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- Exploring the effect of dispersal capacities and reproductive strategies/tactics on the structure of American shad populations across the species native range: **an approach based on a mechanistic species distribution model**

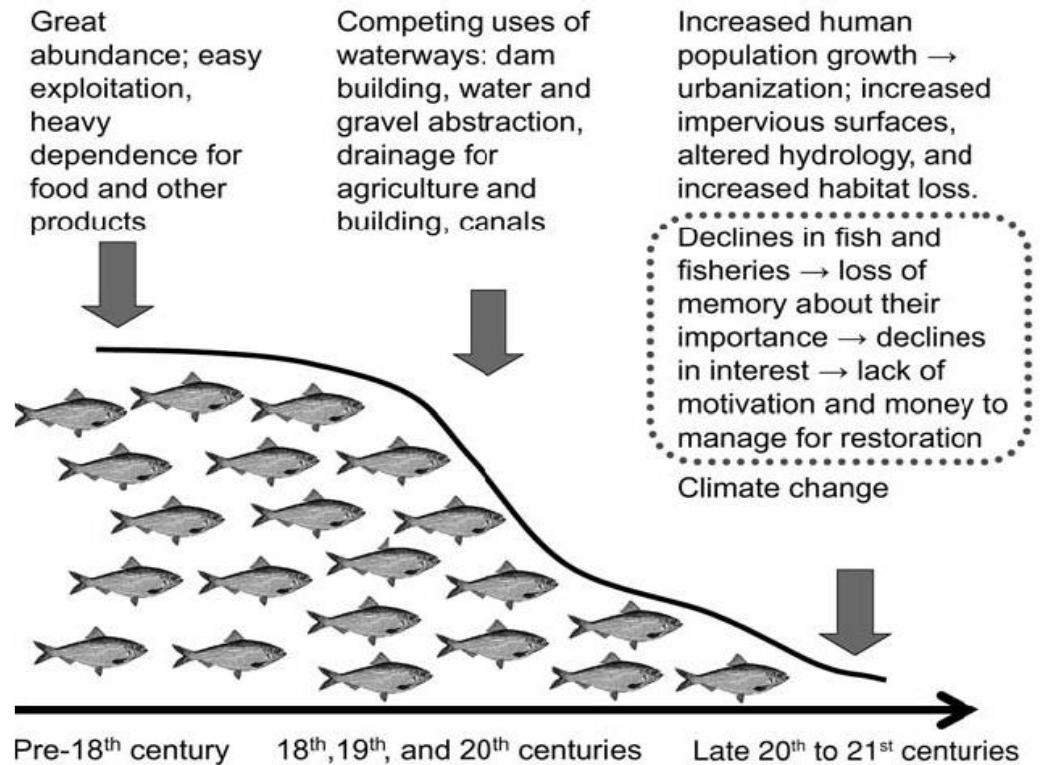
Presentation: Camille Poulet

Supervision: Géraldine Lassalle & Patrick Lambert

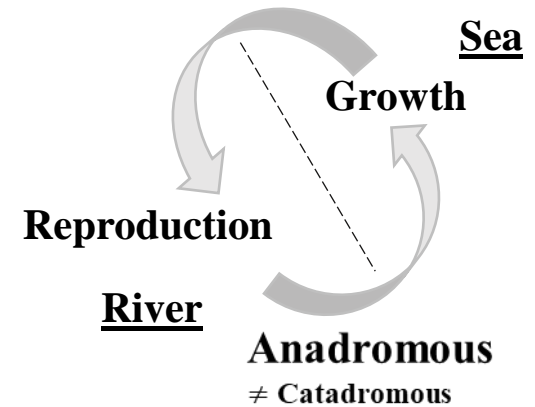


➤ Decline in North Atlantic diadromous fish populations

Diadromy: migration between freshwater and marine environments to complete the life cycle
(McDowall, 1988)



(Limburg and Waldman, 2009)



Global changes



➤ Decline in American shad (*Alosa sapidissima*) population stocks

Implementation of interstate fisheries management program

American Shad Benchmark Stock Assessment
(ASMFC, 2020)

- Assess the population stock status in all the rivers where the American shad were historically abundant
 - ❑ Review on the species ecology
 - ❑ Population size and mortality

- Provide scientific advices to fisheries managers to forecast future stock conditions

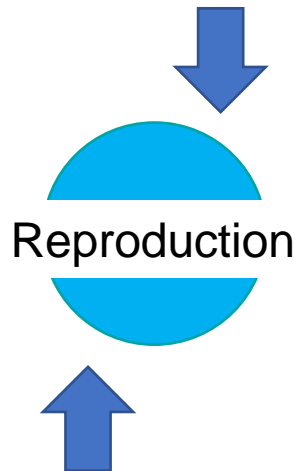


➤ Main knowledge gaps

Allee Effect:

