Habitat use at multiple scales as indicator of fish sensitivity to the artificialisation of large rivers

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HABITAT USE AT MULTIPLE SCALES AS INDICATOR OF FISH SENSITIVITY TO THE ARTIFICIALISATION OF LARGE RIVERS

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Habitat selection and seasonal mobility are major components of the biology of fish populations. The aim of this study is to characterise fish habitat use templates at two different spatial scales (over reaches of 2 vs. 35 km) for two native rheophilic cyprinids (*Barbus barbus* and *Squalius cephalus*) and for the non-native catfish (*Silurus glanis*). The study was carried out in the Upper Rhône River characterised by strong and rapid variations of flow and thermal regimes (caused by hydroelectric and nuclear power plants). Results reveal contrasted mobility patterns, habitat uses and home-range sizes between native and non-native fish species, but also a high inter-individual variability. At a local scale, fish modify their habitat selection when discharge changes in selecting "least constraining" conditions. At a larger scale they are able to travel rapidly between their favoured habitats.

1 INTRODUCTION

Many rivers of the northern hemisphere are heavily affected by human activity causing major changes to the rivers' continuity, morphology, flow and thermal regimes [1]. Habitat selection, mobility, spatial and temporal distribution of fish are major elements of their population dynamics [2, 3, 4, 5]. However, little information is available about the behavioral ecology of holobiotic fish in large European rivers at local as well as at large scale.

We evaluated, at different spatial and time scales, the habitat selection and displacement strategies of two native species of cyprinids (barbel and chub) and of one exotic fish species (catfish) in the artificial hydrological and thermal conditions of the Upper Rhône River at Bugey. The hydrological regime is influenced by peak power generation that generates artificial daily flow variations (hydropeaks). The thermal regime is modified by the warmed water discharges from a nuclear power plant (The Bugey NPP of Electricité de France).

2 MATERIAL AND METHODS

The study reach is a 35.5-km undiverted section of the French Upper Rhône River located north-east of Lyon (Figure 1) between the Sault-Brénaz hydroelectric facility (located upstream; Compagnie Nationale du Rhône - CNR) and the Jons-Cusset hydroelectric facility (located downstream; Électricité De France - EDF). The upstream limit (river kilometer Km0) of the study reach is distinguished by an artificial riprap weir (which cannot be passed by boat). The downstream limit (Km35.5) is identified by the dam of Jons. Sault-Brénaz's and Jons-Cusset's hydroelectric facilities cannot be passed by fish moving upstream and downstream passages remains possible through the turbines or spillways. A nuclear power plant located on the right bank of the study reach at Km 17.5 pumps ≈100 m3/s to cool its four reactors and discharges warmed-up water (between 7 and 10 °C warmer than the upstream water). The warm water discharge creates a strong transversal temperature difference between the left bank and the right bank [6, 7].

We assessed micro-habitat selection and mobility patterns of barbel, chub and catfish using acoustic telemetry. In 2009, n=5 barbel, 7 chub and 6 catfish were intensively tracked with fixed acoustic telemetry equipment to study their microhabitat (hydraulics, temperature and substrate) selection [8]. The fish were located every 3-4 s over 3 months in a 2 km-reach (Km16 – 18; Figure 1). In 2010, we used an active acoustic equipment to track n=37 barbels, 23 chubs and 13 catfishes for 7 months on a weekly basis for assessing longitudinal home ranges and movements patterns between preferred residence areas in a 35.5 km-reach divided in 71 500 m-sections [9] (Figure 1). Seven of the individuals tagged in 2009 were also tracked in 2010.

Local [7] and global [10] habitat availability in the study reaches were simulated by a two-dimensional hydrodynamic model (average water column velocity) calibrated and validated at the study reach scale.

