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FRESHWATER BIOLOGICAL ASSOCIATION

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PROJECT 73

Report to Central Water Planning Unit,
Northumbrian Water Authority and
Natural Environment Research Council

Report No. 2

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Report on two electrofishing surveys carried out between July 10 - 25 1978 and July 9 - 12 1979 in the vicinity of the proposed Kielder Water.

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SUMMARY

Two electrofishing surveys were carried out in the vicinity of the proposed Kielder Water in July 1978 and 1979. These surveys established:-

1. The variety of fish species and their distribution in the tributaries and upper reaches of the N. Tyne.

   The trout was by far the most numerous and widespread of the species sampled. The salmon was confined to the N. Tyne and lower reaches of the Kielder Burn, Lewis Burn, Whickhope Burn and Plashetts Burn. Five other species were caught, namely stone loach, minnow, three-spined stickleback, eel and brook lamprey.

2. The variation in growth rate between fish in the different tributaries.

   Trout growth was generally good in the Belling Burn but poor in the N. Tyne (u). Salmon $>$ 0+ were smaller in size than trout of the same age. Growth of stone loach was fastest in the N. Tyne (u).

3. The size of existing populations in terms of biomass, so that should a follow-up study be carried out in later years an attempt could be made to quantify the effect of the reservoir on the fish populations.

   Data?

4. The number, age and distribution of migratory salmonid fish in these waters.

   Between 26,800 and 46,780 salmon fry and 11,560 salmon parr were estimated to be present in the area to be flooded. It was thought that these fish will be adequately compensated by the proposed N.W.A. stocking programme.

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I INTRODUCTION

The construction of the Kielder water scheme means that approximately 436 km. (271 miles) of river system will be separated from the main N. Tyne by the new Kielder reservoir (Appendix 6). The fish in this river system will have access to the reservoir, but the absence of a fish pass means that they will not easily be able to move downstream of the dam and that the fish from below the dam will be precluded from moving upstream of the reservoir. This prevention of movement is of most import to migratory fish species such as the salmon (Salmo salar) and the sea trout (Salmo trutta), since the adult fish will be prevented from using any spawning grounds above the dam, and any immature fish present in these waters will be hindered in moving downstream to the sea to complete their life cycle. To compensate for the effect on these fish species the N.W.A. (Northumbrian Water Authority) has built a fish hatchery at Kielder to rear juvenile sea trout and salmon for release into the N. Tyne below the dam.

It was thought desirable to carry out a survey of the fish in the waters above the dam site before fish movement was restricted. The purpose of the survey being a) to look at the variety of fish species and their distribution - no such survey has previously been made; b) to compare the growth rates of fish in the various tributaries of the N. Tyne; c) to estimate the size of the existing populations in terms of biomass so that a follow-up study in later years could attempt to quantify the effect of the reservoir on the fish populations; d) to obtain information on the number, age and distribution of any migratory fish in these waters and to estimate the numbers of migratory fish required for compensatory stocking below the dam.

The main electrofishing survey was carried out from July 10 - 25 1978 when the fish populations both within and outside the reservoir basin were examined (Figs. 1 & 2). In the initial survey only one site was fished in the main N. Tyne due to constraints on time and the difficulty of electrofishing such a large river. It subsequently became apparent that without more data on the N. Tyne (m)* only an extremely crude estimate could be made on the numbers of fish required for compensatory stocking, in particular data were lacking on the densities of salmon parr in the main river. A further visit was therefore made to Kielder between July 9 - 12 1979 in order to collect more information. The N. Tyne (m) was very low during the second visit, a condition prerequisite to estimating population densities by electrofishing in such a large river.

* N. Tyne (m) = N. Tyne (main)

N. Tyne (u) = N. Tyne (upper) i.e. that part of the N. Tyne upstream of Kielder.

II DESCRIPTION OF SAMPLING SITES AND METHODS

The major river in the Kielder valley is the river N. Tyne which rises near the Scottish border (NY 604963) and flows over carboniferous limestone to join the S. Tyne near Hexham (NY 918660). Most of the land around Kielder is under the control of the Forestry Commission and under conifer plantation.

In order to carry out the survey the river N. Tyne and its tributaries were divided into 6 main systems:-

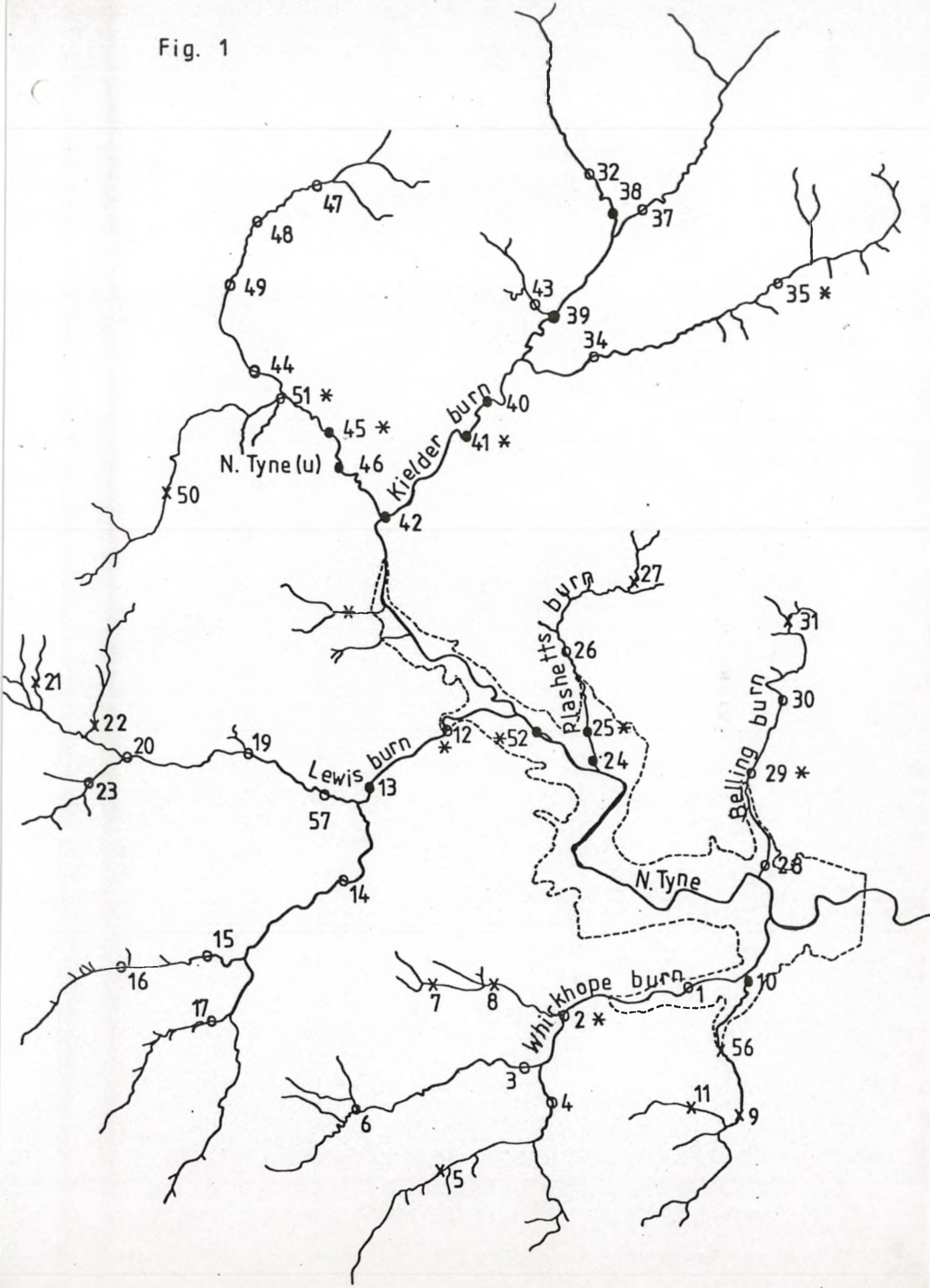
1. Whickhope Burn and its tributaries
2. Lewis Burn and its tributaries
3. Plashetts Burn
4. Belling Burn
5. Kielder Burn and its tributaries
6. N. Tyne a) N. Tyne (upper) and its tributaries

