

# Patchiness of longitudinal fish distributions in a river as revealed by a continuous hydroacoustic survey

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During July and September 1993, the longitudinal distributions of fish communities in five reaches of the River Thames were obtained by mobile acoustic surveys at night, using a BioSonics dual-beam echosounder (420 kHz) with a transducer beaming horizontally across the river. Although acoustic ranges were small (10–20 m), the total sampled volume was large. Continuous records of absolute fish densities in the water column were obtained by echo integration at 20 m or 40 m intervals along the river. The striking feature of the acoustic data is the evidence they offer for different scales of patchiness in continuous longitudinal distributions of fish targets. The scale of patches varied in density and size. Some obvious larger patches could be associated with river features (sewage outfalls) or particular events (mass emergence of insects at dawn). For other larger patches, there were no obvious causes but they were persistent in replicated runs during one night or occupied the same locality in both months. Patchiness at smaller scales was also detectable all along the river course between the larger patches.

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## Introduction

Several authors have drawn attention to the practical problems of surveying quantitatively the longitudinal distribution of fish abundance in large rivers (see review by Cowx, 1983). Direct capture techniques are labour-intensive and have limited sampling capabilities (Jordan and Wortley, 1985) so samples are low in number and are widely spaced along the river. Although the presence of local patchiness in riverine fish species is generally recognized by anglers and fisheries scientists, conventional sampling methods are inadequate to quantify its spatial distribution along a water course.

Our experience gained during an NRA-funded project (Duncan and Kubecka, 1993) suggests that mobile hydroacoustic surveys can satisfy that need by using horizontally orientated sonar with narrow sound beams and short pulse durations to contend with shallow depths and short ranges. Vertical sonar is not a viable technique for shallow inland waters because of fish avoidance and under-sampling of the surface layers.

The aim of this paper is to describe for the first time a continuous longitudinal distribution of the densities

of coarse fish (roach, bleak, chub, dace, bream) along a 34 km stretch of the River Thames in July and September 1993.

## Methods

The transducer on a Videmach pan-and-tilt rotator was mounted on rigid scaffolding 1 m in front of the boat and at 80 cm depth. The sonar beam was directed horizontally and sideways across the middle part of the river, the better to cover the whole water column (2–3 m deep) and to insonify most fish in their side aspect. By remote control of the rotator, the sonar beam could be adjusted to ensure maximal usable range across the river. Bottom and surface reverberations were eliminated from the usable range of low noise levels (<0.1 V) by using the manual bottom tracker, which ends the usable range and prevents any processing of echoes beyond its position.

The sonar beam was generated by a BioSonics Model 102 scientific echo-sounder operating at a frequency of 420 kHz. Two different dual-beam transducers were deployed one at a time: one circular (6°/15°) and one

elliptical ( $3^\circ \times 10^\circ$  narrow and  $7^\circ \times 21^\circ$  wide). Both transducers were calibrated together with the echosounder and cables several times under the prevailing river conditions, using a 21 mm tungsten carbide sphere as a standard target and according to a procedure described in Duncan and Kubecka (1993, 1994). The measured on-axis voltage of the standard target was used to calculate the transducer receiver sensitivity for both 20LogR and 40LogR data (Duncan and Kubecka, 1994; Kubecka, 1994).

The echo-sounder was operated at a ping rate of 20 pings  $s^{-1}$  with a pulse duration of 0.4 ms and a bandwidth of 5 kHz. Both 40LogR (for echo counting and sizing) and 20LogR data (for echo integration) were recorded, by channel multiplexing, on DAT (digital audio tape-recorder) tapes via a BioSonics Model 171 tape-recorder interface for subsequent analysis. The 40LogR data was also processed in real time on the boat using a Biosonics 281 dual-beam processor. Because noise levels in lowland rivers are generally quite high and ranges generally rather short (10–20 m), noise thresholds were set separately at a noise-to-signal ratio of 3:1 in volts for a series of horizontal strata. The ranges 6–12 m in July and 4–12 m in September gave the most reliable estimates of densities with noise thresholds accepting targets of  $-53$  dB, with a 50% probability of recording (Kubecka, 1994).

As the boat was driven forward at a constant speed during mobile surveys, the echo integration (EI) reports were recorded as separate files in the computer at intervals of every 100 pings (roughly 10 s) in July or 250 pings (about 25 s) in September. Bearing in mind the constant speed of the boat, the average sample distance of reports in a reach could be calculated by dividing the linear distance of the reach by the number of EI reports recorded. These varied from 20 m per report in July and 40 m per report in September.

