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Habitat use and preference of adult pike (*Esox lucius* L.) in an anthropogenically impacted lowland river

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ABSTRACT

To efficiently manage northern pike (*Esox lucius*), information is needed on its habitat use and preference. However, knowledge gaps still exist, especially on pike habitat use and preference in rivers characterised by artificial environments. We investigated the use of the main river, tributaries and side arms at the macro-scale, and the use and preference of riparian habitats by adult pike at the meso-scale in an anthropogenically impacted river basin. Adult pike were followed in winter and spring by radio telemetry. At the macro-scale pike intensively used the main river in winter and spring, but also frequented specific side arms in winter and specific tributaries in spring, which may indicate the importance of these habitats to adult pike. At the meso-scale, reedy semi-natural banks were used the most, irrespective of any assumption on habitat availability or use. The findings underline the value of protecting the least impacted, (semi)natural habitats for adult pike in an anthropogenically impacted river system. The large behavioural differences in habitat use between individuals at both habitat scales further underline the importance of habitat heterogeneity. The results also provide insight into the impact of riparian habitat restoration on adult pike and may be used to more efficiently manage pike rivers, e.g. by enhancing the lateral connectivity with river side arms or by reconstructing natural riparian habitats.

1. Introduction

Loss of natural habitat by channelization, water pollution and migration barriers caused pike (*Esox lucius* Linnaeus 1758) population declines and impedes successful restoration programmes (Chapman and Mackay, 1984a; Ovidio and Philippart, 2003; Radomski and Goeman, 2001). Indeed, pike requires natural habitats to successfully survive and reproduce, such as shallow areas with submerged vegetation to spawn and areas with emergent vegetation to hunt for prey and hide from larger cannibalistic pike (Bry, 1996; Casselman and Lewis, 1996; Grimm and Klinge, 1996). Adult pike choose habitat according to intrinsic fitness gradients, equalizing their fitness across habitats (Haugen et al., 2006). They are versatile in their habitat use, depending on availability of prey and meteorological factors (Chapman and Mackay, 1984b). Although they use the open water as well as vegetated areas, they are more often observed in the proximity of vegetated areas than would be expected if they were choosing the habitat randomly (Chapman and Mackay, 1984a). Studies on the impact of river and lake management on pike have mainly focused on juvenile and spawning habitat requirements (Cooper et al., 2008; Engstrom-Ost et al., 2005; Farrell et al., 1996; Hawkins et al., 2003; Miller et al., 2001; Skov and Berg, 1999; Skov et al., 2002, 2003).

The studies that revealed adult pike behaviour were mainly conducted in natural to semi-natural lake (Chapman and Mackay, 1984b; Cook and Bergersen, 1988; Diana et al., 1977; Haugen et al., 2006; Kobler et al., 2008) and river (Masters et al., 2002; Vehanen et al., 2006) systems. However, a gap still exists for river systems characterised by an artificial environment, such as for instance partly channelized rivers. Large pike may use the whole river or lake, including the most impacted areas, or restrict their home range to the least impacted areas. Furthermore, they may use artificial riparian habitats. The only study that compared an impacted habitat to a less impacted habitat was conducted in a reservoir and a lake (Jepsen et al., 2001). Although large behavioural differences were observed between the reservoir and the lake, the study revealed more variation between individuals within each population. Insight into the required physical and ecological habitat conditions of adult pike in a modified river system can further improve the effectiveness of river conservation and restoration plans.

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Therefore, the aim of this study is to investigate adult pike habitat use and preference in a river characterised by an artificial environment. Specifically, radio telemetry was applied to evaluate which river parts are used at the macro-scale and which riparian habitat types are used and preferred at the meso-scale.

2. Materials and methods

2.1. Study area

Pike were studied in the 1101 km^2 drainage area of the 44 km long Belgian part of the river Yser (Fig. 1). The river has a rainfall-dominated hydrology with an average annual flow of 1.44 $m^3 s^{-1}$, a peak flow of 5.7 $m^3 s^{-1}$ and a base flow of 0.8 $m^3 s^{-1}$ (Mouton et al., 2012). The river is navigable and a tidal sluice at the estuary prevents tidal water level fluctuation and inflow of salt water. Directly upstream of the tidal sluice the river flows in a 370 × 1000 m wide basin with a depth of 7 m. There is no migration barrier in the main river, and pike can freely move between the main river and most of its tributaries. Average water depth is 2.5 m (Mouton et al., 2012) with the river thalweg varying in depth from 2.8 to 5 m. Near the French border, the river is 8 to 10 m wide, at the mouth it is 25 m wide (Mouton et al., 2012). In the river Yser, 58% of the river banks were originally artificially embanked. because a significant area of the floodplain lies below sea level. Due to this channelization, depth, substrate and flow velocity are distributed relatively uniformly. To restore the riparian habitat and the associated fish populations, the river managers constructed several artificial foreshores and river side arms between 2002 and 2005.