   b) N. Tyne (main) and minor tributaries

Sampling sites were selected along the length of these systems (Figs. 1, 2 & 3). Each site was approximately 50 m in length and was chosen so as to be representative of the sequence of pools and riffles apparent in that part of the river system. The electrofishing stations in relation to altitude and river gradient are illustrated diagramatically in Fig. 4.

The sites were sampled by electrofishing using a pulsed d.c. technique (Moore 1967). Stop nets were laid across the top and bottom of reaches only where the river was rather wide (> 10 m). Selected sites were fished twice and population estimates computed using the method of Seber and Le Cren (1967) (Appendix 1). The fishing efficiencies estimated from these sites were then applied to like reaches on the same river system which had only been fished once. This procedure enabled a greater part of the river systems to be sampled within the time allotted for the surveys.

Fig. 1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Kielder burn
N. Tyne (u)
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Plashetts burn
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Belling burn
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Lewis burn
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N. Tyne
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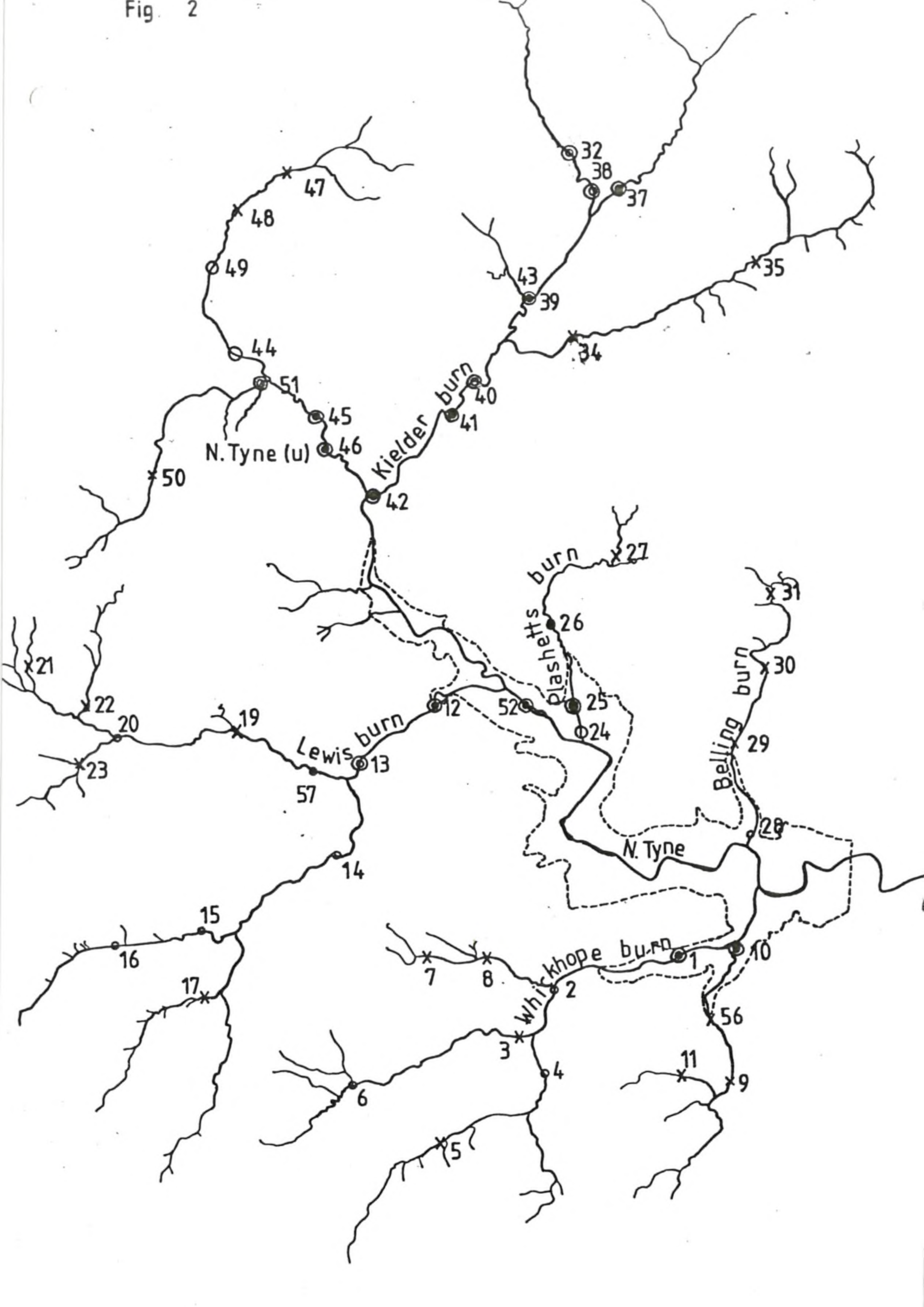
Fig 2



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Kielder burn
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Plashetts burn
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Belling burn
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Lewis burn
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Fig. 3

