# Individual Internship Report

## 4th year

Movement patterns and migration behavior of the Iberian barbel (*Luciobarbus bocagei* Steindachner, 1864) in a context of current habitat fragmentation and future restoration

**Internship supervisors:**
Pedro R. ALMEIDA – Associate Professor with Aggregation
Carlos M. ALEXANDRE - PhD

**Academic advisor:**
Catherine BOISNEAU – ENS researcher

**Elise GUIRAUD**
**IMA**
**2019 - 2020**

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# Acknowledgments

Foremost, I would like to thank my internship supervisor **Mr. Pedro R. ALMEIDA**, Associate Professor with Aggregation, who initially accepted my application for an internship.

I would like to express my sincere gratitude to my other internship supervisor **Mr. Carlos M. ALEXANDRE**, PhD at the sciences center MARE of the University of Évora, which was my main interlocutor in this remote work. His responsiveness and understanding in the context of the COVID-19 crisis allowed me to be able to achieve this internship. I would like to thank him for his trust and support he had towards me. His guidance and knowledge were also crucial in order to help me achieving this work. I would like to express my regret that I was not able to meet Mr. ALEXANDRE and Mr. ALMEIDA in person.

My sincere thanks also go to my academic advisor **Mrs. Catherine BOISNEAU**, which has always been available to answer any questions I have for my work during this internship period.

I also would like to thank **Mrs. Sílvia PEDRO**, **Mrs. Sara SILVA**, **Mrs. Inês OLIVEIRA**, **Mrs. Ana RATO**, **Mr. Roberto OLIVEIRA**, **Mrs. Esmeralda PEREIRA**, **Mr. João Pedro MARQUES** as well as both of my internship supervisors **Mr. Pedro R. ALMEIDA** and **Mr. Carlos M. ALEXANDRE**, who carried out the work of all the field surveys and without whom my internship opportunity would have been impossible.

Finally, I thank the administrative personnel and teaching personnel of the Planning and Environment Department of Polytech Tours who supported me in all the remote administrative procedures.

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# List of Abbreviations

**EU**: European Union

**IUCN**: International Union for Conservation of Nature

**LIFE**: L'Instrument Financier pour l'Environnement

**MARE**: Marine and Environmental Sciences Centre

**RBMP**: River Basin Management Plans

**WFD**: Water Framework Directive

# Glossary

**Anadromous**: fish migrating up rivers from the sea to spawn

**Catadromous**: fish migrating down rivers to sea to spawn

**Ichthyofauna**: indigenous fish population of a region

**Potamodromous**: fish migrating within rivers

**Rheophilic**: preferring or living in fast-moving water

## Introduction

The 2000 EU Water Framework Directive (WFD) and the River Basin Management Plans (RBMP) requires the reestablishment of conditions of a good ecological status via an integrated river basin management in Europe. In this framework is carried out the project LIFE Águeda “Conservation and Management Actions for Migratory Fish in the Vouga River Basin (LIFE16 ENV / PT / 000411)” (Life Àgueda 2018) (Figure 1) whose purpose is the elimination of hydro-morphological pressures identified in the River Àgueda. This project is spread over a five-year period, between August 1, 2017 and July 31, 2022 with a total budget of 3 324 804 €.

*Figure 1 : Life Águeda logo*

*Figure 2 : Life logo*

Created in 1992, the LIFE programme is the European Commission’s funding instrument for the environment and climate change (Figure 2). Both sub-programmes “Environment” and “Climate action” are the components of the funding period 2014 – 2020 with a budget of €3,4 billion (European Commission 2020).

The construction of hydraulic structures such as dams and weirs result in the loss of aquatic habitat in rivers and its fragmentation, main cause of the dramatic decline in the abundance of migratory fish species. Becoming the most common measure for the restoration of longitudinal connectivity in river, fishways constructions were combined to these artificial barriers. Although they aid in most cases the movement of fish through the structures, their design is not always suited to every migratory species. The purpose of fish passes restoration is to rectify this problematic, but it has been focused on anadromous fish species (especially salmonids). Due to their low commercial value, information and data on cyprinids, often potamodromous, species are limited (C.M. Alexandre 2013). Because of their role on the composition of fish assemblage and their abundance in Iberian rivers, it is essential to integrate the cyprinids migratory behavior in the design of fishways. In order to achieve this objective, the following internship subject was determined: “Movement patterns and migration behavior of the Iberian barbel (*Luciobarbus bocagei* Steindachner, 1864) in a context of current habitat fragmentation and future restoration.”

Fundamental element required to validate my 4$^{th}$ year of engineer’s school in aquatic environments, the purpose of this internship is to implement the knowledge acquired so far. Considering I have chosen to orientate my career in the field of fish species preservation, my searches led me to contact the University of Évora in Lisbon, Portugal, for its numerous studies on this issue.

With a nationwide territorial implementation, this research center combines technical and scientific expertise to address all types of aquatic ecosystems, river basins, coastal and ocean systems in a current context of regional and global changes and cumulative anthropogenic impacts. Its wide diversity of expertise on freshwater, estuarine and marine species was also an important point in my choice: with more than 800 km of coasts of the Atlantic Ocean, Portugal is a huge area of study on those fish populations, including the numerous migratory ones.

The COVID-19 sanitary crisis made the MARE work project temporarily stopped and made me unable to travel. My internship supervisor has, however, offered me the opportunity and the chance to work on the subject previously mentioned by teleworking. This internship subject is a pre-operational phase of the Life Àgueda project: the main objective of this workplan is to analyze the movement patterns of the Iberian barbel and evaluate the impacts of existing obstacles, from different sizes and typologies, on the species migration behavior. Currently existing obstacles in the study area are planned to be removed when they are obsolete or have nature-like passes be built on in the scope of the project LIFE Àgueda. This objective will be achieved through three interdependent main tasks:

- Task 1: Analysis of radiotelemetry location data, previously collected during an entire annual cycle, to evaluate movements patterns and determine home ranges of the target species, within the study area.
- Task 2: Analysis of the relationship between observed movements and estimated home ranges, and the number and characteristics of the existing obstacles
- Task 3: Estimation of home range gains and changes to the observed movement patterns of the target species, resulting from foreseen habitat restoration actions.

This internship report will be structured as follow, with the Hosting structure presentation in the first part, then the Materials and Methods part will precede the Results part. Finally, the Discussion part will allow to compare and analyze the results previously obtained.

# 1. Hosting structure presentation

## *University of Évora*

The University of Évora is a public University organized in 4 Schools: Arts, Sciences and Technology, Social Sciences and Nursing. Research and Development (R&D) covers several scientific areas through a network of 18 Research Units, all of them submitted to international evaluation under the coordination of the Institute for Research and Advanced Studies. The University of Évora has established 5 Chairs in areas of excellence (Biodiversity, Renewable Energies, Heritage and Health), participates in the National Roadmap of Strategic Research Infrastructures and has several research infrastructures in agronomy, biodiversity, environment, computer sciences, business studies and entrepreneurship, aerospace engineering, solar energy and heritage. Over the last years, the University has fostered a close link with the community. Such interaction has been possible through the creation of working networks, the participation in the Science and Technology Park as well as through the establishment of protocols and co-promotion research projects. The 255 running R&D projects among 12 different areas are developed through national and international partnerships, such as ERASMUS +, LIFE, H2020, PT2020, Alentejo2020 or private sponsorship.

## *MARE – Marine and Environmental Sciences Centre*

MARE - Marine and Environmental Sciences Centre (classification by Fundação para a Ciência e a Tecnologia, the national funding agency for science, technology and innovation: excellent) is a multipolar RD&I Centre, presently with seven poles, six of them located at higher education campus in Portuguese mainland, plus one pole in the Madeira archipelago.

MARE combines expertise allowing approaching scientifically and technologically all types of aquatic systems, from river basins and associated landscapes, to estuaries, coastal, and large marine ecosystems.

Structurally, MARE integrates two ecosystem-oriented Research Groups (1. River Basins; 2. Coastal Systems and Ocean), since most of the societal challenges and needs for the next decades will have to be addressed in an integrated manner, and seven research Thematic Lines, which are supported by one or both Research Groups, implementing a real interchange of ideas, expertise, methodological approaches, applications and dissemination within the MARE structure.

The main goals of MARE Strategic Program are: 1 - Improve the knowledge on the functioning of marine ecosystems, and interrelated estuarine and freshwater systems; 2 - Develop scientific and technological tools towards the sustainable use of freshwater, estuaries and marine ecosystems under the framework of regional, national and international priorities; 3 - Develop scientific knowledge and sound technology to help providing food and other biotic and non-biotic resources to society; 4 - Promote good ecological and healthy status of oceans and seas, estuaries and river basins; 5 - Drive international cooperation to advanced education and training resulting in a new generation of scientists and professionals prepared for the Blue Economy; and, 6 – Promote Ocean literacy and contribute to a participative Blue Society.

# 2. Materials and Methods

## *Study area*

At the confluence of land and ocean with a total area of 92 391 km², Portugal is located at the extreme west of the European continent as well as the Iberian Peninsula (Routard 2019). This region is characterized by a Mediterranean type climate with a strong inter-annual flow variation and accentuates seasonal events of flooding and drying over an annual cycle (C. M. Alexandre 2015).

Mainland Portugal is composed of eight River Basin Management Plan (RBMP), adopted in 2016 under the Water Framework Directive (Commission 2019). These include a total of 14 sub-river basins including the Vouga one in the north of the country with a total drainage area of 3 535 km² (Figure 3). This catchment area shows an Atlantic influence due to its large coastline, characterized by a high annual rainfall (1196 ± 347 mm) and low air temperature (12,6 ± 1,23 °C) (Ministério do ambiente 2008). The field surveys focus on two main watercourses within this river basin: the Alfusqueiro and Águeda rivers.

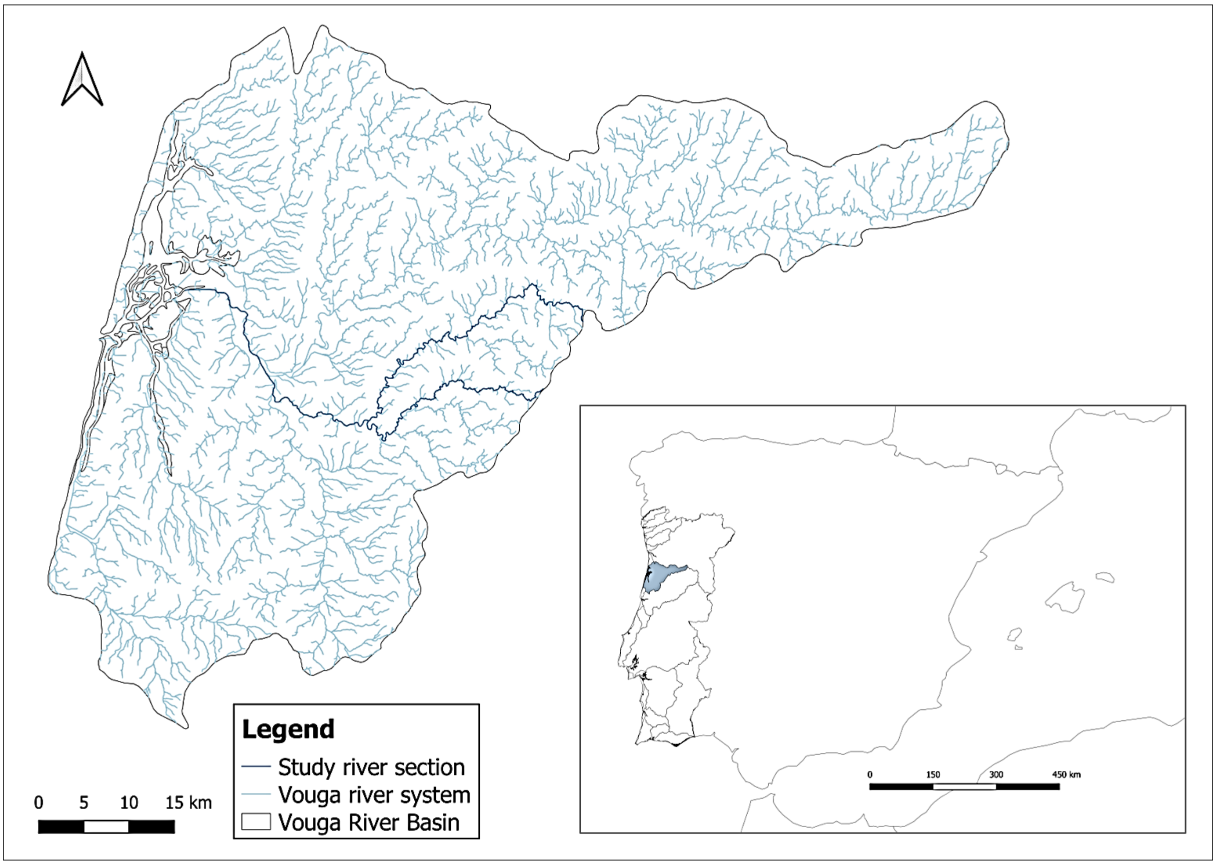



*Figure 3 : Vouga river basin with the study river section signaled*

## *Studied fish specie*

Target species for this project, the Iberian barbel *Luciobarbus bocagei* (Steindachner, 1864) is a potamodromous fish endemic to the Atlantic region of the Iberian Peninsula (Figure 4 and Figure 5). This cyprinid occurs in a wide range of lotic and lentic habitats in almost all the river basins of northern and central Portugal (C.M. Alexandre 2013) and is able to travel large distances for reproduction, refuge and feeding purposes. Its natural reproductive season generally takes place in spring, from March to June, period in which adults migrate upstream to spawn in gravel or sandy riverbed areas with fast water flow, thus being considered a rheophilic species (C.M. Alexandre 2013). On the opposite, summer season is a migration period towards downstream areas to reach refuge zones. The Iberian barbel is not considered a threatened species, it is classified as least concern on The IUCN Red List of Threatened Species 2008 (Luciobarbus bocagei IUCN Red List 2008).

