Sampling fish communities in shallow lowland lakes: point-sample electric fishing vs electric fishing within stop-nets

M.R. PERROW & A.J.D. JOWITT

ECON, School of Biological Sciences, University of East Anglia, Norwich, UK

L.ZAMBRANO GONZÁLEZ

Centro de Ecología, UNAM, Mexico

Abstract Fractional or point-abundance sample (PAS) electric fishing was compared with conventional electric fishing within stop-nets in several shallow, structurally complex, lowland lakes. The two methods tended to sample the fish community in different ways. PAS provided significantly higher total population estimates, partly as a result of the higher estimates for the dominant small fish (e.g. 0 + perch, *Perca fluviatilis* L.). Fish hidden by cover (macrophytes, branches, etc.) or substrate, such as eels *Anguilla anguilla* (L.) and ruffe *Gymnocephalus cernuus* (L.), were also sampled at a higher rate and for eel, this led to considerable variation in biomass estimates between the two methods. It is argued that PAS, rather than electric fishing within stop-nets, provided more accurate estimates of fish population parameters and that PAS had several distinct advantages when used for qualitative and quantitative stock assessment, particularly in shallow lakes dominated by emergent and submerged vegetation.

KEYWORDS: electric fishing, fractional sampling, lakes, stock assessment, UK.

Introduction

Shallow (< 3 m) lowland lakes are highly productive and typically dominated by extensive stands of emergent and submerged aquatic vegetation (Moss 1980). They support diverse fish communities (Willemsen 1980; Perrow 1991), provided that enrichment is not excessive (Hartmann 1977; Barthelmes 1983). In Europe, temperate shallow lake communities may contain percids, pike, *Esox lucius* L., and a range of cyprinids (De Nie 1987), and may be valuable commercial and recreational fisheries (e.g. Biró 1977; Moss, Leah & Clough 1979; Bninska 1991).

Sampling fish in structurally complex environments has always been problematic. Substantial coverage of emergent or submerged vegetation precludes standard quantitative techniques such as seine-netting and trawling. The use of piscicides, such as rotenone, within stop-nets may provide good quantitative estimates of fish populations (Davies & Shelton 1983) but, as the technique is destructive, it is unlikely to be acceptable. Dual beam echo-sounding may be used

Correspondence: Dr Martin Perrow, ECON, School of Biological Sciences, University of East Anglia, Norwich, NR4 7TJ, UK.

in lakes containing vegetation if calibrated correctly (Kubečka, Duncan & Butterworth 1992), although species composition cannot be easily determined. Passive techniques such as trapping are generally only useful for qualitative measures, although traps encapsulating a known area may be used quantitatively in very shallow water (Kushlan 1981). Overall, electric fishing, with gears which have the ability to draw fish from cover towards the anode by galvanotaxis, is likely to be the most suitable technique.

Conventional quantitative electric fishing often employs stop or block-nets (Hickley 1990). However, as this is time-consuming the number of samples tends to be reduced with a corresponding increase in sampling variance, leading to a lack of confidence in the stock estimates (Bohlin, Heggberget & Strange 1990). In contrast, the use of fractional or point-abundance sampling (PAS) (Persat & Copp 1989) with a high number of samples and reduced mean to variance ratio, should lead to more accurate relative or absolute estimates (Regis, Pettee & Lebreton 1981; Copp & Peňáz 1988; Persat & Copp 1989; Copp 1990a). So far, this strategy has tended to be used for larval or very small fishes (Copp & Peňáz 1988), but because larger fish, as a simple function of size, respond well to electric fishing (Zalewski & Cowx 1990), there is clearly scope for more general use of the technique.

In this paper sampling strategies using a modified point-sampling technique and standard electric fishing within stop-nets are compared in four small (< 6 ha), shallow (< 2 m) lakes (broads) in the Broads National Park in eastern England. The overall aims of the study were to understand the nature of fish communities in clear-water broads dominated by submerged macrophytes and/or filamentous algae and to develop suitable sampling techniques for use in further monitoring programmes. It was important for the methods selected to be cost-effective with human and financial resources.