EI processing was scaled by average backscattering cross-sections, obtained from dual-beam processing of 40LogR data and provided “numbers of fish  $m^{-2}$  area of side-scanning cross-section” which, when divided by the average usable range in each EI report, gave target densities of numbers of fish  $m^{-3}$ . Fish densities are given as fish numbers  $100 m^{-3}$ .

## Results and discussion

All surveys were carried out by night (dusk to dawn) when the fish were active in the water column and could be detected by a horizontally directed sonar beam. Mobile surveys in rivers sample large volumes of water for fish densities and five reaches defined by weirs were surveyed several times by travelling both upstream and downstream so that, in this study,  $4.8 \cdot 10^6 m^3$  of water was sampled in July and  $7.0 \cdot 10^6 m^3$  during the longer nights of September.

### Longitudinal distribution of fish densities in July and September

The spatial distribution of fish densities per  $100 m^3$  in Reach 1 is compared for July and September in Figure 1. The data were collected whilst passing downstream. The most striking feature of Figure 1 is the marked patchiness of the distribution of fish densities along the reach. Although the river here passes through typical southern English parkland of fields with grazing cattle and with no apparent marked environmental heterogeneity, the distribution of areas of higher and lower densities along the reach is similar in both months, as are the locations of the higher density patches between river miles 105–107. The two patches had mean fish densities and 95% confidence limits of  $7.07 \pm 2.37$  and  $7.11 \pm 2.98$  fish  $100 m^{-3}$  and patch sizes of 720 m and 480 m, whereas in September both patches were more extensive (920 m), with densities of  $6.34 \pm 1.80$  and  $3.15 \pm 0.91$  fish  $100 m^{-3}$ . It seems that the location of favourable sites for fish remained the same at three-month intervals in 1993.

### Replicated runs along one reach during one night

The question arises whether these sites of higher densities were occupied consistently throughout one night. During the longer nights of September, Reach 3 was surveyed acoustically three times from midnight to dawn by going first downstream, then upstream and again downstream. Figure 2 shows that the spatial distribution of fish densities was very similar on each occasion, with two dense patches of  $4.21 \pm 0.93$  and  $5.98 \pm 0.79$  fish  $100 m^{-3}$  occupying the upper part of the reach where the river runs through undisturbed banks apart from the site of an industrial intake and outfall at river mile 101. Throughout the night, the higher density patch extended downstream and tended to increase in density. The three distinct patches of moderate densities and patch size seen at midnight (0030–0115 h) had coalesced during the next hour (0115–0200 h) into one patch 880 m long with a density of  $9.14 \pm 1.68$  fish  $100 m^{-3}$  between 0115 and 0300 h and enlarged to 2200 m with a density of  $7.51 \pm 1.42$  fish  $100 m^{-3}$  as dawn approached (0430–0530 h). Without further studies, it is difficult to determine whether the enhanced densities at the outfall site or the decreased densities (between 0.33 and 0.69 fish  $100 m^{-3}$ , half usual levels) in the lower half of the reach are associated with the presence of an active industrial outfall at river mile 101 producing a local warmed area. Water is abstracted from the river throughout the day and night for cooling purposes and is discharged as a warmed effluent at the Outfall.

### Environmental causes of larger fish patches

Larger-scaled patches of fish densities were associated with more obvious environmental events. An active

