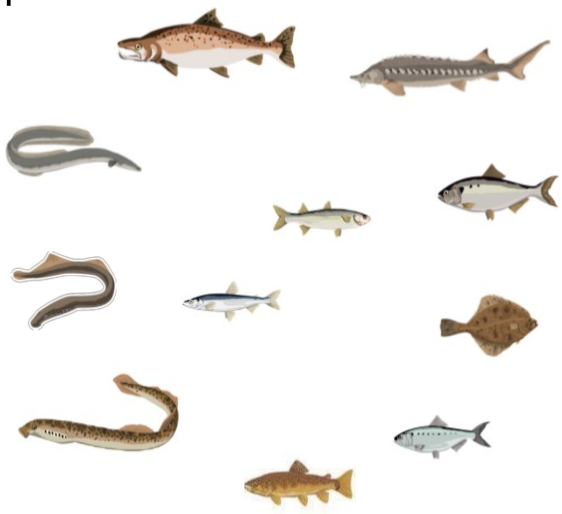
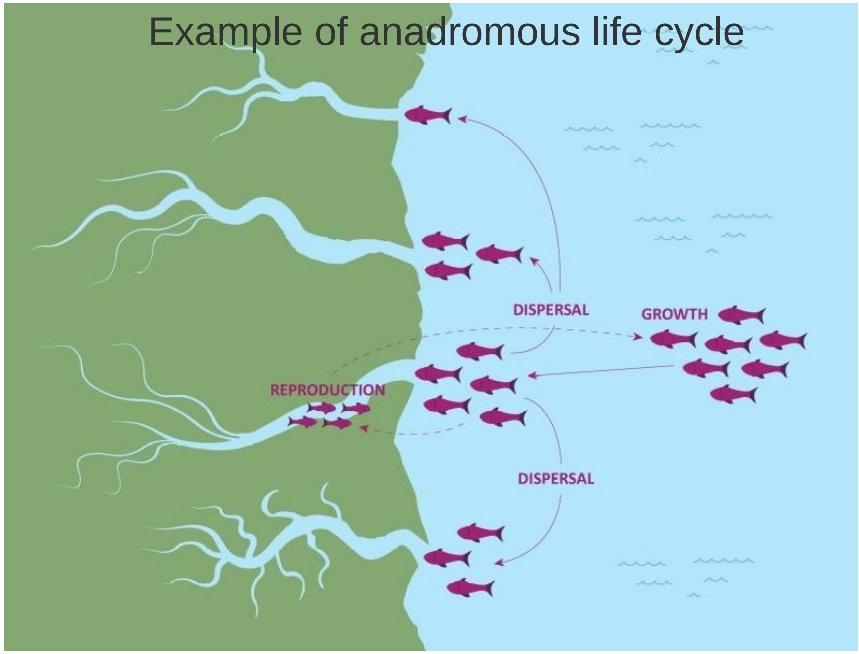
Interreg Atlantic Area European Regional Development Fund EUROPEAN UNION DiadES

Context : **Assemblage of 11 diadromous species in the European Atlantic Area facing a changing environment**

Diadromous species

- They share their life cycle between freshwater and marine domains,
- They disperse between catchments, in addition to reproduction and growth processes.





This originality leads to **territorial interdependences** (land-sea, latitudinal) which call for new management strategies.

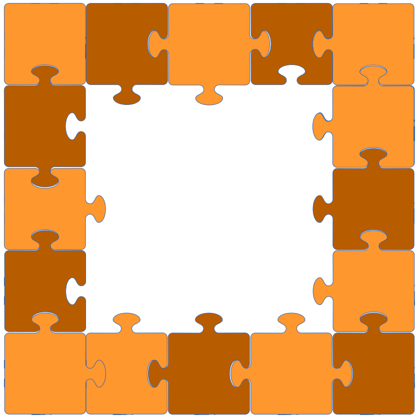
Climate changes will exacerbate these interdependences.