Study sites, materials and methods

The environmental conditions in the four broads; Cromes, Upton, Cockshoot and Pound End; are highly variable. Cockshoot and Pound End have been subject to extensive biomanipulation (Perrow 1994), Upton retains an ancestral macrophyte community dominated by holly leaved naiad, *Najas marina* L., whilst Cromes has only recently developed a macrophyte community dominated by hornwort, *Ceratophyllum demersum* L. All broads have a variable littoral plant community with reed, *Phragmites australis* (Cav.), reedmace, *Typha latifolia* L. or *T. angustifolia* L., sedges, *Carex* spp., alder, *Alnus glutinosa* (L.), and sallow, *Salix cinerea* L., all represented in varying proportions.

All four sites were sampled on two occasions, late May/early June and September, during 1994. At each site, both point-sample electric fishing over the entire lake and electric fishing within littoral and limnetic stop-nets were undertaken on consecutive days. All sampling was conducted from a 3-m fibreglass boat, with one electric fishing operator and one person controlling the boat using 'push-rowing', which allows the latter to keep the operator in sight at all times. High frequency (600 Hz) pulsed DC (rectangular wave at 300 V with a variable duty cycle of 0–50%) electric fishing equipment (Electracatch WFC11–12 volt) was used. This induces effective galvanotaxis of fish at a higher voltage gradient than conventional frequencies of 50–100 Hz, but has the advantage of decreasing recovery time (Bird & Cowx 1993) and, therefore, may be less physiologically damaging (Lamarque 1990). The single anode was large

(45 cm in diameter) to reduce the danger zone close to the anode, and thus fish mortality (Novotny 1990).

During PAS, the boat was rowed systematically along imaginary transect lines covering the whole lake. Points were taken every 8–10 oar strokes and between 126 and 219 points were sampled in different broads. All habitats within each broad were thus sampled in proportion to their abundance. At each point, the anode was immersed rapidly and swung through a 1 m arc. This modification on the procedure used by Copp & Peňáz (1988) resulted in a larger area being sampled which is likely to be more effective in sampling larger, rarer fish. The sampling area was quantified using a volt meter to determine at what distance from the anode the voltage gradient was reduced to 0.12 V, which is the minimum effective voltage at which inhibited swimming occurs (Copp & Peňáz 1988; Lamarque 1990). The effective sampling area was calculated to be 2.4 m^2. Fish from each point were transferred to individual buckets of water within the boat before being processed; identified to species, measured to the nearest mm fork length and weighed to the nearest g. A maximum of ten samples were taken before the fish were processed and returned unharmed to the water.

Sampling with stop-nets was undertaken with a lightweight 60-m multifilament nylon net with a 6.5-mm mesh, specifically designed for fast release from a moving boat. In margins this was set at some 2–4 m parallel to the bank. Both ends were sealed and the bottom of the net pushed into the sediments to prevent the escape of fish. Fishing was undertaken over at least two runs until no further fish were captured. In open water, the net was set in a circle, by attaching one end to a pole and rowing in a circle until the two ends of the net overlapped to create an effective seal. The bottom of the net was then pushed into the sediments as above. Electric fishing was undertaken systematically back and forth within the net and around the inside perimeter, until no further fish were captured. All captured fish from both margin and open water stop-nets were held in plastic dustbins before being processed.

At least three samples were taken from each habitat from each site on each occasion. To derive estimates of population density (fish m^{-2} or fish ha^{-1}) or biomass (g m^{-2} or kg ha^{-1}) for the whole broad, data from the littoral and limnetic samples were adjusted according to their contribution to the total area of the broad. This was achieved by estimating the area of the littoral zone (length $\times$ mean width of stop-net) and expressing this, and consequently the area of the limnetic zone, as proportions of the area of the whole broad. The mean value from each sub-set of littoral and limnetic samples, was then weighted accordingly to generate separate stock estimates for both the littoral and limnetic zones. These values were then combined and divided by the total area of the broad.