Positive relationship between aspects of fitness and population size

Decreased per capita growth rate at small population sizes (*Encyclopedia of Ecology, 2008*)



Iteroparity

Reproducing several times during a life time

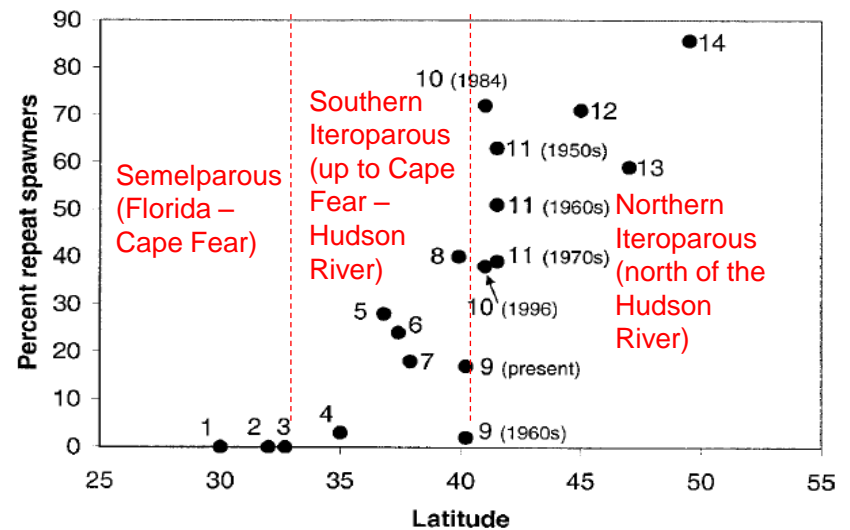


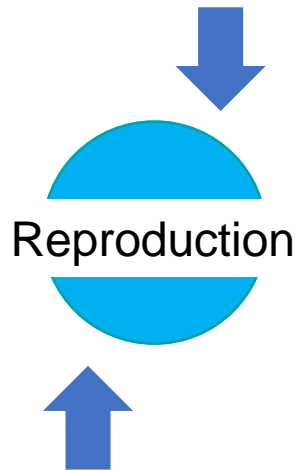
Fig.1: Percentage of fish having spawned more than once for different rivers (*Limburg et al. 2009*)

➤ Main knowledge gaps

Allee Effect:

Positive relationship between aspects of fitness and population size

Decreased per capita growth rate at small population sizes (*Encyclopedia of Ecology, 2008*)

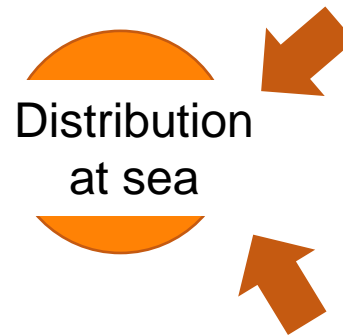


Iteroparity

Reproducing several times during a life time

Migration routes

How shads are distributed at sea? Do shads experienced the same environments?



Straying

Fish do not return to their natal rivers to reproduce (\neq homing)

➤ Objectives

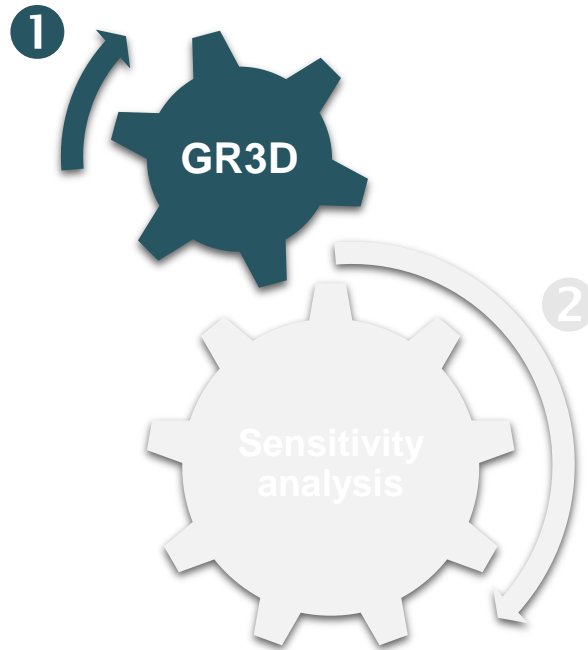
Investigate the effect of dispersal and 'reproductive strategies' on population structuring and spatial distribution

- Identify knowledge gaps and new insights to provide a better understanding of shad population dynamics over the species entire distribution range
- Helpful to find more effective management plans for the species and trigger relevant scientific studies

➤ Experimental design

HOW ?