Method : **HyDiaD, a hybrid model for diadromous species distribution**

(Singer et al., 2016; Baber-O'Malley et al., 2022a)

HyDiaD combines

- the classical approach of **habitat suitability** (correlative model)



Method : **HyDiaD, a hybrid model for diadromous species distribution**

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HyDiaD combines

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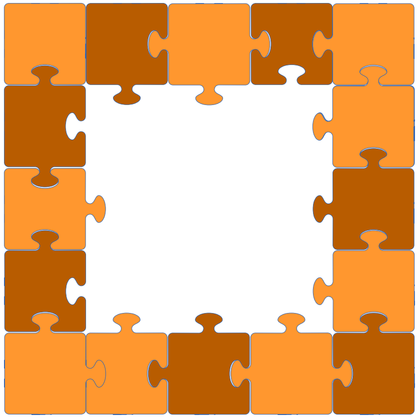
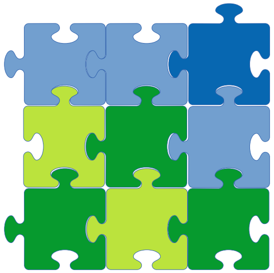


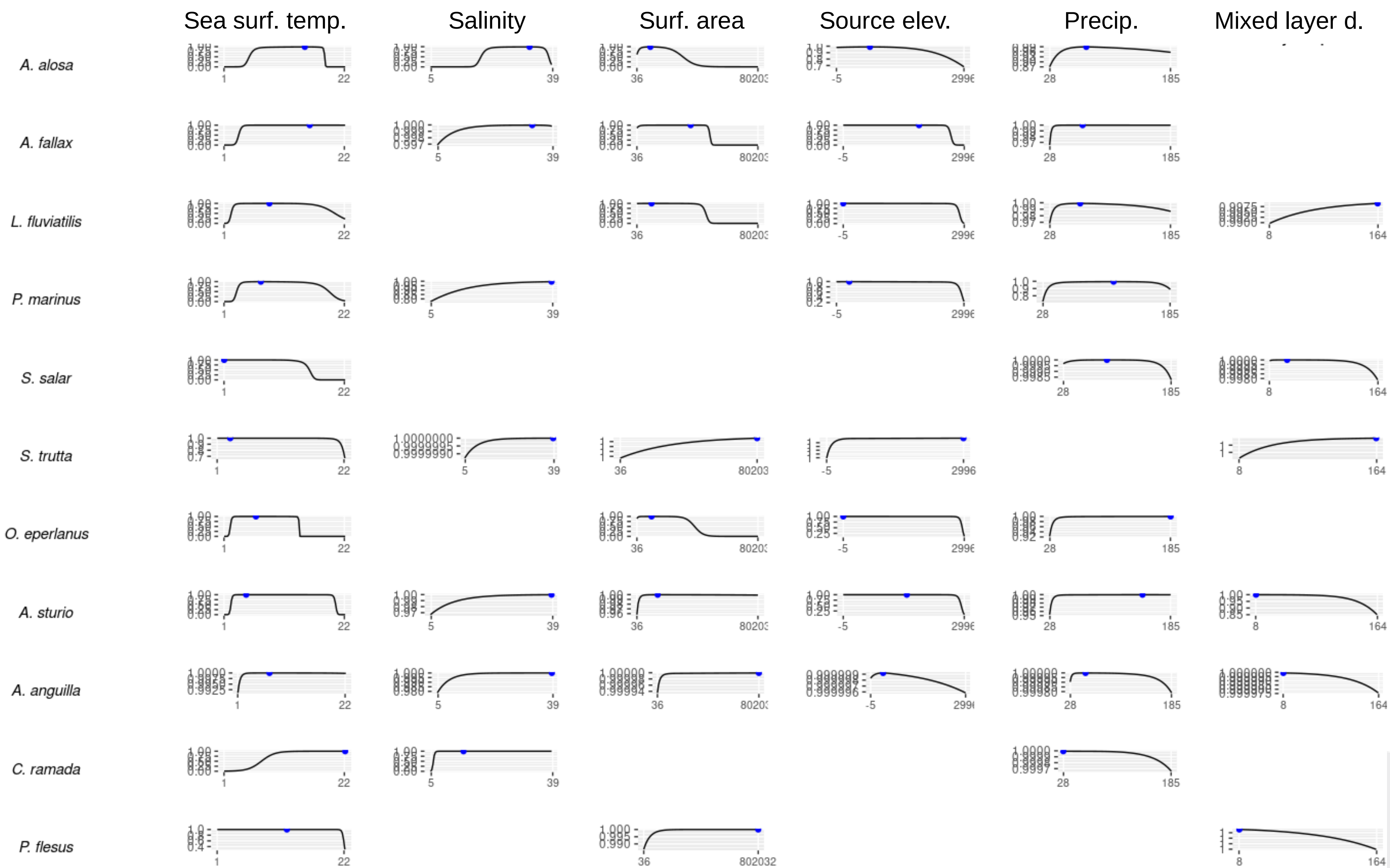
- with 2 modules
  - **Dispersal**
  - **Population dynamics**