Each broad tended to differ greatly in the absolute and relative abundance and biomass of fish between sampling occasions, principally as a result of recruitment of young fish (Fig. 1). As a result, and for the purposes of comparison between the sampling methods, each site on each occasion was considered to be an independent sample. Statistical comparison between the two sampling strategies was performed in a number of ways. The number of species, individual species abundance and biomass at a site was compared using Wilcoxon signed rank tests; relative frequency of the abundance and biomass of different species in both littoral and limnetic habitats was compared by χ^2 tests; and differences in the size distributions of fish in both the littoral and limnetic habitats were tested using Kolmogorov-Smirnov tests (Siegel & Castellan 1988).

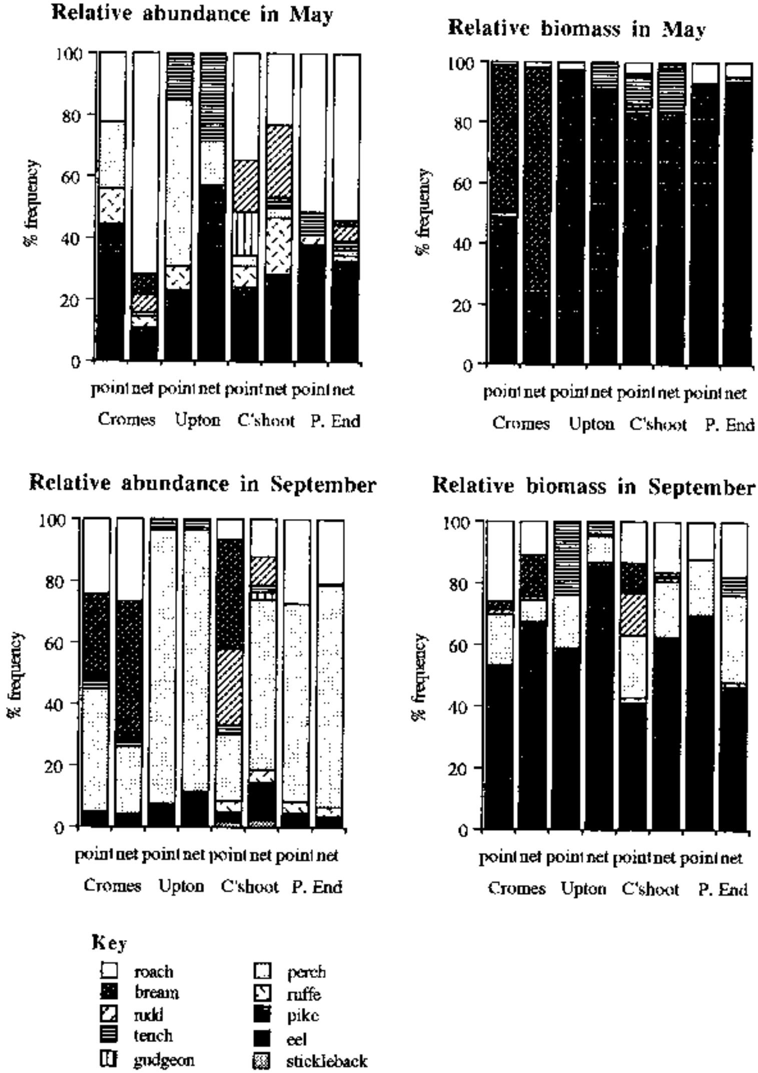

Figure 1. Relative (%) abundance and biomass of fish species at all sites on each occasion, as sampled by point-sample electric fishing and electric fishing within stop-nets.

Results

At a site, both approaches tended to sample a similar number of species (Wilcoxon signed rank test, $T^+ = 9.5$, $P = 0.8$). The relative frequencies of the different species sampled by each strategy in each of the sites on each occasion are shown in Figure 1 by abundance and biomass. Of the 19 possible χ^2 tests (those with > 20% of $n > 5$; Siegel & Castellan 1988), all but one were highly significant, indicating that the two approaches typically sample the relative proportions of fish within the population in different ways. Furthermore, PAS tended to provide significantly higher estimates of population size (Table 1). However, there was no overall significant difference for estimates of population biomass (Table 2). For individual species, that were represented in at least five of the eight samples, estimates of numbers of perch, *Perca fluviatilis*, L. ruffe, *Gymnocephalus cernuus* (L.), and eels, *Anguilla anguilla* (L.), were significantly higher for point sampling. This trend was mirrored in the biomass estimates for these species (Table 2).