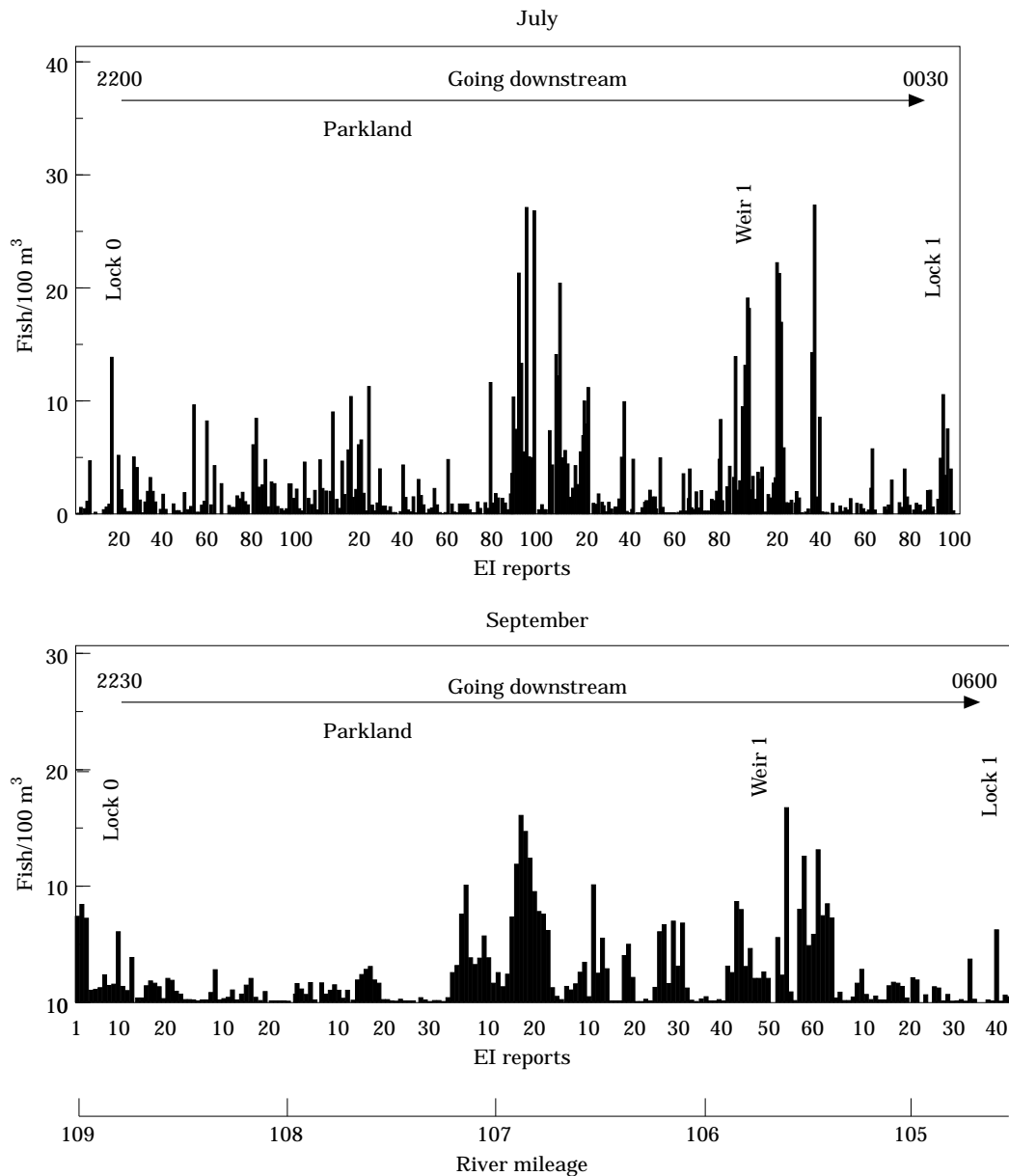


Figure 1. Fish densities along Reach 1 by downstream mobile survey during July (top graph) and September (bottom graph) 1993. One EI Report is equivalent to 20 m in July and 40 m in September.

sewage outfall in July appeared to attract fish such that a patch 600 m long with fish densities of  $33.17 \pm 12.61$  fish  $100 \text{ m}^{-3}$  was recorded at river mile 103 below a long artificially embanked stretch passing through a small town where fish densities of about 2 fish  $100 \text{ m}^{-3}$  were detected. On another night in July the patch at river mile 103 was more extensive (1320 m) with  $13.81 \pm 1.92$  fish  $100 \text{ m}^{-3}$ . In September, when this sewage outfall was not operating, fish densities here were as low as elsewhere. Another more extensive and dense

patch of fish appeared in Reach 3 in July 1993, which coincided with a mass emergence of mayflies as dawn approached. Over an area of 2080 m, large numbers of fish ( $21.61 \pm 3.20$  fish  $100 \text{ m}^{-3}$ ) were rising to feed.