Modelling: **Habitat suitability index**

based on shape-constraint GAM (Citores et al., 2020; Valle et al., 2023)

using presences and absences from Eurodiad 4.0 database (Baber-O'Malley et al., 2022b)



Modelling: **Dispersal and population dynamics**

(adapted from De Cáceres and Brotons, 2012)

The number of fish is calculated with →

$$N_{i,t} = min\left(B_{i,t} \frac{B^2_{i,t}}{B^2_{i,t} + \left(\lambda \cdot D_{max} \cdot A_i\right)^2} r, \quad HSI_{i,t} \cdot D_{max} \cdot A_i \cdot e^{-h_1} \right)$$

a stock-recruitment relationship (Barrowman and Myers 2000)

The number of spawners,

that are active (Allee effect),

and give offsprings,

with a maximum production limited by the habitat suitability defined by the CC,

reduced by a anthropogenic mortality (habitat reduction)

The number of spawners sums →

$$B_{i,t} = \left(\left[\sum^{S} \frac{N_{i,t-S}}{n_c} \cdot (1-\gamma) \right] + \sum_{j \neq i \in \Omega} \left[\sum^{S} \frac{\frac{N_{j,t-S}}{n_c} \cdot \gamma \cdot e^{-\alpha d^{\beta}_{j-i}}}{\sum_{l \neq j \in \Omega} e^{-\alpha d^{\beta}_{j-l}}} \cdot e^{-M_{disp} d_{j-i}} \right] \right) e^{-h_2}$$

the number of homers from previous cohorts

the number of strayers from other basins that survive during the journey

reduced by an anthropogenic mortality (fishery, pollution,...)

Modelling: **Dispersal and population dynamics** (adapted from De Cáceres and Brotons, 2012) **calibrated using an expert knowledge elicitation** (Delphi method, Elmer et al., 2010)

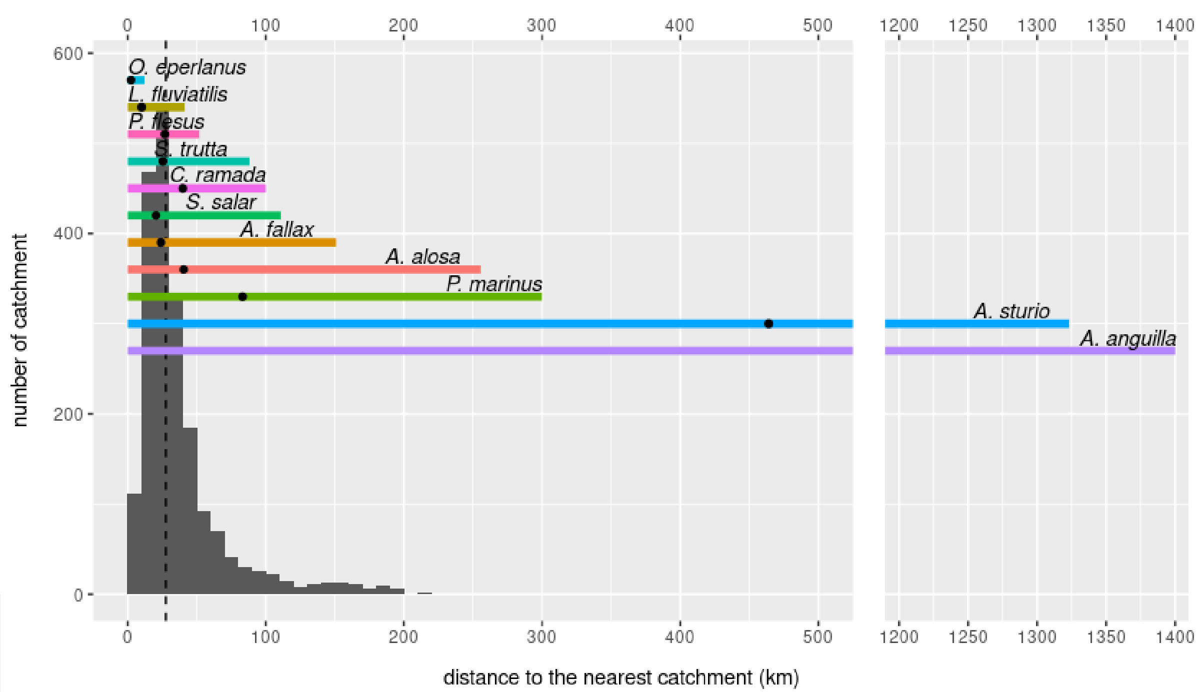
For question 3, we are trying to estimate an Allee effect. For our modeling purposes, this effect essentially prevents a population from becoming established unless there are a certain number of spawners present to participate in reproduction. This number can depend on the species, but also the size of the catchment. For this question, we are asking you to provide both the number of spawners and the size of the catchment or marine spawning ground for this group of spawners.