*Figure 4 : Luciobarbus bocagei, right profile view*

*Figure 5 : Luciobarbus bocagei, head profile right*

*Source: Sartore, Joel. FIS039-00051, Iberian barbel or Barbo-do-Norte (Luciobarbus bocagei) at the Environmental Education Center of the Ribeiras de Gaia. Digital picture. Joel Sartore National Geographic Photographer and Speaker. Web https://www.joelsartore.com/keyword/luciobarbus-bocagei/ 24/07/2020*

The main objective of this work is to study the home range study of this target species in the context of current fragmentation and future habitat restoration within the study area of rivers Águeda and Alfusqueiro. In order to compare the obtained results, it is relevant to carry out an overview of the previous results cited in the scientific literature. Iberian Peninsula is home to two barbels genera: *Luciobarbus* and *Barbus*. The species *B. haasi* is the most represented of its genus within this area, while the others *Barbus* are in the Central Europe rivers (Hugo F. Gante 2015). Previous studies conducted in this area showed that the average home range of *L. bocagei* is about 1 108 m. It is considered as a relatively short value compared to the individuals from regulated rivers having significantly larger home ranges (C. M. Alexandre 2015). On the other hand, this home range value is higher than the mean estimated for other identical cyprinid species, such as *B. haasi* and *L. sclateri*, with an average home range of 100 to 200 m (C. M. Alexandre 2015). Studies mainly conducted in England and Belgium on *Barbus barbus* show much higher results. In the River Nidd, North East England, resulted showed the ability for some individuals moving nearly 20 km upstream (LUCAS et FREAR 1997). A similar study conducted in the Great Ouse River, England, has provided home range results between 645 to 6 842 m (Twine 2013). A 2018 study conducted in Western England showed a home range average result of 4 600 m with a minimum and maximum lengths between 700 and 12 200 m. This same study also showed that *Barbus barbus* populations are mainly comprised of individuals that are relatively sedentary, characterized by relatively small home ranges (±1 km) and a small proportion of individuals, generally around 10% of the population, tend to be more mobile, with regular movements within a relatively large home range (±10 km) (Twine 2013). A similar study conducted in Belgium in the River Meuse provided results of spawning migration range from 250 to 22 700 m (Michaël Ovidio 2007). The study of two groups of *Barbus barbus*, each living in a defined living area of the River Meuse resulted in obtaining average annual home ranges of 1,5 km and 12,5 km, depending on the zone where they were captured. This overview allowed to have an idea of the order of magnitude of the home range we are going to obtained for our study species.

### *Fish capture and tagging procedure*

In order to follow the geographical positions of the Iberian barbels, radiotelemetry is the biotelemetry used in this work. Tagged with radio transmitters, their moves and migration patterns were tracked during a year-cycle. During two fishing campaigns in Águeda river, a sample of 19 individuals with relatively large dimensions allowing individual tagging was selected. The average weight of the studied fishes is 1 424 g and the average length is 52 cm. Conforming to the 2% tag/body mass rule, transmitters weighed between 0,56% and 1,08% of barbel's body weight in the air (C. M. Alexandre 2015). As the study took place for one year, the radio transmitter's battery had to be large enough to cover this period. The model used is an ATSF1820 (Figure 6) with a total weight of 8 g in air and dimensions of 12 mm in diameter and 46 mm in length, manufactured by Advanced Telemetry Systems (ATS), Minnesota, USA.


*Figure 6 : Radio transmitter fish implant ATS F1830 (Source: Specification sheet ATS)*

Fishes were anaesthetized by immersion in 2-phenoxyethanol at a concentration of 0.4 $ml.L^{-1}$ and placed on a V-shaped surgical table, ventral side-up, where they were continuously supplied with the anesthetic solution to maintain anesthesia and gills oxygenated during the tagging procedure. An incision was made in the mid-ventral line (Figure 7 and Figure 8), and the transmitter was implanted anteriorly in the intraperitoneal cavity with the antenna placed through an independent hole made in the lateral area of the abdomen, after which the wound was sutured and disinfected with a iodine solution (Betadine). All surgical material used in this procedure was previously sterilized with a 96% alcohol solution. The complete surgical procedure took approximately 10 min. All fishes were left to recover for 1-2h in the river before being released near the site of capture (C. M. Alexandre 2015).

Figure 7 : transmitter implantation on an Iberian barbel

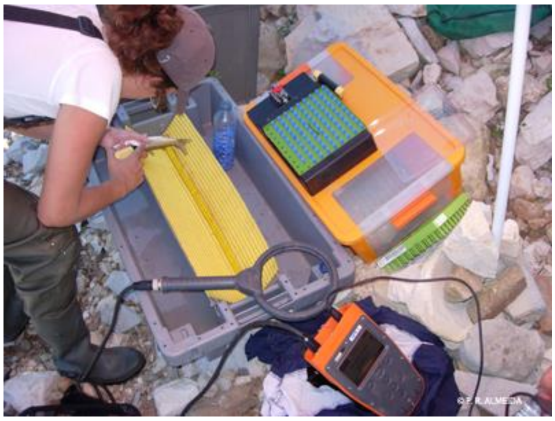


Figure 8 : required material for the tagging procedure

*Source : E. PEIRERA and P.R. ALMEIDA. Universidade de Évora. 2015. Habitat restoration for diadromous fish in river Mondego, Portugal. http://www.rhpdm.uevora.pt/gallery.html*

The two sampling and tagging campaigns have been realized in two different locations (Figure 9) with an interval of two months (Table 1). 10 barbels were captured on the first one and 9 on the second one: each one of them got its unique radio frequency.

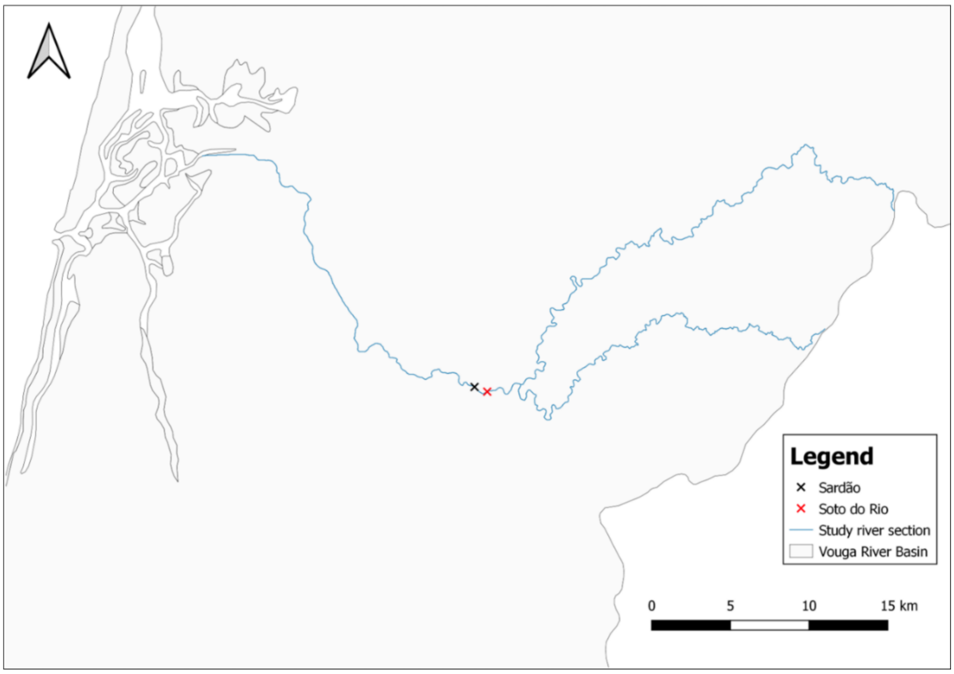



*Figure 9 : Location map of the sites of the two fishing campaigns, Sardão and Soto do Rio*

*Table 1 : Details on barbel used in this study*

| Location | Date of capture/release | ID | Length (cm) | Weight (g) | Pit Tag | Frequency | Detections number |
|---|---|---|---|---|---|---|---|
| Sardão<br><br>40º 33' 43,9''N<br>8º 25' 58.5''W | 22/03/2019 | B#1 | 61 | 2 147,5 | 3DD003D420AD7 | 150 931 | 18 |
| | | B#2 | 57 | 1 561,9 | 3DD003D420B13 | 150 812 | 13 |
| | | B#3 | 56 | 1 485,2 | 3DD003D420AE3 | 150 841 | 18 |
| | | B#4 | 58,2 | 1 625 | 3DD003D420B16 | 150 692 | 18 |
| | | B#5 | 59,5 | 2 025,5 | 3DD003D420B0D | 150 754 | 19 |
| | | B#6 | 57,5 | 1 761,7 | 3DD003D420B07 | 150 662 | 1 |
| | | B#7 | 55,8 | 1 419,4 | 3DD003D420B21 | 151 021 | 11 |
| | | B#8 | 66,7 | 2 518,3 | 3DD003D420AD2 | 150 962 | 4 |
| | | B#9 | 53,7 | 1 248,8 | 3DD003D420ACA | 151 201 | 13 |
| | | B#10 | 57 | 1 633,1 | 3DD003D420B1C | 151 140 | 11 |
| Soto do Rio<br><br>40°33'40,76''N<br>8°25'31,36''W | 29/05/2019 | B#11 | 43 | 659,1 | 3DD003D420A58 | 150 783 | 8 |
| | | B#12 | 51,5 | 1 159,6 | 3DD003D420A60 | 150 720 | 8 |
| | | B#13 | 50 | 1 347,1 | 3DD003D420A3E | 151 082 | |
| | | B#14 | 50,5 | 1 250,6 | 3DD003D420A37 | 150 992 | 9 |
| | | B#15 | 48,5 | 1 042,3 | 3DD003D420A61 | 151 051 | 9 |
| | | B#16 | 50,5 | 1 117,4 | 3DD003D420A5C | 150 872 | |
| | | B#17 | 51 | 1 137,9 | 3DD003D420A03 | 150 902 | 8 |
| | | B#18 | 43 | 664,2 | 3DD003D420(??) | 151 111 | |
| | | B#19 | 52,5 | 1 253,9 | 3DD003D420(??) | 151 171 | 9 |

Legend : Barbels that never transmitted any signal after their release, or not enough to have usable data

Barbels with identification numbers B#13, B#16 and B#18 never transmitted any signal after their release and B#6 has only been detected once, therefore the study will be conducted on a total of 15 individuals.

Tracking campaigns were conducted with an average regularity of twice a month. The procedure is conducted by foot, using a R410 scanning receiver and a Yagi antenna, both from Advanced Telemetry Systems (Figure 10): barbel's position was determined with a ~10m² precision and geo-referenced with the help of a Global Positioning System hand-held unit (C. M. Alexandre 2015). However, the Covid-19 sanitary crisis had led to the suspension of those campaigns during a 3-months period, from the 10/03/2020 to the 13/06/2020.

*Figure 10 : R410 scanning receiver and Yagi antenna. Source : Universidade de Évora. 2015. Habitat restoration for diadromous fish in river Mondego, Portugal. http://www.rhpdm.uevora.pt/gallery.html*

## *Obstacles*

The obstacles identification method is done manually through the survey of their GPS coordinates, walking along the river and sometimes by wading in water. Two field surveys were done, a first one in 2017 and a second one in 2019, the latter aimed at identifying new or removed obstacles in order to select those included in the restoration programme. The area of interest within Vouga river basin includes a total of 16 obstacles, with 10 on the Águeda river and 6 on the Alfusqueiro river. LIFE Águeda has as a project the modification of 14 of these obstacles to achieve the elimination of hydro-morphological pressures objective. Among them, 3 are going to be partially removed, 6 completely removed and 5 are going to be subject to the construction of fish passes (Figure 11).

