Adaptability and responses of young stages of diadromous fish to environmental conditions, shads and chemical contamination case study

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Summary

Diadromous fish are among the most endangered aquatic species and their populations exhibited drastic decline of abundance. Global changes are generally mentioned as responsible but it is however very difficult to clearly identify and weight the impacts of environmental and anthropogenic factors. This thesis focuses on the adaptability of embryos from two shad species to environmental conditions, especially those encountered on their spawning grounds. We will pay a special attention to the chemical contamination. This proposal will combine on both species i) an ecophysiological approach to get reference knowledges on embryo stages; ii) ex situ expositions to understand the responses of embryo to environmental conditions on spawning grounds. To do this we will develop and use different biomarkers (physiological, behavioural…) and also new molecular methodologies "omics". The ex situ exposure method will be used to address two key points to assess the quality of the environment, i) the vulnerability of shads populations, testing individuals from different origins; ii) to propose a diagnosis approach.

Context

Introduction

Importance of embryo-larval stages

Due to the sensitivity of young specimens to temperature, hypoxia and contaminants the embryo larval phase is a critical period with numerous lethal and sublethal effects (Secor & Gunderson, 1998 ; Niklitschek & Secor, 2009 ; Aluru et al., 2010 ; Lo et al., 2011 ; Barjhoux et al., 2012 ; Barjhoux et al., 2014). Under strong environmental influence this life period is a key component of the population dynamics and therefore of the viability of populations. It explains probably an important part of the realised ecological niche of the species.

Diadromous fish, goods and services

Diadromous fish constitute a small group of 160 fish species (0.6% of known fish species). To achieve their life cycle they have to use habitats in both marine and rivers and to migrate between them. Two third of them reproduce in freshwater (anadromous species) and realize most of their growth at sea (salmons, sturgeons, lampreys…). They could be found mainly in cold to temperate waters in both hemispheres. The remaining third reproduces in marine water (catadromous species) and mainly achieves its growth in freshwaters (eels, mullet…). They could be found in tropical to temperate areas of the southern hemisphere (McDowall, 1988). There are various goods and services associated to these species: livelihoods resources in Africa (Charles-Dominique & Albaret, 2003) and Asia (Blaber et al., 2003), gastronomic resources in the rest of the world (caviar, smoked fish…), support of recreation (fisheries, ecotourism) (Stoll et al., 2009), heritage and symbols with important economic weight, but also an original component of ecosystems, single flow of materials

from the sea to freshwaters (Naiman et al., 2002 ; Helfield & Naiman, 2006)(Figure 1).

Figure 1 : Some illustrations of our relationships with diadromous fish : sturgeonss caviar, Atlantic tomcod *Microgadus tomcod* winter fishery under the ice in Quebec, smelts *Osmerus eperlanus* on the armorial bearings of a small French city and the Allis shad fish of the year 2007 in Germany.

These species have been exhibiting a strong decline from the middle of the 19th century (Limburg & Waldman, 2009). Reasons of this decline vary depending on species and regions but in most cases that results from a combination of unpassable dams, habitats of poor quality and non-sustainable exploitation. Some of them are now listed as more or less threatened and benefit of cautious management or even conservation actions. To improve the status of these species we need to get a better understanding of their ecophysiology, ecology and populations dynamics. We also need to characterise their sensitivity to other pressures as the chemical contamination.

Context and aims of the thesis subject: european shads and their decline in the Gironde Garonne Dordogne

Their ecology

Alosa alosa and *Alosa fallax* are two migrating species of clupeids. Until the middle of the XXth century Allis shad *A. alosa* was present from Marocco to Germany (Baglinière et al., 2003), while the twaite shad *A. fallax* was distributed from Italy to Germany and British Isles (Aprahamian et al., 2003). Their diets at sea are different, Allis shad mainly feed on small preys of the plankton and twaite shad eat larger preys as small fish and crustaceans (Aprahamian, 1989 ; Oesmann & Thiel, 2001).