The fish populations were always dominated by small fish with around 70% of fish in all samples less than 6 cm in length and 90% less than 12 cm (Fig. 2). Of the 16 possible Kolmogorov-Smirnov tests, five showed significant differences in the size distribution of fish. This was always in categories of fish less than 10 cm, although there was no consistent trend as to which method selected for particular size categories. It was, therefore, concluded that point and stop-net sampling tended to sample the size distribution of fish in a similar manner.

Discussion

Clear differences were found between the two sampling strategies. Although a similar number of species were encountered, the relative proportions of certain species, whether by abundance or biomass, were significantly different (Tables 1 and 2). In the present study, this accrued mainly from perch, ruffe and eels being captured at a higher rate by PAS. In addition, differences in the population estimates from the two sampling approaches were because of the greater number of small specimens, mainly perch, and roach, *Rutilus rutilus* (L.), and to a lesser extent, ruffe. Similarly, variations in biomass were mainly due to eels, which may reach a large size (to 1 kg) and make a disproportionate contribution to the population biomass (Table 3).

Which method is more accurate? Does PAS overestimate fish density and biomass or does electric fishing within stop-nets underestimate such variables? Although this may only be unequivocally tested by sampling known populations of fish (e.g. Boccardy & Cooper 1963; Mahon 1980; Halyk & Balon 1983), insight into the relative accuracy of the two methods may be gained if the various components of error when sampling with electric fishing are considered.

Both methods suffer from the possibility that fish escape from the sampling zone, i.e. on the approach of the boat before the anode is immersed in PAS and during the setting of the stop-net. However, this error is compounded in stop-net fishing because unless the sampling area is small compared to the span of the electrodes, some fish will inevitably avoid capture even within the confines of the net (Kennedy & Strange 1981). As efficiency is related to the size of an individual within a species or between species of similar body shape and habits (Zalewski & Cowx 1990) it is the small individuals or species that are more likely to avoid capture. Furthermore, if fish evade capture during a run, there is evidence that such fish become increasingly difficult to catch (Bohlin, Heggberget & Strange 1990). In contrast, during PAS, if the approach was discreet and the application of the electrical current occurred before any fish fled, intuitively the chance of capture within the effective sampling zone was very high. Moreover, if few fish were stunned at each point, the efficiency of capturing an individual increased. With stop-net sampling, shoaling species in particular were often driven before the moving electrodes and were encountered *en masse* at the end of the run. It is possible that some individuals escaped collection, and may be subsequently missed in other runs.

Table 1. The total and individual species abundance (numbers m^{-2}) by point and stop-net sampling at four sites on different occasions.