2-step process



1

Adapt an existing species distribution model GR3D (Global Repositioning Dynamics of Diadromous Fish Distribution) to the dynamics of the American shad across its distribution range with respect to water temperature
(Rougier et al. 2014)

➤ GR3D (Global Repositioning Dynamics for Diadromous fish Distribution)



Model parameterization

Expert elicitation

- 11 American researchers
- Virtual workshops
- Online survey



SHADS - understand SHADs Distribution at Sea

Developed by Camille Poeschl, Geraldine Lussac, and Patrick Lambert (INRAE)

This questionnaire was developed under the SHADs project to complete the workshop organized on the 29th of April on shad population dynamics and distribution at sea. Results from the survey will help us to define several parameters related to dispersal and population dynamics that will be used in the mechanistic species distribution model GR3D (Global Repositioning Dynamics of Diadromous fish Distributions).

There are 9 questions in the survey which are split into three sections. Most of the questions are related to the three major points highlighted during the workshop: dispersal, growth and diurnal strategy.

There is space at the end of each section to provide questions or comments.

****Important Note for Submitting the Survey****

We have set up the survey so that responses can be edited multiple times in case there are questions about what is being asked. After you submit your survey, you can go back and edit your answers up until June 30.

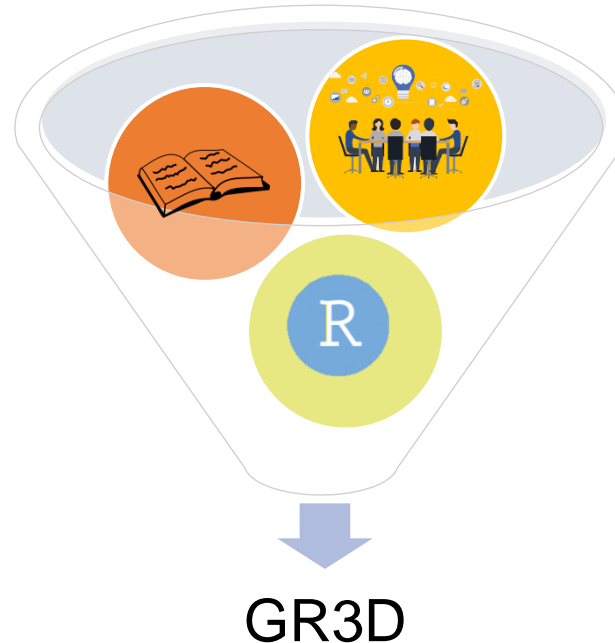
You don't have to answer every question in order to submit answers, but you do need to click submit in order for your current progress to be saved.

However, sections are independent of each other, so that means you have to answer all the questions in a given section to go to the next one.

*Obligatoire

Literature review

Find parameter values that best fit the species ecology

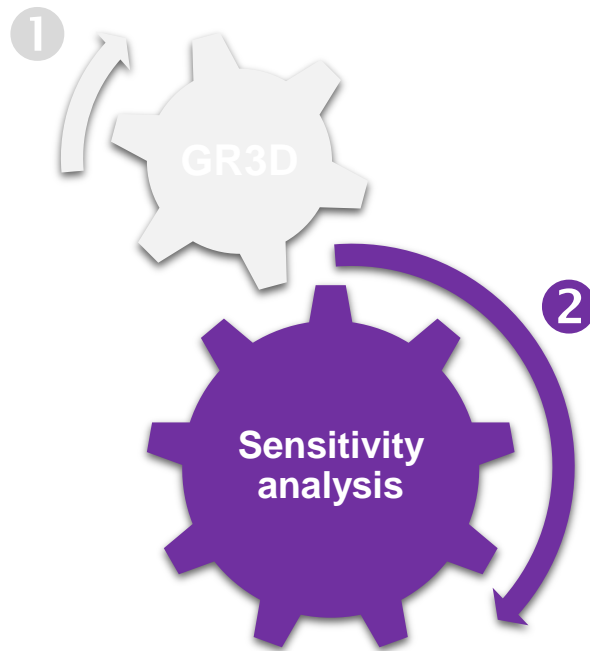


R-optimization (R Core Team 2018)

Minimize the squared distance between simulations and observations of parameter values

➤ Experimental design

2-step process



HOW ?

1

Adapt an existing species distribution model GR3D (Global Repositioning Dynamics of Diadromous Fish Distribution) to the dynamics of the American shad across its distribution range with respect to water temperature
(Rougier et al, 2014)

2

Run a sensitivity analysis to explore the influence of uncertain life-history traits on the overall population structuring through time and space (Saltelli et al. 2000; Ginot et al. 2006)

> Model outputs

Model outputs

❑ Log Likelihood

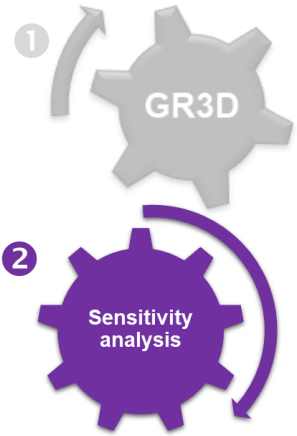
- ➔ Provide information on the global model accuracy regarding presences and absences