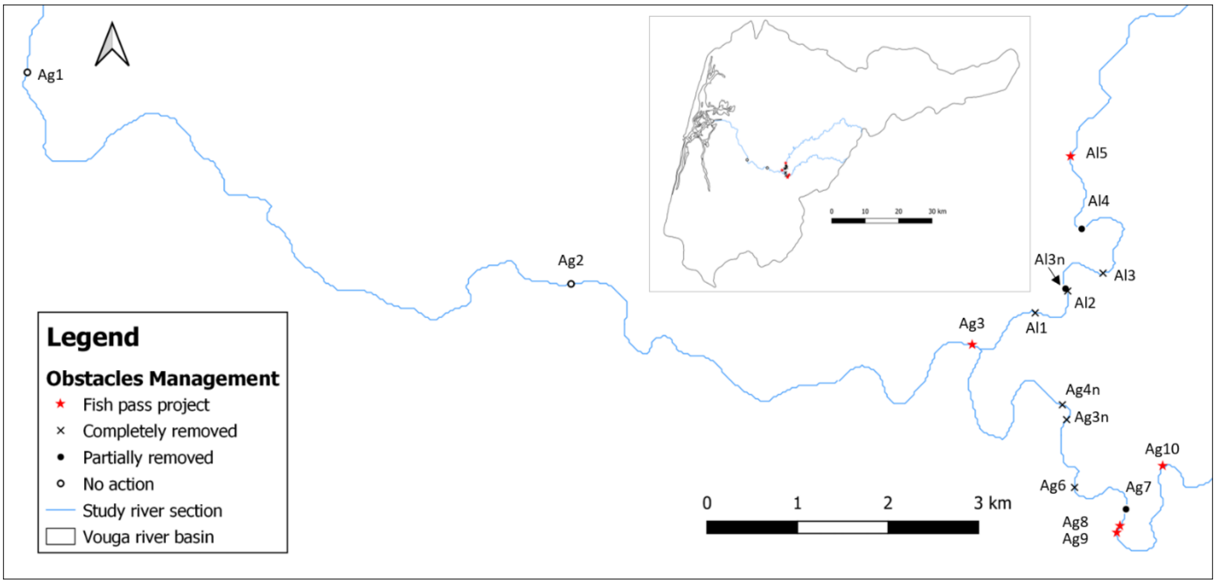



*Figure 11 : Obstacles management location map*

Work projects on obstacles are designed from downstream to upstream in such a way that the effects are not only beneficial to the target species, but also to all migratory species occurring in this area. Indeed, anadromous and catadromous species are also dependent on the longitudinal continuity of this part of the watercourse. Direct access to the ocean being vital for both migratory fish behaviors, it makes sense to start restoration projects downstream in order to make it easier for them to reach and/or migrate from the estuary area. In this way, the first positive effects on the migration will be visible.

The six development projects involving the complete removal of the structures Ag3n, Ag4n (Figure 12), Ag6 (Figure 13), Al1 (Figure 14), Al2 (Figure 15) and Al3 (Figure 16 and Figure 17) all follow the same protocol: it is proposed to demolish and completely remove the constituent material of the weir and to rearrange it in such a way that it does not constitute an obstacle to the ichthyofauna passage (Fabio Santos 2019).


*Figure 12 : Ag4n obstacle*


*Figure 13 : Ag6 obstacle*


*Figure 14 : Al1 obstacle*


*Figure 15 : Al2 obstacle*


*Figure 16 : Al3 obstacle, upstream side*


*Figure 17 : Al3 obstacle, downstream view*

For structures intended to be partially removed, the intervention to be carried out will be on a smaller scale. For two of them, Al3n (Figure 18) and Al4 (Figure 19), the stones constituting these obstacles are easily passable for most ichthyfaunistic species, except in situation of low flow. In such a way that their circulation is possible regardless of the hydrological regime, it is proposed to rearrange the stones by removing some of the existing ones in order to create alternate openings with a minimum width of 0,50 m. In the areas of the openings it should be ensured that the gap between the threshold of the opening and the downstream bed does not exceed 0,20 m.

*Figure 18 : Al3n obstacle*

*Figure 19 : Al4 obstacle*

The Ag7 obstacle (Figure 20) is not a problem for the longitudinal continuity of the ichthyofauna but, for a concern human use, the exposed faces of the stones are going to be regularized in order to make safe the passage of people (Figure 21).

*Figure 20 : Ag7 obstacle*

*Figure 21 : exposed faces of the stones constituting the Ag7 obstacle*

Within the study area, none of the obstacles have a fishway included in their design. That is why on five of them, being impossible to completely or partially removed, will be built three different types of fishway. On the Ag8 (Figure 22), Ag9 (Figure 23) and Ag10 (Figure 24) obstacles, ramp fishways will be integrated into the main structures.

*Figure 22 : Ag8 obstacle*

*Figure 23 : Ag9 obstacle*

*Figure 24 : Ag10 obstacle*

As the obstacle Al5 structure (Figure 25) cannot be modified, a bypass channel will be built in order to create a usable passageway for the ichthyofauna.

*Figure 25 : Al5 obstacle*

The pool-type fishway built on the Ag3 obstacle (Figure 26) will be temporary and can be removed during high flow conditions, period during which fish can migrate more easily and where the obstacles is also not present. This LIFE project is an integrated management plan which considers the different uses of the river, the Ag3 obstacle having a recreational use, modify it instead of removing it will maintain this use.

*Figure 26 : Ag3 obstacle*

This Life Águeda project take its lead from the previous one *Habitat restoration for diadromous fish in River Mondego* carried out between 2013 and 2015 which worked well. The fishway designs solution will be based on those adopted for the restoration of the River Mondego longitudinal continuity: nature-like fish passes. Using natural materials, the aim is to simulate natural stream characteristics by fitting with the specific riverine environment they are constructed in (Wildman Laura s.d.). Providing suitable passage conditions over a range of flows for a wide variety of fish species and other aquatic organisms, they can also be used for anthropogenic purposes, such as kayaking for example (Évora 2015).

It is planned to be installed two automatic monitoring antennae units to assess the efficiency of the Ag10 ramp fishway and on the Al5 bypass channel. A first one will be installed upstream of each fish passage and a second one downstream, as well as a shelter is to be set up for the installation of the other equipment and electrical installations associated with the metering unit.

## 3. Results

### *Home range and behavioral differences*

Potamodromous fish populations can be differentiated according to their migratory behavior, which may be more or less significant. This variation expresses on the home range results of the 15 Iberian barbels we work with. The home range parameter expresses the distance between the most downstream and the most upstream location of each fish, it is simply obtained with the "Measure" tool in QGIS. Two main categories are identified: 8 of them display a resident behavior with a small home range lower than 3 000 meters, while 7 of them migrates on an area between 3 041 and more than 29 900 meters (Table 2). Fish who traveled these longer distances had to pass from 1 to 7 obstacles when only two individuals from the sedentary group went through a single obstacle.

*Table 2 : Home range distances and number of passed obstacles of each individuals*

| | ID | Home range (m) | Passed obstacles |
|---|---|---|---|
| Resident behavior | B#1 | 1 164 | 0 |
| | B#2 | 462 | 0 |
| | B#3 | 933 | 0 |
| | B#4 | 1 136 | 0 |
| | B#7 | 616 | 0 |
| | B#11 | 2 702 | 1 |
| | B#14 | 1 830 | 1 |
| | B#15 | 2 490 | 0 |
| Migratory behavior | B#5 | 9 067 | 7 |
| | B#8 | 3 935 | 1 |
| | B#9 | 5 060 | 1 |
| | B#10 | 3 041 | 0 |
| | B#12 | 29 943 | 4 |
| | B#17 | 10 566 | 2 |
| | B#19 | 5 950 | 3 |

*Table 3 : average values of home range length and the number of passed obstacles for each sub-group*

| Behavior | Average home range (m) | Average passed obstacle |
|---|---|---|
| Resident | 1 417 | 0,25 |
| Migratory | 9 652 | 2,57 |
| Total | 5 260 | 1,33 |

The resident Iberian barbel group is composed of individuals restricted in small areas (Figure 27). Obstacles do not seem to be the reason for this non migratory behavior because as observed, the Ag2 obstacles they are able to overcome is not going to be subjected to any modification due to its small impact or just temporary operation. Considered as passable by the work done in the pre-operational phase of this project, this observation confirms that these both obstacles do not pose any problem in the longitudinal continuity. Moreover, there is no obstacle further downstream and the following obstacle upstream is Ag3, on which a fish passage will be installed. However, Ag3 is more than 2 000 meters away from the most upstream detection of a tagged barbel considered to have a resident behavior, as the home range average is about 1 400 meters for this group, it is unlikely that any of these individuals tried to pass it.

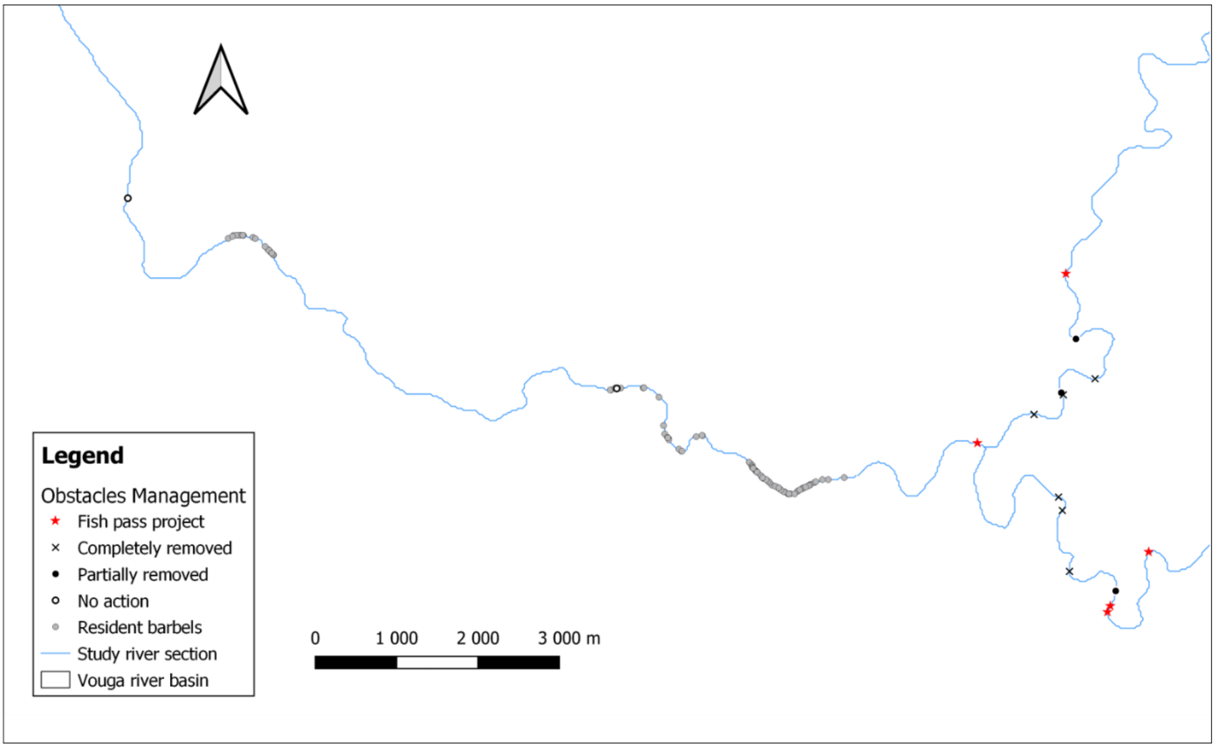



*Figure 27 : Location map of the total number of locations of the Iberian barbel showing a resident behavior*

The migratory Iberian barbel show a more diffuse mobility area, with a clear willingness to migrate upstream (Figure 28). Although some of them manage to get through some obstacles, these block the migration of the rest of the individuals.