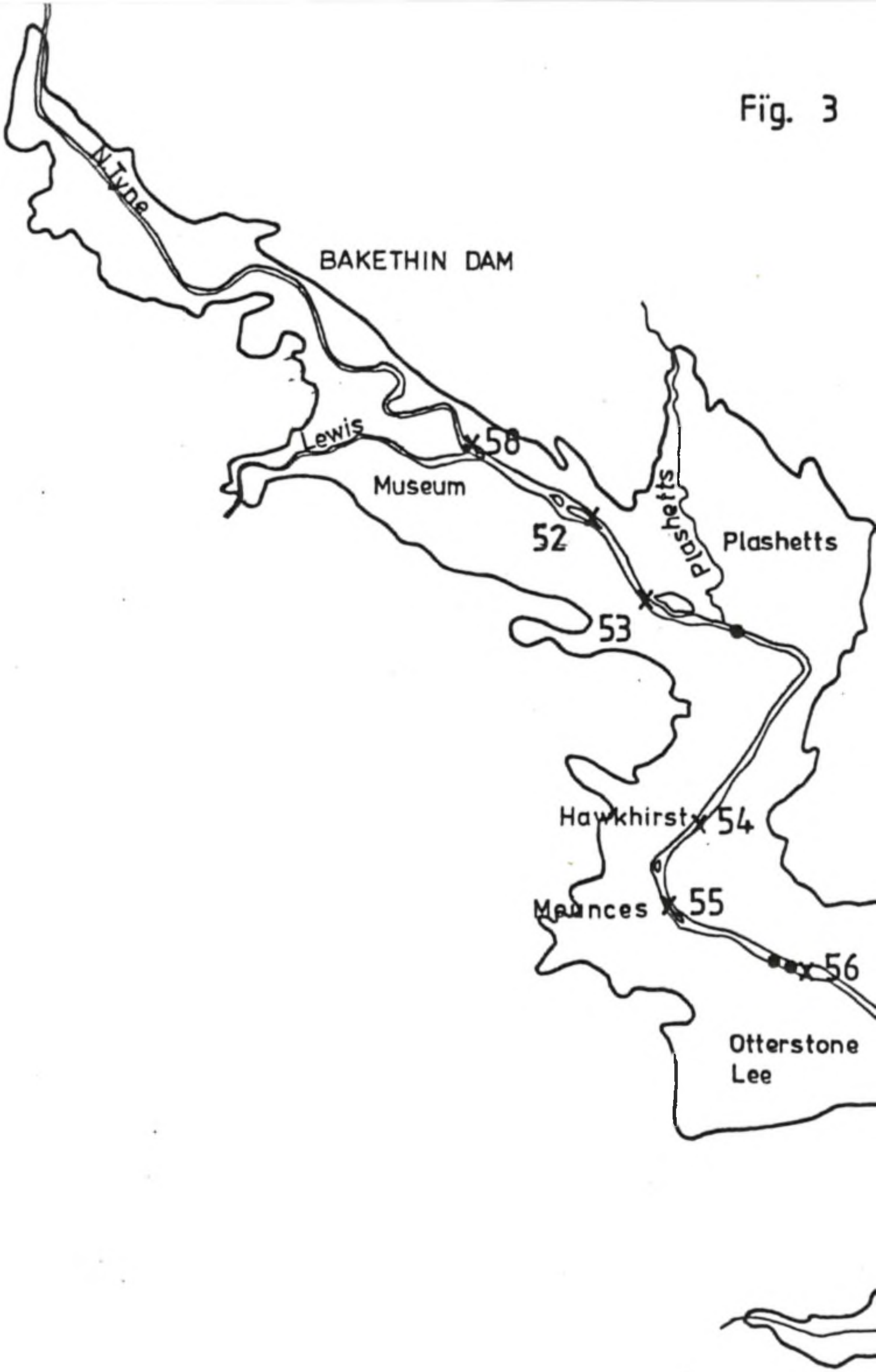

N.Tyne
BAKETHIN DAM
Lewis
58
Museum
52
Plashetts
Plashetts
53
Hawkhirst
54
Mounces
55
56
Otterstone
Lee

Diagram of the N.Tyne (m) and the proposed Kielder Water showing the sites sampled July 9-12 1979