❑ Spawner abundances

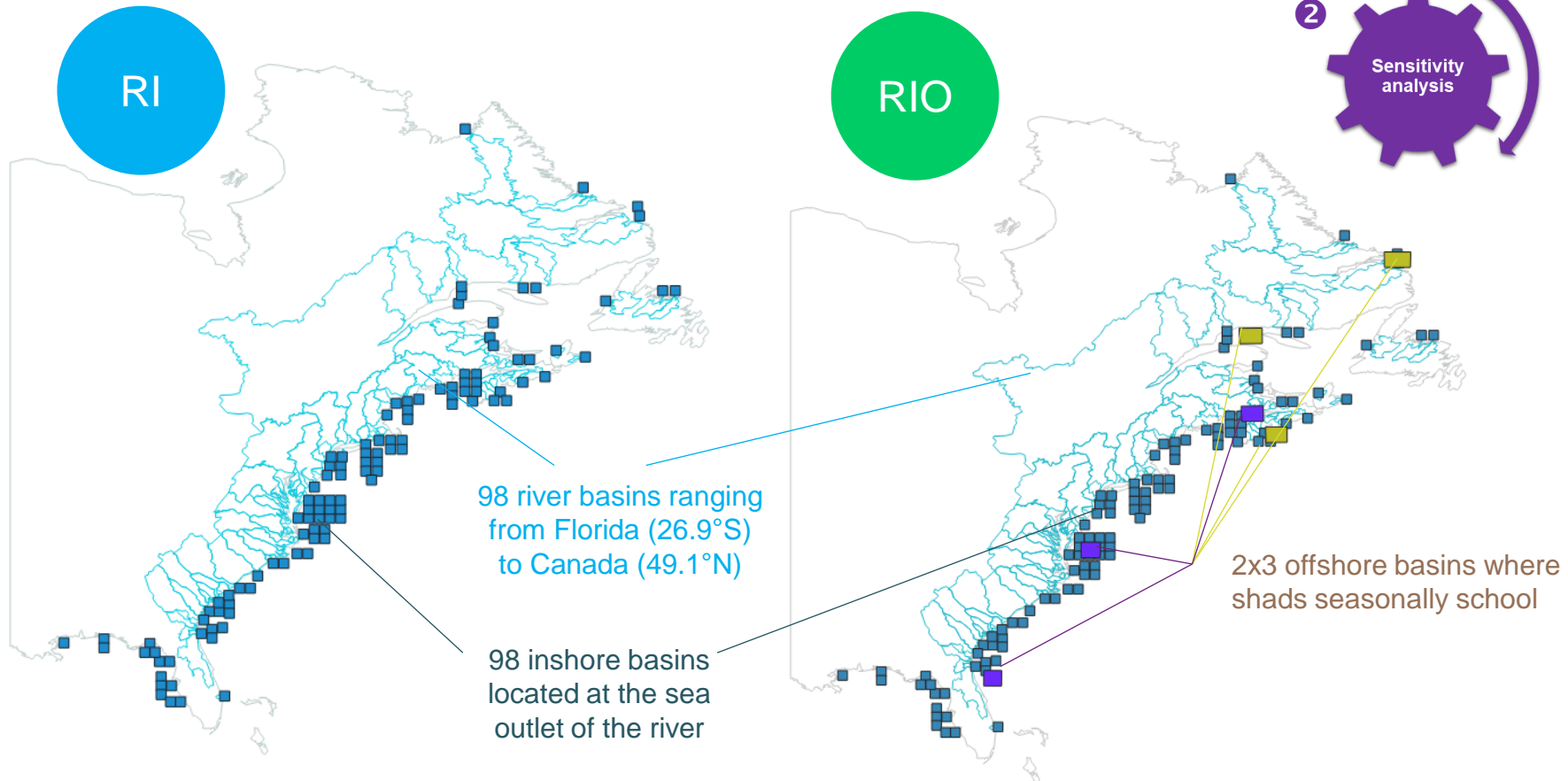
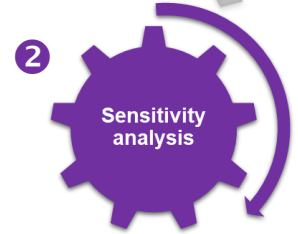
- ➔ Number of spawners entering the river in spring to reproduce across the entire species distribution range

❑ Number of emerging metapopulations *(Hanski 1998)*

- ➔ Populations that exchange more than 5% of fish are grouped into the same metapopulation until there is less than 5% of fish exchanges between metapopulations



