A comparison of adjacent natural and channelised stretches of a lowland river

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Comparisons of fish assemblages of adjacent stretches of natural and channelised river are rare. We compared the species richness, ichthyomass (kg) and fish density (ind.$\cdot$m^{-2}) in ten pairs of adjacent stretches on the River Lee (Hertfordshire, UK) and River Stort (Essex, UK) to assess the influence of channelisation on fish community structure. Significantly lower values (paired t-test) for all aspects were found in the channelised stretches compared to the natural stretches.

Key words: river regulation, channelisation, fish community structure, species richness.

Introduction

The impacts of channelisation and other river regulation practices on fishes have received considerable attention (ZALUMI, 1970; TRAUTMAN & GARTMAN, 1974; KELLER, 1976; SWALES, 1982; BROOKES et al., 1983; LINFIELD, 1985; COWX et al., 1986, 1995; MANN, 1988; COPP, 1990; WILCOCK, 1991). Most studies have compared natural and channelised reaches upstream and downstream on the same river channel (PORTT et al., 1986; SWALES, 1988; MOYLE, 1976; CONGDON, 1971; HANSEN & MUNCY, 1971; GOLDEN & TWILLEY, 1976; TRAUTMAN & GARTMAN, 1974; BERREBI DIT THOMAS et al., 1998; JURAJDA et al., 2000, 2001; HOLČÍK & MACURA, 2001), referred to as the "within stream" method (SWALES, 1982), or between sites on different rivers (SCHLOSSER, 1982; COECK et al., 1993). However, few studies have compared natural and adjacent channelised stretches, providing spatially and temporally comparable data on the differences in habitat quality for fish communities. The comparison of adjacent channels avoids site specific differences that can influence fish densities and distributions, such as differences in suspended solid loadings, river discharge, bed substratum and river bed slope. In most cases of river channelisation, the original river channel is significantly modified, leaving no natural remnants. However, in some cases, such as in the River Lee and River Stort (SE England), the rivers were channelised for navigation during the 18th century but side loops and original meanders were left intact, with the flow regime designed to allow flow through these elements of the original flood plain. This provides a relatively unique opportunity to compare snapshots of fish communities within natural and channelised water courses of the same system within the same season. With respect to fish species richness, ichthyomass and fish density, the aim of the present study was to test for differences in fish community structure to assess the impact of river channelisation and habitat modification in the rivers Lee and Stort. This investigation was intended to complement a concurrent, wider study of fish-habitat associations in the rivers Lee and Stort (PILCHER & COPP, 1997).

Study area, material and methods

The River Lee rises from springs near Luton in Bedfordshire (National Grid Reference TL 061 248) and flows south-easterly to Hertford, where a number of smaller rivers converge. Above Hertford, the flow is provided mainly by treated sewage effluent (PILCHER & COPP, 1997), but the physical habitat of the river is largely unmodified and exhibits good flow rates, extensive pool and riffle habitat and a mixed substrate of gravel and silt. At Hertford, the Lee was channelised in the late 19^{th} century to form the Lee Navigation Canal. The River Stort, which arises north of Bishops Stortford near Clavering (NGR TL 466 340), is channelised for navigation along the majority of its lower course during the same period and converges with the River Lee Navigation near Hoddesdon in Hertfordshire (NGR TL 391 092). From the convergence, the River Lee Navigation Canal runs south through urban north London, to join the River Thames near Bow. The navigation channels were constructed at or near the centre of the flood plain, similar to descriptions of similar work on the River Morava (REICHARD et al., 2002) except that in the Lee and Stort the cut-off meanders form 'loops' fed with water by overspill weirs from the canal and converging with the canal again at a downstream point in the system. The connections between the navigation channel and the remnant meanders are by way of numerous pairs of lock gates. River discharge in the River Lee varies between 1 and 5 $m^3 \cdot s^{-1}$, with the peaks usually occurring in winter periods (FAULKNER & COPP, 2001). This flow is shared by the navigation channels, which are generally slow flowing and possess predominantly muddy substrata, and the remnant side-loops, which receive any excess flow and are relatively narrow pool and riffle systems (asymmetric bed profiles) with diverse in-stream macrophyte assemblages and bankside plant communities.

