HyDiaD, a new species distribution model for diadromous species

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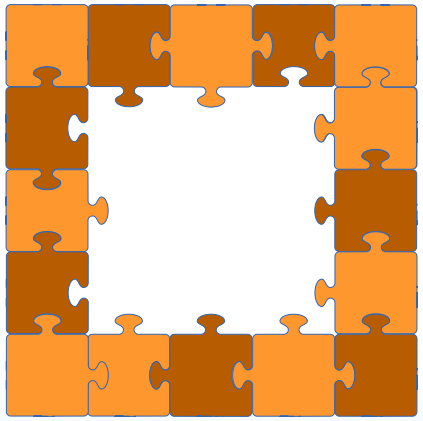
LOCAL AND GLOBAL INITIATIVES:

HOW SCIENCE SUPPORTS MANAGEMENT ACTIONS ON DIADROMOUS FISH

What is the HyDiaD model?
A hybrid model (Singer *et al.*, 2016)

That complements

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



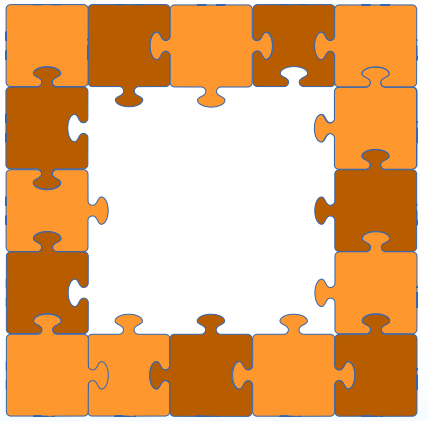
What is the HyDiaD model?
A hybrid model (Singer *et al.*, 2016)

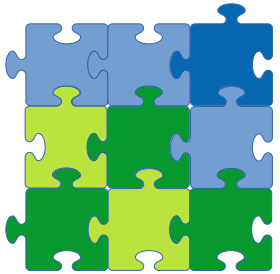
That complements

- the classical approach of **habitat suitability** (correlative model)
- with 2 modules

➢ **Dispersal**

➢ **Population dynamics**





What is the HyDiaD model?

Based on two "big" formulas (adapted from De Cáceres and Brotons, 2012)

The number of fish is calculated with

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

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 sum

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

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

the number of homers from previous cohorts

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

What is the HyDiaD model?

Application to 11 species

with variable model trust

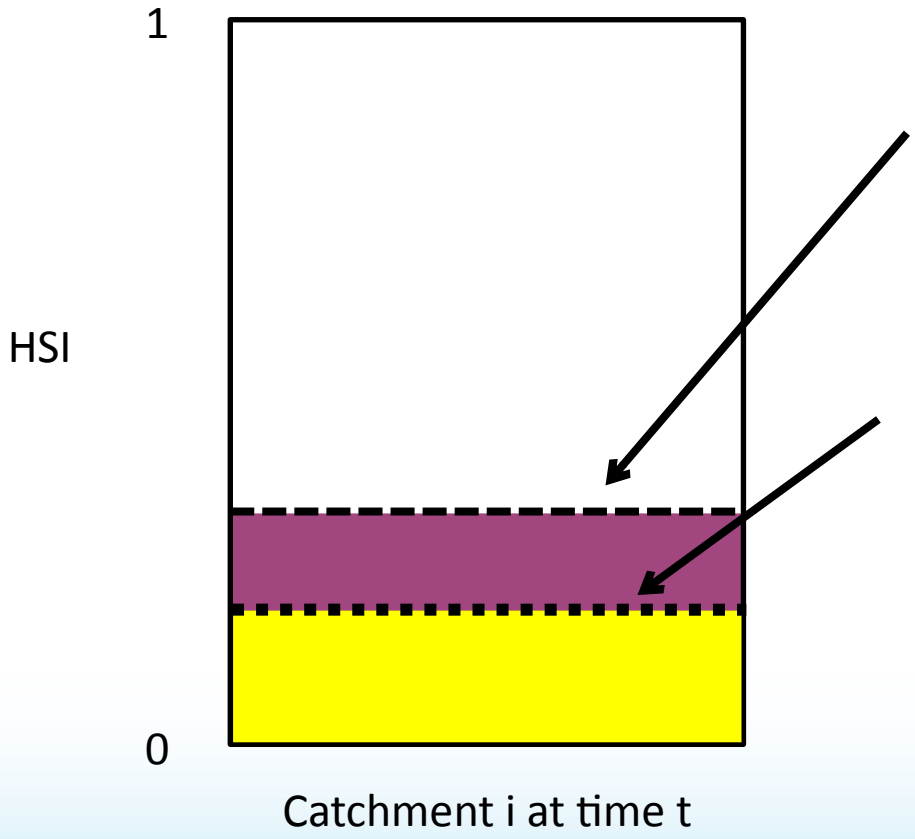
(Barber O Malley, pers.comm.)

	Trust			
Species	**habitat suitability**	**biological parameters**	**modeler expertise**	**value**
Salmo salar	1	3	4	**2.67**
Alosa alosa	0	3	3	**2.00**
Alosa fallax	0	3	3	**2.00**
Platichthys flesus	1	2	2	**1.67**
Salmo trutta	0	3	2	**1.67**
Osmerus eperlanus	1	2	2	**1.67**
Petromyzon marinus	1	3	1	**1.67**
Chelon ramada	1	1	2	**1.33**
Anguilla anguilla	1	3	0	**1.33**
Lampetra fluviatilis	1	1	1	**1.00**
Acipenser sturio	0	0	2	**0.67**

What is the HyDiaD model?

a new interpretation of species distribution: **the saturation rate**

(Barber O'Malley *et al.*, 2022)



Habitat Suitability Index for this catchment in this time step

How close is the population to the limit set by the HSI?