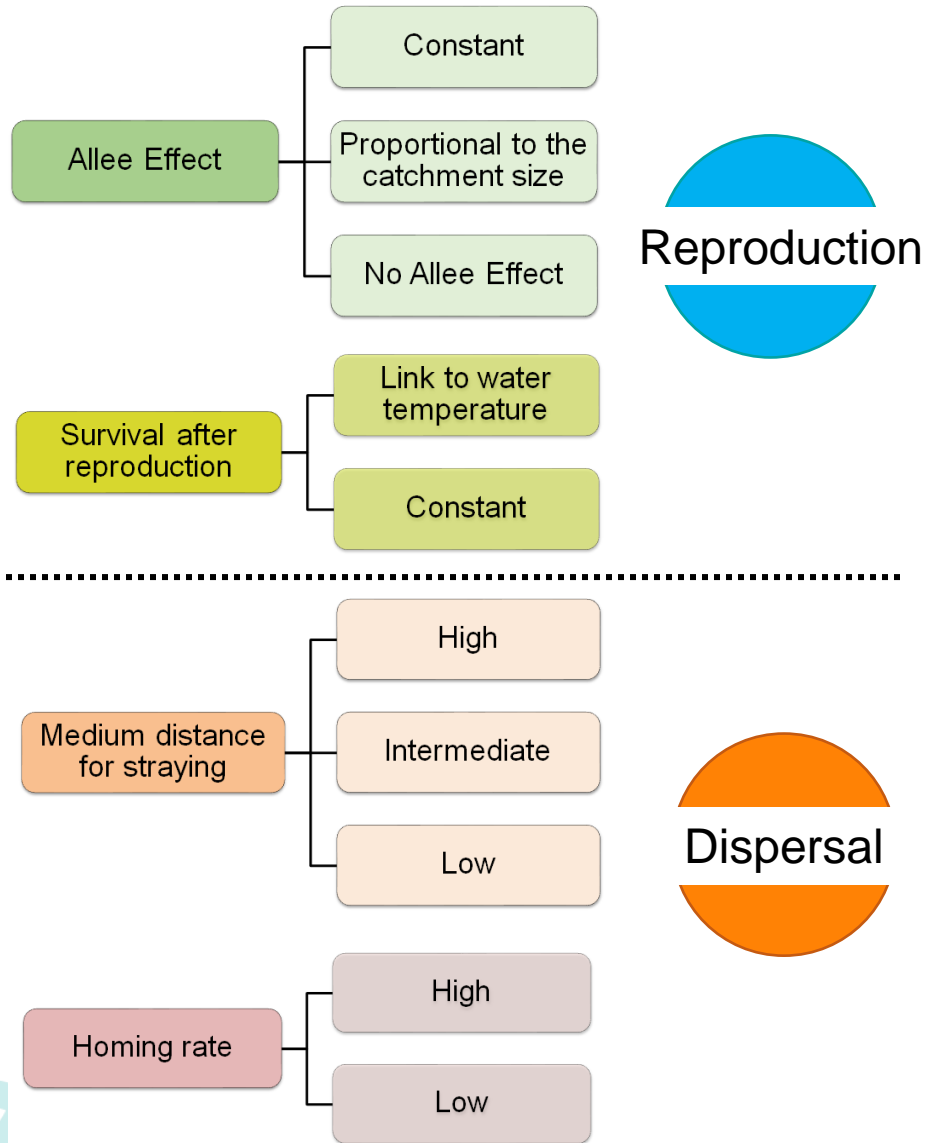
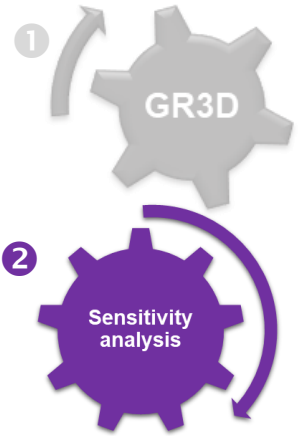
➤ American shad distribution at sea



RI: Shads do not mix in the ocean and stay in the vicinity of their natal river to grow at sea (*Rougier et al. 2014*)

RIO: Shads display seasonal trophic migrations at sea to find more suitable conditions to grow (*Dadswel et al. 1987*)