	Cromes May		Cromes September		Upton May		Upton September		Cockshoot May		Cockshoot September		Pound End May		Pound End September		Wilcoxon signed rank tests
	point	net	point	net	point	net	point	net	point	net	point	net	point	net	point	net	
Roach	0.02 ±0.02	0.11	0.24 ±0.07	0.25	0.00	0.00	0.00	0.00	0.10 ±0.07	0.01	0.04 +0.02	<0.01	0.15 ±0.11	0.03	0.16 ±0.12	0.07	ns
Bream	<0.01	<0.01	0.27 ±0.12	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.21 ±0.20	0.00	0.00	<0.01	0.00	0.00	–
Rudd	0.00	0.01	0.01 ±0.01	<0.01	0.00	0.00	0.00	0.00	0.05 ±0.05	0.01	0.15 ±0.08	<0.01	0.00	<0.01	0.00	0.00	–
Tench	0.00	0.00	0.03 ±0.01	0.02	0.02 ±0.01	<0.01	0.01 ±<0.01	<0.01	<0.01 ±<0.01	<0.01	0.02 ±0.01	<0.01	0.02 ±0.01	<0.01	0.00	<0.01	ns
Gudgeon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04 ±0.03	<0.01	0.00	<0.01	0.00	<0.01	0.00	0.00	–
Perch	0.01 ±<0.01	<0.01	0.40 ±0.08	0.21	0.07 ±0.02	<0.01	0.24 ±0.04	0.09	0.01 +<0.01	<0.01	0.13 ±0.06	0.02	<0.01 ±<0.01	<0.01	0.38 ±0.11	0.24	**
Ruffe	0.01 ±0.01	<0.01	0.00	<0.01	0.01 ±0.01	<0.01	0.00	0.00	0.02 ±0.01	<0.01	0.02 ±0.01	<0.01	0.01 ±0.01	<0.01	0.02 ±0.01	0.01	*
Pike	0.01 ±0.01	<0.01	0.04 ±0.01	0.03	0.01 ±<0.01	<0.01	<0.01 ±<0.01	<0.01	0.02 ±0.01	<0.01	0.01 +<0.01	<0.01	0.02 ±0.01	<0.01	0.01 ±<0.01	<0.01	ns
Eel	0.03 ±0.01	0.01	0.01 ±<0.01	<0.01	0.02 ±0.01	<0.01	0.02 ±0.01	<0.01	0.05 ±0.01	0.01	0.01 ±0.01	<0.01	0.09 ±0.02	0.02	0.02 ±0.01	0.01	*
Stickleback	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01 ±<0.01	<0.01	0.00	0.00	0.00	0.00	-
Total	0.10 ± 0.03	0.16	1.00 ±0.17	0.95	0.13 ±0.03	<0.01	0.27 ±0.04	0.10	0.28 ±0.10	0.06	0.06 ±0.29	0.04	0.28 ±0.11	0.06	0.58 ±0.16	0.33	*

Table 2. The total and individual species biomass (g m^{-2}) by point (mean ± SE) and stop-net sampling at four different sites on different occasions.

	Cromes May		Cromes September		Upton May		Upton September		Cockshoot May		Cockshoot September		Pound End May		Pound End September		Wilcoxon signed rank tests
	point	net	point	net	point	net	point	net	point	net	point	net	point	net	point	net	
Roach	0.22 ±0.15	0.52	2.40 ±0.73	1.34	0.00	0.00	0.00	0.00	0.43 ±0.31	0.02	1.01 ±0.51	0.21	1.25 ±0.76	0.06	1.23 ±0.63	0.54	ns
Bream	10.34 ±10.34	19.03	0.23 ±0.12	1.72	0.00	0.00	0.00	0.00	0.00	0.00	0.74 ±0.69	0.00	0.00	0.00	0.00	0.00	–
Rudd	0.00	0.25	0.18 ±0.14	0.15	0.00	0.00	0.00	0.00	0.10 ±0.10	0.03	1.08 ±0.55	0.02	0.00	0.00	0.00	0.00	
Tench	0.00	0.00	0.02 ±0.01	0.01	0.02 ±0.01	0.67	1.24 ±1.12	0.21	1.12 ±1.12	0.36	0.01 ±0.01	0.01	0.08 ±0.07	0.00	0.00	0.17	ns
Gudgeon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12 ±0.11	0.00	0.00	0.01	0.00	0.00	0.00	0.00	–
Perch	0.24 ±0.24	0.02	1.46 ±0.26	0.91	0.25 ±0.25	0.03	0.92 ±0.14	0.36	0.12 ±0.08	0.04	1.54 ±0.71	0.24	0.03 ±0.03	1.49	1.81 ±0.53	0.87	ns
Ruffe	0.15 ±0.08	0.06	0.00	0.02	0.12 ±0.06	0.00	0.00	0.00	0.08 ±0.03	0.02	0.15 ±0.12	0.01	0.12 ±0.10	0.01	0.05 ±0.03	0.04	*
Pike	5.61 ±3.08	3.53	4.15 ±2.17	7.44	10.50 ±8.48	6.32	0.32 ±0.32	2.27	5.75 ±3.57	1.16	1.57 ±0.94	0.46	8.21 ±4.78	0.02	3.65 ±2.60	0.20	ns
Eel	4.94 ±1.76	2.55	0.81 ±<0.49	0.93	1.47 ±0.70	0.47	2.80 ±1.23	1.46	4.30 ±1.41	1.18	1.58 ±1.11	0.33	9.24 ±3.75	1.24	3.32 ±1.51	1.22	*
Stickleback	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01 ±<0.01	0.01	0.00	0.00	0.00	0.00	–
Total	21.49 ±0.10	26.17	9.24 ±2.53	12.52	12.36 ±8.50	7.49	5.28 ±0.27	4.31	12.03 ±3.96	2.81	7.69 ±0.60	1.30	18.92 ±6.19	2.83	10.06 ±3.06	3.05	ns