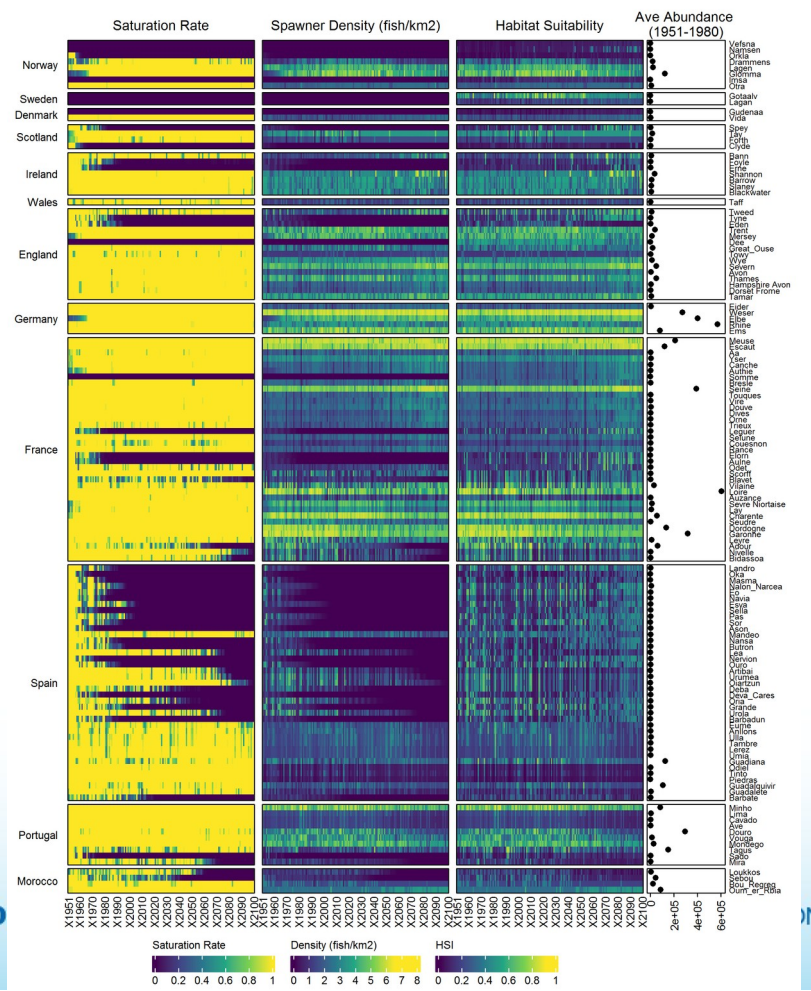
$$Saturation\ rate = \frac{N_{i,t}}{HSI_{i,t} \cdot D_{max} \cdot A_i}$$

What is the HyDiaD model?

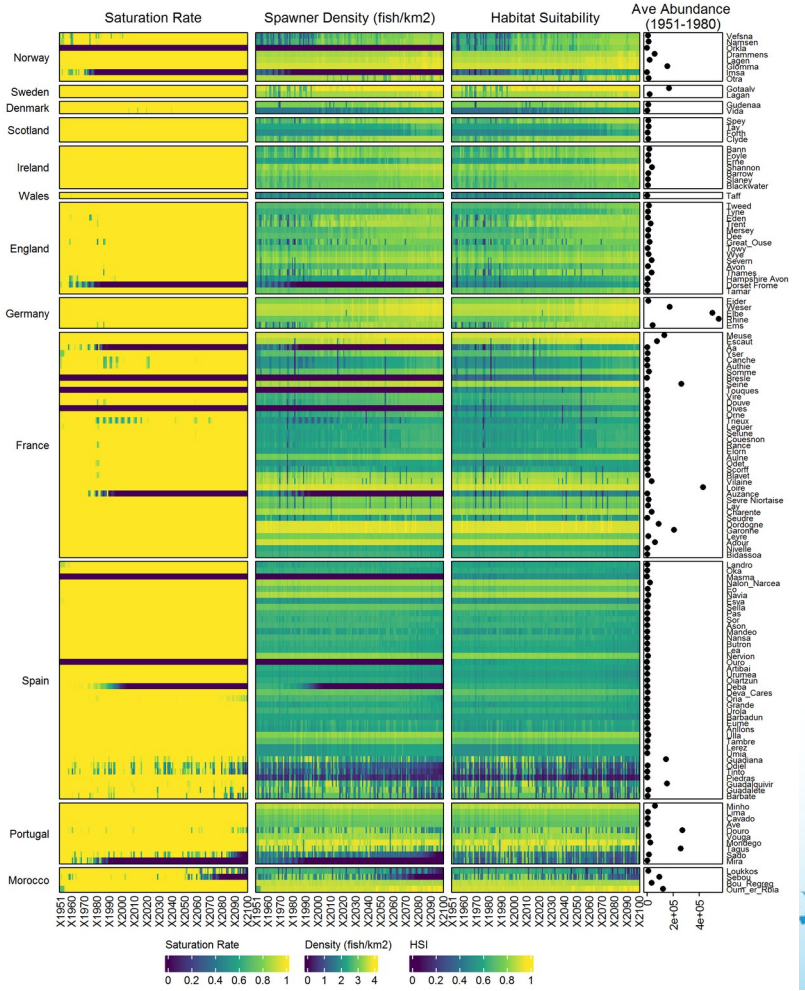
Application to shads from nowadays to the end of the century