➤ Sensitivity analysis

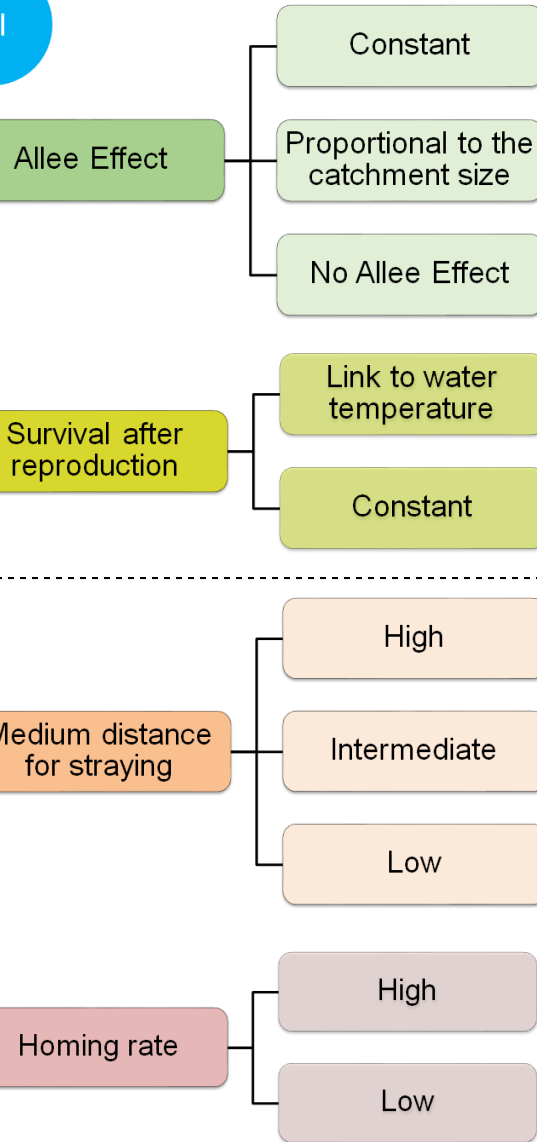


DESIGN

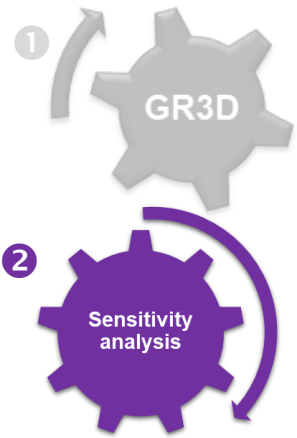
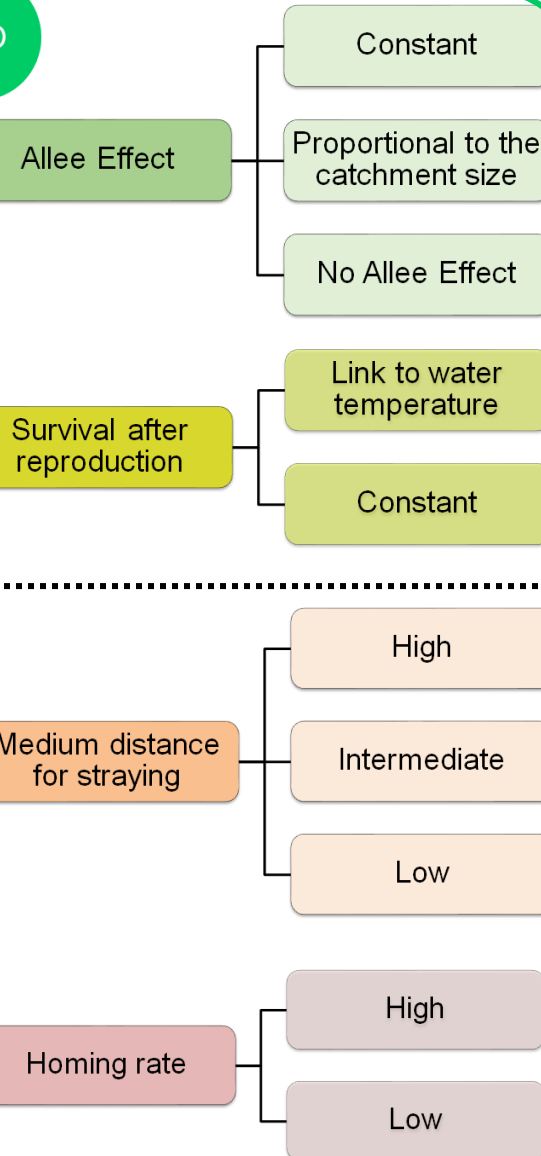
- ☑ Complete factorial plan
- ☑ ANOVA –sensitivity index (*Ginot et al. 2006*)