x electrofishing site
• gill netting site

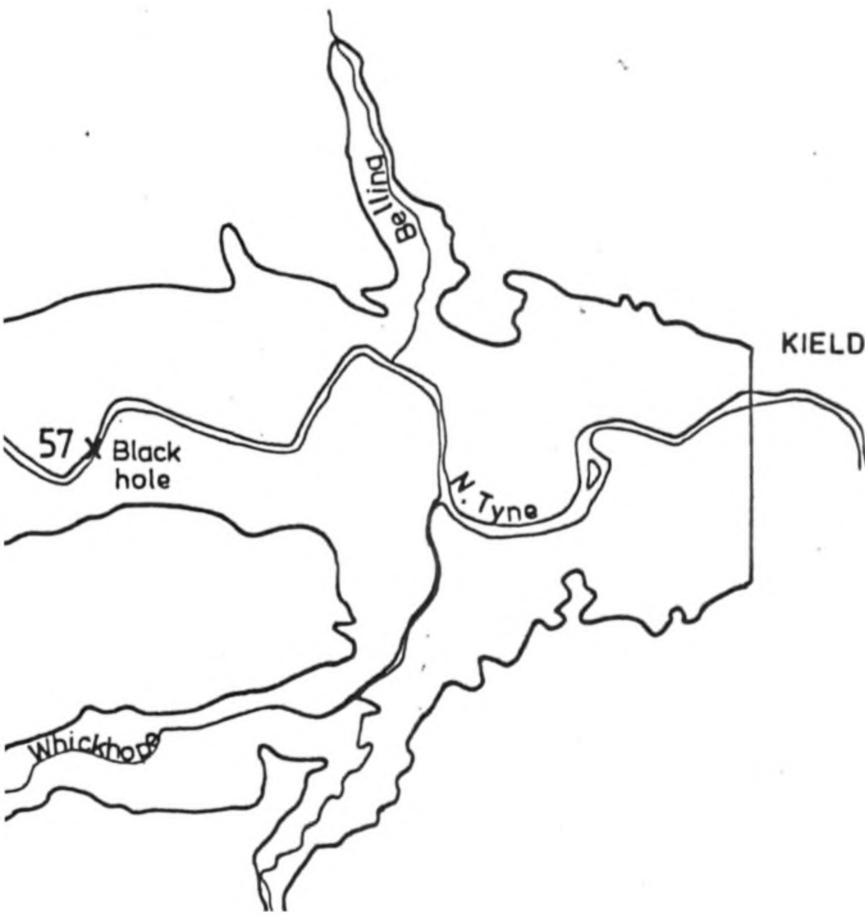


Fig. 4 The electrofishing stations in relation to altitude and river gradient

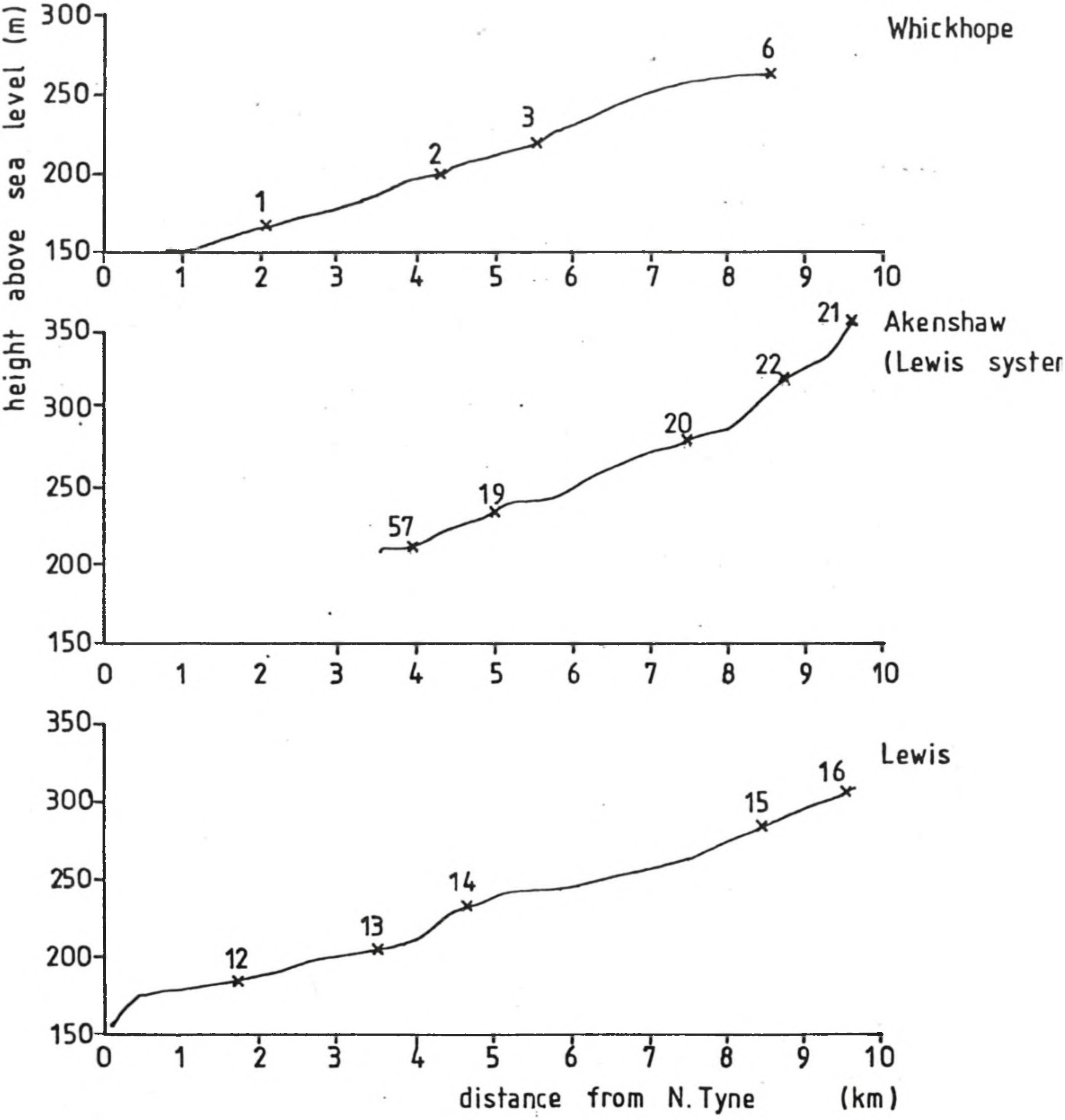
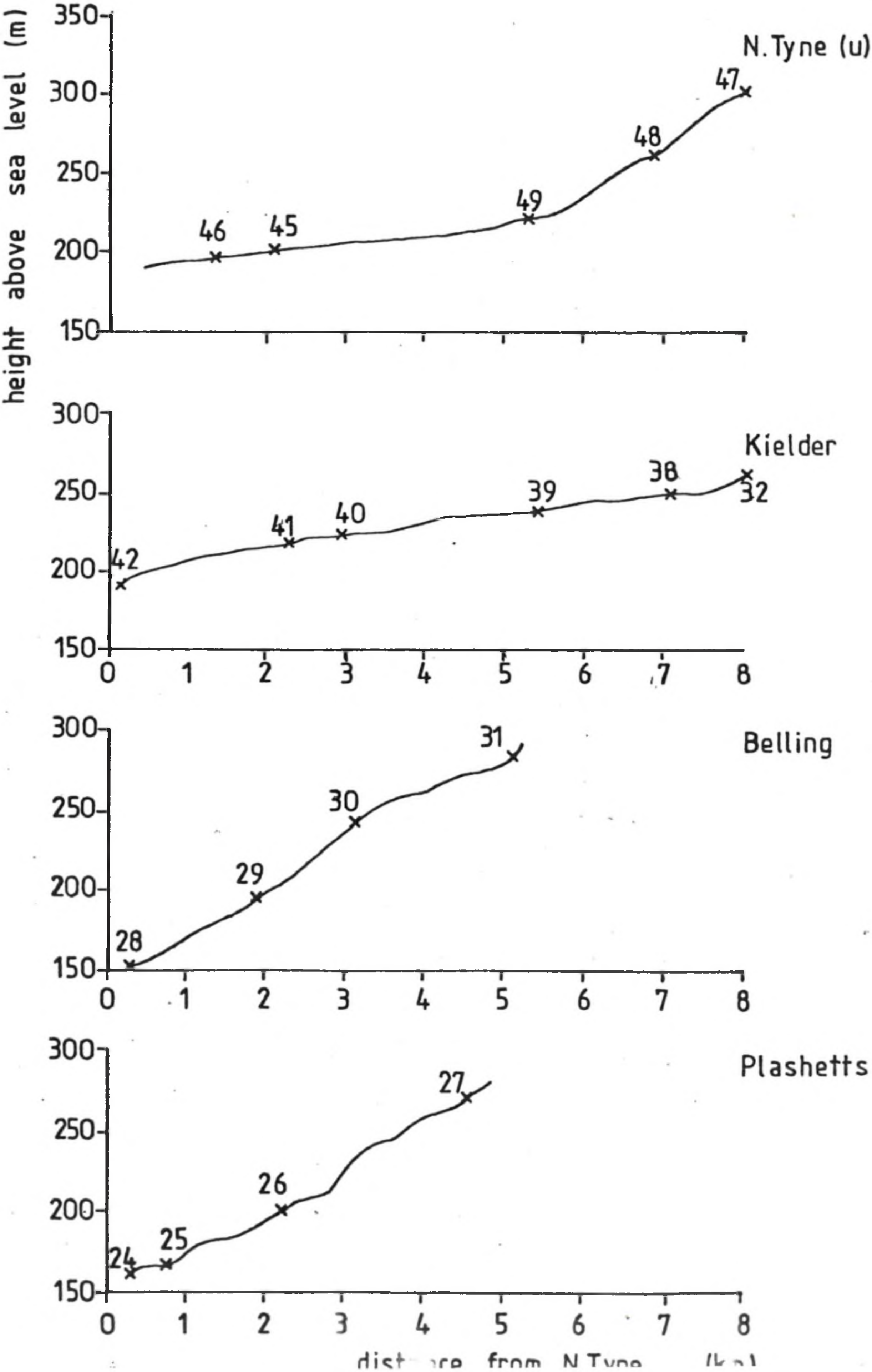