Sampling took place in winter between November and February in 1990, 1992 and 1993 at ten pairs of adjacent stretches (natural/channelised) on the River Lee (Dicker Mill/Herts Basin, Ware Priory/Kingsmead, PowderMill/Windmill, Flour Mill/Rammy Marsh) and its main tributary the River Stort (Thorley Marsh/Spellbrook, Tednambury Loop/Tednambury, Sawbridge Ditch/Sawbridge, Pishiobury/Harcamlow, Eastwick loop/Eastwick, Briggins/Brick Lock). To ensure that a range of complete macrohabitats were surveyed (HANKIN & REEVES, 1988), survey site lengths varied between 65 and 285 m (mean = 123.2 m, SD = 50.08) according to each site's character. All sites were delineated using small mesh (20 mm) nets and fish removed by electrofishing (wading or boat) using the successive removal method (SEBER & LE CREN, 1967) with 240 V DC equipment. In wide and deep channels (> 10 m wide, > 1.5 m deep), central stop nets were used to sub-divide the site so as to improve fish capture efficiency. Most pairs of sites sampled within three to four weeks of each other, except Dicker Mill/Herts Basin (nine weeks, the former in early September), PowderMill/Windmill (12 weeks), Flour Mill/Rammy Marsh (10 weeks), and Eastwick loop/Eastwick (13 weeks, the former in late September).

Sub-adult and adult fish of > 100 mm fork length were identified, measured for fork length (FL) weighed (g), counted and subsequently returned to the water. Fish densities, biomass, species richness S (number of species) were calculated for each site. To adjust for the effect of density on species richness ($S = 1.781 \ln \text{Fish Density} + 11.982$; $r^2 = 0.679$, $df = 18$, $F = 38.11$, $P = 0.0001$), we calculated the residuals for each site from this relationship. Paired comparisons were undertaken using the Student's t-test. Removal of those pairs of sites with greater discrepancies in sampling date had little effect on the test probabilities from the comparisons.

Results and discussion

In total, 2,366 fish (547.3 kg in total) were captured at a mean density of 0.13 $\text{ind.} \cdot m^{-2}$. Fish species number per site ranged from 2 to 11 (mean = 7, SE = 0.68), whereas richness ranged from 14.7 to 500 (mean = 158.3, SE = 31.6). As predicted, natural stretches had a significantly higher fish density, biomass and number of species than channelised stretches (Fig. 1), with five species demonstrating significant differences in biomass between natural and channelised stretches (Tab. 1). And although adjusted richness in natural channels was higher for some pairs, it was lower for others (Fig. 1). So, contrary to prediction, adjusted species richness did not differ between natural and channelised stretches. This emphasizes the importance of taking the impact of density on species number into consideration when evaluating species richness. Lower fish density, biomass and species number in channelised stretches of the Lee and Stort resemble patterns observed in other European (e.g. SWALES, 1988; COECK et al., 1993) and N American streams (e.g. HANSEN & MUNCY, 1971; GOLDEN & TWILLEY, 1976). However, values are not always lower in channelised stretches, as demonstrated by HOLČÍK & MACURA (2001) in a Slovak mountain stream (see