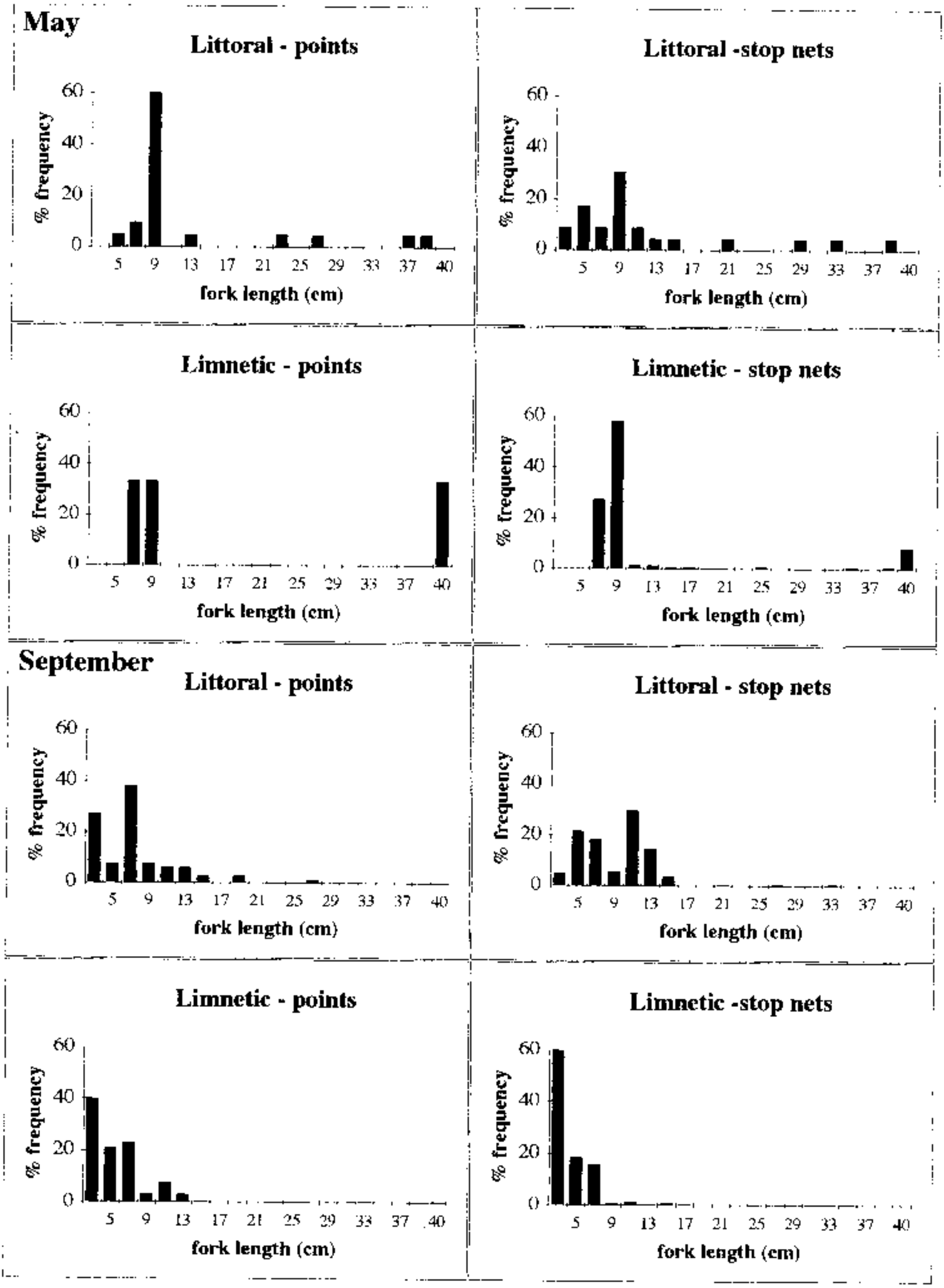

Figure 2. Examples of size frequency distributions of fish in littoral and limnetic habitats, as sampled by point samples and within stop-nets. Data for Cromes Broad from both May and September is presented.