Question 3A: For each species, what is the minimum spawning stock size (in the number of spawners) necessary for all spawners to participate in annual reproduction? We do not need an exact number, but rather an order of magnitude that represents the ***best possible answer***. To apply this question to all species, spawning stocks can be considered as either within a catchment (anadromous) or at sea (catadromous). If a species does not experience an allee effect, select the first option (2 spawners).

	2 spawners (No allee effect)	100 spawners	1 000 spawners	10 000 spawners	100 000 spawners	>100 000 spawners
Salmon	○	○	○	○	○	○
Sea Trout	○	○	○	○	○	○
Sturgeon	○	○	○	○	○	○
Smelt	○	○	○	○	○	○
Allis Shad	○	○	○	○	○	○
Twaite Shad	○	○	○	○	○	○
Sea Lamprey	○	○	○	○	○	○
River Lamprey	○	○	○	○	○	○
Eel	○	○	○	○	○	○
Flounder	○	○	○	○	○	○
Mullet	○	○	○	○	○	○

But we faced

- inconsistencies for some parameters
  - population growth rate
  - Allee effect
- limitations
  - Dispersal kernel function



Method: **Turn-over** (Crossman et al., 2012; Allins et al. 2020)

Species sensitivity to climate change

Based on HSI, Based on density,

the sensitivity ***w*** *is* the ratio of the absolute value of change between future (2071-2100) and current (2001-2030) periods in species distribution to the extent of species distribution.

The higher the sensitivity, the greater the changes in species are.

$$w1_s^{HSI} = \frac{\sum_{b=1}^{n_b} \left| HSI_{s,b}(c) - HSI_{s,b}(f) \right|}{\sum_{b=1}^{n_b} HSI_{s,b}(f)}$$

$$w1_s^{D} = \frac{\sum_{b=1}^{n_b} \left| D_{s,b}(c) - D_{s,b}(f) \right|}{\sum_{b=1}^{n_b} D_{s,b}(f)}$$

The contributions ***c*** to the sensibility allow to rank catchment influences.

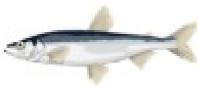
- **The sign of contribution indicates whether it corresponds to an increase or a decrease.**

$$C_b^{w1_s^{HSI}} = \frac{HSI_{s,b}(c) - HSI_{s,b}(f)}{\sum_{b=1}^{n_b} HSI_{s,b}(f)}$$