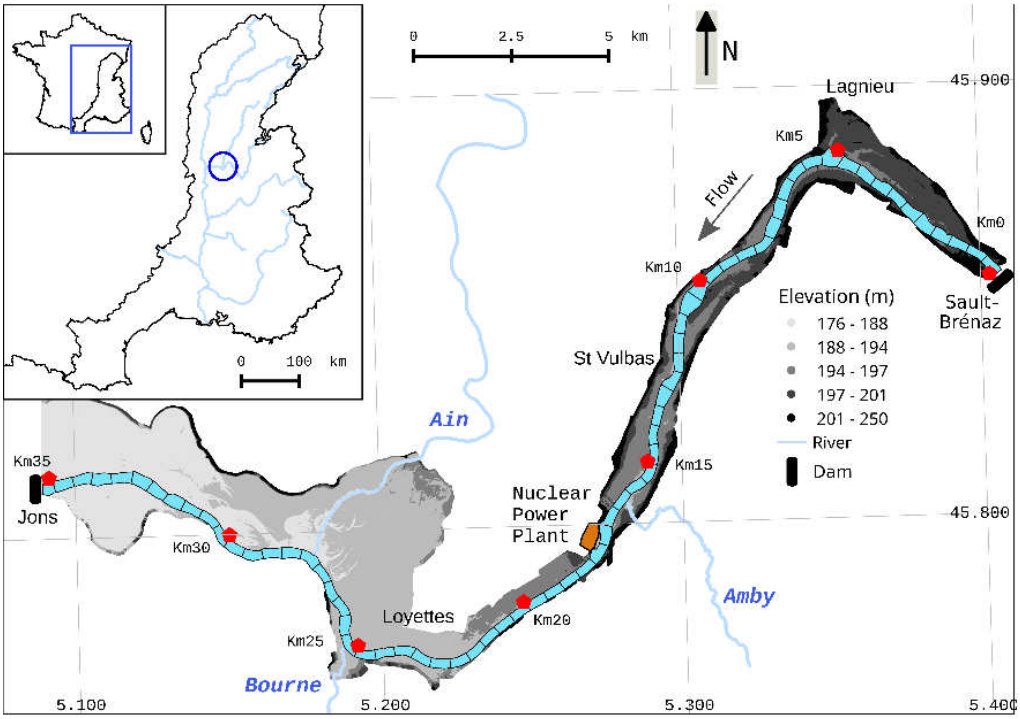

Figure 1. The 2010 study reach of the upper Rhône River was located upstream of Lyon, between Sault-Brénaz (Km0; 45°51'19.74"N; 5°24'23.40"E) and Jons's (Km35.5; 45°46'4.23"N; 4°54'49.90"E) hydroelectric facilities. The main riverbed is shown within a digital elevation model (elevations in m) in order to illustrate the section's 15-m level difference [9]. The 2009 study reach was located from Km16 to Km18, in front of the nuclear power plant.

3 RESULTS AND DISCUSSION

At the local scale, the fish tracked in 2009 modified their microhabitat selection when the flow changed by selecting hydrodynamic conditions that were the least constraining. Avoiding fast-flowing midstream habitat, fish generally live along the banks in areas where the dewatering risk is high. When discharge decreased, however, they selected higher velocities but avoid both dewatering areas and very fast-flowing midstream habitat [11].

At large-scale the fish tracked in 2010 moved rapidly between specific (and thus probably favoured) habitats (Figure 3). In comparison with catfish, barbel and chub demonstrated wider longitudinal home ranges, move more and over longer distances with greater inter-individual variability of behaviours [9]. Catfish selected habitats with a morphology that was little diversified, less sensitive to variations in flow, and with warmer water temperature (i.e. downstream from the discharges of the Bugey nuclear power plant). Hydrodynamic description at 500 m-section scale showed that barbel selected mainly shallow sections characterized by high wetted surface area variability and high range of flow velocity. Chub selected mainly sections with high range of depth and flow velocity. Catfish mainly selected sections characterized by low wetted surface area variability, warmer temperature and high range of depth and flow velocity.

In the Rhône River, the observations of movements along potential preferential routes suggest that fish can memorize the bathymetry (Figure 2) but also the hydraulic and thermal variations of their environment . The results suggest that habitat degradation is more damaging to cyprinids than catfish in large anthropogenic rivers.

