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The habitat use of young-of-the-year fishes during and after floods of varying timing and magnitude in a constrained lowland river

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ABSTRACT

Globally, channelisation and artificial levee construction have reduced rivers to single-thread channels isolated from their floodplains. These modifications may be particularly detrimental to fish during floods, because of increased severity of conditions in the main river channel, prevention of fish finding refuge in floodplain habitats, and stranding of fish when floodwaters recede after artificial levees are 'over-topped'. Notwithstanding, few studies have examined the habitat use by young-of-the-year (YoY; age 0+ year) fish in constrained lowland rivers during floods in slackwaters (main channel with little or no discernible current) and after floods on floodplains. This study investigated the community structure and density of 0 + fish species before (main river), during and after floods of varying timing and magnitude in the River Yorkshire Ouse, a constrained lowland river in north-east England. Slackwaters provided refuge for high densities of mainly eurytopic 0+ fishes during floods and high densities of 0+ fishes were found stranded on floodplains after floods. Community composition in slackwaters during floods and on floodplains after floods was significantly different to the main river catches during average daily flows, possibly related to species-specific morphology and behavioural responses to elevated flow. Despite there being floods of greater magnitude during the winter, peak densities of 0+ fish stranded on floodplains occurred in the summer, and probably related to habitat use immediately prior to floods. Fish were also found stranded on floodplains actively managed to store floodwater to protect property and are presumed to permit safe egress for fish. The results are discussed in relation to lowland river rehabilitation, which is particularly important because of potential conflicts between obligations under various European directives to improve the status of fish populations in degraded rivers (Water Framework Directive) whilst at the same time minimise flooding of societal assets (Flood Directive).

1. Introduction

Natural lowland river–floodplain ecosystems have a complex gradient of aquatic and riparian habitats that collectively contribute high structural diversity (Welcomme, 1979; Junk et al., 1989). In addition, natural rivers are characterised by high hydrological connectivity during floods that cause lateral expansion of the main river channel onto the floodplain (Welcomme, 1979), connecting various landscape patches and determining the availability of previously isolated habitats to fish. Specifically, river–floodplain connectivity allows fish to disperse freely and take advantage of different floodplain habitats for refuge, spawning, nursery and feeding. Thus, lateral connections are essential for the functioning and integrity of natural floodplain ecosystems (Amoros and Bornette, 2002).

To prevent damage to property caused by flooding many rivers have been subjected to channelisation and artificial levee construction reducing them to single-thread channels and isolating them from their floodplains (Ward and Stanford, 1995; Cowx and Welcomme, 1998). Reduced floodplain habitat has been reported to affect fish species that are adapted to use periodically-inundated floodplains as spawning and nursery habitats (Kwak, 1988; Lucas and Baras, 2001; Grift et al., 2003). Such modifications can also have adverse consequences for fishes during floods and high flow events because of increased severity of conditions (e.g. increased water velocity and bedload transport) in the main channel (Lusk et al., 1998; Poff et al., 2006), prevention of fish finding floodplain habitats for refuge (Ross and Baker, 1983; Kwak, 1988), and the stranding of fish when floodwaters recede after artificial levees are 'over-topped'. This is of particular importance to young-of-the-year (YoY; age 0+) fish because of their poor

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swimming capabilities (Harvey, 1987; Mann and Bass, 1997). Although river discharge and the timing of floods are increasingly being recognised as an important cause of inter-annual variability in the recruitment success of cyprinid fishes (Nunn et al., 2007), the influence of floods on 0+ fish habitat use during and after floods in modified lowland rivers is poorly known. In addition, flood frequency and magnitude are predicted to increase under the influence of climate change (Kundzewicz et al., 2007) and interact with existing riverine alterations and further impact ecosystem functioning (Peterson and Kwak, 1999; Gibson et al., 2005).

The aim of this study was to determine the habitat use of 0+ fishes during (slackwaters; main channel with little or no discernible current, Humphries et al., 2006) and after (floodplains isolated from the main river) floods of varying timing and magnitude in a constrained lowland river, the River Yorkshire Ouse, in north-east England. Specifically, the objectives were to: (1) compare fish community structure in slackwaters during floods with that in the main river during average flows; (2) evaluate the community structure of fish stranded on floodplains isolated from the main river by artificial levees after floods; and (3) assess the propensity for fish stranding on floodplains with differing floodwater ingress and egress routes.

2. Study area

The Yorkshire Ouse (Fig. 1) is one of the UK's largest single-thread rivers and has been isolated from its floodplain by channelisation and levee construction. The river drains 10,000 km^2 of predominantly rural catchment, has an average width of 50 m and a depth of 3–4 m; water quality is generally good (Neal and Robson, 2000). Precipitation run-off from the Pennines often results in elevated river levels and out-of-bank floods, such as those which occurred in August, October and December 2004, October 2005, March and December 2006, and January 2007 (Fig. 2).