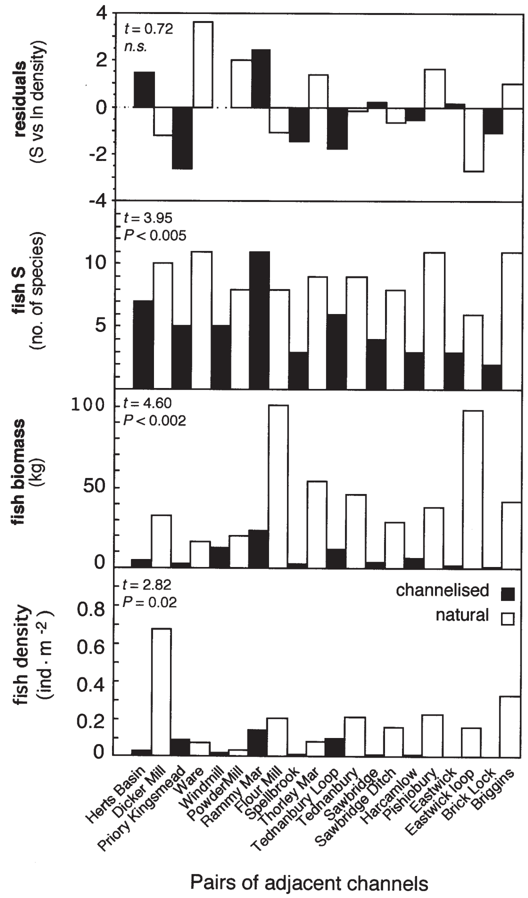

Fig. 1. Number of species, total biomass (kg) and estimated total density (ind.·m^{-2}) of fish in adjacent natural and channelised stretches of the lower River Lee (UK).

also bleak and tench in Tab. 1). The lower values observed in the River Lee, as with the other water courses cited above, probably result from reduced habitat heterogeneity (JUNGWIRTH et al., 1993), which includes less variable discharge rates, general channel uniformity, absence or insufficiency of in-stream structures (branches, logs, vegetation). In natural stretches of the rivers Lee and Stort, fish in general were distributed throughout the site, whereas in some channelised sections fish were captured in large, isolated shoals, often containing a high number of smaller specimens. Small or young fish may dominate in channelised or managed stretches, where lower ichthyomass values have been attributed to changes in age-class structure, species composition and growth rates due to a loss of suitable habitat (e.g. PORTT et al., 1986; SWALES, 1988; COPP & BENNETTS, 1996). Our sampling protocol excluded fishes < 100 mm FL, so we cannot provide evidence of a shift towards a dominance of age-0 fishes in the channelised reaches of the Lee and Stort.

Declines in fish species number resulting from reduced habitat diversity are often attributed to river regulation and maintenance operations (e.g. HANSEN & MUNCY, 1971; GOLDEN & TWILLEY, 1976), but these may not be linked to differences in water quality and channel depth profile (COECK et al., 1993) and species number increases with increasing fish density, so care is needed in assessing differences in species richness (e.g. Fig. 1). Similarly, differences in fish community structure may not result directly from channelisation but from changes associated with fish habitat preferences (limnophilous species more prominent in channelized stretches (PILCHER & COPP, 1997) as well as from other impacts. Maintenance operations such as weed-cutting can have negative effects on zooplankton distribution and fish growth (GARNER et al., 1996) as well as on the invertebrates associated with the vegetation (PEARSON & JONES, 1978). Recovery from channelisation or management operations can be slow. Fish densities in the River Soar (England) after channelisation were lowest in a downstream natural reach and highest in a partially-channelised stretch, which was downstream of two channelised sections (SWALES, 1988). Density and biomass in the natural stretch gradually increased over a six-year period (COWX et al., 1986), but the channelised stretch was avoided by fish until five years after channelisation. COWX et al. (1986) suggested that fish used the natural stretch of the Soar as a refuge, such as floodplain annexes are used by fish as refuges from hydrological disturbances (ROSS & BAHES, 1983). In the rivers Lee and Stort, fish movement between channelised and natural stretches is generally impeded by water regulation structures, but in some cases movement is possible via an open connection at the downstream confluence of the two stretches. Nonetheless, fish density and biomass were always greater in the natural stretches (Fig. 1).

Our study emphasizes the benefits of conserving natural water bodies, natural side channels and meanders, which help maintain fish biodiversity and population densities. Although these smaller aquatic systems are often overlooked as regards their amenity value, ecologically they support the most important elements of the catchment fish communities and as such, these historic floodplain habitats should be protected at all cost.

Table 1. Total estimated biomass ($g \cdot m^{-2}$) values for fish species in adjacent natural and channelised stretches of the River Lee, England (for mean biomass for a species, divide value by number of sites = 10).