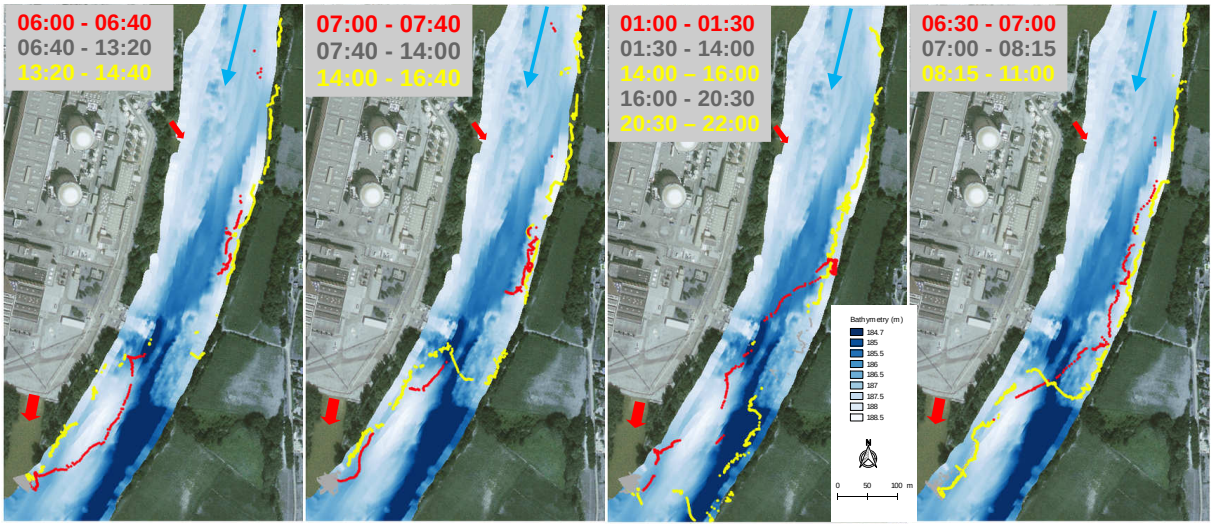

Figure 2. Movements of the catfish-#3856 during four days (3, 6, 15 and 25 from left to right) in August 2009 between Km17 and Km18. This fish always arrived from upstream (red dots) moving to the main release of warm water (thick red arrow; thin red arrow indicates the secondary release of warmed water), stayed there for a few hours (grey dots) and went back in upstream direction (yellow dots). Time corresponding to the different steps of the daily movements are indicated in the upper left corner for each day. The bathymetry of the study reach is indicated in blue (184.7 m, dark blue to 188.5 m, white). Flow direction is indicated with the blue arrow.

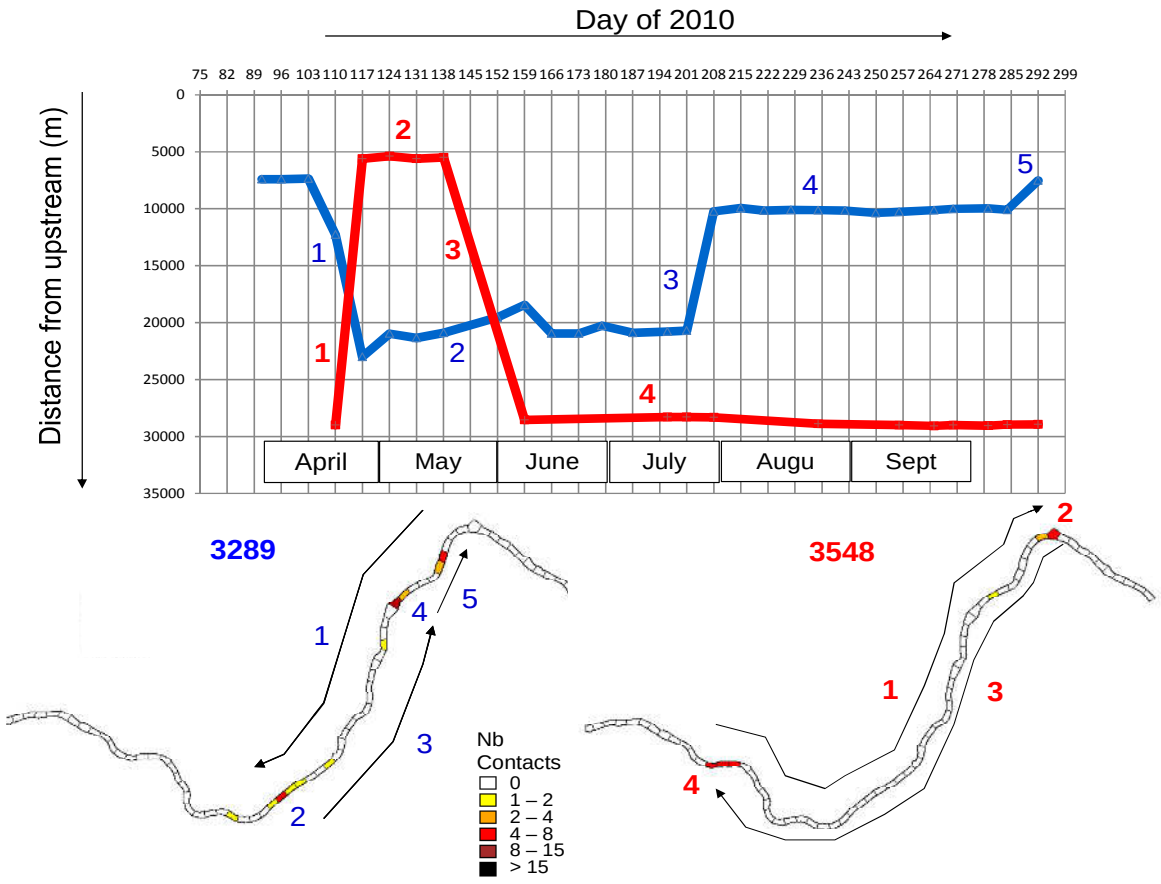

Figure 3. Movements of the barbel #3289 (blue) and #3548 (red) in 2010 in the Rhône River at large scale in time (top) and in space (bottom; see Figure 1 for 500 m- sections description). Color of each 500m- section corresponds to the number of contact of fish in this section. Arrows indicate the main steps (with the same numbers in top and bottom figures) of fish's movements.

4 ACKNOWLEDGMENTS

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