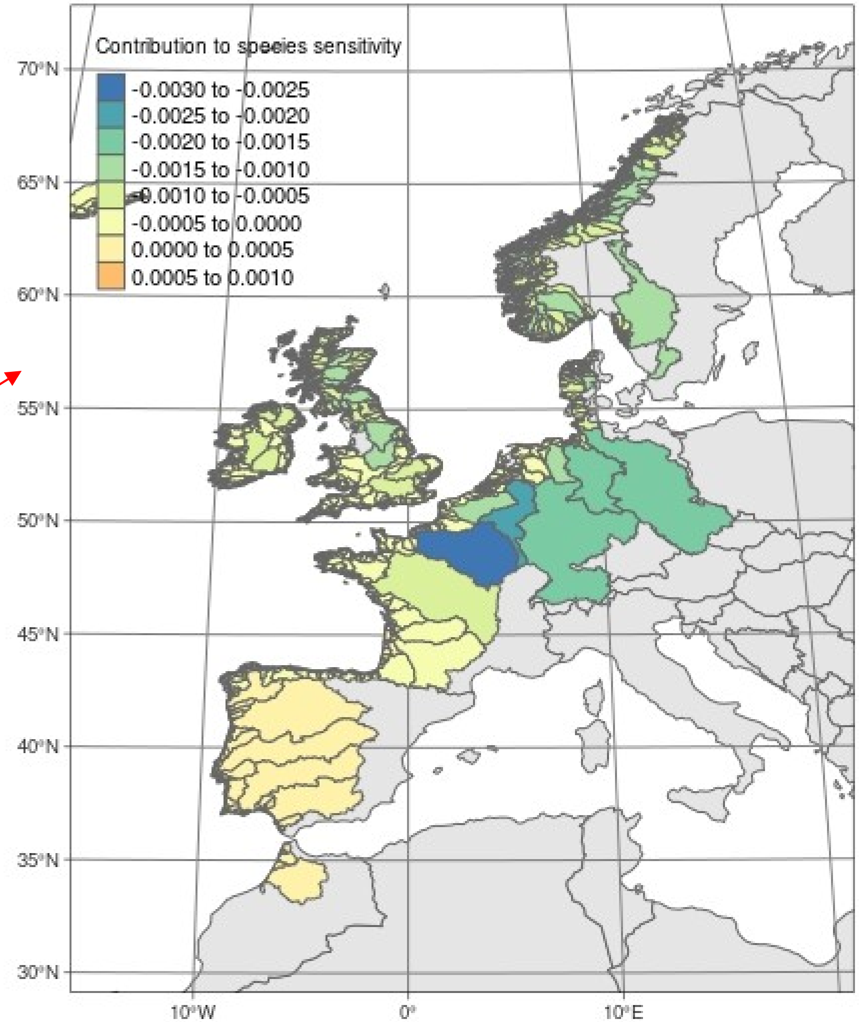
$$C_b^{w1_s^{D}} = \frac{D_{s,b}(c) - D_{s,b}(f)}{\sum_{b=1}^{n_b} D_{s,b}(f)}$$

Results: **Turn-over** (Crossman et al., 2012; Allins et al. 2020)
Species sensitivity to climate change

- Based on HSI

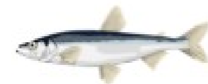


	RCP 4.5		RCP 8.5	
Species	**W**	**rank**	**W**	**rank**
A. fallax	0.0672	3	0.1418	1
P. flesus	0.0560	1	0.1440	2
A. anguilla	0.0644	2	0.1624	3
C. ramada	0.1089	6	0.1944	4
S. trutta	0.0862	4	0.2171	5
A. alosa	0.1179	7	0.2287	6
P. marinus	0.0886	5	0.2325	7
A. sturio	0.1679	8	0.3812	8
S. salar	0.2303	9	0.7156	9
L. fluviatilis	0.2475	10	0.7913	10
O. eperlanus	0.3112	11	1.1102	11