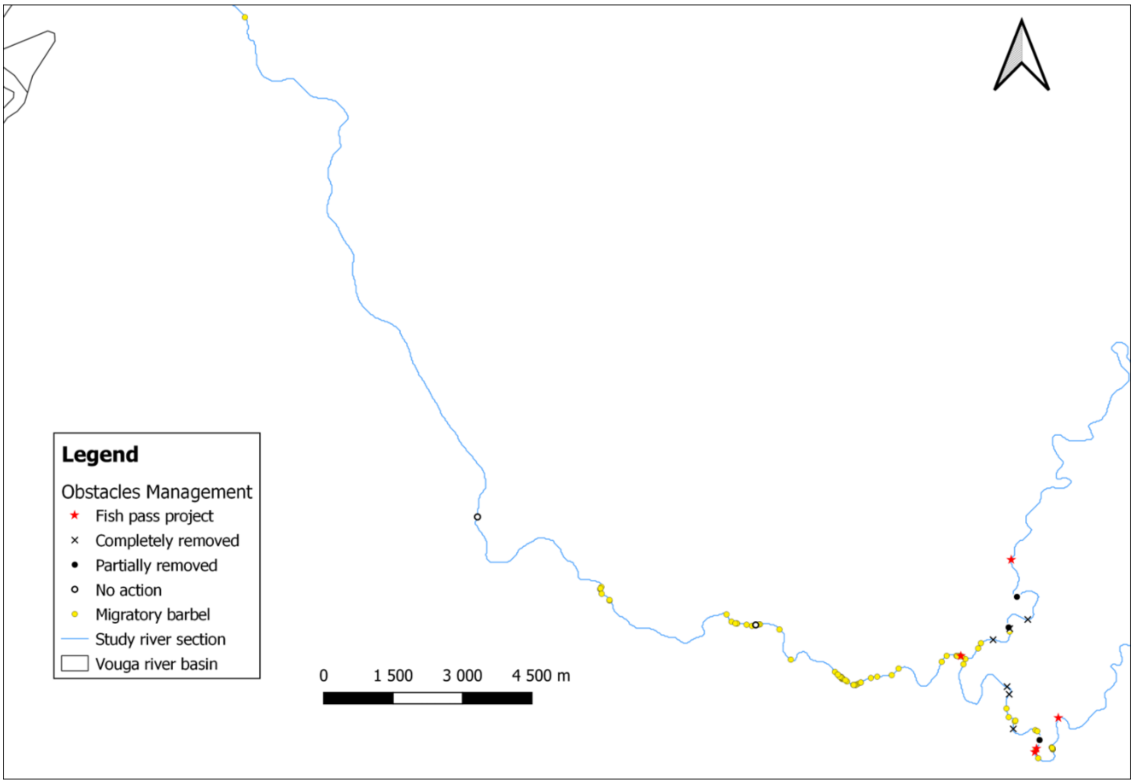



*Figure 28 : Iberian barbel showing a migratory behavior location map*

Different behaviors can be observed among this group. B5's home range is particularly large with a value of more than 9 km and contains areas where it stays for several weeks (Annex 1). However, its migratory periods do not coincide with those in the literature. Indeed, its signals on the most downstream part of its territory are recorded from the beginning of April to the end of June, period during which it is supposed to migrate upstream for reproduction. Following the same pattern, its presence in the most upstream part of its home range is recorded during the summer period. Overcoming a total of 7 obstacles, this individual is making a huge effort to achieve its migration goal. The obstacle located at 700 m from the furthest upstream point of its territory is Ag10. This distance only representing 8% of its home range, the ramp fishway implementation is likely to have an impact on its length.

B8 migration pattern follows the one set out in the literature, with recorded signals on the furthest upstream section of its home range between April and June (Annex 2). Its migratory direction towards the Alfusqueiro river is blocked by the Al1 obstacle, planned to be completely removed.

We can notice that although B9 and B10 show a rather sedentary behavior, they do, however, express a willingness to migrate further upstream (Annex 3 and Annex 4). For both, the obstacle directly upstream of their home range is Ag3, on which the pool-type fishway will be built. It makes sense to project that once the work has been carried out, their home range distances are going to increase. The same projection can be made for B17's home range as the same obstacle prevents him from traveling further. The latter's migration pattern is characterized by many backs and forth within its territory in short periods of time (Annex 5).

B19 also shows a migratory behavior that deviates from the literature with a great upstream migration from July to December and then stays in a restricted area located halfway across its home range from January to June (Annex 6). The Ag6 obstacle, planned to be completely removed, seems to impede its upstream migration as its location is only at 370 meters from its furthest upstream detection, only representing 6% from its home range length.

B12 has the most remarkable migration pattern with a length of almost 30 km. Moreover, the seasonality of this migration is coherent, with a trip between March and June from the extreme downstream to the extreme upstream of its territory (Annex 7). Its ability to overcome a total of four obstacles is however stopped by the succession of the Al2 and Al3n obstacles, respectively planned to be completely and partially removed. This individual really tried to go upstream: the modification of the latter will probably result in an increase in its home range value.

Two distinct portions of the watercourse can be defined according to the resident individuals' home range (Figure 29).

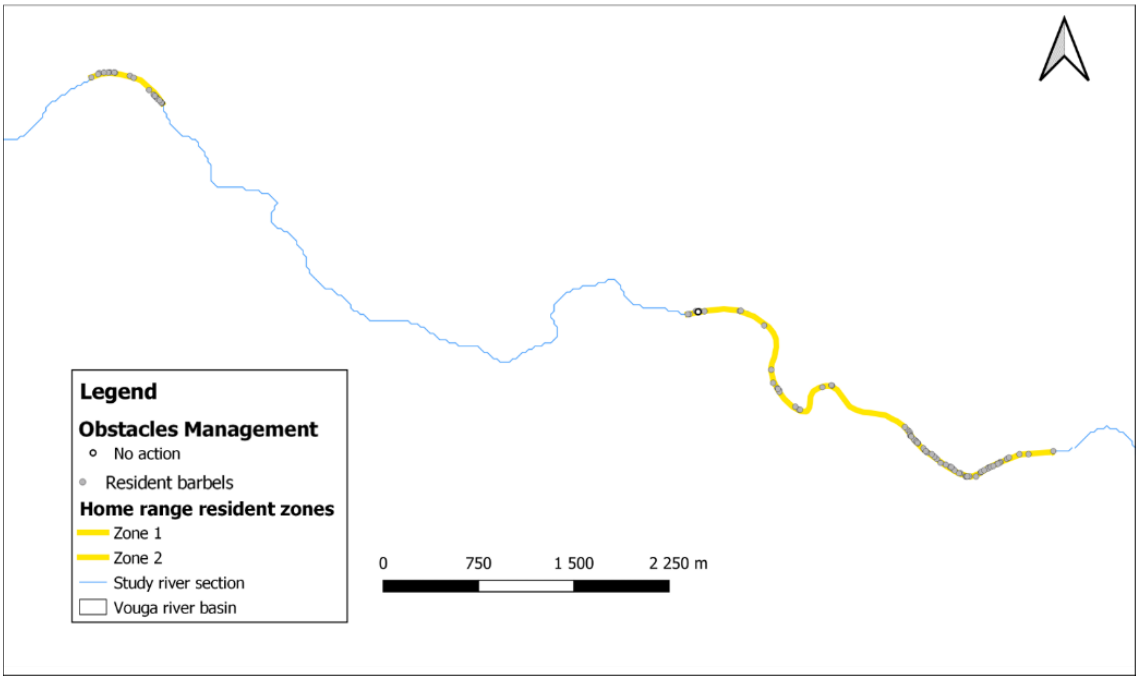



*Figure 29 : Sedentary individuals presence zone map*

The delimitation of these areas shows us that these locations are not specific to the resident behavior group. Indeed, all the seven individuals within the migratory group stay between the downstream part of the Zone 1 and the upstream part of the Zone 2 during different time periods (Figure 30). From a simple one-month passageway for B12 to a year-round residence prior to the reproduction period for B9 and B10, this observation shows that despite their differences in behavior, the main living areas and their habitat preferences are similar for both groups. This resident period within this area is mostly between early summer and the beginning of autumn.

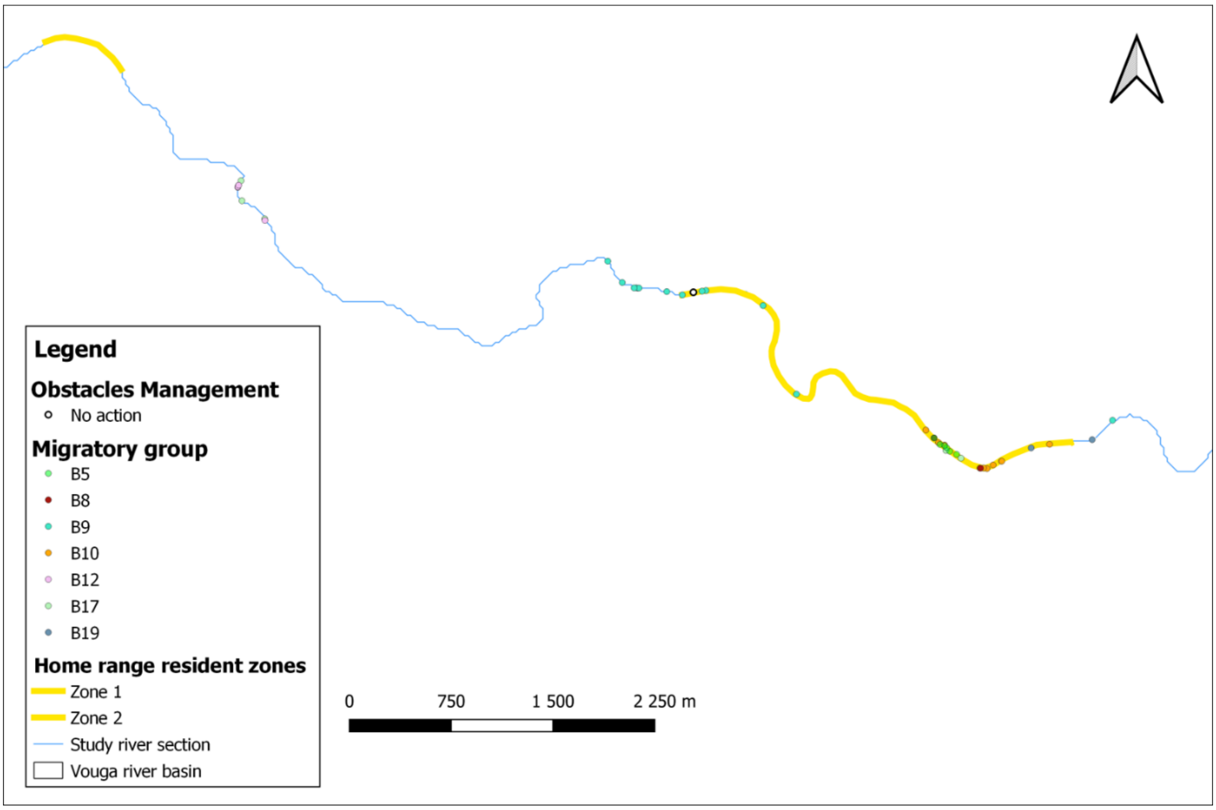



*Figure 30 : Migratory group presence on the home ranges' resident zones map*

## *Morphological characteristics*

We will now try to explain if the difference in behavior between these two groups could be correlated to their physical characteristics (Table 4). Three hypotheses can thus be stated, (i) migratory barbels are bigger in size and weight in order to cross more easily the various obstacles, (ii) making direct use of all available nutrient resources without having to make an effort to travel long distances, resident barbels get bigger, (iii) weight and length are neither a cause nor a consequence of the barbels' behavior.

*Table 4 : Length and weight of the two studied groups of Iberian barbels*

| | ID | Length (cm) | Weight (g) |
|---|---|---|---|
| Resident behavior | B#1 | 61 | 2147,5 |
| | B#2 | 57 | 1561,9 |
| | B#3 | 56 | 1485,2 |
| | B#4 | 58,2 | 1625 |
| | B#7 | 55,8 | 1419,4 |
| | B#11 | 43 | 659,1 |
| | B#14 | 50,5 | 1250,6 |
| | B#15 | 48,5 | 1042,3 |
| Migratory behavior | B#5 | 59,5 | 2025,5 |
| | B#8 | 66,7 | 2518,3 |
| | B#9 | 53,7 | 1248,8 |
| | B#10 | 57 | 1633,1 |
| | B#12 | 51,5 | 1159,6 |
| | B#17 | 51 | 1137,9 |
| | B#19 | 52,5 | 1253,9 |

The maximum and minimum length of the migratory group, with respective values of 66,7 cm and 51 cm, are higher than those of the resident group with respective values of 61 cm and 43 cm (Figure 31). Similarly, the average is higher for the same group, with a value of 55,99 cm against a value of 53,75 cm. The trend reverses for the median, with a value equals to 55,9 cm for the resident group against a value of 53,7 cm for the migrative group. The left-hand box plot shows a median with a data concentration above it, meaning that 50% of the individuals have a size between 55,9 cm and 61 cm. On the opposite, the right-hand box plot shows a median with a data concentration below it, meaning that 50% of the individuals have a size between 51 cm and 53,75 cm. To get another perspective, the respective interquartile ranges of these boxes show that 50% of the individuals within the resident group have a size between 50 cm and 57,3 cm, whereas 50% of the individuals within the migrative group have a size between 52 cm and 58,25 cm.