(Barber O'Malley *et al.*, 2022)

Allis shad



Twaite shad

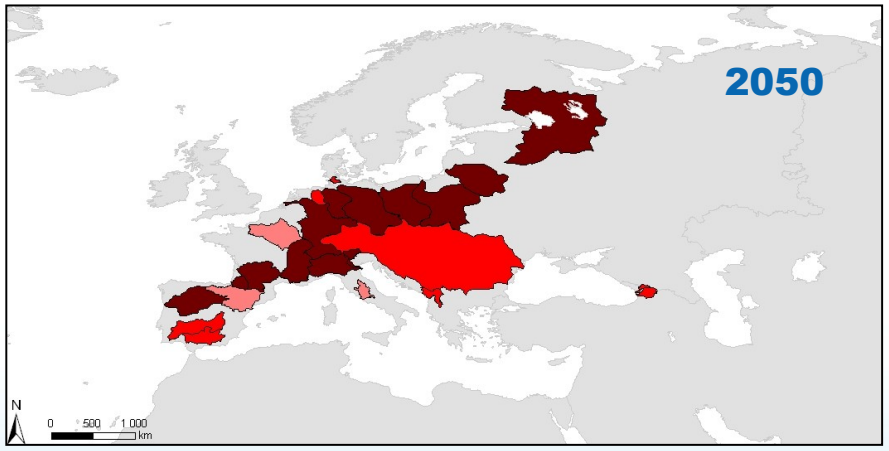


What is (not so) complicated ?
The Habitat Suitabilty

Calculated with species distribution model, often used in ecology and conservation biology to (Manel, 2001; Guisan and Thuiller, 2005; Pearson, 2007):

- project potential future changes in the geographic ranges of species
- identify sites for species reintroduction

In response to changing climate



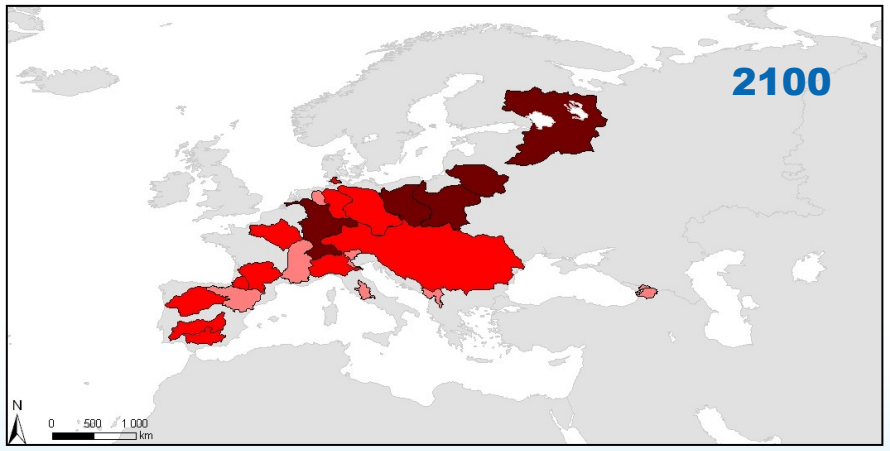
Habitat Suitabilty

[0; 0.15]

]0.15; 0.50]

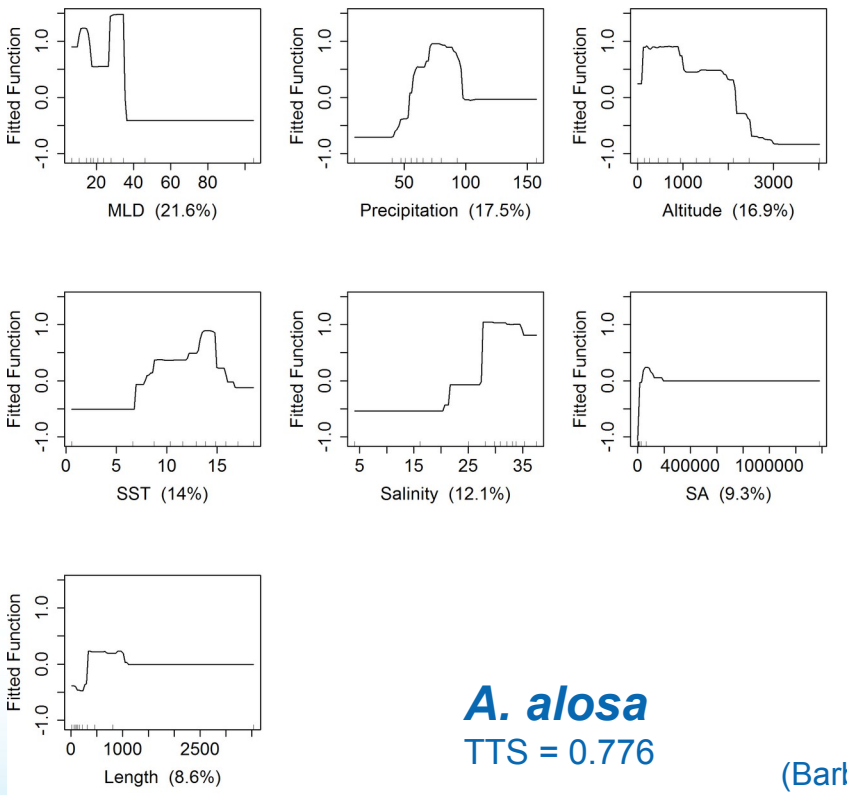
]0.50; 1]