The intensity of fishing at a particular point is high, which may give sufficient time for species buried in sediments or in cover to be drawn to the anode. During electric fishing runs within stop-nets there is a compromise between moving too slowly and missing fast-moving

Table 3. Total population biomass estimates (kg ha^{-1}) from point and stop-net samples at all sites. The former with and without eels.

Site	PAS	PAS (without eels)	stop-nets
Cromes–May	215 ± 109	165 ± 107	262
Cromes–September	92 ± 25	84 ± 24	125
Upton–May	124 ± 85	109 ± 85	75
Upton–September	53 ± 3	25 ± 12	43
Cockshoot–May	120 ± 40	73 ± 38	28
Cockshoot–September	77 ± 6	61 ± 17	13
Pound End–May	189 ± 62	96 ± 48	13
Pound End–September	100 ± 31	67 ± 27	31

shoaling species or moving too quickly and giving insufficient time for secretive species to be drawn from cover. Normal practice would be to move the anode relatively quickly and explore all available habitats. In such circumstances electric fishing operators may easily be distracted by large numbers of fast-moving shoaling species at the expense of single fish emerging from cover. In this study it is suggested that ruffe and eels, with their propensity for shelter, combined with the cryptic coloration of ruffe and the efficient escape response of eels, were underestimated in stop-nets. It is of interest that Copp (1990b) did not capture ruffe at sites where these were known to occur in the River Ouse. However, electric fishing was limited to the shallow parts of the river, whereas ruffe may have preferred deeper areas.

For a combination of these reasons, it is suggested that PAS provided more realistic estimates of fish populations in the lakes in this study, principally by sampling the dominant small species and individuals, as well as eels, more effectively. However, it must be noted that there is no evidence to suggest that either method tended to select for particular size categories of fish; electric fishing within stop-nets underestimates the stock. Indeed, Bohlin *et al.* (1990) considered this to be the typical pattern where conventional electric fishing was used to sample known populations.

Several other advantages of PAS became obvious during the study. First, the entire surface area of the small lakes under study could be systematically covered, thus sampling the available habitats in proportion to their abundance. This is important in statistical terms as fish populations (particularly shoaling species) are often clumped in space and time in particular habitats (Persat & Copp 1989; Bohlin *et al.* 1990). This pattern may be exacerbated by spawning or wintering aggregations (Jordan & Wortley 1985). With more conventional large-scale methods of stock assessment, stratified sampling within particular habitats is typically used. The number of samples to be taken in each habitat being in proportion to its abundance, and calculated prior to sampling (Bohlin *et al.* 1990). For example, in the current study at Upton Broad, ten stop-net samples from the open water zone would have been required for every one taken from the littoral zone.

This leads on to the cost efficiency of the two approaches and the constraints imposed by available resources. The PAS regime was undertaken over the course of one day by a minimum of two persons and was thus highly cost-effective. The stratified regime required at Upton could not be achieved in one day and thus the pragmatic approach of taking as many samples as possible in the available time, including some from the principal habitats, was adopted. The data from each habitat was then adjusted according to the abundance of the two habitats, although a mean value and confidence limits could not be calculated. Without a sound statistical basis, the confidence in any conclusions drawn from these data would be greatly reduced, thus potentially failing to meet the original scientific and management objectives of the study. Finally, as only a relatively small proportion of the population may be handled during PAS, by the capture of only a few fish at each point, stress and mortality levels are much reduced (Copp 1990a). This also saves on fish data collection time, which further contributes to the cost-effectiveness of the technique (Copp 1990a).

In conclusion, PAS deserves more attention as a tool for relative and absolute stock assessment, particularly in structured habitats in shallow lakes.

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