Adults' migration dynamics have been widely analysed in rivers, the triggers (Aprahamian & Lester, 2001 ; Lambert et al., 2001) or its son progress (Boisneau et al., 1985 ; Aprahamian & Aprahamian, 2001 ; Rochard, 2001). Several works addressed their reproduction focusing on physiology (Bengen, 1992 ; Gonnet et al., 2016) or behaviour (Boisneau et al., 1990). Figure 2 represents the life cycle of Allis shad. Shads reproduce in freshwaters in spring (April-May) swimming up the rivers, juveniles go rapidly to the ocean where they realise most of their growth (Baglinière & Elie, 2000 ; Aprahamian et al., 2002). During their spawning run Allis shad generally migrate more upstream that twaite shad which generally spawn in tidal freshwater areas (Caswell & Aprahamian, 2001 ; Esteves & Andrade, 2008). Eggs of small size (1-2 mm) and slightly sticky are explused in the water column during a special behavioral sequence characterised for *A. alosa* (Boisneau, et al., 1990 ; Belaud et al., 2001) and *A. fallax* (Caswell & Aprahamian, 2001) for long time (Roule, 1924). Their development is rapid (4_8 days for *A. alosa* when temperature is over 17°C and 3 to 5 days for *A. fallax*) within gravel and substratum cavities (ICES, 2015). Our knowledge is very limited concerning young stages in freshwater. At hatching larva measures 7-12 mm (TL) and is found in low current areas (Véron et al., 2003). Some works about older shad stages in freshwater focused on the ecology and parasites of juveniles from the Minho river (Mota

& Antunes, 2012 ; Mota, 2014). Some behavioral aspects of young stages were studied experimentally as for example their reaction to the light (Jatteau et al., 2004) and their sensitivity to temperature (Jatteau et al., 2017). Their estuarine stays as widely analysed with works focusing on the duration of their stay in the different compartments (Taverny, 1991 ; Lochet, 2006 ; Bardonnet & Jatteau, 2008 ; Lochet et al., 2008 ; Lochet et al., 2009) ; some anthropogenic impacts (Taverny, 1990 ; 1991) and the characteristics of the habitats used (Gerkens & Thiel, 2001). Our knowledge of the marine phase are limited to information provided by oceanographic campaigns. We know their geographic distributions (Taverny & Elie, 2001b ; Trancart et al., 2014) and their diet (Taverny & Elie, 2001a). The dynamics of these populations was studied in the Gironde (Taverny & Elie, 1989 ; Taverny, 1991 ; Martin Vandembulcke, 1999), in the Adour (Prouzet et al., 1994), rivers Ulla and Minho (Mota et al., 2015 ; Nachon-Garcia, 2016) and in UK (Aprahamian & Lester, 2001). A source (Dordogne) – sink (Garonne) dynamics mentioned for the first time by Tomas et al (2005) and later bt Martin et al (2015) was recently confirmed by Randon et al. (2017).