(Lassalle et al., 2010)

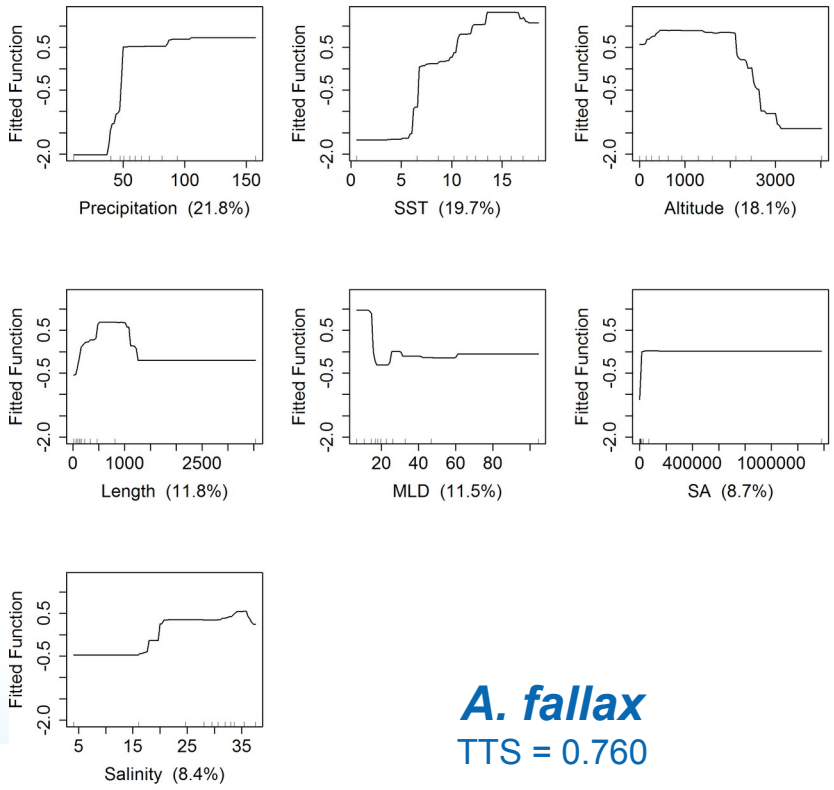


What is (not so) complicated ?
The Habitat Suitabilty calibration

using Boosted Regression Tree (Elith *et al.*, 2008) with presence and absence (around 1900) from Eurodiad 4.0 (Baber-O'Malley et al., 2022)



A. alosa
TTS = 0.776



A. fallax
TTS = 0.760

(Barber O'Malley *et al.*, 2022)

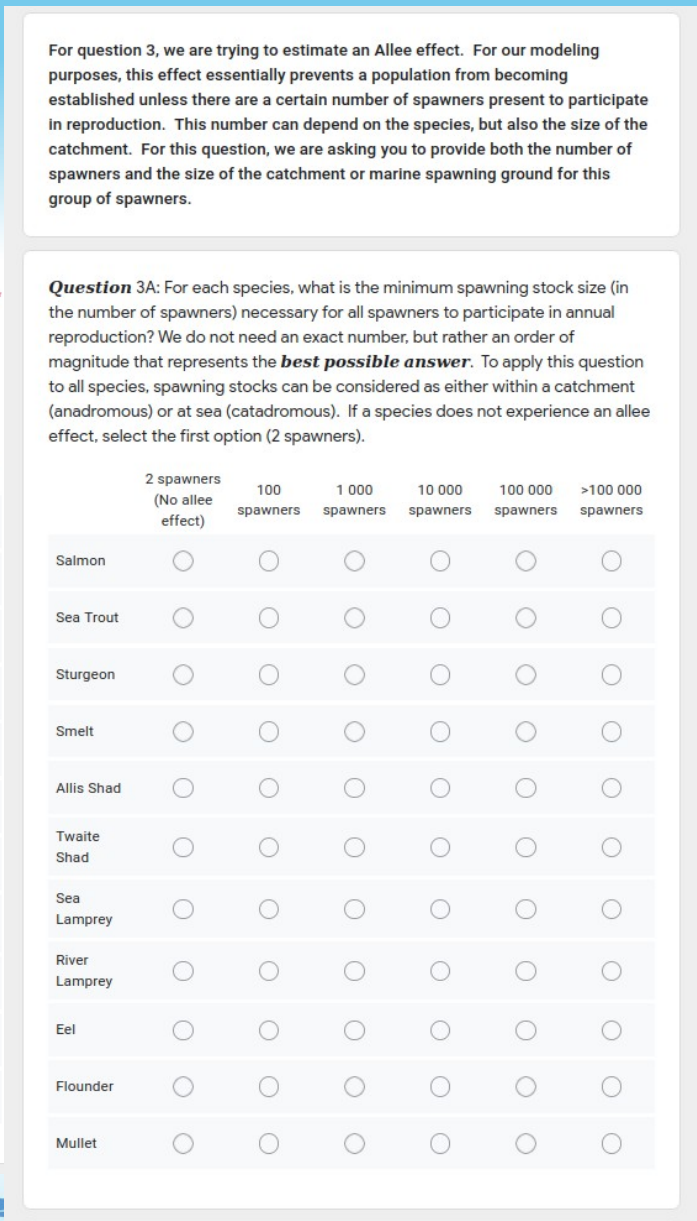
What is (still) complicated ?
The biological processes calibration

using an expert knowledge elicitation (Delphi method, Elmer *et al*., 2010)