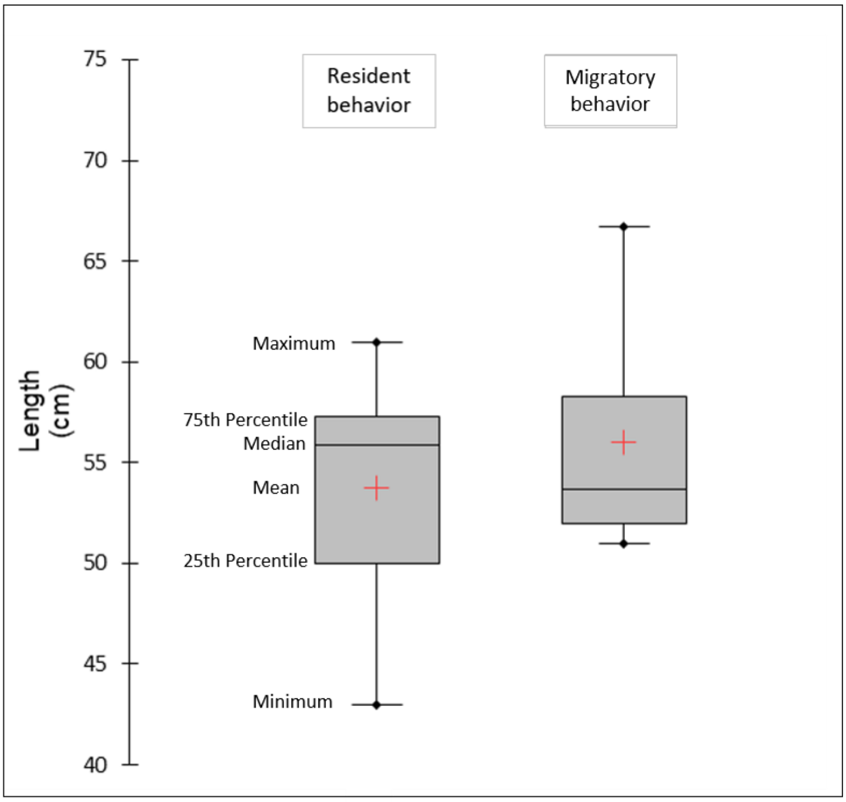



*Figure 31 : Comparative length box plot between the resident behavior group and the migratory behavior group*

Although the size of the right-hand box plot highlights a composition of individuals larger in size than those of the left-hand box plot, the analysis of the graphs shows that using the median value as the reference, half of the individuals from the resident group is actually larger than half of the individuals from the migratory group. This analysis allows to show that individuals with a resident behavior are generally larger than those with a migrative behavior.

The maximum and minimum weight of the migrative group, with respective values of 2518,3 g and 1137,9 g, are higher than those of the resident group with respective values of 2147,5 g and 659,1 g (Figure 32). Similarly, the average is higher for the same group, with a value of 1569,16 g against a value of 1398,88 g. The trend reverses for the median, with a value equals to 1452,3 g for the resident group against a value of 1253,9 g for the migrative group. The left-hand box plot shows a median with a data concentration above it, meaning that 50% of the individuals have a weight between 1452,3 g and 1577,68 g (the third quartile value is preferred to the maximum value considered as an outlier). On the opposite, the right-hand box plot shows a median with a data concentration below it, meaning that 50% of the individuals have a weight between 1137,9 g and 1253,9 g. To get another perspective, the respective interquartile ranges of these boxes show that 50% of the individuals within the resident group have a weight between 1198,53 g and 1577,68 g, whereas 50% of the individuals within the migrative group have a weight between 1204,2 g and 1829,3 g.

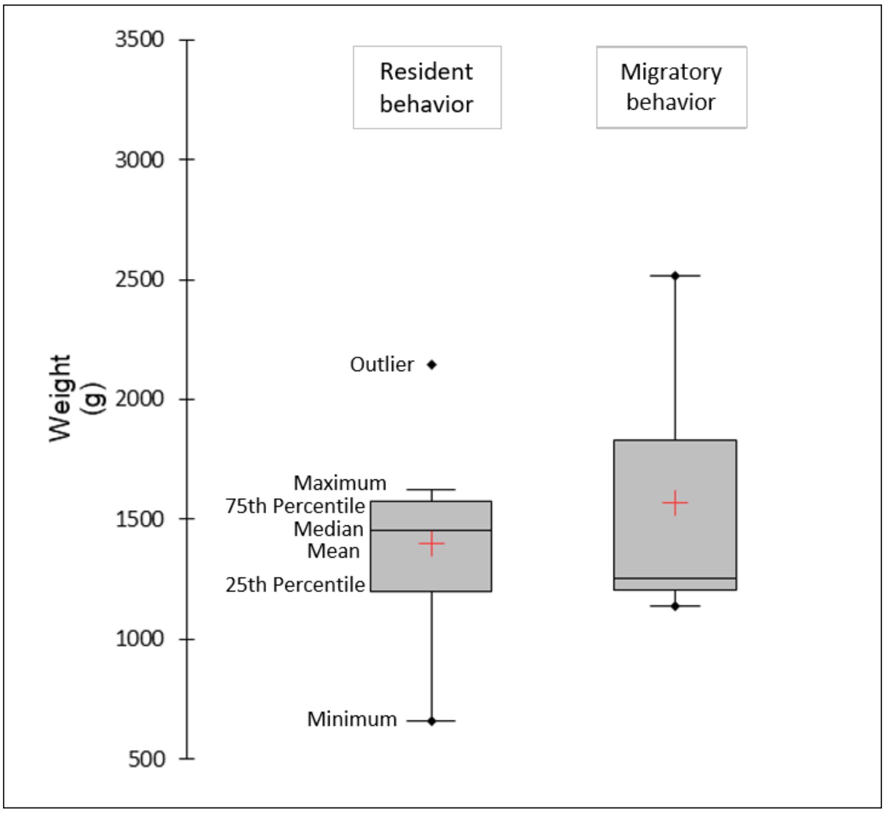



*Figure 32 : Comparative weight box plot between the resident behavior group and the migratory behavior group*

Although the size of the right-hand box plot highlights a composition of individuals larger in size than those of the left-hand box plot, the analysis of the graphs shows that using the median value as the reference, half of the individuals from the resident group is actually bigger than half of the individuals from the migrative group. This analysis allows to show that individuals with a resident behavior are generally bigger than those with a migrative behavior.

The conduct of a nonparametric Mann-Whitney statistical test at a 5% level of significance clarifies these analyses. For both “length” and “weight” variables, the p value is greater than the α value (Table 5). The difference between the medians is not statistically significant and does not reject the null hypothesis whereby the values distribution is the same in both groups. The 15 Iberian barbels composing this sample can thus not be precisely differentiated according to their size and weight.

*Table 5 : Mann-Whitney statistical test results for the "length" and "weight" variables*

| | Variables | |
|---|---|---|
| | Length (cm) | Weight (cm) |
| p-value | 0,634 | 0,779 |
| α | 0,05 | 0,05 |

However, we will try to highlight if individuals who have been successful in overcoming an obstacle have stand out physical characteristics. Ag3 is the obstacle symbolizing the upstream limit of the resident behavior Iberian barbel group and none of them crossed it through the study period. Among the migratory behavior group, B5, B8, B12 and B19 managed to overcome it. If we look beyond B8, which is the largest of the sample in weight and size, the other fish that were able to cross the Ag3 obstacle don’t stand out physically from the others (Table 6 and Table 7).

*Table 6 : Iberian barbel sample sorted in ascending order of size*

| ID | Length (cm) |
|---|---|
| B#11 | 43 |
| B#15 | 48,5 |
| B#14 | 50,5 |
| B#17 | 51 |
| B#12 | 51,5 |
| B#19 | 52,5 |
| B#9 | 53,7 |
| B#7 | 55,8 |
| B#3 | 56 |
| B#2 | 57 |
| B#10 | 57 |
| B#4 | 58,2 |
| B#5 | 59,5 |
| B#1 | 61 |
| B#8 | 66,7 |

*Table 7 : Iberian barbel sample sorted in ascending order of weight*

| ID | Weight (g) |
|---|---|
| B#11 | 659.1 |
| B#15 | 1042.3 |
| B#17 | 1137.9 |
| B#12 | 1159.6 |
| B#9 | 1248.8 |
| B#14 | 1250.6 |
| B#19 | 1253.9 |
| B#7 | 1419.4 |
| B#3 | 1485.2 |
| B#2 | 1561.9 |
| B#4 | 1625 |
| B#10 | 1633.1 |
| B#5 | 2025.5 |
| B#1 | 2147.5 |
| B#8 | 2518.3 |

These results of comparison in length and weight of Iberian barbels from both groups allows us to say that resident individuals are generally bigger, but the small difference in values and the small sample sizes does not permit to validate the (ii) hypothesis. For the rest of this study, we will admit that weight and length are neither a cause nor a consequence of the Iberian barbels' behavior. However, it has previously been shown that Iberian barbel can be classified in two categories according to their morphological response to spatial variability in streamflow characteristics (Carlors M. Alexandre 2014), that is, depending on whether their habitat corresponds to a non-regulated or a regulated river. As we know, the studied watercourses Águeda and Alfusqueiro are both permanent rivers. So, it makes sense that the physical characteristics of the individuals within the studied group are nearly homogeneous.

## *Home range gain calculation*

One of the objectives of this study is to analyze the improvement of the longitudinal continuity by quantifying the home range gain of the studied sample of Iberian barbels. The procedure is as follows: considering the interventions that are going to be carried out on the 14 obstacles, we calculate with the QGIS "Measure" tool which will be the home range gain for each fish. To do that, it is necessary to link the obtained data on each fish to the information previously obtained in the literature.

As stated above, the nearest obstacle to the home range of the resident Iberian barbels is located over 2 000 meters. This value being much higher than the home range average of this group, the fish pass construction on this Ag3 obstacle does not seem to interfere with the nature of their behavior. To this is added the fact that throughout the year-cycle covered by this study, none of the individuals have shown a willingness to migrate upstream. So, the home range gain calculation will be done on the Iberian barbels migratory group, considering that the remaining obstacles not yet subject to any intervention prevent their upstream migration (Figure 33).

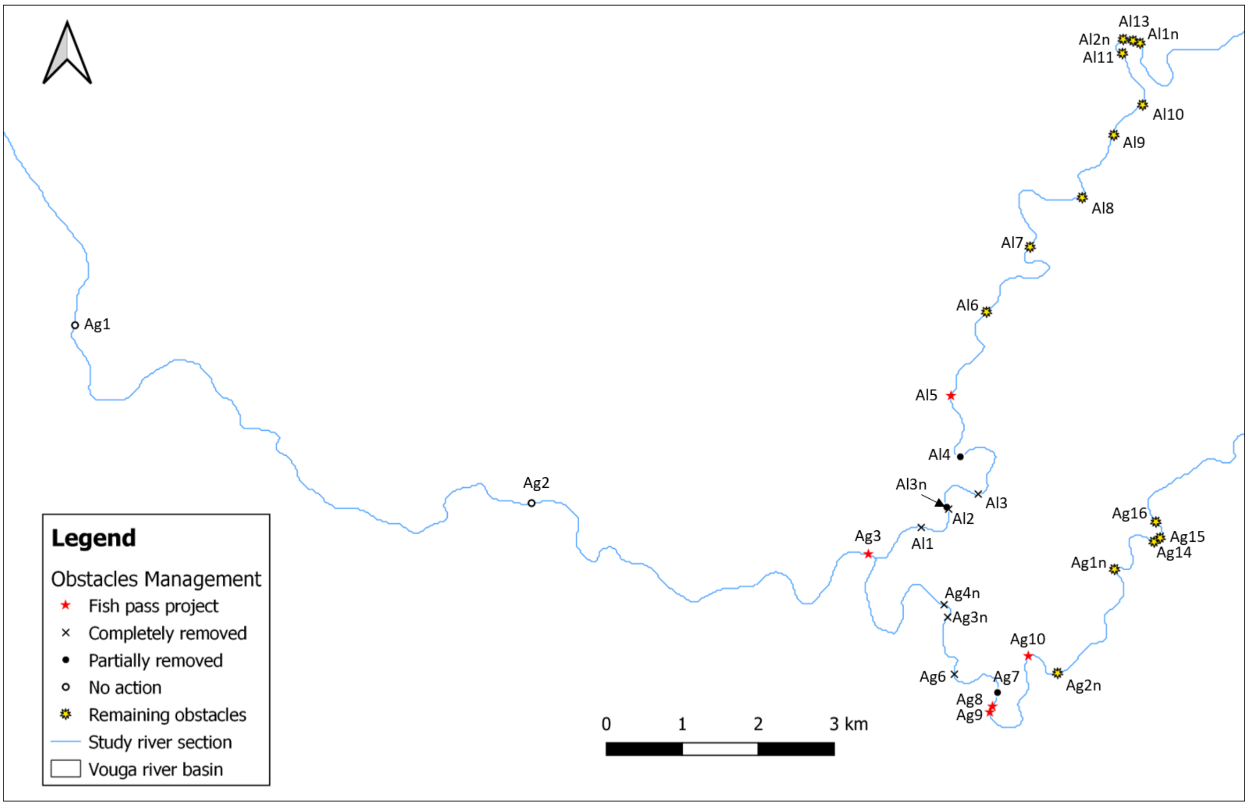



*Figure 33 : Location map of the 16 obstacles that are planned to be intervened within the LIFE Águeda project and of the 14 still uninvolved in any restoration program*

It is possible to estimate the minimum home range gain of B5 at 700 meters, distance from which is Ag10. The next obstacle is Ag2n, located at 1 257 m from the last B5 detection. As it is not included in this project, we admit that it will delimit its new territory. The ramp fishway construction on Ag10 will allow this individual to continue his upstream progression. It can be analyzed that this obstacle is problematic because if this individual, who has previously been able to overcome 7 obstacles that others could not, can't cross it, so the others probably can't either.