Fig. 4



height above sea level (m)
N.Tyne (u)
Kielder
Belling
Plashetts
350
300
250
200
150
0
1
2
3
4
5
6
7
8
46
45
49
48
47
42
41
40
39
38
32
28
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30
31
24
25
26
27

The fork length of every fish caught was measured. Otoliths were removed from a selection of stone loach and scales were taken from the mid-body region of all salmonid fish for ageing purposes. At certain sites the salmonid fish older than 0+ together with stone loach and eels were weighed using spring balances. The weights of these fish were used to establish length/weight relationships so that the weights of the fish captured at all the sites could be estimated. The spring balances were not sufficiently accurate to attempt to weight salmonid fry. Weights of fry were therefore estimated from the same length/weight regression equations computed for the older fish. By using this procedure the weights of fry can be overestimated by up to 45%.

Water samples from each of the various river systems were collected on the final day of the first survey. The pH's of the samples were determined later the same day and the samples were then sent for further analysis by Mr. J. Heron at the F.B.A. laboratories.

A photographic record was kept of all sites.

Gill nets were set at certain points on the N. Tyne (m) (Appendix 5). The nets used were of man-made fibre and were not highly selective for size of fish. The nets were set in pools or the N. Tyne (m) and left for several hours - usually overnight or for the duration of the working day. In deeper areas, a boat was used to lay the nets.

RESULTS AND DISCUSSION

1. Water chemistry

Table 1 shows the analyses of the water samples collected. The streams with the highest fish densities such as the N. Tyne (u), Bells Burn, Kielder Burn and Belling Burn (Appendix 1), were generally those with the highest cation levels.

The sulphate levels were unusually high in all the water samples analysed, which suggests industrial pollution and/or deposits of barytes. The geological description of the Kielder basin (Taylor et al, 1971) would appear to indicate that the high sulphate levels were mainly due to mineral deposits.

How about Ba analyses

The sample from March Syke was taken out of interest since the beck contained no fish. The pH and total ion measurements were very low in the water sample from this beck, and sulphate replaced bicarbonate as the major anion. Salmonids can survive in waters of such low pH and salmonid eggs have been shown to hatch successfully in acid waters (Carrick, 1979), however the disappearance of salmonid populations in Norway and Sweden has been related to the acidity of the water, especially in its effect on recruitment (Braekke, 1976; Edwards and Hjeldnes, 1977). Acid stress is also related to the amount of dissolved salts (Braekke, 1976) and those were low in March Syke.

2. Fish Distribution

Seven different species of fish were caught in the Kielder basin :- trout (*Salmo trutta*), salmon (*Salmo salar*), stone loach (*Nomacheilus barbatulus*), minnow (*Phoxinus phoxinus*), three spined stickleback (*Gasterosteus aculeatus*), eel (*Anguilla anguilla*) and brook lamprey (*Lampreta planeri*).

The distribution of these species is indicated in Figs. 1 and 2.

Table 1. Chemical analyses of water samples. Values given in milli equivalents per litre.

River system	Whickhope	Lewis	-	Plashetts	Belling	Kielder		N. Tyne (u)		N. Tyne (m)
Sample site	Whickhope Burn	Lewis Burn	March Syke	Plashetts Burn	Belling Burn	Kielder Burn	Ridge end Burn	N. Tyne	Bells Burn	N. Tyne
O.S. Ref. of sampling pt.(NY)	663860	645904	628918	664902	692899	644947	691972	623946	615951	660901
pH	7.7	7.6	5.2	7.9	8.2	8.0	7.5	7.8	7.7	7.8
Total ANIONS ions	0.897	0.947	0.624	1.393	2.962	1.385	0.777	2.608	1.545	1.336
Cations Ca^{++}	0.590	0.590	0.280	0.880	2.045	0.760	0.470	1.630	0.955	0.805
Mg^{++}	0.162	0.226	0.157	0.337	0.734	0.442	0.182	0.885	0.493	0.387
Na^{+}	0.131	0.131	0.131	0.148	0.183	0.150	0.135	0.196	0.142	0.131
K^{+}	0.009	0.009	0.007	0.018	0.038	0.016	0.012	0.024	0.015	0.016
Sum of cations	0.892	0.956	0.575	1.383	3.000	1.368	0.779	2.705	1.605	1.339
Anions Alkalinity(HCO_2)	0.389	0.423	0.004	0.784	1.700	0.898	0.325	1.724	0.971	0.722
Chloride Cl	0.113	0.118	0.158	0.176	0.195	0.146	0.153	0.183	0.128	0.140
Sulphate + Nitrate SO_4''	0.395	0.406	0.462	0.433	1.067	0.341	0.299	0.701	0.446	0.474
NO_3'	Sum 0.897				2.962					

Trout

The trout was by far the most numerous and widespread of the species sampled. The highest density of trout fry was found at the Bells Burn (site 51) where it was estimated that there were 5,0 fry m^{-2} in 1978. This is reported by fisheries bailiffs to be a popular spawning site for sea trout. Le Cren (1973) proposed that trout fry older than 40 days were not found in nature in densities in excess of 6 m^{-2}, and the densest mid-summer fry population that he measured was 5.8 m^{-2}. The number of fry found in the Bells Burn is therefore very high. The site was revisited in 1979 and although trout fry were still numerous, the estimated density was only 1.5 fry m^{-2}.