- Solicitation of 23 experts to provide their opinion based on their experience, knowledge, and expertise working with a particular fish species
- Group averages are weighted based on a “confidence level” specified for each question and species combination (Bevington 1969; Kirchner 2006)

Confidence Level ***Question*** 2: Pick the option that best describes how confident you feel providing information about each species for Question 2 (including both parts A and B). Consider your answer as a measure of your general knowledge of this species and question that will be used to weigh individual responses when averaging the results for all participants.

	0% - Not confident	25% - Somewhat confident	50% - Confident	75% - Quite confident	100% - Completely confident
Salmon	○	○	○	○	○
Sea Trout	○	○	○	○	○
Sturgeon	○	○	○	○	○
Smelt	○	○	○	○	○
Allis Shad	○	○	○	○	○
Twaite Shad	○	○	○	○	○
Sea Lamprey	○	○	○	○	○
River Lamprey	○	○	○	○	○
Eel	○	○	○	○	○
Flounder	○	○	○	○	○
Mullet	○	○	○	○	○



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	○	○	○	○	○	○

What is (still) complicated ?
The biological processes calibration

Some inconsistencies in the “population growth rate”

fecundity (from Fishbase)	survival (from the survey)	population growth rate = fecundity * survival

« What is the estimate of natural survival between egg and adult, in the number of adults per egg? »

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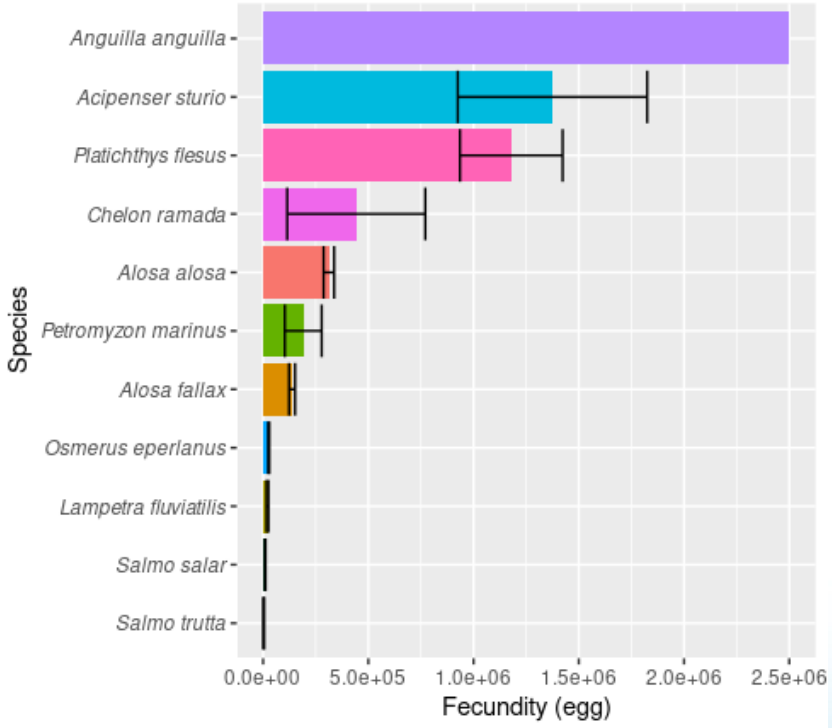
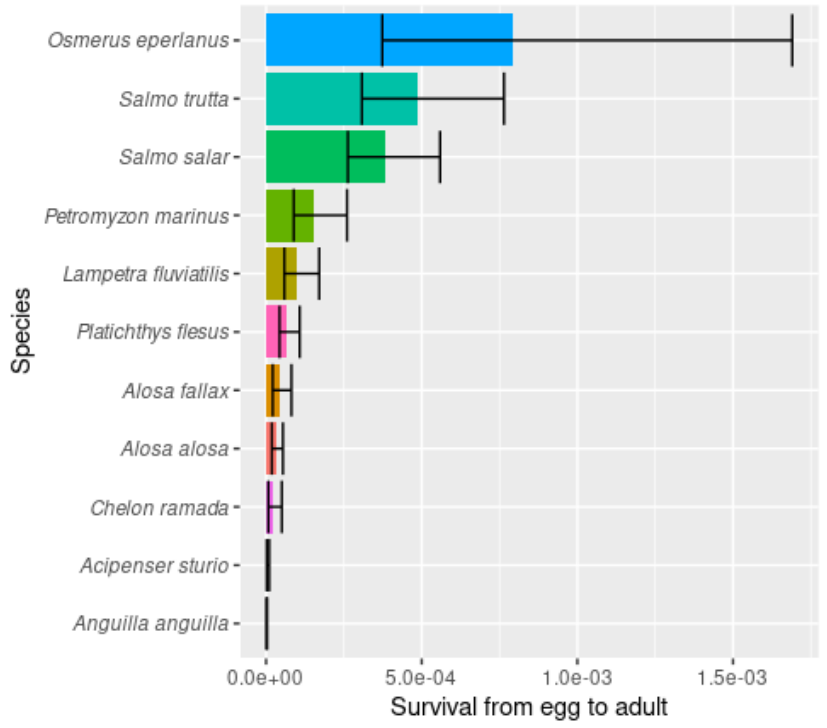
Some inconsistencies in the “population growth rate”