The water quality of the river Yser varies little throughout the year (Flemish Environment Agency, www.vmm.be). The conductivity averages 0.75 mS cm^{-1} but can exceed 1 mS cm^{-1} in extremely dry periods. The fish fauna in the study area consists of 24 species, however not all 24 species are present everywhere in the study area. The most dominant species, occurring everywhere in the study area and being dominant in numbers and biomass are white bream (*Blicca bjoerkna* L.), roach (*Rutilus rutilus* L.), European eel (*Anguilla* L.), freshwater bream (*Abramis brama* L.) and common carp (*Cyprinus carpio* L.). Two dominant predators beside pike are European perch (*Perca fluviatilis* L.) and pikeperch (*Sander lucioperca* L.; see Research Institute for Nature and Forest, www.vis.inbo.be, for the full species list). Fisheries legislation prohibits fishing from March 1st to May 31st in the tributaries of the river Yser, however, on the main river fish can be caught throughout the year. All fish have to be released immediately after they were caught.

In this study we investigated pike habitat use and preference at the meso- and macro-scale. At the meso-scale, eight different riparian habitat types were defined based on a combination of the vegetation types and river bank types. The riparian vegetation in the study area can be classified as bare (B), reedy (R) and woody (W) vegetation. Three river bank types, characterised by a different degree of anthropogenic disruption, are present in the study area: artificial vertical banks (AVs; high disruption), artificial foreshores (AFs; moderate disruption) and semi-natural banks (SNBs; low disruption). AVs are vertically straightened and reinforced with concrete, while AFs consist of a row of 0.2 m diameter wooden posts that are positioned in the river channel between 0.7 m and 2.5 m from the river bank. The posts are placed at 0.05–0.2 m distance from each other to protect the riparian habitats from shipping wave action. Vegetation in the zone between the posts and the river bank consists mainly of reed and vegetation cover ranges from 0 to 100%. SNBs are highly heterogeneous and characterised by varied bank vegetation such as trees, reed and other emergent vegetation (Mouton et al., 2012). The combination of the different vegetation and river bank types led to eight different riparian habitat types in the study area: bare, reedy and woody artificial vertical banks (B:AVs, R:AVs and W:AVs, respectively), bare, reedy and woody semi-natural banks (B:SNBs, R:SNBs and W:SNBs, respectively) and bare and reedy artificial foreshores (B:AFs and R:AFs, respectively; Fig. 2).

The smallest scale at which variation in the defined riparian habitat types occurred was 20 m. Consequently, the riparian habitat use and preference was assessed by dividing the banks of the main river, the tributaries and side arms in segments of 20 m length. For segments consisting of more than one riparian habitat type, the habitat type that covered more than 50% of the segment was selected. The riparian habitat type within each segment was determined based on riparian habitat data retrieved from a digital map (Research Institute for Nature and Forest, unpublished data) in ArcMap (ArcGIS 10, ESRI BeLux). Riparian habitat use and availability were defined as the number of segments used and available, respectively (Fig. S6).

At the macro-scale, five different habitat types were distinguished: the main river, the large and small tributaries and the artificial and natural side arms. The main difference between the large and small tributaries is their width and depth. The two largest tributaries of the river Yser (the Handzamevaart (T1) and the Ieper-Yser Canal (T2; Fig. 1) are 10 to 15 m wide and 1 to 2.5 m deep, whereas the small tributaries are 4 to 10 m wide and maximally 2 m deep. Two small tributaries that were used by tagged pike are the Landdijkgracht (T3) and the Boezingegracht (T4; Fig. 1). Side arms are shallow (0.5 to 1.5 m deep) and stagnant, with banks that are dominated by tall herbs and reed, and are connected to the main river. Two of the six side arms in the study area are natural (S1 to S2; Fig. 1) and four are artificial (S3 and S6; Fig. 1). The artificial side arms were created between 2002 and 2005 to restore the riparian habitat in the river Yser. Although they are relatively young, the reed vegetation is similar to the reed vegetation in the natural side arms. All side arms in the study area are between 150 and 500 m long and between 10 and 20 m wide. All meso-scale riparian habitat types are present in the main river. The two largest tributaries are characterised by B:SNBs, R:SNBs and W:SNBs, except the most downstream part of T1 in the city of Diksmuide that consists of B:AVs and R:AVs. The riparian habitat types in the small tributaries are B:SNBs, R:SNBs and (less abundant) B:AVs.

2.2. Fish capture and tagging

Although historical evidence of a high-density (estimate based on historical angling reports of 26 kg ha^{-1}) population of pike in the river Yser exists, densities have been low since the first standardised observations in 1996 (Research Institute for Nature and Forest, www.vis.inbo.be). For the tracking study, pike were sampled at 15 different locations in the river between 3 and 32 km upstream of the tidal sluice (Fig. 1) by fyke sampling during nine events between November 24th and December 13th 2010. At each sampling location, two double fykes were placed in the river for 48 h. In total, nine females and six males were caught at five of the 15 different locations during seven of the nine different sampling events (Table 1). The pike were anaesthetised immediately in a 1:9:10000 clove oil:ethanol:water solution (C8392, Sigma, Bornem, Belgium), measured, weighed and tagged with a 68 mm long and 18 mm wide body implant radio transmitter (Model: F1230, coil antenna, Advanced Telemetry Systems Inc., Isanti, MN, USA; weight: 23 g in air and 6 g in water, battery life: 502 days). Each transmitter had a different frequency between 40000 and 41000 MHz. The minimal, median and maximal female and male mass and length were 1057, 3700 and 8750, and 1100, 5540 and 8150 g, and 55, 78 and 99, and 67, 83 and 97 cm, respectively. Thus, the transmitters never exceeded 2% of the body mass (Jepsen et al., 2002; Table 1). The transmitters were inserted into the body cavity through a ventral

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