Salmon

The salmon had a more restricted distribution (Fig. 1) being mainly confined to the wider reaches fished such as the sites on the N. Tyne, Kielder Burn and lower reaches of the Lewis Burn, Whickhope Burn and Plashetts Burn. Since adult salmon attain a far greater size than mature beck trout, their occurrence is probably limited by the distribution of adequate spawning gravel. The highest salmon fry density found in 1978 was at site 40 on the Kielder Burn where there were 0.6 fry m^{-2}. No salmon fry were found in 1979 even though site 52 was re-fished where salmon fry had been caught the previous year.

The salmon par were mainly confined to the N. Tyne (m) although some were sampled in the N. Tyne (u) and Kielder systems.

Eel

Next to the trout, the eel was the most frequently occurring species (Fig. 2). They were never found in very great densities, although in terms of biomass, the weight of eels per m^2 was appreciable (see section 4). At sites 5 and 50 eels were the only species of fish caught, demonstrating their ability to survive in the very narrow upper reaches of becks.

Stone loach

These appeared to be mainly confined to the N. Tyne (m & u) and lower reaches of the Tyne tributaries. The largest estimated density of stone loach was 1.5 m^{-2} at site 24 on the Plashetts Burn. It was interesting to find that there was an absence of bullheads (Cottus gobio) in the Kielder valley. This is a fish which fills, and even sometimes shares, a similar ecological niche to the stone loach.

Minnow

The shoaling habit of minnows makes their population estimation difficult (Mann, 1971). Due to the movement of the shoals, the absence or presence of minnows during one sampling session is not very meaningful. Minnows were however caught in large numbers in consecutive years at site 52 (i) (1.9 m^{-2} 1978, 1.2 m^{-2} 1979), and were generally fairly numerous in the N. Tyne.

Three-spined stickleback

The stickleback was something of a rarity in the survey being found only in the N. Tyne system. The numbers caught on any one occasion never exceeded 3 individuals.

Lamprey

The main system in which lampreys occurred was the N. Tyne (u & m). They were not sampled quantitatively in the 1978 survey (see Appendix 1). In 1979, the greatest density found was at site 52 (0.2 m^{-2}).

3. Age and growth

i) Trout

Length frequency histograms were constructed for trout caught in each of the different systems in 1978 (Fig. 5). The histograms were used to divide the fish into year classes and the divisions between