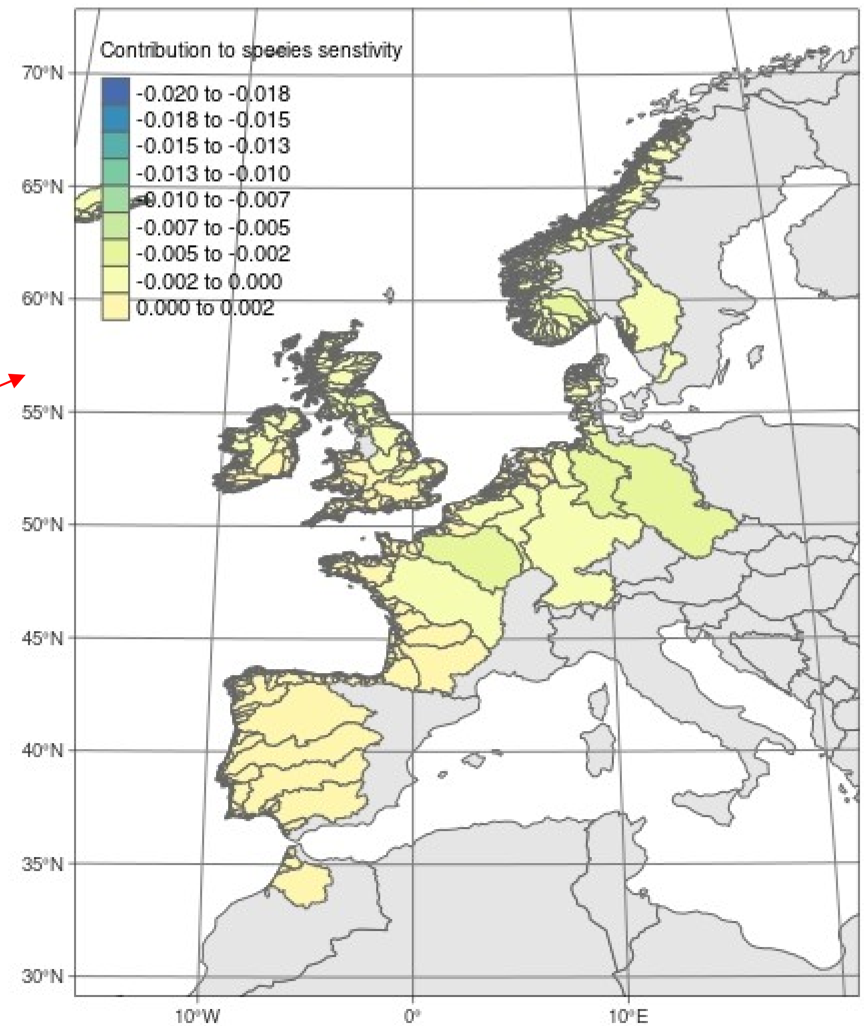


Results: **Turn-over** (Crossman et al., 2012; Allins et al. 2020)
Species sensitivity to climate change

- Based on scaled density



	RCP 4.5		RCP 8.5	
Species	**W**	**rank**	**W**	**rank**
C. ramada	0.0487	1	0.0827	1
P. flesus	0.0650	3	0.1450	2
A. anguilla	0.0646	2	0.1629	3
S. trutta	0.1340	4	0.2466	4
A. fallax	0.2060	5	0.3144	5
A. sturio	0.2569	6	0.4837	6
A. alosa	0.3290	8	0.5900	7
S. salar	0.3083	7	0.7787	8
O. eperlanus	0.5765	9	1.3993	9
L. fluviatilis	0.8139	10	1.5813	10
P. marinus	1.6804	11	1.8206	11



Method: **Turn-over** (Crossman et al., 2012; Allins et al. 2020)
Catchment sensitivity to climate change