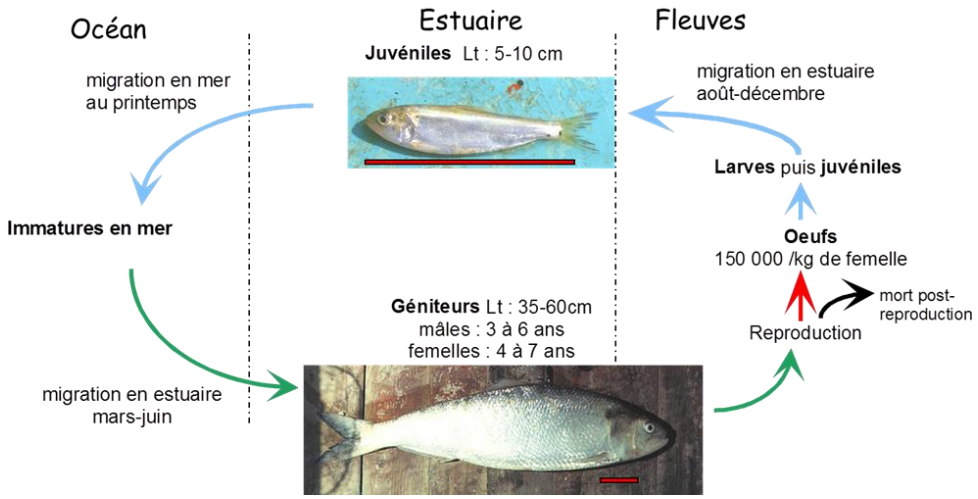

Figure 2 : life cycle of the Allis shad *Alosa alosa*

Status of populations

The Allis shad population of the Gironde Garonne Dordogne system was for a long time considered as the most important of the species. Assessment of the spawning runs were realised at several occasions (Chanseau et al., 2005). This population crashed at the beginning of the XXIst century (Castelnaud et al., 2001 ; Rougier et al., 2012) (Figure 3) and the twaite shad population also exhibited a strong decline A moratorium has been implemented for the Allis shad fishery in 2007 on the Gironde system. The stock has not recovered and indicators (adults or juveniles) are still historically low. Less than 5000 adults have been counted on fish pass in Tuilières (Dordogne) and Golfech (Garonne) in 2013 (Association MIGADO, 2013). To help the management of this population special tools were designed and transferred to managers (Collin & Rochard, 2012).

The Allis shad population of the Rhine was extinct in the middle of the XXth century (De Groot, 1990 ; Castelnaud et al., 2000). From some years there is an ambitious program of restocking from juveniles born in captivity from adults captured in Garonne and Dordogne (Jatteau & Rouault, 2004 ; Scharbert et al., 2011 ; Jatteau et al., 2016). Some of these hatchery born individuals have been maintained in captivity on the long term (Morinière et al., 2016). Recent reproduction in the Rhine has been mentioned (Hundt et al., 2015). Portuguese populations, historically very abundant are nowadays very constraint by numerous dams which limit the availability of suitable habitats. The Ebre's population of *Alosa fallax* (Spain) is under study (Lopez et al., 2007), and a Life program focusing the conservation of diadromous fish is ongoing .

Figure 3: Captures of adults *Alosa alosa* in the Gironde-Garonne Dordogne system (Beaulaton, 2008)

Possible reasons of this crash of the Gironde population?

An exhaustive analysis of available data to try to identify the mechanism which led to the crash was realised (Rougier, et al., 2012). Several possible approaches to better understand the system have been identified and are in progress within two programs (Fauna and Shad'Eau[1]) in which this subject is placed:

Mortality at sea – It is considered high but stable. Increasing at the end of 1990 ? : poor assessment of marine captures or insufficient suitability or marine zones (Trancart et al., 2014), leading to a decline from the 2000.

Lack of trophic resources in river – This hypothesis is linked with the global decrease of the productivity of rivers induced by the generalisation of sewage treatments. We know that the availability of preys of the good size is crucial for young shads (Limburg, 1995) but we lack of data to test this functional hypothesis.

Climate change effect – This has been largely advocated to explain the contraction and the northward movement of the distribution of this species. Expected changes in the characteristics of adults have been examined (Lassalle et al., 2008b). Potential effects on the distributions have been studied using empirical modelling approaches for both species (Béguer et al., 2007 ; Lassalle, 2008 ; Lassalle et al., 2008a ; 2009a ; Lassalle et al., 2009b ; Lassalle & Rochard, 2009). Possibilities of dynamic adjustment of the distribution were analysed as well with a determinist model (Rougier, 2014 ; Rougier et al., 2014a ; Rougier et al., 2014b ; Rougier et al., 2015). From all these approaches the Gironde system remains suitable for these species. Experiments focused on the sensitivity of young stages to temperature confirms these results (Figure 4) with a wide tolerance to temperature (Jatteau, et al., 2017).