Fig. 5 Length frequency distribution - trout July 1978

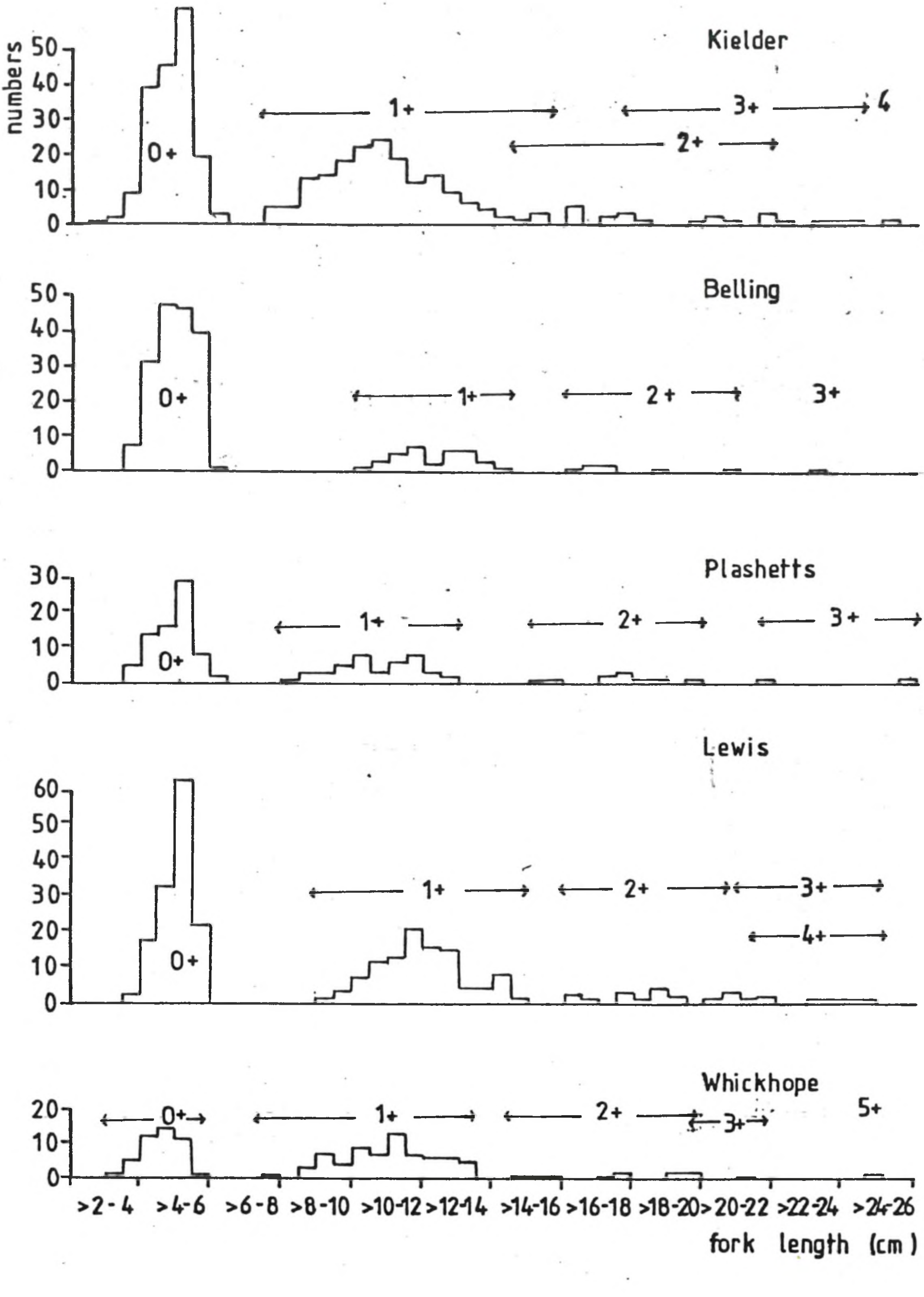


Fig. 5 Length frequency distribution - trout

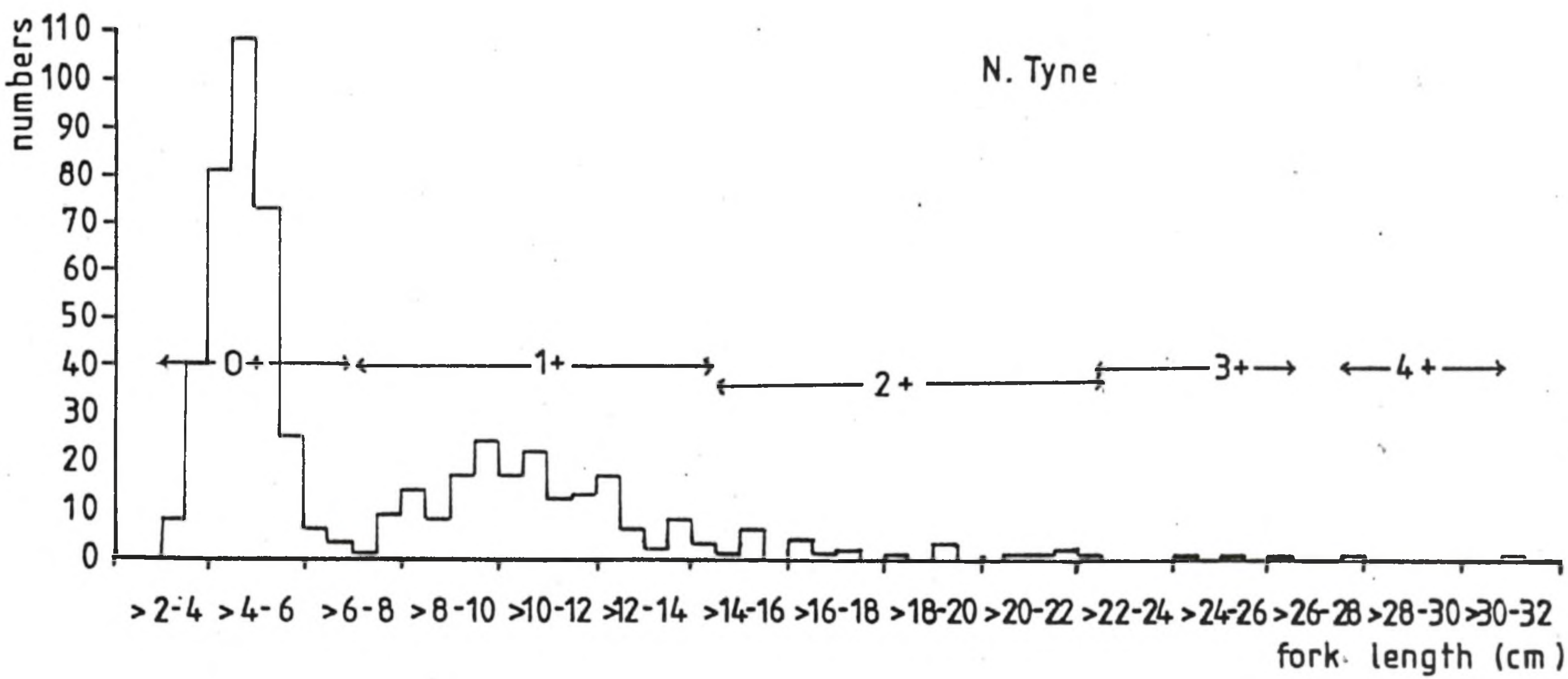


TABLE 2

i) BROWN TROUT - JULY 1978 - mean size for age

Age	size range (cm)	n	Mean ± s.e. (cm)
Whickhope			
0+	3.10 - 6.00	44	4.68 ± 0.08
1+	7.95 - 13.50	73	11.17 ± 0.15
2+	14.80 - 19.55	8	17.23 ± 0.68
3+	19.70 - 21.40	2	20.55
5+	-	1	25.00
Lewis			
0+	3.60 - 6.00	168	5.02 ± 0.04
1+	9.30 - 14.80	98	12.02 ± 0.12
2+	16.10 - 22.05	17	18.71 ± 0.40
3+	21.00 - 24.70	5	22.99 ± 0.75
4+	21.45 - 25.20	2	23.33
Plashetts			
0+	3.10 - 6.50	73	4.97 ± 0.07
1+	8.50 - 12.70	40	10.67 ± 0.18
2+	15.10 - 19.90	10	17.68 ± 0.46
3+	21.70 - 25.80	2	23.75
Belling			
0+	3.10 - 6.50	171	5.06 ± 0.04
1+	10.00 - 14.50	33	12.35 ± 0.19
2+	16.30 - 21.00	7	17.79 ± 0.68
3+	-	1	23.30
Kielder			
0+	2.50 - 6.50	180	4.92 ± 0.05
1+	7.95 - 16.15	166	10.76 ± 0.11
2+	13.65 - 21.90	20	17.18 ± 0.59
3+	17.80 - 24.10	5	20.54 ± 1.30
4+	-	1	25.20

TABLE 2 i) (continued)

Age	size range (cm)	n	Mean ± s.e. (cm)
N. Tyne (u)			
0+	3.10 - 7.00	344	4.75 ± 0.03
1+	7.10 - 14.50	176	10.64 ± 0.13
2+	14.60 - 22.60	20	17.45 ± 0.51
3+		1	24.20
N. Tyne (m)			
2+	21.30 - 22.00	2	21.65
3+	21.00 - 26.40	3	24.20
4+	27.80 - 31.00	2	29.40

ii) BROWN TROUT - JLUY 1979 - mean size for age

N. Tyne (m)			
0+	3.90 - 5.60	68	4.59 ± 0.05
1+	10.20 - 12.40	6	11.57 ± 0.33
2+	14.55 - 15.80	2	15.18
3+	20.60 - 26.40	4	23.43 ± 1.38
4+		1	28.30
5+		1	37.90

year classes were checked by reading scales from selected fish. Mean size for age of trout caught is shown in Table 2.

The fry were all about 5.0 cm in fork length although there were slight variations in size. Whickhope fry were significantly smaller than any other fry closely followed in size by N. Tyne (u) fry (Table 3). The largest 0+ trout were found in the Belling Burn. The system ranking for size changed a little in the 1+ age group although growth in the N. Tyne system was again not very good (Table 3).

Relatively few fish older than 1+ were caught (Table 2) and the distinction between year classes in terms of fork length was not so clear (Fig. 5). The greatest overlap between age groups was apparent in the Kielder system, but this was mainly due to the small length for age of fish caught at sites 34 and 35 - Ridge End Burn.