Based on HSI, Based on density,

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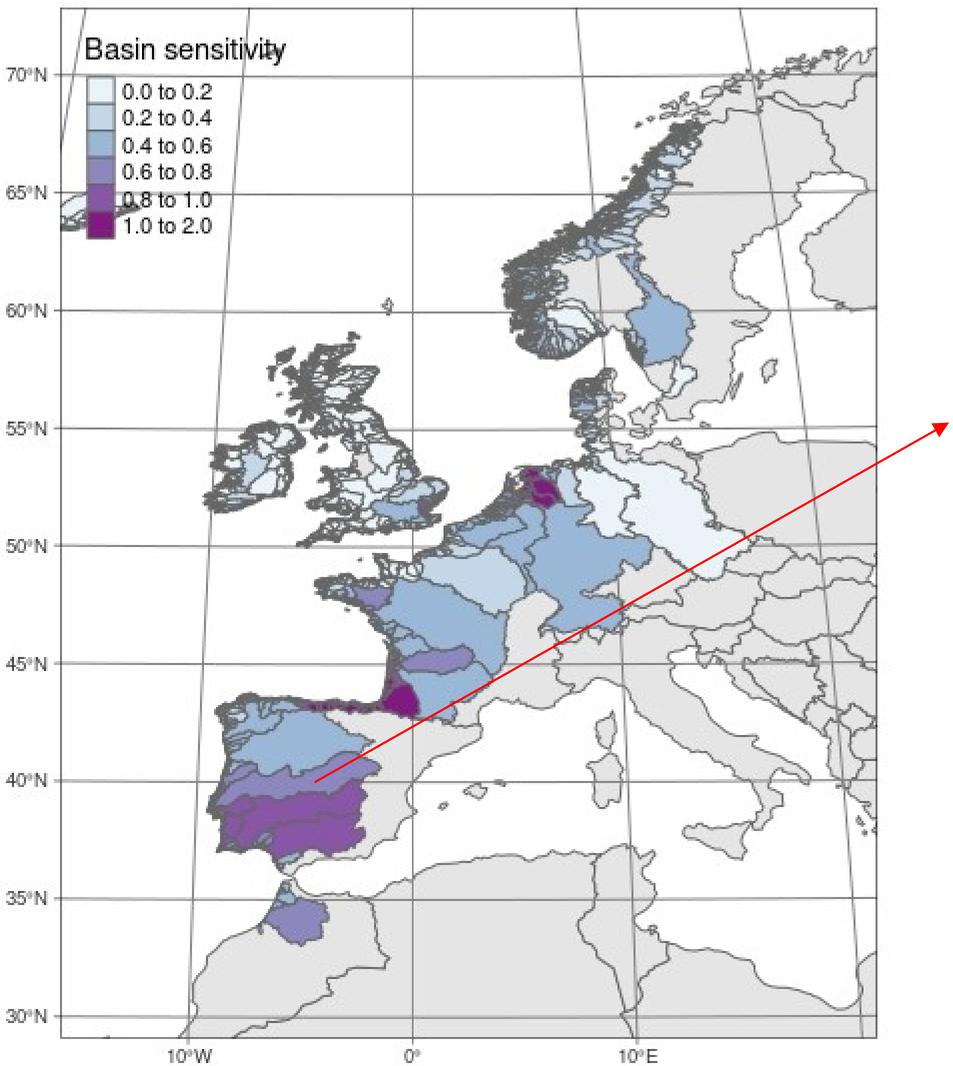
$$C_s^{w1_b^{D}} = \frac{D_{s,b}(c) - D_{s,b}(f)}{\sum_{s=1}^{n_s} D_{s,b}(f)}$$

Results: **Turn-over** (Crossman et al., 2012; Allins et al. 2020)