[1] Funding Région Nouvelle Aquitaine and Agence de l'Eau Adour Garonne

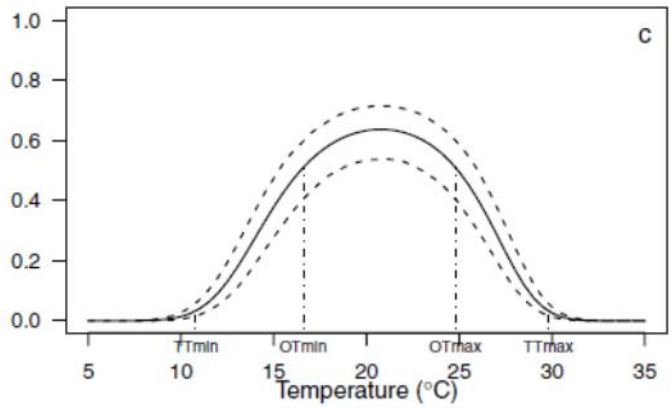

Figure 4: Survival of young *A. alosa* from hatching to 14 days post hatching (Jatteau, et al., 2017)

Some hypoxia events have been observed in Garonne near Bordeaux at the moment the juveniles move downstream. These events were not observed every year and don't seem to be able to explain the crash. A first experiment was conducted to assess the sensitivity of juveniles to hypoxia (Jatteau & Fraty, 2012) and it will be in depth studied. The decline of the twaite shad in the Scheld have been explained by the global degradation of the water quality and especially hypoxia events (Maes et al., 2008).

Métapopulation - Movements of individuals between Allis shad populations were analysed with genetics and microchemistry tools (Tomás et al., 2005 ; Martin, et al., 2015 ; Randon, et al., 2017). An ongoing post doc aims to precise this process and to quantify exchanges between basins.

Plasticity of the species – We postulate that the two species *Alosa alosa* et *Alosa fallax* have not the same plasticity versus the environment. An ongoing pHD is focusing on the use of habitats and trophic resources in freshwater for the two species.

Effects of chemical contaminants – There are very few information in the literature about the effect of chemical contaminants on shads. Some works about toxic blooms or study of the impact of microcystines. One north American study about the toxicity of an insecticide pyréthrinoïde (Bifenthrine) on *Dorosoma cepedianum*, using an experiment in mesocosm showing changes in behavior (Drenner et al., 1993). Most of available information concern their level of contamination in organic contaminants as PCBs, DDTs (Bettinetti et al., 2012) or metals (Simionov et al., 2016 ; Makedonski et al., 2017). Only one concerns a French population of shad, in the Vilaine system, Vilaine, studying the levels of contamination in organochloride pesticides, PCBs, dioxines and PBDEs. One interesting study was realised by Schultz et al. (1999) on the specific variability of the accumulation of hydrophobic compounds on fish. As an example on *D. cepedianum* the accumulation rate in herbicide Trifluraline is proportional to the oxygen consumption and consequently directly influenced by the oxygenation or the environment.

Aims of the study and suggested methodologies:

The aim of the phD thesis is to study the adaptability and responses of young stages of shads to the environmental conditions of the Gironde Garonne Dordogne basin. And more precisely those encountered on the spawning grounds. This work will consider two species Allis shad and twaite shad and will examine the possibility that the observed decline is at least partly due to what happened during the embryo larval stage.

Expected work:

The project could be organised in two sections.

- The first aims to get knowledge in ecophysiology and ecology of young stages of both species. That means to define criteria and physiological parameters which characterize the development of these species. And also to assess the impact of environmental factors in order to assess reference values of biological markers.
- In the second the work will focus on the field with experiments in more or less controlled experiments

Part 1: Development and proposition of biological markers and associated baseline

It would be organised in two sections :

- **Study of the ecophysiology of the two species**: this part will consist to define and analyse a biotest set up in optimum conditions and to propose associated protocols to measures biomarkers. This will be realised in our fied station in St Seurin /Isle.
- **Definition of a baseline** – Based on protocols established during the first section the aim will be to understand, describe and define the impacts of main environmental factors, including oxygenation on biomarkers and their variability. These works will provide information in ecophysiology and ecology of the young stages of shads and will help to assess the importance of the factors in the decline of the populations.

Part 2: Study of the quality of spawning grounds – toxicological impacts and sensitivity of species

In this part we will use the biomarkers set up experimentaly in the previous.

It would be organised in two sections:

- **Characterisation of the potential toxicityof spawning grounds for shads** .
- **Quality of spawning grounds**

Profil du candidat

We are looking for a candidate with very good theoretical basis in ecology and ecophysiology and a secondary skill in ecotoxicology. He/she has to be interested by experimentation and field work.

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