The projection of the home range evolution of B8 is more delicate because only four detections have been registered. However, this individual showed a real motivation to migrate upstream before being blocked by the Al1 obstacle, planned to be completely removed. Upstream of this obstacle are the Al2, Al3n, Al3, Al4 and Al5 obstacles, all of which are going to be subject to interventions. Assuming that this individual will thus be able to cross all of them, the value of its home range would increase by more than 5 200 m, always considering that the Al6 obstacle not included in the project blocks its migration.

The migration patterns of B9 and B10 being identical, the same extrapolation will be admitting for both. Ag3 is the obstacle directly located upstream of their home range, the fishway construction will thus open two migration options for these individuals. The first in the North direction, towards the River Alfusqueiro. In this direction, a total of 6 obstacles (excluding Ag3) are planned to be modified before reaching Al6, not included in the project. Consequently, the increase in the home range value could be as much as 7 700 m for B9 and 6 240 m for B10. The second option is if barbels choose the South direction, always on the River Águeda. In this case, a total of 7 obstacles (excluding Ag3) are planned to be modified before reaching Ag2n, not included in the project. Consequently, the increase in the home range value could be as much as 8 818 m for B9 and 7 358 m for B10.

B17 also being restricted by the same Ag3 obstacle, the evolution of its migration pattern after the interventions can follow the same estimate as the one of B9 and B10. So, if B17 chooses to go towards River Alfusqueiro, its home range gain would be about 5 806 m and if it chooses to keep going on River Águeda, it would be about 6 924 m.

The modification of the 5 obstacles between the B19 last detection and the Ag2n obstacles not included in the project would allow a 3 540 m gain of its home range.

In the same way, the modification of 5 obstacles between the B12 last detection on River Alfusqueiro and the Al6 obstacle not included in the LIFE project would allow a 4 276 m gain of its home range.

The total values of the home ranges as follows (Table 4) correspond to those found in the literature. These may even exceed 20 kilometers, a second phase of intervention of the 14 obstacles further upstream of the 16 ones included in the project could allow to expand those Iberian barbels territories. The B12 home range total value is far larger than the others, but the distance gain only represents 14% of its initial home range. Its migratory behavior is thus much more pronounced as the one of the other members within the same group.

*Table 8 : Estimation of home range gains of the Iberian barbels migratory group after planned restoration interventions*

| | ID | Current home range (m) | Home range gain (m) | | Total Estimated home range (m) | |
|---|---|---|---|---|---|---|
| | | | Alfusqueiro | Águeda | Alfusqueiro | Águeda |
| Migratory behavior | B#5 | 9 067 | | 1 257 | | 10 324 |
| | B#8 | 3 935 | 5 272 | | 9 207 | |
| | B#9 | 5 060 | 7 700 | 8 818 | 12 760 | 13 878 |
| | B#10 | 3 041 | 6 240 | 7 358 | 9 281 | 10 399 |
| | B#12 | 29 943 | 4 276 | | 34 219 | |
| | B#17 | 10 566 | 5 806 | 6 924 | 16 372 | 17 490 |
| | B#19 | 5 950 | | 3 540 | | 9 490 |

# 4. Discussion

The 5 260 m home range average obtained value for all the 15 studied Iberian barbels asserts the fact that barbels inhabiting regulated rivers uses a large and continuous river extension (C. M. Alexandre 2015). However, if we take the home range average obtained for both subgroups with a resident and a migratory behavior, the values significantly differ. The 1 417 m home range average value for the group with a resident behavior is indeed closer to the value obtained for barbels inhabiting the non-regulated watercourses in the study "*Effects of flow regulation on the movement patterns and habitat use of a potamodromous cyprinid species*", being about 1 108 m. The 9 652 m home range average value for the group with a migrative behavior is, in contrast, far greater than those obtained for the individuals studied in the Iberian Peninsula. This value is similar to those of the *Barbus barbus* home ranges in Central Europe (Twine 2013) (LUCAS et FREAR 1997) (Michaël Ovidio 2007). The QGIS "Measure" tool, used for the home range calculation includes the "non-used" riverine area, especially for individuals with a migratory behavior who have several residential areas depending on the season. This home range calculation reflects values that are lower but at the same time, allows to correctly highlight the actual distance that barbels had to travel.

47% of the barbels from the study sample have a migratory behavior. It is a lot more than the 10% of the population that tend to be more mobile in the previous study (LUCAS et FREAR 1997). On the other hand, we find that 53% of the study sample have a resident behavior compared to the 90% in the 1997 study. This observation raises question about the fact that the resident behavior is something natural or artificial. To know the total number of obstacles that barbels had to pass in this previous study would allow to evaluate if this residency behavior is promoted by the fragmentation of its habitat.

The home range gain estimations are approximate calculations due to factors that have not been considered. First, it was accepted that every barbel has been able to overcome each of the modified obstacles. However, especially for the fishways interventions, it is common that a percentage of individuals is still not capable to pass them. So, it might have been interesting to establish a success rate to apply it to the home range gain results. Moreover, to possess information about the type of the upstream obstacles not included in the project would have allowed to adjust those estimations. For example, an obstacle considered easily passable for the target species, would have resulted in a higher home range gain.

Another remark can be made about these home range calculations: was considered that barbels with resident behavior do not have an increase in territory because they have never showed any desire to migrate upstream. However, the 3-months suspension of the tracking campaigns between March and June did not allow to record whether they attempted and failed to migrate upstream for the spawning period. It would thus be interesting to repeat the same experience a future year-cycle with the same individuals to prove that their behavior is not related to the obstacle presence. If, despite these improvements a large proportion of individuals remain sedentary, maybe it would be interesting to think about restoring fish refuges. However, it is essential to consider that this behavior variation within the species is usual for potamodromous fish. So, even if the various obstacles interventions do not lead to an increase in migration of all individuals, it is important to keep in mind that these changes will also benefit to other species.

The two automatic monitoring antennae units planned to be installed on the Ag10 ramp fishway and on the Al5 bypass channel have key roles. Indeed, in a perspective of improving the design of a fishway to allow the passage of a target fish species, it would be possible to use these data to determine the adequate hydraulic arrangement to increase the efficiency of these facilities (C.M. Alexandre 2013). In the same perspective of efficiency monitoring, electromyogram telemetry is a validated method that could be used to evaluate and to understand barbel's response within these fishways. Indeed, this technic allows to record nerves and muscles activity while moving through fishways or other hydraulic structures, to assess the effect of hydraulic variables that should be considered for the successful development of future designs (Ana T. SILVA 2010).

# Conclusion

The main objective of this internship "Movement patterns and migration behavior of the Iberian barbel (*Luciobarbus bocagei* Steindachner, 1864) in a context of current habitat fragmentation and future restoration" was to analyze the movement patterns of the target species within the Vouga river basin and evaluate the impacts of existing obstacles on the species migration behavior. As part of the LIFE Águeda project, the workplan also included to estimate potential gains foreseen restoration actions on the migration of the Iberian barbel.

By the survey of the geographical points of 15 tagged barbels on a year-cycle, it was possible to differentiate these individuals into two groups according to the value of their home ranges and their migratory behavior. As a result, 47% showed a real determination to migrate upstream with an average home range of 9 652 m, whereas 53% showed a resident behavior in a restricted area with an average home range value of 1 417 m. As no causal link has been established between the physical characteristics of the fishes and their ability to cross obstacles, we can thus hypothesize that their behavior is more a willful intent than a consequence to a disability.

This result will affect the impact estimation of the longitudinal restoration. It is indeed impossible to predict whether once the interventions made on the 14 obstacles, the Iberian barbels with a resident behavior are going to remain sedentary or migrate upstream. However, it can be said that the partial and total removal of the structures on the rivers Águeda and Alfusqueiro, as well as the fishways construction, will benefit at least 47% of the study sample. Although this study focusses on *Luciobarbus bocagei*, improvements will also allow the passage of many other species such as lampreys, shads, mullets and eels.

River engineering is an anthropogenic disturbance which mainly results in the reduction of habitat diversity and river connectivity, impacting nursery habitats and access to spawning gravels. Update these structures by removing those no longer useful or by constructing fishways, is the key element in order to ensure le longitudinal connectivity of river systems and avoid fragmentation of the populations.

# Bibliography


Alain De Vocht, F. Van Belleghem, Etienne Baras, Jean-Clause Philippart. «Effect of hydropeaking on migrations and home range of adult Barbel (Barbus barbus) in the river Meuse.» *Aquatic telemetry: advances and applications. Proceedings of the Fifth Conference on Fish Telemetry held in Europe.* , 13 06 2003: p.295.

Ana T. SILVA, José M. SANTOS, Maria T. FERREIRA, António N. PINHEIRO and Christos KATOPODIS. «Effects of water velocity and turbulence on the behaviour of Iberian barbel (Luciobarbus bocagei, Steindachner 1864) in an experimental pool-type fishway.» *Wiley Online Library.* 02 02 2010. https://onlinelibrary.wiley.com/doi/epdf/10.1002/rra.1363 (accès le 07 01, 2020).

Batley, Martyn C. Lucas and Emma. «Seasonal Movements and Behaviour of Adult Barbel Barbus barbus, a Riverine Cyprinid Fish: Implications for River Management.» *Applied Ecology*, 12 1996: 1345-1358.

C. M. Alexandre, P. R. Almeida, T. Neves, C. S. Mateus, J. L. Costa and B. R. Quintella. «Effects of flow regulation on the movement patterns and habitat use of a potamodromous cyprinid species.» *Ecohydrology, published online in Wiley Online Library*, 2015.

C.M. Alexandre, B.R. Quintella, A.T. Silva, C.S. Mateus, F. Romão, P. Branco, M.T. Ferreira, P.R. Almeida. «Use of electromyogram telemetry to assess the behavior of the Iberian barbel (Luciobarbus bocagei Steindachner, 1864) in a pool-type fishway.» *Ecological Engineering*, 2013: 191-202.

Carlors M. Alexandre, Bernado R. Quintella, Ana F. Ferreira, Filipe A. Romão, Pedro R. Almeida. «Swimming performance and ecomorphology of the Iberian barbel Luciobarbus bocagei (Steindachner, 1864) on permanent and temporary rivers.» *Ecology of freshwater fish*, 2014: 244 -258.

Catherine Gutmann Roberts, Andrew M. Hindes, J. Robert Britton. «Factors influencing individual movements and behaviours of invasive European barbel Barbus barbus in a regulated river.» *Hydrobiologia*, 03 01 2019: 213-228.

Commission, European. *Portugal's RBMPs.* 07 08 2019. https://ec.europa.eu/environment/water/participation/map_mc/countries/portugal_en.htm (accès le 07 23, 2020).

*European Commission.* 01 2020. https://ec.europa.eu/easme/en/life (accès le 06 10, 2020).

Évora, Universidade de. *Habitat restoration for diadromous fish in River Mondego, Portugal.* 2015. http://www.rhpdm.uevora.pt/action1.html (accès le 07 29, 2020).

F.J. Sanz-Ronda, F.J. Bravo-Córdoba, J.F. Fuentes-Pérez and T. Castro-Santos. «Ascent ability of brown trout, Salmo trutta, and two Iberian cyprinids - Iberian barbel, Luciobarbus bocagei, and northern straight-mouth nase, Pseudochondrostoma duriense - in a vertical slot fishway.» *Knowledge and Management of Aquatic Ecosystems*, 2016: 10.

Fabio Santos, UÉvora - MARE. «Interventions Drawings.» Confidential internal project document, 2019.

Hugo F. Gante, Ignacio Doadrio, Maria Judite Alves and Thomas E. Dowling. «Semi-permeable species boundaries in Iberian barbels (Barbus and Luciobarbus, Cyprinidae).» *BMC Evolutionary Biology*, 2015: 15-111.

*Life Àgueda.* 2018. http://www.life-agueda.uevora.pt/en/objectivos.php (accessed 06 09, 2020).