Species names		Total biomass	
Latin	Common	Natural	Channel
Alburnus alburnus L., 1758	bleak	0.702	2.990
Abramis brama (L., 1758)	common bream	74.864	0.065
Anguilla anguilla (L., 1758)	eel	18.007	5.375
Barbus barbus (L., 1758)	barbel	2.023	–
Cyprinus carpio L., 1758	common carp	6.660	–
Esox lucius L., 1758†	pike	150.890	40.538
Leuciscus cephalus (L., 1758)†	chub	90.779	0.860
Leuciscus leuciscus (L., 1758)†	dace	12.003	0.114
Perca fluviatilis L., 1758†	Eurasian perch	10.862	2.687
Rutilus rutilus (L., 1758)†	roach	100.874	14.927
Sander lucioperca (L., 1758)	pikeperch	–	0.007
Tinca tinca (L., 1758)	tench	0.147	11.890
Totals		467.811	79.453

Key: †indicates significant differences (Mann-Whitney U-test) between natural and channelised stretches for that species.

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References

Berrebi dit Thomas, R., Tales, E. & Boët, P. 1998. Caractéristiques des peuplements piscicoles sensibles aux altérations du milieu dans les cours d'eau du bassin de la Seine. Bull. Fr. Pêche Piscic. **348:** 47–64.

Brookes, A., Gregory, K. J. & Dawson, F. H. 1983. An assessment of river channelisation in England and Wales. Sci. Tot. Envir. **27:** 97–111.

Coeck, J., Vandelannoote, A., Yseboodt, R. & Verheyen, R. F. 1993. Use of the abundance/biomass method for comparison of fish communities in regulated and unregulated lowland rivers in Belgium. Regul. Rivers **8:** 73–82.

Congdon, J. C. 1971. Fish populations of channelized and unchannelized sections of the Chariton River, Missouri, p. 52. In: Schneberger, E. & Funk, J. L. (eds) Stream channelization: A symposium, N. C. Div. Amer. Fish. Soc. Spec. Publ. No. 2.

Copp, G. H. 1990. Effect of regulation on 0+ fish recruitment in the Great Ouse, a lowland river. Regul. Rivers **5:** 251–263.

Copp, G. H. & Bennetts, T. A. 1996. Short-term effects of removing riparian and instream cover on barbel (*Barbus barbus*) and other fish populations in a stretch of English chalk stream. Folia Zool. **45:** 283–288.

Cowx, I. G., Pitts, C. S., Smith, K. L., Hayward, P. J. & van Breakden, S. W. F. 1995. Factors influencing coarse fish populations in rivers. Research & Development Note 460, Bristol: National Rivers Authority.

Cowx, I. G., Wheatley, G. A. & Mosley, A. S. 1986. Long-term effects of land drainage works on fish stocks in the upper reaches of a lowland river. J. Envir. Mgmt. **22:** 147–156.

Faulkner, H. & Copp, G. H. 2001. A model for accurate drift estimation in streams. Freshwat. Biol. **46:** 723–733.

Garner, P., Bass, J. A. B. & Collett, G. D. 1996. The effects of weed cutting upon the biota of a large regulated river. Aquat. Conserv. Mar. Freshwat. Ecosys. **6:** 21–30.

Golden, M. F. & Twilley, C. E. 1976. Fisheries investigations of a channelized stream, Big Muddy Creek watershed. Kentucky. Trans. Kent. Acad. Sci. **37:** 85–90.

Hankin, D. G. & Reeves, G. H. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Can. J. Fish. Aquat. Sci. **45:** 834–844.

Hansen, D. R. & Muncy, R. J. 1971. Effects of stream channelisation on fishes and bottom fauna in the Little Sioux River, Iowa. Iowa State Wat. Resources Res. Inst., Iowa State Univ., Ames, Iowa, 119 pp.