3. Materials and methods

3.1. 0+ fish surveys

Sampling occurred at eight river sites (during average daily flows), six slackwater sites (during elevated flows) and five floodplain sites (after floods) (Table 1). The river sites were in the margins of the main channel in areas devoid of large woody debris, in water ≤1.5 m deep, where water velocity was slow and where 0+ fishes tend to aggregate. 0+ fish aggregations were surveyed at river sites from April 2004 to February 2007 (fortnightly during May–July and monthly during August–April), inclusive, in daylight hours. The slackwater areas sampled only existed during elevated river levels and floods, and consisted of plateaus between the main river channel and levees (S1, S2 and S3), a 'backed-up' tributary (S4), a slipway between two buildings (S5) and a bay downstream of some large marginal willows (*Salix* spp.) (S6). Floodplains were sampled after flood events as soon as areas of water became isolated from the main river channel. Four of the floodplain sites flooded because levees overtopped. Two of these (F1 and F2) drained through underground pipes, one (F3) drained via a 'flap-gated' ditch but left a substantial area of water isolated from the main river, and one (F4) emptied through a sluice with any residual water extracted by pumping. The fifth floodplain site (F5) was flooded by a manually operated sluice (upstream end) and was drained through a sluice (downstream end) after river levels receded; any residual water was extracted by pumping.

All samples were collected using a micromesh seine net (25-m long by 3-m deep, 3-mm hexagonal mesh) set in a rectangle parallel to the bank by wading or pulled between two people stood at the upstream and downstream end of where the net was set using a rope when it was too deep to wade along the river. All sites sampled, except a small area of S4, were shallower than the depth of the seine net (Table 1) and thus sampling efficiency was assumed to be comparable. The seine net captured larvae as small as 5 mm, although its efficiency was reduced for fish smaller than ~15 mm (Cowx et al., 2001). Captured fish were identified to species (Pinder, 2001), separated into six larval (L1–L6) and one 0+ juvenile (J) developmental step (Copp, 1990; Peňáz, 2001), and measured for standard length (SL, nearest mm). 0+ fishes were aged by analysis of length-frequency distributions or by scale reading (Bagenal and Tesch, 1978).

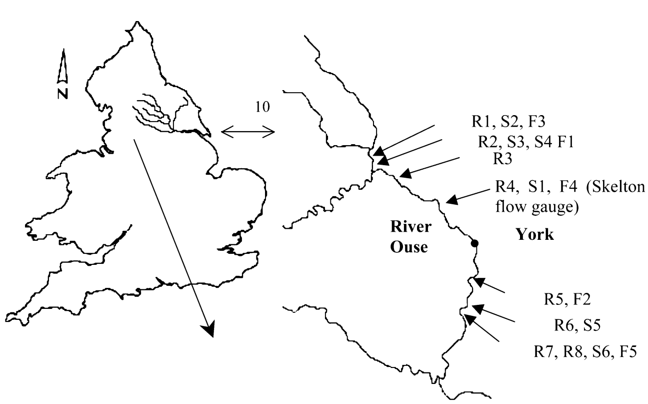

Fig. 1. A map of England showing the location of the Ouse catchment, and a more detailed catchment map showing river, slackwater and floodplain sampling sites, and Skelton flow gauge. Site codes are as in Table 1.

3.2. Data analysis

At each site, the frequency of occurrence and relative abundance of each fish species was calculated from all surveys (Hynes, 1950), and the Shannon–Wiener diversity index (H'), Margalef's species richness index (d) (Washington, 1984) and the relative density (fish m^{-2}) of 0+ fishes (all species combined) was calculated for each sampling occasion. Frequency of occurrence of a given species was defined as the number of surveys in which the species occurred, expressed as a percentage of the total number of surveys carried out. Relative abundance of a species was defined as the percentage of total catches (numbers) in all surveys contributed by the given species.

Mann–Whitney *U*-tests were used to test the null hypothesis that the mean H' and d of 0+ fishes for all surveys at each site did not differ significantly between the river and slackwater/floodplain sampling units. Non-parametric multi dimensional scaling (MDS, Clarke and Warwick, 2001), based on Bray–Curtis similarity (Bray and Curtis, 1957) of mean percentages of each 0+ fish species was carried out to investigate similarity in 0+ fish species composition between sites. One-way, a priori analysis of similarities (ANOSIM, Clarke and Warwick, 1994) was used to test the null hypothesis that there was no significant difference in 0+ fish species composition between main river (R), slackwater (S) and floodplain (F). SIMPER (similarity percentages–species contributions, Clarke and Warwick, 1994) analysis was used to calculate the percentage contribution of each key species to the overall dissimilarity of 0+ fish communities caught in the main river to those in slackwaters and on floodplains.

All statistical analyses were performed with SPSS version 16. Multivariate analysis were carried out using PRIMER (Plymouth routines in multivariate ecological research) (version 6.1).