LUCAS, M. C., et P. A. FREAR. «Effects of a flow-gauging weir on the migratory behaviour of adult barbel, a riverine cyprinind.» *Journal of Fish Biology*, 1997: 382-396.

*Luciobarbus bocagei IUCN Red List.* 01 01, 2008. https://www.iucnredlist.org/species/2584/9458518 (accessed 06 18, 2020).

*MARE Marine and Environmental Sciences Centre.* 2020. http://www.mare-centre.pt/en (accès le 07 06, 2020).

Michaël Ovidio, Denis Parkinson, Jean-Claude Philippart & Etienne Baras. «Multiyear homing and fidelity to residence areas by indivudal babrel (Barbus barbus).» 07 2007: 183-190.

Ministério do ambiente, do ordenamento, do território e do desenvolvimento regional. «Tipologia de rios em Portugal continental no âmbito da implementaçao da directiva quadro da água.» *Agência Portuguesa do Ambiente.* 01 2008. https://apambiente.pt/dqa/assets/tipologia-de-rios-em-portugal-continental.pdf (accès le 07 24, 2020).

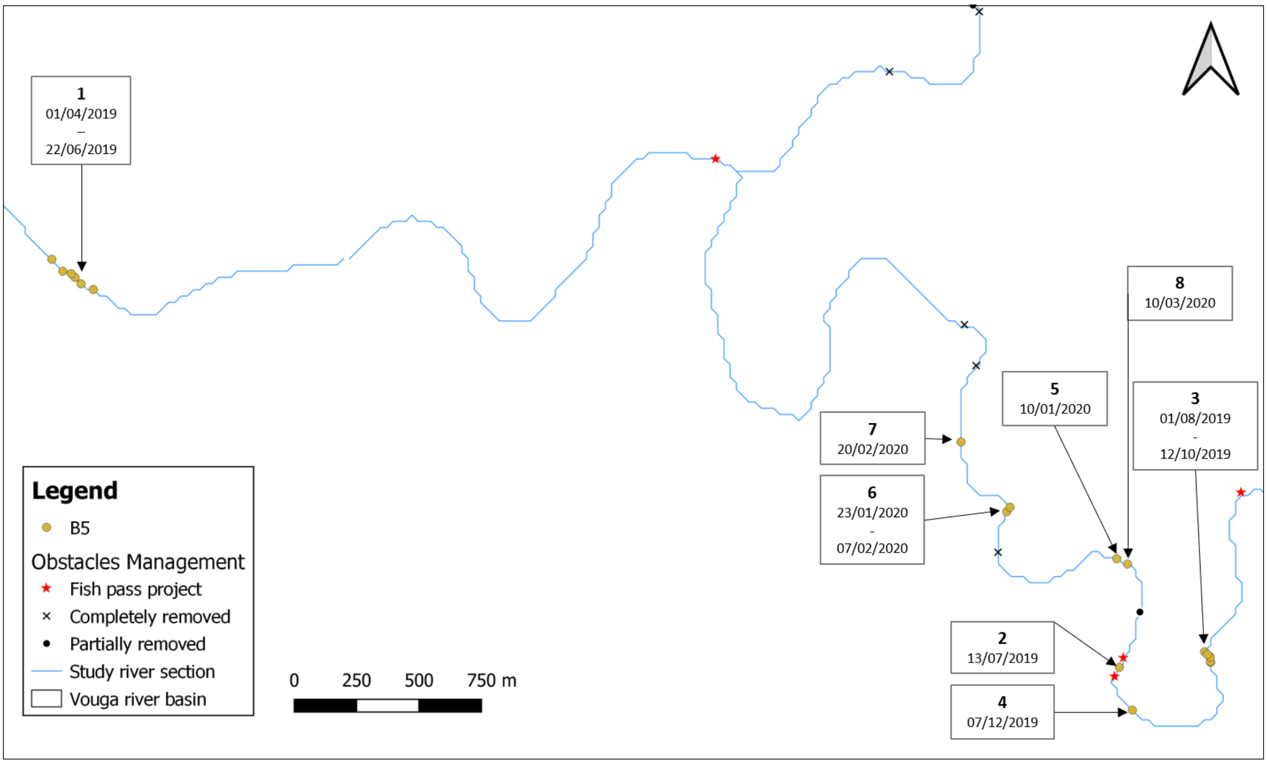
Routard, Le. *Portugal.* Hachette, 2019.

Twine, Karen Gemma. *Conservation of barbel (Barbus barbus) in the River Great Ouse.* Thesis, University of Hull, 2013.

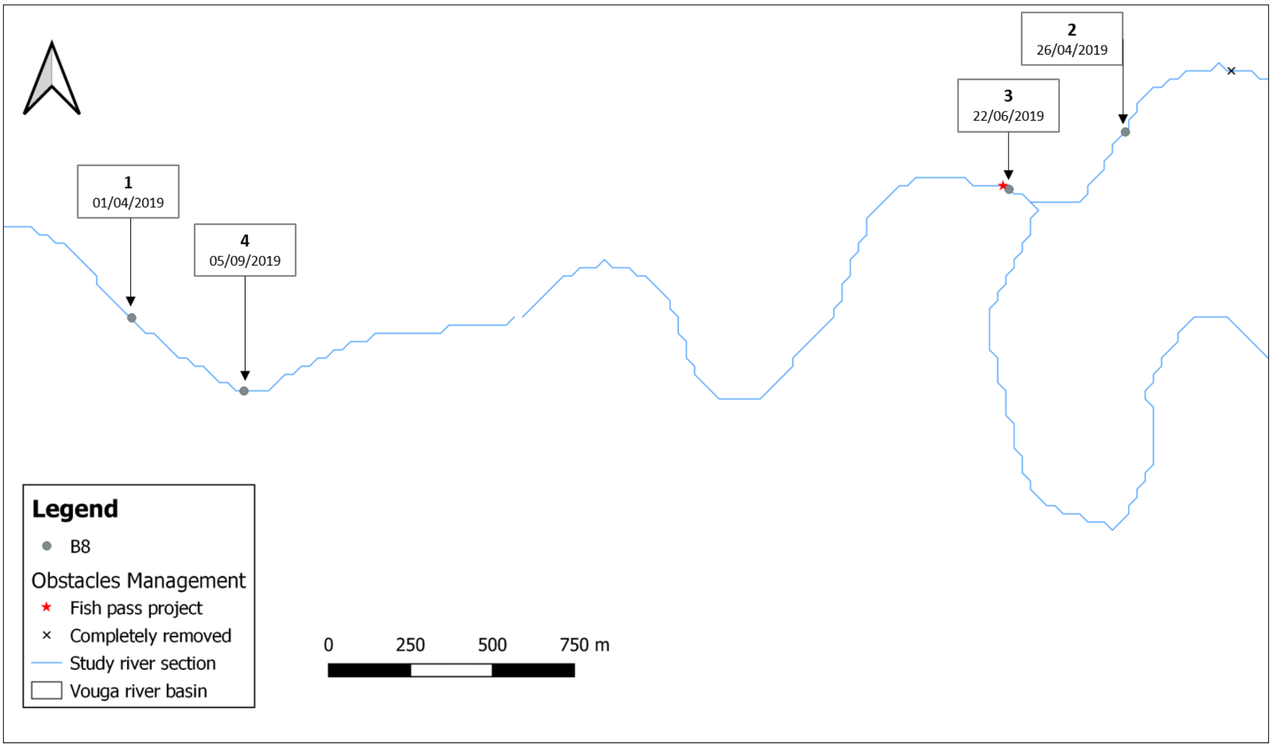
Wildman Laura, Parasiewicz Piotr, Katopodis Christos, Dumont Ulrich. *An illustrative handbook on Natur-Like Fishways - Summarized version.* Glastonbury, CT, s.d.