➤ Sensitivity analysis

RI



RIO



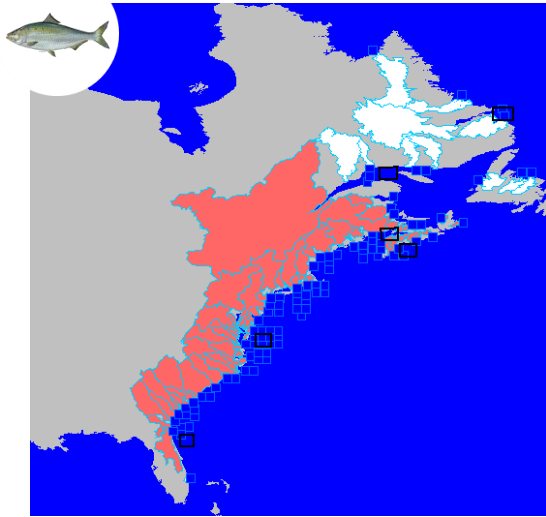
SIMULATION COMPUTATION

×10 replicates

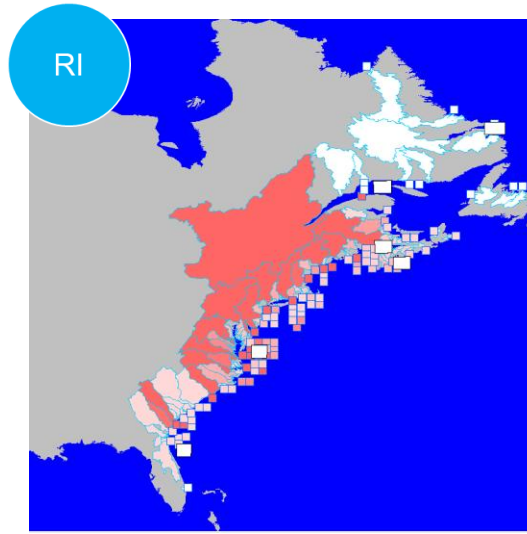
$$3 * 2 * 3 * 2 * 10 = 360$$

$$360 * 3\text{min} \sim 9\text{h}00$$

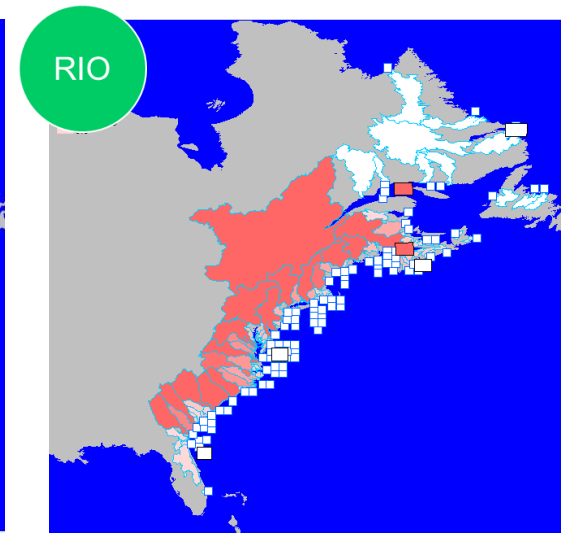
➤ Simulated distributions



Observation of the pristine distribution of American shad over 1900-1950



Simulated distribution of American shad in summer 1925 using the GR3D model under the RI hypothesis



Simulated distribution of American shad in summer 1925 using the GR3D model under the RIO hypothesis

LogL

-18.2 ± 17.4

-12.4 ± 8.88

Spawner abundances

$7.38 \times 10^6 \pm 0.56$

$9.29 \times 10^6 \pm 0.57$

Number of metapopulations

19.9 ± 7.43

21.4 ± 7.84

➤ Influence of dispersal and reproduction

Table 1. Comparison of the ANOVA global sensitivity index (TSI) for the different input factors on the 3 model outputs under the two hypotheses regarding shad distribution at sea

	RI				RIO			
	Homing	Allee effect	Straying distance	Survival after spawning	Homing	Allee effect	Straying distance	Survival after spawning
LogL	23.25	84.88	0.15	0.57	16.12	84.39	0.22	0.29
Number of metapopulations	97.01	2.86	0.21	0.16	99.18	0.76	0.02	0.02
Spawner abundances	49.10	16.31	0.52	6.09	54.52	1.45	1.30	3.60