#### Patch scales in the spatial distribution of fish density

A close examination of Figure 1 shows that fish patchiness also occurred at smaller scales than those described

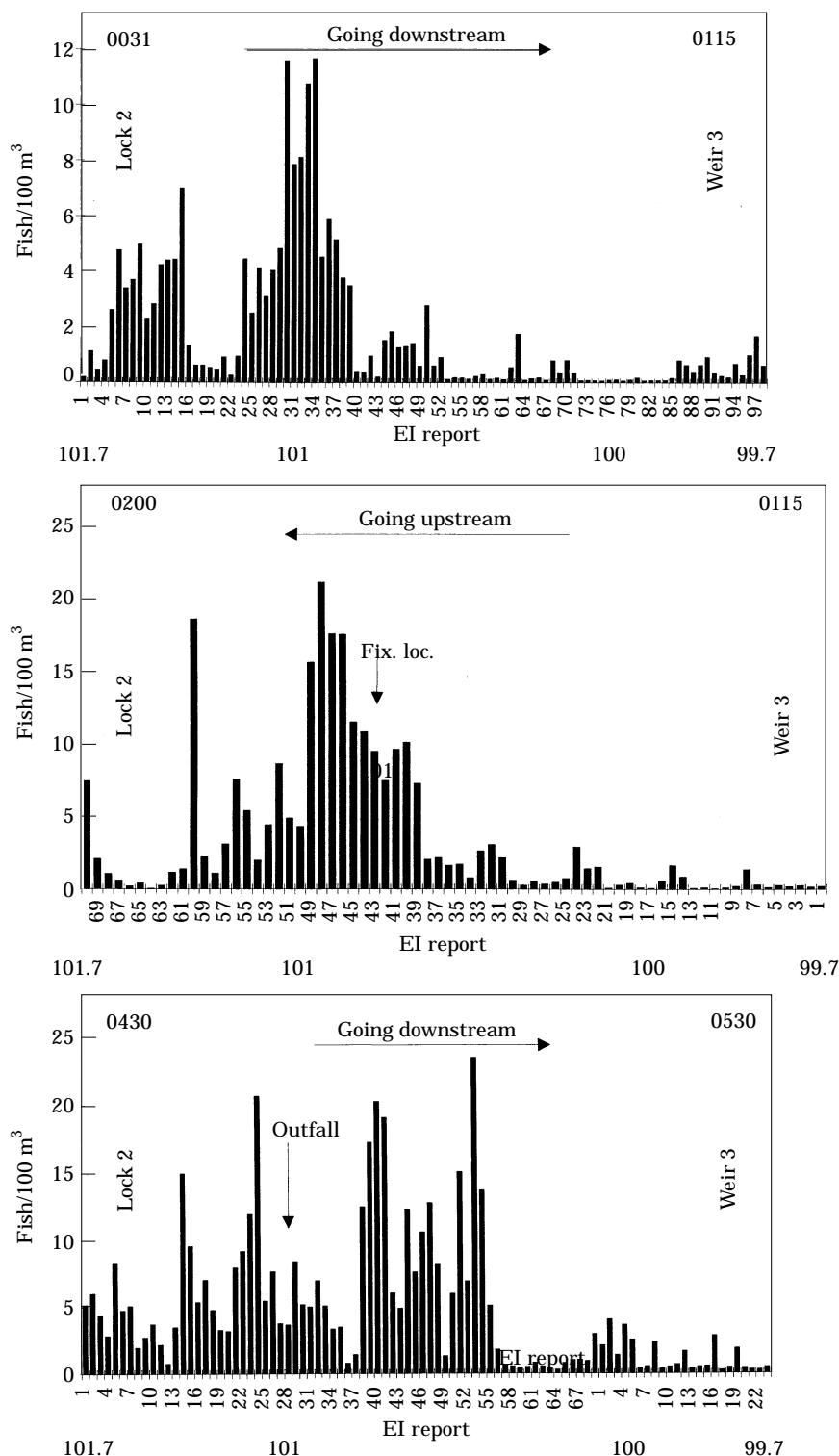


Figure 2. Fish densities along Reach 3 by mobile survey during one night in September 1993. Top graph: going downstream between 0030 and 0115 h; middle graph: going upstream between 0115 and 0200 h; bottom graph: going downstream between 0430 and 0530 h. Note the position of the industrial outfall at river mile 101. Note different vertical scale at top.

above. These need a more detailed analysis than simple means and variances in order to detect and quantify what appears by eye to be underlying cyclical patterns in fish densities. As the purpose of spectral analysis is to explore and define cyclical fluctuations of different period (=length) in a continuous spatial-temporal series like these longitudinal distributions of fish densities, this seems an appropriate analysis to try out.

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