Ecology and conservation of North-Atlantic shads in a climate change context: inputs from a mechanistic species distribution model

Supervision

Supervisor: Géraldine Lassalle, CR, UR EABX, FREEMA lab
Co-supervisor: Patrick Lambert, IDAE, UR EABX, FREEMA lab

Host organisation

Irstea, UR EABX, Aquatic ecosystems and global changes, 50 avenue de Verdun, 33612 Gazinet-Cestas

Doctoral school

Bordeaux University, « Sciences and Environments » doctoral school (ED 304)

Description

Most north-Atlantic diadromous fish stocks are in decline due to multiple anthropogenic and environmental pressures acting on their life cycle. Among these species, Allis shad (*Alosa alosa*) experienced a severe and continuous drop in abundance despite a fishing ban since 2008 in the core of its distribution range and a reintroduction programme at its northern edge in the Rhine River (PLAGEPOMI Garonne 2015-2019). From this generalized declining trend emerged the need for modelling the distribution of main European diadromous fish species, including Allis shad, to determine the environmental factors explaining their geographic patterns (Béguer et al., 2007). Then, using these statistical models, the favourability of European watersheds under climate change for these species was assessed for the end of this century (Lassalle et al., 2008; Lassalle et al., 2009; Lassalle and Rochard, 2009). European diadromous fish future distributions were predicted to contract, expand, or remain stable, in accordance with main responses found for other taxonomic groups (Lassalle, 2008; Lassalle et al., 2008). Allis shad most likely belongs to the first category with watersheds negatively affected at its southern margin. This first modelling exercise was followed by the construction of a mechanistic species distribution model (named GR3D) that applies to any anadromous fish species (Rougier, 2014; Rougier et al., 2014). The physical environment represents Western Europe and the model was first calibrated for Allis shad. The first attempts to reproduce the historic species distribution range and simulate the impact of climate change were successful with conclusions in agreement with the ones obtained from the statistical approach described above (Rougier et al., 2015). Since then, numerous complementary works were performed on Allis shad: modelling their marine suitable habitats (Trancart et al., 2014; Dambrine, 2017), studying the populations' structure (Niarfeix, 2015; Randon et al., 2017), and the homing/straying processes (Martin et al., 2015; Randon et al., 2017). Results tended to show that marine suitable habitats: (i) followed a seasonal pattern of distribution with more offshore habitats during the fall, and (ii) that they formed a continuous "band" along the shores without major spatial structuration. Also, results highlighted significant exchanges of individuals between watersheds and supposed a metapopulation structure. These new data and knowledge must be integrated into GR3D because they could dramatically improve model realism and performances, and thus the possibility for users to address theoretical and applied questions related to climate change impacts and biodiversity conservation. Mechanistic species distribution models are not numerous despite the emerging field of predictive ecology, and they represent a unique framework to test ecological hypotheses or to apply plausible management scenarios.

The first part of the PhD will be dedicated to the improvement of GR3D simulations regarding Allis shad historic distribution in Europe. The first set of simulations was solid but tended to localize the northern distribution limit in the Seine River while it was observed in the Rhine River. First, the marine environment in the current version of GR3D is composed of a "marine watershed" positioned at the continental watershed outlet, 73 in total. This methodological choice was driven by the assertion that shads most probably live at sea close from their natal watersheds. This assertion needs to be revised based on recent knowledge regarding the marine habitat suitability (Dambrine, 2017) and the natal origin of individuals captured at sea (Nachon-Garcia et al., in prep). This "dialogue" between the marine and continental environments in G3RD must be designed to allow the application of GR3D to the American shad (*Alosa sapidissima*), a "sister" species from the north-western Atlantic ocean which is also declining and that was the focus of modelling efforts regarding its marine distribution but with other methods and outputs (Nye et al., 2009; Lynch et al., 2015; Cheung et al., 2015). This new version of GR3D will be used to assess carbon flows between the marine and continental domains operated by shads (*Alosa alosa* and *A. sapidissima*) along their Atlantic distribution and through time to estimate the "loss" of services associated to their decline. This approach of comparative ecology could enhance conclusions related to shad roles in ecosystem functioning but also will test the applicability of GR3D to other anadromous species.

Secondly, several studies supported the hypothesis of a metapopulation functioning for Allis shad (Niarfeix, 2015; Randon et al., 2017). Metapopulation limits and estimations of flows of individuals must be considered in GR3D as this information could contribute to improve the realism of shad historic distribution simulations. Furthermore, the consequences of a metapopulation functioning with "sources" and "sinks" in terms of range shift response and conservation should be explored.

Finally, after modifying GR3D as detailed above, the impacts of climate change on shad distribution will be simulated for the end of the century (~2100). Several processes in GR3D are dependent of the temperature. This exercise will be realized following three alternatives: (i) by considering all the watersheds in a pristine state, by applying different and plausible degree of pressures among watersheds (Steffen et al., 2015), and by taking into account that some basins are under restoration measures. The main prerequisite of this exercise is to correctly "reproduce" the current species distribution in GR3D by simulating the main anthropogenic pressures acting on fresh waters such as fragmentation and fisheries. The main goal of this section is to assess the relative capacity for Allis shad to operate a range shift depending on the conservation state of populations and their associated habitats.