➤ Influence of dispersal and reproduction

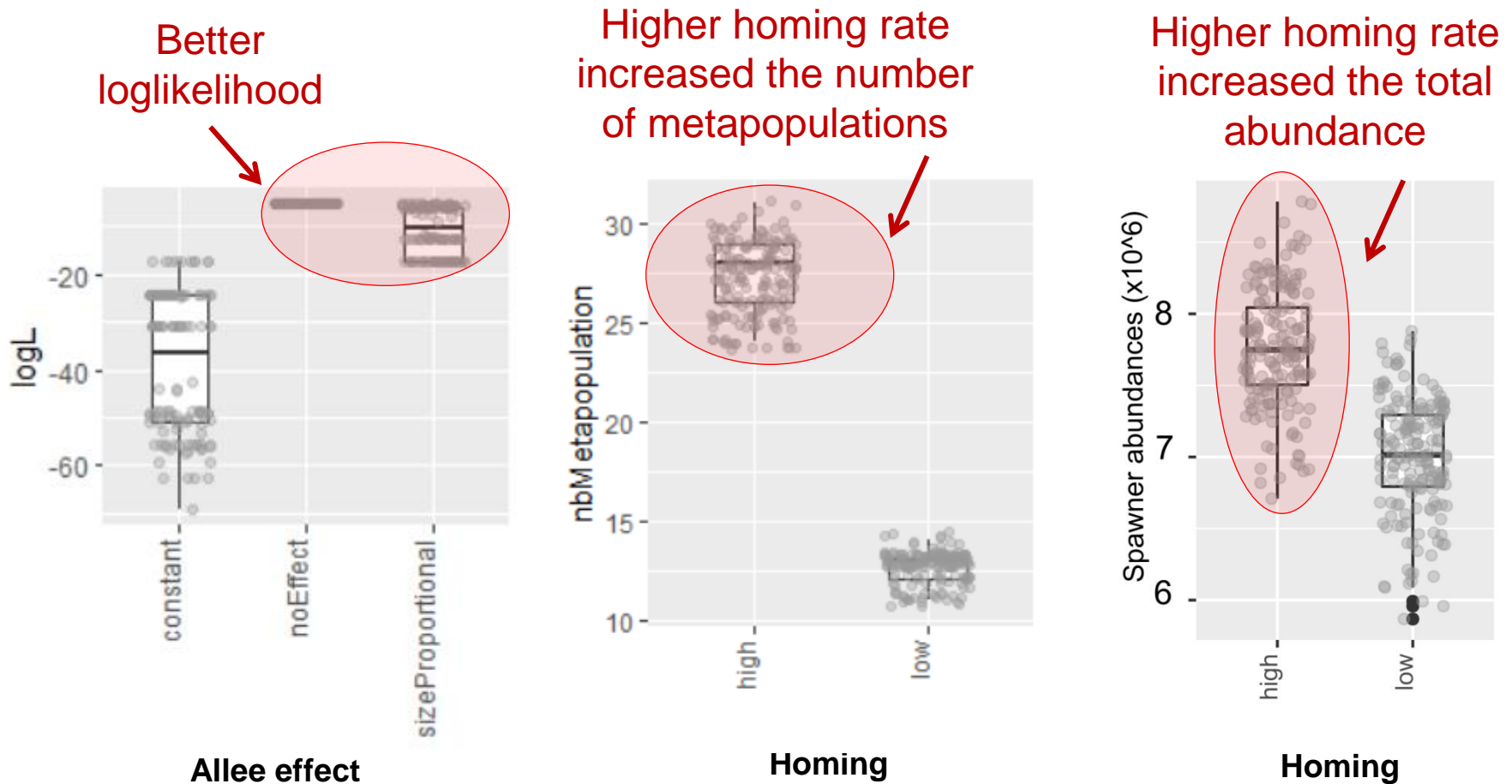


Fig 2. Influence of the main factors on the 3 considered outputs

➤ Conclusions

RECOMMENDATIONS

- ❑ Consideration of trophic migration routes at sea important for more realistic models
- ❑ Large-scale modeling approach – consider the interdependencies between river basins through dispersal abilities
- ➔ In a climate change context, dispersal abilities are closely related to range-shift dynamics (*Thomas et al. 2004*)



➤ Acknowledgments



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➤ Acknowledgments



References:

- Dadswell M, Melvin G, Williams PJ, Themelis DE (1987)** Influences of origin, life history, and chance on the Atlantic coast migration of American shad. *Am Fish Soc Symp* 1:313–330
- Ginot V, Gaba S, Beaudouin R, et al (2006)** Combined use of local and ANOVA-based global sensitivity analyses for the investigation of a stochastic dynamic model: Application to the case study of an individual-based model of a fish population. *Ecol Model* 193:479–491. <https://doi.org/10.1016/j.ecolmodel.2005.08.025>
- Hanski I (1998)** Metapopulation dynamics. *Nature* 396:41–49. <https://doi.org/10.1038/23876>
- Jørgensen SE, Fath BD, Elsevier Science (Firm) (2008)** Encyclopedia of ecology. Elsevier, Oxford
- Limburg K, Hattala KA, Kahnle A (2003)** American shad in its native range. *Biodivers Status Conserv Worlds Shads* 2003:125–140
- Limburg KE, Waldman JR (2009)** Dramatic Declines in North Atlantic Diadromous Fishes. *BioScience* 59:955–965. <https://doi.org/10.1525/bio.2009.59.11.7>
- McDowall RM (1988)** Diadromy in fishes: migrations between freshwater and marine environments. Croom Helm
- R Core Team (2018)** R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna
- Rougier T, Drouineau H, Dumoulin N, et al (2014)** The GR3D model, a tool to explore the Global Repositioning Dynamics of Diadromous fish Distribution. *Ecol Model* 283:31–44. <https://doi.org/10.1016/j.ecolmodel.2014.03.019>
- Saltelli A, Chan K, Scott EM (eds) (2000)** Sensitivity analysis. Wiley, Chichester ; New York
- Thomas CD, Cameron A, Green RE, et al (2004)** Extinction risk from climate change. *Nature* 427:145–148. <https://doi.org/10.1038/nature02121>