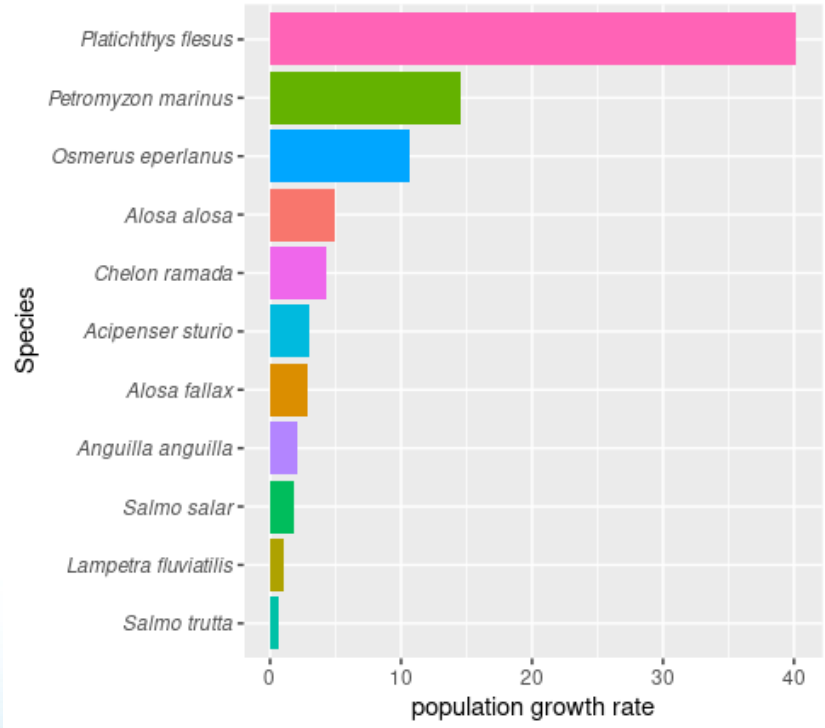
fecundity
(from Fishbase)



survival
(from the survey)