Candidate profile

The suitable candidate will hold a Master degree or engineering degree in agronomy or environment. During his (her) academic formation and internships, he (she) was trained in the fields of climate change ecology and predictive ecology. He (she) will be familiar with notions regarding species distribution range shift and underlying mechanisms. Preferentially, the suitable candidate will be interested in the conservation of biodiversity. He (she) has solid knowledge or, at least, a strong affinity for biomathematics/bioinformatics and programming (Java for simulations and R for statistical analyses). The candidate should be self-sufficient but be able to surround him(her)self with qualified people to finalize his (her) project. Good basis in English are required as the candidate will, most probably, interact with American colleagues and make short stays in American labs during his (her) PhD.

Contacts: geraldine.lassalle@irstea.fr and patrick.lambert@irstea.fr

References

Béguer, M., Beaulaton, L., Rochard, E. (2007) Distribution and richness of diadromous fish assemblages in Western Europe: large scale explanatory factors. Ecology of Freshwater Fish 16: 221-237.

Cheung, W.W.L., Brodeur, R.D., Okey, T.A., Pauly, D. (2015) Projecting future changes in distributions of pelagic fish species of Northeast Pacific shelf seas. Progress in Oceanography 130: 19-31.

Dambrine, C. (2017) Distribution en mer de la grande alose et de l'alose feinte : apports de la modélisation empirique de niche écologique. Stade de fin d'études de l'ENSAIA – Nancy.

Lassalle, G. (2008) Impacts des changements globaux sur la distribution des poissons migrateurs amphihalins - Une approche par modélisation à l'échelle continentale. PhD Thesis, Université Bordeaux I, 244 pages.

Lassalle, G., Béguer, M., Beaulaton, L., Rochard, E. (2008) Diadromous fish conservation plans need to consider global warming issues: an approach using biogeographical models. Biological Conservation 141: 1105-1118.

Lassalle, G., Béguer, M., Beaulaton, L., Rochard, E. (2009) Learning from the past to predict the future: responses of European diadromous fish to climate change. In: *Challenges for diadromous fishes in a dynamic global environment.* Vol. 69. *AFS Symposium* (Eds. A.J. Haro, K.L. Smith, R.A. Rulifson, C.M. Moffitt, R.J. Klauda, M.J. Dadswell, R.A. Cunjak, J.E. Cooper, K.L. Beal and T.S. Avery). American Fisheries Society, Bethesda, Maryland, pp. 175-193.

Lassalle, G., Rochard, E. (2009) Impact of 21st century climate change on diadromous fish spread over Europe, North Africa and the Middle East. Global Change Biology 15: 1072-1089.

Limburg, K.E., Waldman, J.R. (2009) Dramatic decline of North Atlantic diadromous fish. BioScience 59: 955-965.

Lynch, P.D., Nye, J.A., Hare, J.A., Stock, C.A., Alexander, M.A., Scott, J.D., Curti, K.L., Drew, K. (2015) Projected ocean warming creates a conservation challenge for river herring populations. *ICES Journal of Marine Science* 72: 374-387.

Martin, J., Rougemont, Q., Drouineau, H., Launey, S., Jatteau, P., Bareille, G., Berail, S., Pécheyran, C., Feunteun, E., Roques, S., Clavé, D., Nachón, D.J., Antunes, C., Mota, M., Réveillac, E., Daverat, F. (2015) Dispersal capacities of anadromous Allis shad population inferred from a coupled genetic and otolith approach. Canadian Journal of Fisheries and Aquatic Sciences 72: 991-1003.

Niarfeix, T. (2015) Influence de la structuration spatiale de l'environnement physique dans un modèle mécaniste de distribution d'espèces – Changement d'aire de distribution de la grande alose dans le contexte du changement climatique. Stade de fin d'études de l'ISARA – Lyon.

Nye, J.A., Link, J.S., Hare, J.A., Overholtz, W.J. (2009) Changing spatial distribution of fish stocks in relation to climate and population size on the Northeast United States continental shelf. Marine Ecology Progress Series 393:111-129.

Randon, M., Daverat, F., Bareille, G., Jatteau, Ph., Martin, J., Pecheyran, C., Drouineau, H. (2017) Quantifying exchanges of Allis shads between river catchments by combining otolith microchemistry and abundance indices in a Bayesian model. ICES Journal of Marine Science.

Rougier, T. (2014) Repositionnement des poissons migrateurs amphihalins européens dans un contexte de changement climatique - Une approche exploratoire par modélisation dynamique mécaniste. PhD Thesis, Université de Bordeaux, 189 pages.

Rougier, T., Drouineau, H., Dumoulin, N., Defuant, G., Rochard, E., Lambert, P. (2014) The GR3D model, a tool to explore the Global Repositioning Dynamics of Diadromous fish Distribution. Ecological Modelling 283: 31-44.

Rougier, T., Lassalle, G., Drouineau, H., Dumoulin, N., Faure, T., Deffuant, G., Rochard, E., Lambert, P. (2015) The combined use of correlative and mechanistic species distribution models benefits low conservation status species. PLoS ONE 10, e0139194.

Steffen, W, Broadgate, W, Deutsch, L, et al (2015) The trajectory of the Anthropocene: The Great Acceleration. The Anthropocene Review 2: 81-98.

Trancart, T., Rochette, S., Acou, A., Lasne, E., Feunteun, E. (2014) Modeling marine shad distribution using data from French bycatch fishery surveys. Marine Ecology Progress Series 511, 181-192.