# Annexes

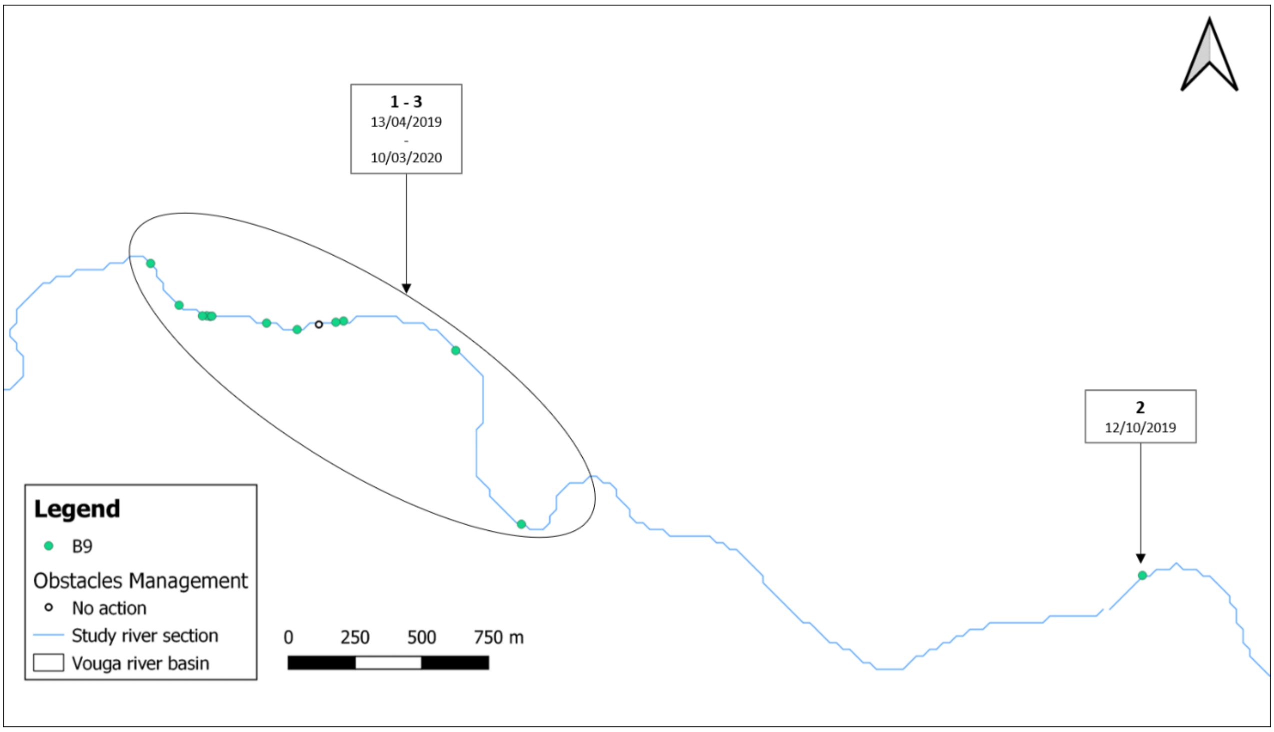
*Annex 1 : B5 movements location map*



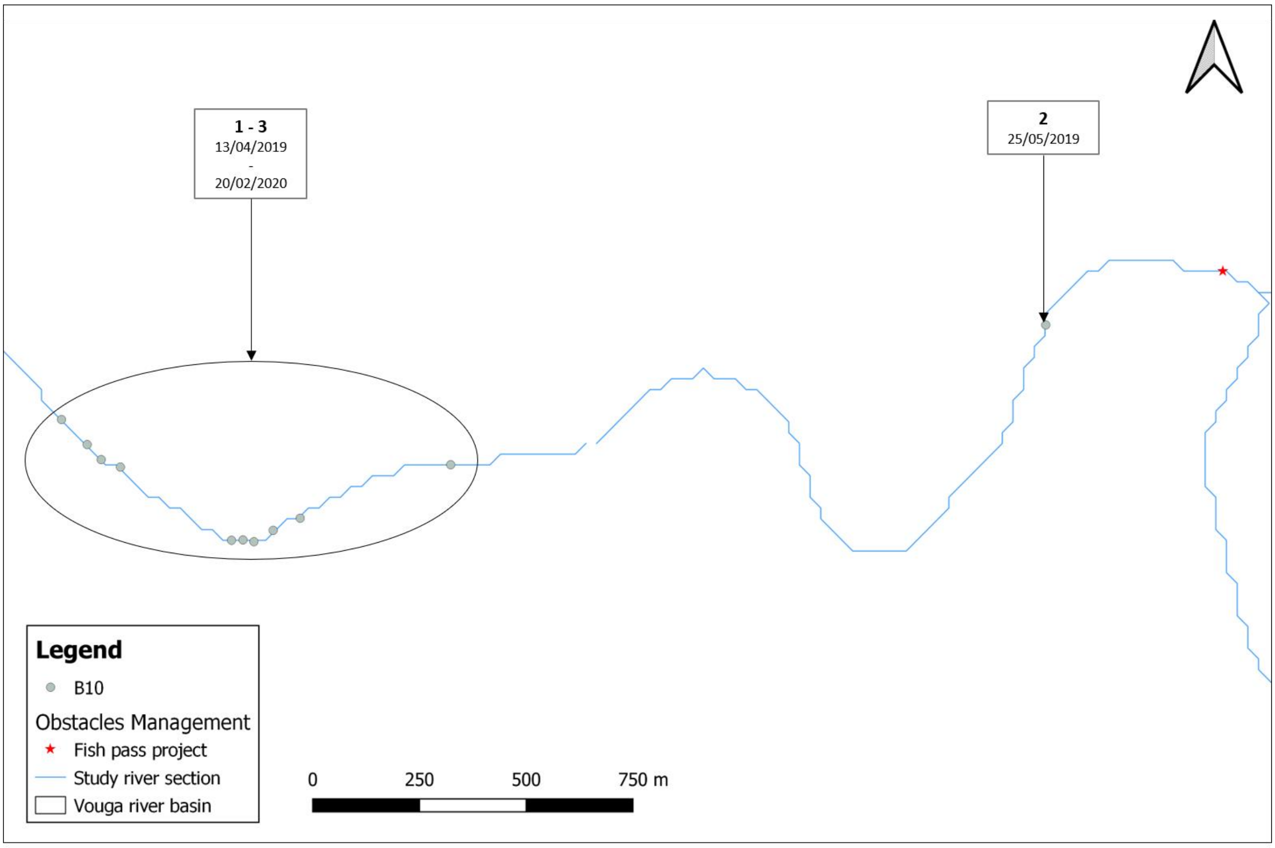

*Annex 2 : B8 movements location map*



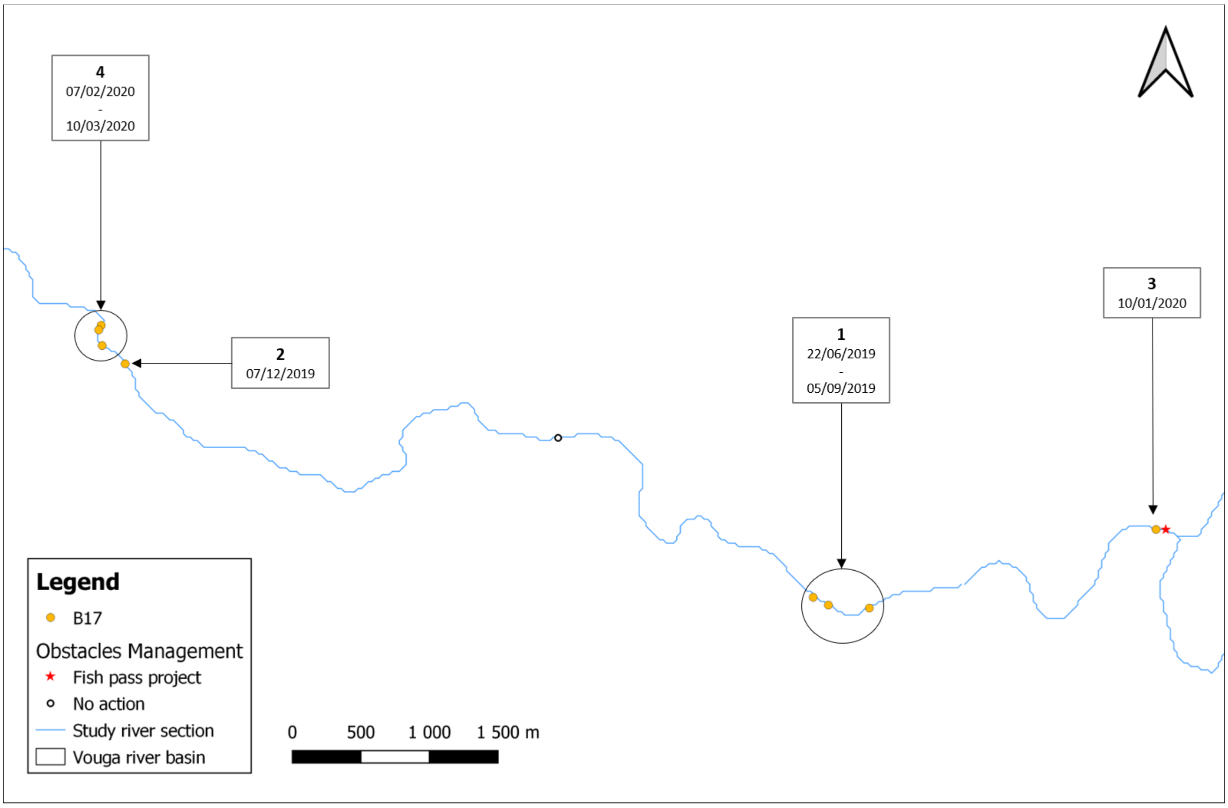
*Annex 3 - B9 movements location map*



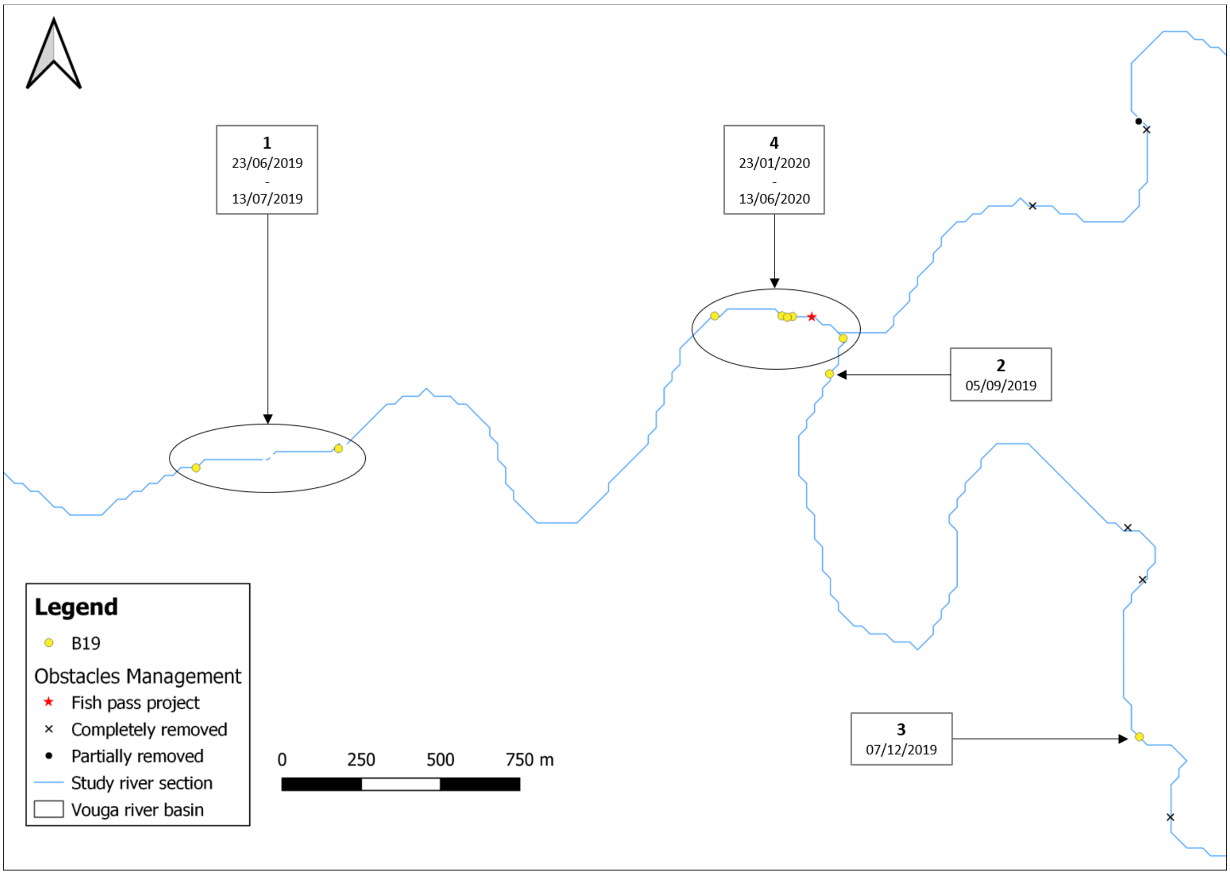

*Annex 4 - B10 movements location map*



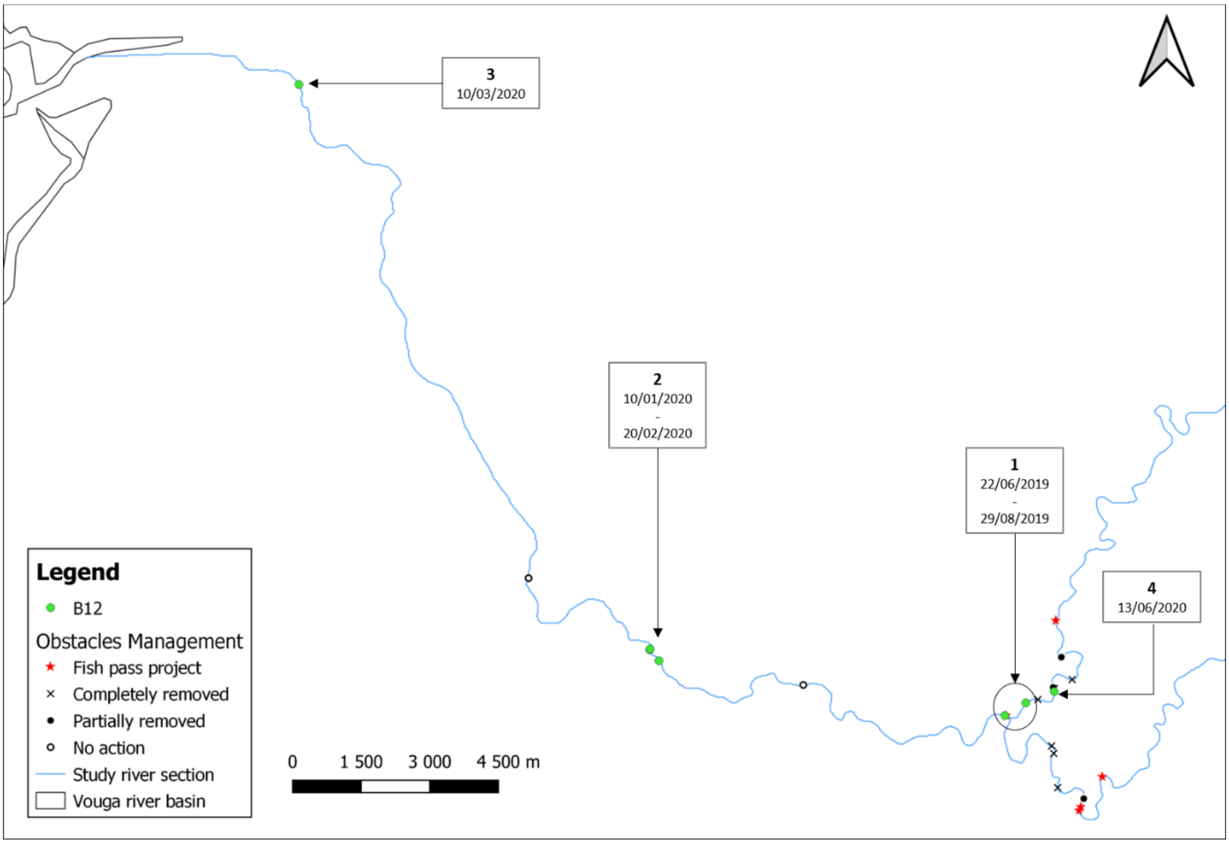
*Annex 5 : B17 movements location map*




*Annex 6 : B19 movements location map*



*Annex 7 : B12 movements location map*



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Elise GUIRAUD
IMA
2019 - 2020

# Movement patterns and migration behavior of the Iberian barbel (*Luciobarbus bocagei* Steindachner, 1964) in a context of current habitat fragmentation and future restoration.

This internship's workplan is a pre-operation phase for the **elimination of hydro-morphological pressures** project in the Àgueda river within the Vouga river basin in Center Portugal. First, an analysis of **radiotelemetry location data** previously collected during an entire annual cycle on 19 tagged *Luciobarbus bocagei* is made to evaluate **movement patterns** and determine **home ranges**. Integrated on a **GIS** program, an analysis of the relationship between observed movements and estimated home ranges, and the number and characteristics of the **existing obstacles** is made. Lastly, an estimation of home range gains and changes to the observed movement patterns of the target species, resulting from foreseen **habitat restoration** actions is build up.

UNIVERSIDADE DE ÉVORA

MARE

**Internship supervisors:**
Pedro R. ALMEIDA – Associate Professor with Aggregation
Carlos M. ALEXANDRE - PhD

**Academic advisor:**
Catherine BOISNEAU – ENS researcher