population growth rate =
fecundity * survival



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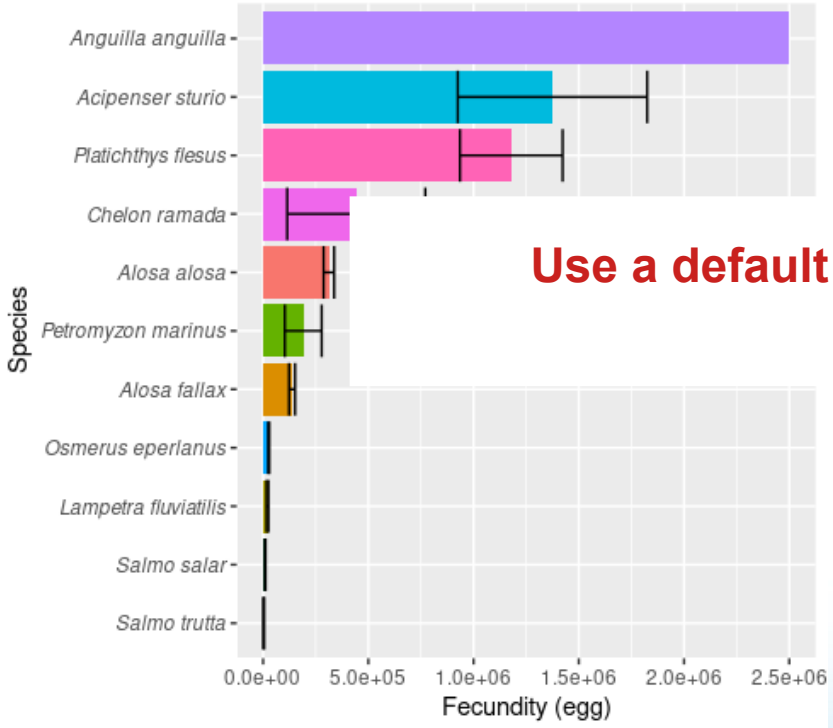
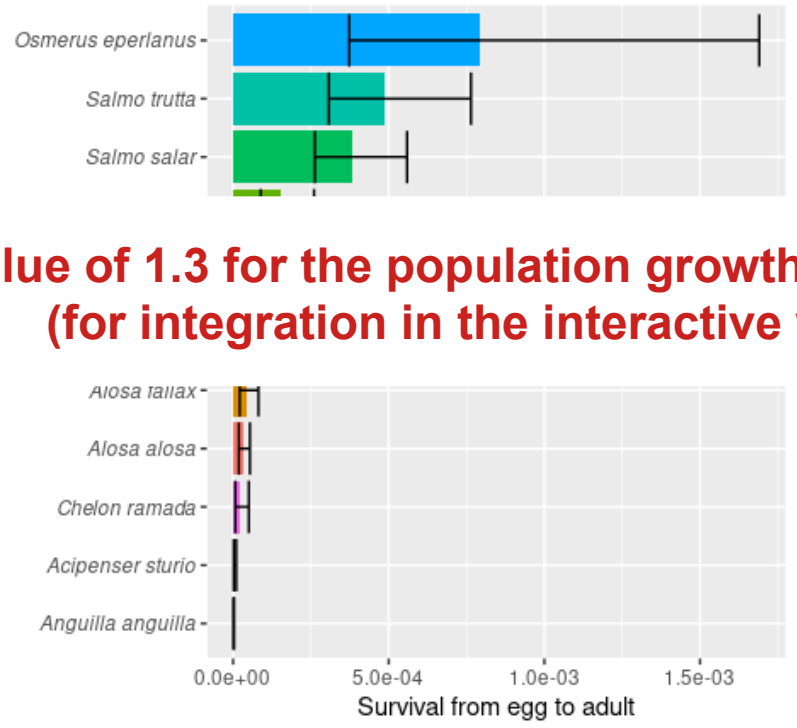
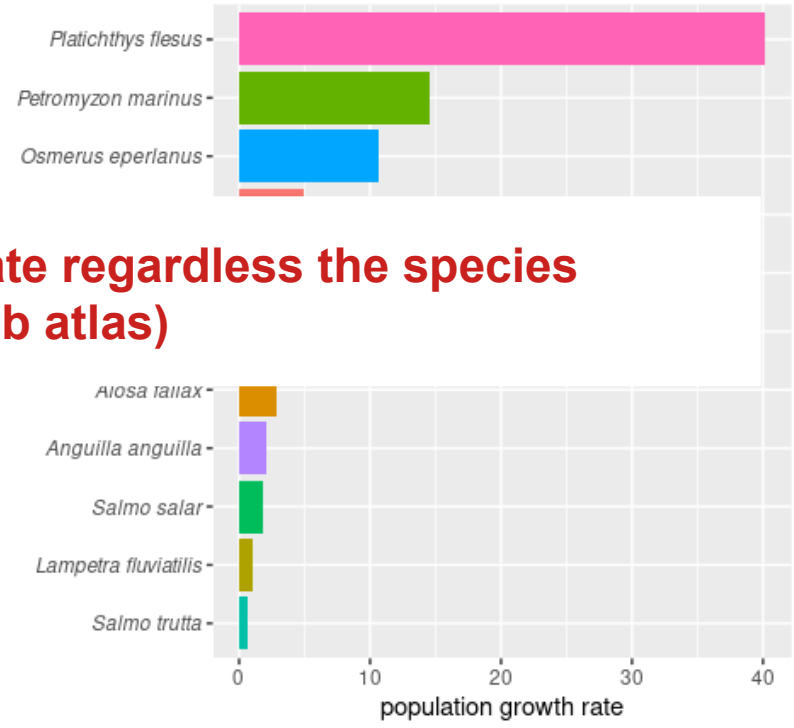
fecundity
(from Fishbase)



survival
(from the survey)



population growth rate =
fecundity * survival



Use a default value of 1.3 for the population growth rate regardless the species (for integration in the interactive web atlas)

What is (still) complicated ?
The biological processes calibration

Some inconsistencies in the “straying rate”

mean straying distance
(from the survey)

distance between catchments
(from Eurodiad database)

straying rate
(from the expert survey)

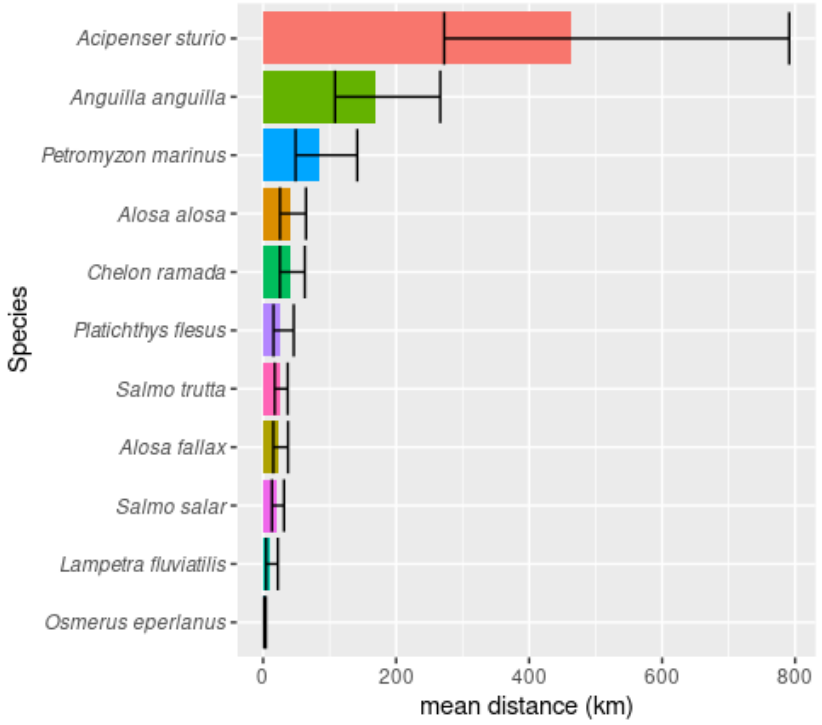
« *For all species except eels, what is the mean distance in km an emigrant is likely to disperse between its origin catchment and a new destination catchment?* »