Holčík, J. & Macura, V. 2001. Some problems with the interpretation of the impact of stream regula-

tions upon the fish communities. Ekológia, Bratislava **20:** 423–434.
JUNGWIRTH, M., MOOG, O. & MUHAR, S. 1993. Effects of river bed restructuring on fish and benthos of a fifth order stream, Melk, Austria. Regul. Rivers **8:** 195–204.
JURAJDA, P, REICHARD, M, ČERNÝ, J. & HOHAUSOVÁ, E. 2000. Biodiverzita pludkových společenstev dvou rozdílných úseků dolního toku řeky Moravy [Diversity of 0+ fish communities of two different stretches of the lower River Morava], pp. 79–86. In: Biodiverzita ichtyofauny České republiky (III), Brno.
JURAJDA, P., REICHARD, M., HOHAUSOVÁ, E. & ČERNÝ, J. 2001. Comparison of 0+ fish communities between regulated-channelized and flooplain stretches of the River Morava. Large Rivers **12** (2–4), Arch. Hydrobiol., Suppl. **135** (2): 187–202.
KELLER, E. A. 1976. Channelization: environmental, geomorphic and engineering aspects, pp. 115–140. In: COATES, D. R. (ed.) Geomorphology and engineering, Dowden, Hutchinson, Ross, Penn. USA.
LINFIELD, R. S. J. 1985. The effect of habitat modification on freshwater fisheries in lowland areas of eastern England, pp. 147–155. In: ALABASTER, J. S. (ed.) Habitat modification and freshwater fisheries, Butterworths, London.
MANN, R. H. K. 1988. Fish and fisheries of regulated rivers in the UK. Regul. Rivers **2:** 411–424.
MOYLE, P. B. 1976. Some effects of channelisation on the fishes and invertebrates of Rush Creek, Modoc County, California. Calif. Fish Game **62:** 179–186.
PEARSON, R. G. & JONES, N. V. 1978. The effects of weed-cutting of the macroinvertebrate fauna of a canalized section of the River Hull, a Northern English Chalk Stream. J. Envir. Mgmt. **7:** 91–97.
PILCHER, M. W. & COPP, G. H. 1997. Winter distribution and habitat use of fish in a regulated lowland river system of South-East England. Fish. Mgmt. Ecol. **4:** 199–215.
PORTT, C. B., BALON, E. K. & NOAKES, D. L. G. 1986. Biomass and production of fishes in natural and channelised streams. Can. J. Fish. Aquat. Sci. **43:** 1926–1934.
REICHARD, M. JURAJDA, P. ŠIMKOVÁ, A. & MATĚJUSOVÁ, I. 2002. Sized-related habitat use by bitterling (*Rhodeus sericeus*) in a regulated lowland river. Ecol. Freshwat. Fish **11:** 112–122.
ROSS, S. T. & BAHES, J. A. 1983. The response of fishes to periodic spring floods in a southeastern stream. Amer. Midl. Natur. **109:** 1–14.
SCHLOSSER, I. J. 1982. Trophic structure, reproductive success, and growth rate of fishes in a natural and modified headwater stream. Can. J. Fish. Aquat. Sci. **39:** 968–978.
SEBER, G. A. & LE CREN, E. D. 1967. Estimating population parameters from catches large relative to the population. J. Anim. Ecol. **36:** 631–643.
SWALES, S. 1982. A 'before and after' study of the effects of land drainage works on fish stocks in the upper reaches of a lowland river. Fish Mgmt. **13:** 105–114.
SWALES, S. 1988. Fish populations of a small lowland channelised river in England subject to long-term river maintenance and management works. Regul. Rivers **2:** 493–506.
TRAUTMAN, M. B. & GARTMAN, D. K. 1974. Reevaluation of the effects of man made modification on Gordon Creek between 1887 and 1973 and especially as regards its fish fauna. Ohio J. Sci. **74:** 162–173.
WILCOCK, D. N. 1991. Environmental impacts of channelization on the River Main, County Antrim, Northern Ireland. J. Envir. Mgmt. **32:** 127–143.
ZALUMI, S. G. 1970. The fish fauna of the lower reaches of the Dneiper: its present composition and some features of its formation under conditions of regulated and reduced river discharge. J. Ichthyol. **10:** 587–596.

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