Modelling approaches to assess potential climate change impacts on allis shad distribution

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Context: allis shad, *Alosa alosa*, an endangered species?

Anadromous species maturing at sea and spawning in rivers (approximately between 3 and 6 years) (*Baglinière and Elie, 2000*)

- Originally distributed along the Atlantic coast from Norway to Morocco (*Baglinière and Elie, 2000*)
- Its distribution area decreased considerably since the middle of the 20th century (overfishing, dam construction, pollution…) (*Limburg and Waldman, Bioscience 2009*)
- Current IUCN status: Least Concern…

High patrimonial value and past high economic importance (*Castelnaud et al., kmae 2001*)

![Map of Europe showing distribution areas of allis shad.](image)
Context: a global changing environment, an additional pressure for the species…

“Recent climatic and atmospheric trends are already affecting species physiology, distribution and phenology” (Hughes, TREE 2000)

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Species physiology (e.g. Daufresne et al., PNAS 2009)

Species phenology (e.g. Graham and Harrod, J. Fish. Biol 2009)

Species distribution (e.g. Perry et al., Science 2005)

We studied climate change impact on allis shad distribution (and other diadromous fish) using:

- Empirical Species Distribution Models (SDMs) (correlative approach) (Lassalle, PhD 2008)
- Mechanistic Species Distribution Model (Rougier, PhD 2014)
1. The empirical species distribution models

1.1 description (Guisan and Zimmerman, Ecol. Mod. 2000)

Empirical species distribution model

Calibration

OBSERVED DISTRIBUTION

Species occurrence data (presence/absence)

GIS dataset (longitude, latitude, altitude, river flow, temperature...)

Evolution scenario of T°C, precipitation from IPCC

Predicted potential future distribution (probability of occurrence)
1. The empirical species distribution models

1.2 Allis shad application (Lassalle et al., AFS 2009; Lassalle and Rochard, GCB 2009)

Best variables explaining the distribution:
1. The longitude
2. The summer temperature at the mouth
3. The watershed area

Example of curve response:

Allis shad observed distribution around 1900

- Historical absence (around 1900)
- Historical presence (around 1900)
1. The empirical species distribution models
1.2 Allis shad application (Lassalle et al., AFS 2009; Lassalle and Rochard, GCB 2009)

- HadCM3 Climate model and A2 SRES scenario

**Observed 1900**
- Absence
- Historical presence (around 1900)

**Simulated 2100**
- Stable missing
- Stable presence
- Conditions become suitable
- Conditions become unsuitable
- Uncertainties in modelling results
1. The empirical species distribution models

1.3 Limits of the empirical SDMs

Many ecological processes are at the origin of an observed distribution and these processes are captured (but ignored) in empirical species distribution models

(Kearney, Oikos 2006; Kearney and Porter, Ecol. Lett. 2009)
1. The empirical species distribution models

1.4 Toward mechanistic SDMs

(adapted from Kearney and Porter, Ecol. Lett. 2009)
Towards mechanistic species distribution models…

Mechanistic species distribution model

Habitat
- Climate
- Topography
- Vegetation
- Soil

Traits
- Morphology
- Physiology
- Behaviour

Habitat alteration

Processes
- Survival
- Development
- Growth
- Reproduction
- Dispersal

Realized niche ~ Pop. dynamics ~ Fundamental niche

(adapted from Kearney and Porter, Ecol. Lett. 2009)

Species data (life traits, life history)

GIS dataset (longitude, latitude, altitude, river flow, temperature…)

Evolution scenario of T°C, precipitation from IPCC

Calibration

OBSERVED DISTRIBUTION

Precipitated distribution (life traits, population dynamics features)

Predicted potential future distribution

T. Rougier, River Herring TEWG - Climate Change Subgroup, 14/08/2014
We developed a **mechanistic modelling approach** aiming at assessing diadromous fish local persistence, global persistence and potential evolution of their distribution area in the context of climate change: the **GR3D model**

- Model developed in **Java** using the **SimAquaLife** framework (individual-based toolkit for aquatic life simulation) *(Dumoulin, 2007)*

- **Mechanistic simulation model**

- **Generic model designed to potentially work on several species (including virtual species) using a life-trait database of European diadromous fish (TraitDiad 1.0; Rougier, PhD 2014)*

- Model incorporating an original dispersal process and including explicitly environmental effects in processes
The GR3D model covers the entire life cycle of any anadromous species:

Six biological processes with different level of complexity in terms of parameters number (total of 42 parameters)

The breeding dispersal process concerns strayed spawners (i.e. not doing homing) that choose a reproduction basin according to:

- its accessibility
  ~ dispersal distance + fish length (Slone, Ecol. Mod. 2011) (McCauley and Mabry, TREE 2011)

- its attractiveness
  ~ watershed area (Barinaga, Science 1999; Jessop, AFS 2003)

Three processes are directly linked to water temperature
2. The mechanistic species distribution model

2.2 Allis shad application \textit{(Rougier et al., in prep)}

How to use GR3D to study the future of allis shad?

The model could help to understand the evolution of the distribution area of the species between 1900 and 2000 and could give some clues about its evolution until 2100 \textit{(Rougier et al., in prep)}

- **Step 1**: Simulate a 1900 stable distribution using GR3D
  - Observed 1900 distribution
  - Calibration

- **Step 2**: Simulate the evolution of the populations until 2000
  - Observed 2000 distribution
  - Comparison

- **Step 3**: Simulate the evolution of the populations until 2100
  - Simulated 2100 distribution with empirical SDM
    - \textit{(Lassalle and Rochard, GCB 2009)}
2. The mechanistic species distribution model

2.2 Allis shad application *(Rougier et al., in prep)*

Preliminary results:

**Step 1**

→ **GR3D shows good capacities to reproduce the 1900 observed distribution**

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**Allis shad observed distribution around 1900**

*GR3D environment*

**Allis shad simulated distribution around 1900**

*Screen capture of GR3D model output*

- [Absence](#)
- [Historical presence (around 1900)](#)
- [Presence](#)
2. The mechanistic species distribution model

2.2 Allis shad application (Rougier et al., in prep)

Preliminary results:

→ Simulations until 2100 strongly suggest that allis shad could be able to cope successfully with the ongoing climate change and the results were consistent with the empirical modelling approach (Lassalle and Rochard, GCB 2009)

Step 3

Allis shad simulated distribution around 1900 (screen capture of GR3D model output)

200 years of simulations with GR3D

HadCM3 Climate model and A2 SRES scenario

Allis shad simulated distribution around 2100 (screen capture of GR3D model output)
3. Conclusions

- Allis shad is in serious decline for a number of years... and could be impacted by climate change...

**Policy makers**
- Long term conservation plan?
- Restocking program in the Gironde basin?... a program already exists in the Rhine river (Germany) since 2008...

**Ongoing field and experimental studies**
- Large scale study on allis shad homing using otoliths and genetics (Martin et al., in prep)
- Use of bycatch survey to model marine shad distribution (Trancart et al., in press)
- Experimental study on juvenile survival under different thermal and oxygen concentration conditions (Lambert et al., in prep)

**Modelling approaches**
- **Local scale:**
  - Gironde population dynamics (Rougier et al., ICES JMS 2012)
- **Large scale:**
  - Empirical approaches (Lassalle et al., PhD 2008)
  - Mechanistic approach with the GR3D model (Rougier et al., Ecol. Model. 2014)
Thank you for your attention…

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