« *For a group of juveniles leaving a catchment in a given year, what is the approximate proportion of emigrant fish (in %)?* »

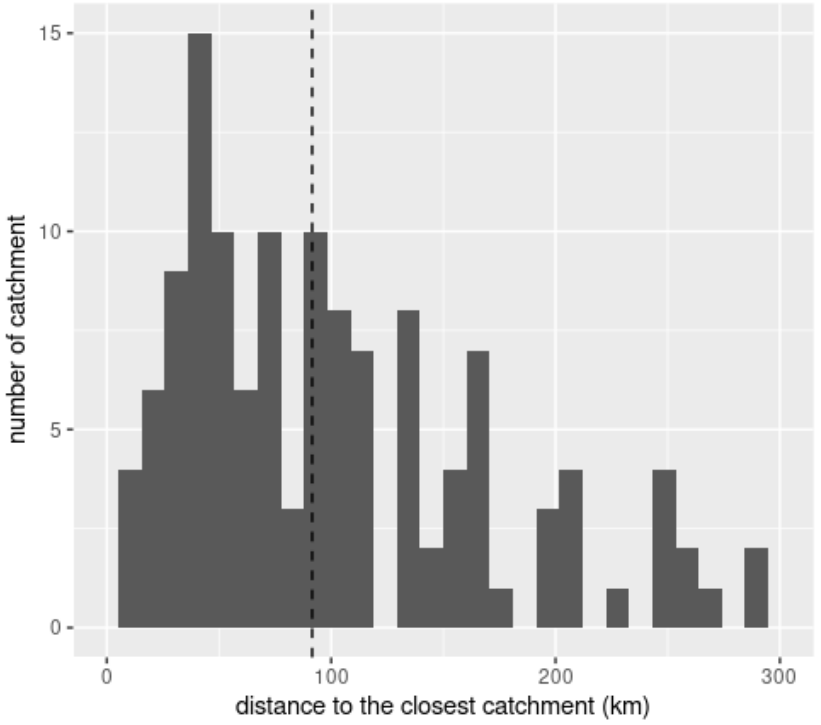
What is (still) complicated ?
The biological processes calibration

Some inconsistencies in the “straying rate”

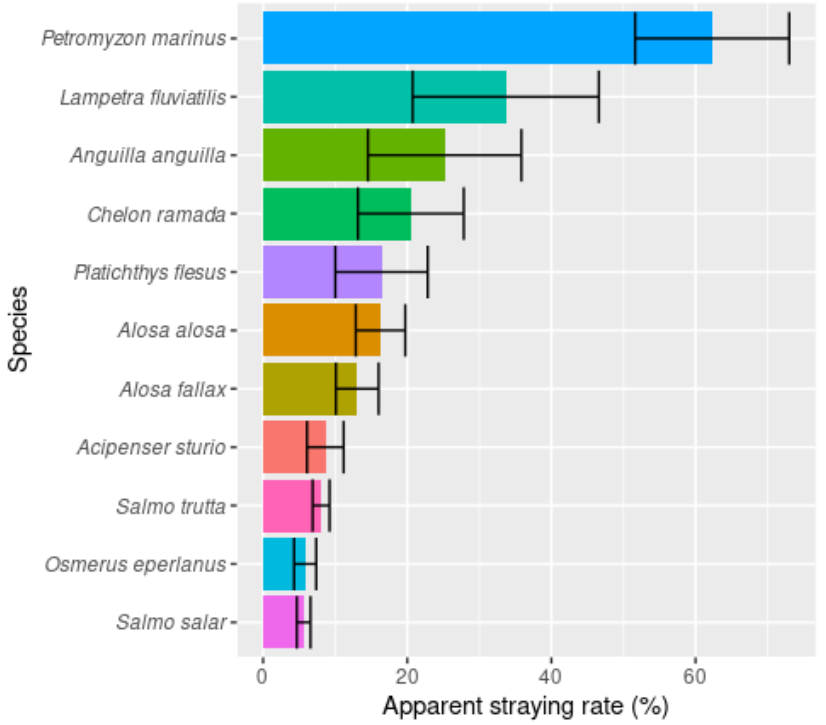
mean straying distance
(from the survey)



distance between catchments
(from Eurodiad database)



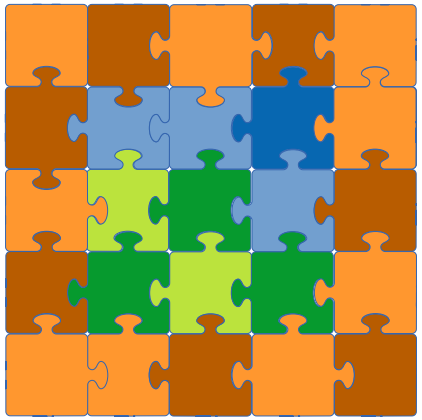
straying rate
(from the expert survey)



Conclusions

The HyDiaD model: a new tool,

- still in development (continue model calibration)
- but which already proposes a large scale, long term, dynamic perspective in diadromous species distribution



Perspectives

- Determine
  - ✓ Catchments with high turn-over of species
    - ➢ Anticipate management plan adaption
  - ✓ Species with a high turn-over of catchments
    - ➢ Identification species sensitive to global warming
- Integrate new biological process (iteroparity), anthropogenic mortalities
- Connect with ecosystem service valuation to identify ecosystem service trajectories

Thank you for your attention...