Basin sensitivity to climate change

- Based on HSI

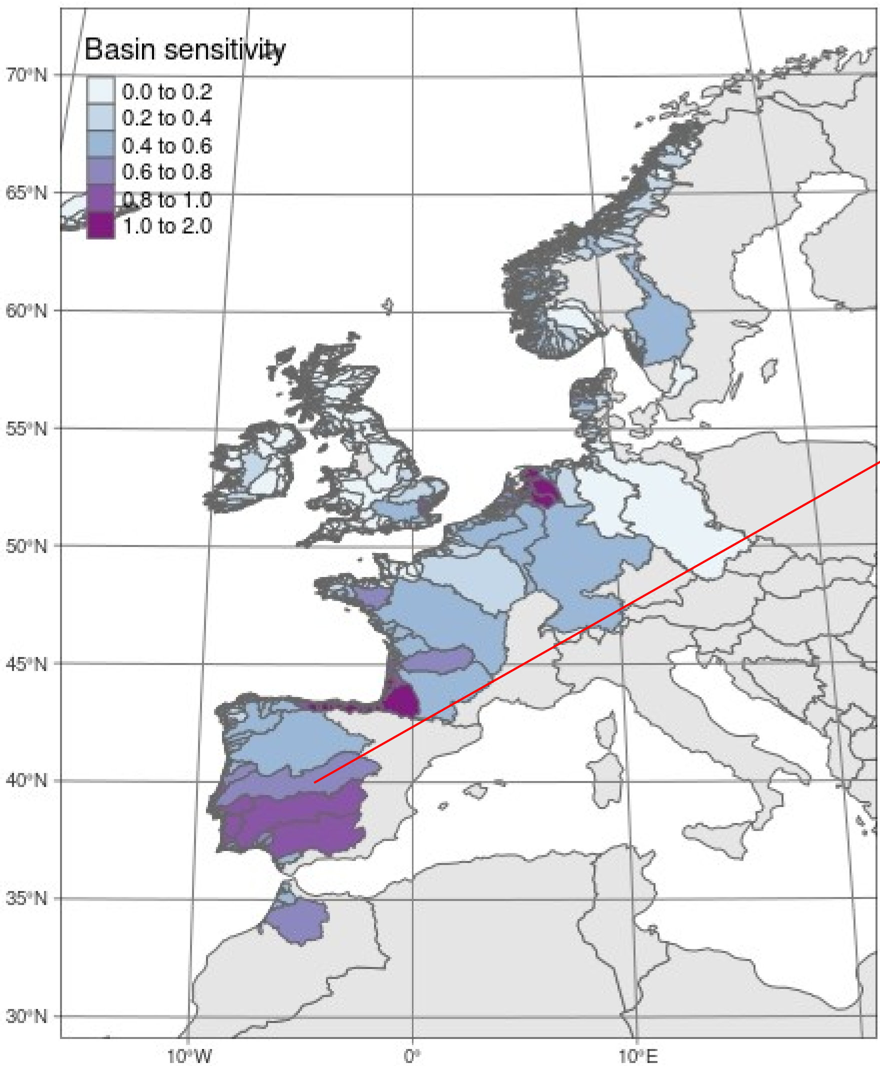


For the Tagus River

	RCP 4.5		RCP 8.5	
Species	**W**	**rank**	**W**	**rank**
P. flesus	-0.0727	1	-0.1541	1
A. sturio	-0.0190	5	-0.1367	2
A. alosa	-0.0590	2	-0.1353	3
S. trutta	-0.0485	3	-0.1238	4
P. marinus	-0.0302	4	-0.0776	5
A. fallax	-0.0024	7	-0.0479	6
L. fluviatilis	-0.0161	6	-0.0378	7
A. anguilla	-0.0006	9	-0.0129	8
S. salar	-0.0012	8	-0.0018	9
O. eperlanus	0.0000	10	0.0000	10
C. ramada	0.0003	11	0.0006	11

Results: **Turn-over** (Crossman et al., 2012; Allins et al. 2020)
Basin sensitivity to climate change

- Based on scaled density



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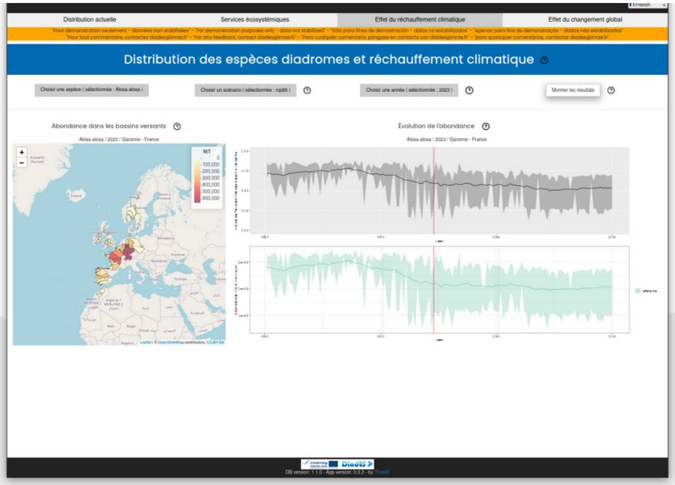
A. alosa	-0.1352	2	-0.2212	2
A. fallax	-0.0463	5	-0.2193	3
A. sturio	-0.0577	3	-0.0756	4
S. trutta	-0.0476	4	-0.0592	5
A. anguilla	0.0011	11	-0.0193	6
P. marinus	-0.0000	6	-0.0000	7
L. fluviatilis	0.0000	8	0.0000	9
O. eperlanus	0.0000	8	0.0000	9
S. salar	0.0000	8	0.0000	9
C. ramada	0.0005	10	0.0009	11

Conclusions

- HyDiaD : One-size-fit-all model
  - Somewhere between a strictly correlative model and a full mechanistic model,
  - Applied for 11 (different) species in 2010 (unique) catchments which will always be challenging,
  - Simplifies comparison of model outputs between species,
  - Allows interpretation at the level of the diadromous species assemblage.
- New insights for long-term and large-scale management of diadromous species.
- Feeds the DiadES interactive web atlas.

https://iwa.diades.org/



Thank you for your attention…

And thanks to the many contributors

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the 11 experts in the second panel,
the DiadES partners