A crude yearly instantaneous mortality rate (Z) was calculated by comparing the number of each year class caught (Table 4). Z was variable in the first year, but reasonably constant in subsequent years. A difference in age structure was apparent in the Whickhope system where more 1+ fish were caught than 0+. This could have been due either to poor sampling of the 0+ age group in Whickhope or possibly to a particularly successful spawning in 1977.

ii) Salmon

The fish were aged by the same procedure as for the trout. No distinction was made between the various systems in the 1978 data but the 1979 data comprise salmon parr exclusively from the N. Tyne (m), (Fig. 6). Only three age classes of salmon were found in the survey 0+, 1+, and 2+. According to Pyefinch (1955) in the Tyne 94% of the salmon are 2 year migrants - which explains the lack of any older salmon parr. Table 5 shows the mean length for age in July 1978 of the salmon caught. It is evident that the 0+ salmon sampled were slightly larger than the 0+ trout, the 1+ salmon slightly smaller and the 2+ salmon

TABLE 3. Student's t-test significance levels of compared mean fork lengths (trout - 1978)

System	W	L	P	B	K	N.T. (u)
W		0.001	0.05	0.001	n.s.	0.01
L	0.001		0.001	n.s.	0.001	0.001
P	0.01	n.s.		n.s.	n.s.	n.s.
B	0.001	n.s.	n.s.		0.001	0.001
K	0.02	n.s.	n.s.	0.05		n.s.
N.T.(u)	n.s.	0.001	0.01	0.001	0.01	

1+

0+

W rep. Whickhope

L rep. Lewis

P rep. Plashetts

B rep. Belling

K rep. Kielder

N.T. (u) rep. North Tyne (upper)

n.s. rep. non significant.

TABLE 4. •Yearly instantaneous mortality rate (Z) of trout for age groups:

River system	0	1	2	3
Whickhope	!	2.21	1.39	
Lewis	0.54	1.75	1.22	
Plashetts	0.60	1.39	1.61	
Belling	1.65	1.55	1.95	
Kielder	0.08	2.12	1.39	1.61
N. Tyne (u)	0.67	2.17	1.61	0.69
Mean	0.71	1.87	1.53	1.15

$$\bullet Z = -\log_e \frac{N_1}{N_0}$$

where N_1 = total no. of fish of age x + 1 present in July 1978 caught in the river system (all sites combined).

N_0 = total no. of fish of age x present in July 1978 caught in the river system (all sites combined).

Fig. 6 Length frequency distribution - salmon

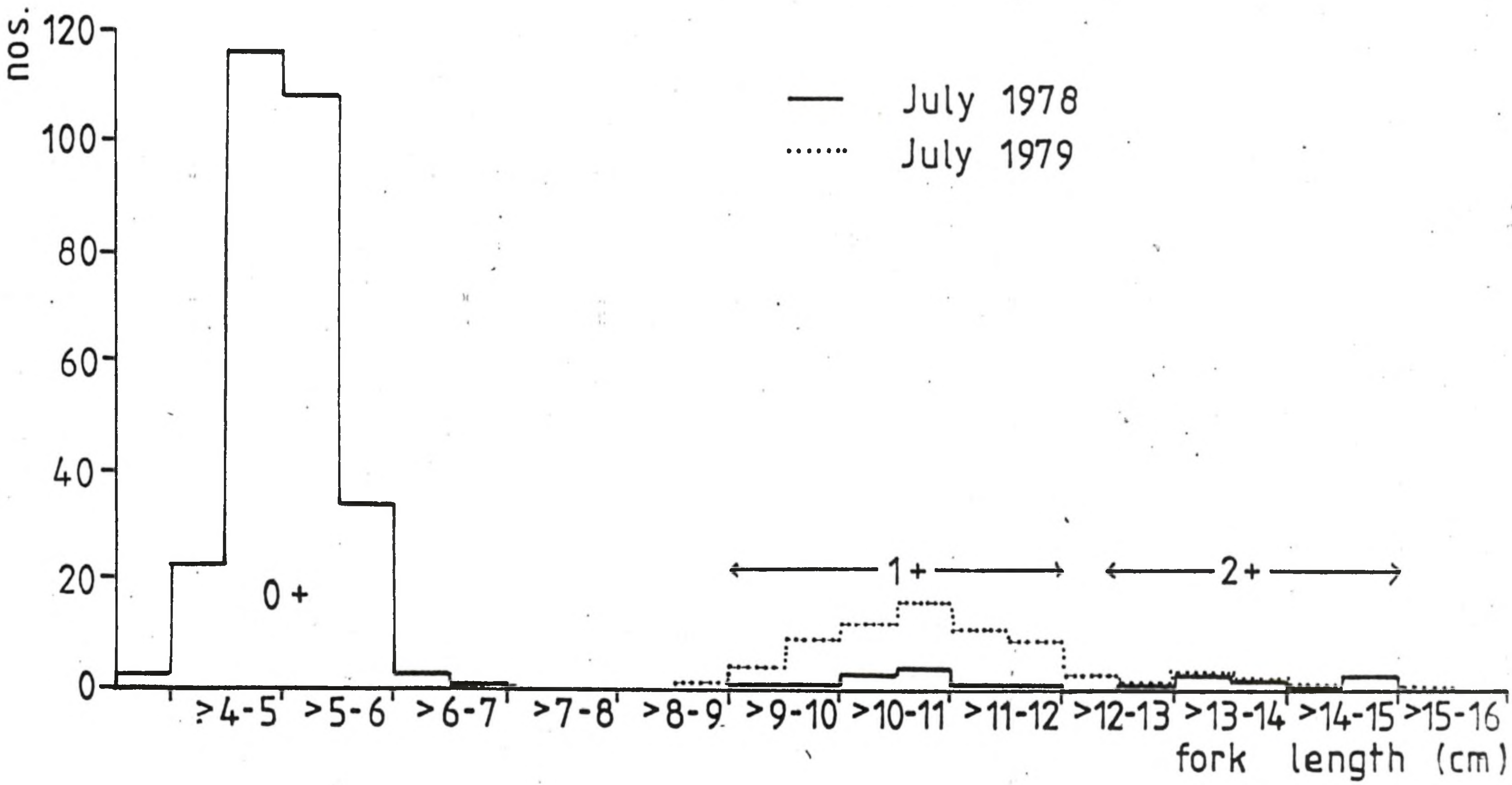


TABLE 5. Mean length for age of juvenile salmon in the Kielder survey July 1978 (all systems combined)

Age	Mean length (cm) $\pm$ s.e.	n
0+	5.09 $\pm$ 0.03	287
1+	10.60 $\pm$ 0.21	11
2+	14.13 $\pm$ 0.30	12

Mean length for age of juvenile salmon in the Kielder survey July 1979 (N. Tyne (m))

Age	Mean length (cm) $\pm$ s.e.	n
0+	-	0
1+	10.81 $\pm$ 0.12	65
2+	13.79 $\pm$ 0.52	8

considerably smaller. A previous study in Scotland showed that 0+ trout generally achieve a greater size than 0+ salmon by the end of the first growing season mainly due to continued growth in the autumn by the trout (Egglishaw & Shackley, 1977).

iii) Stone loach

Otoliths were read from fish caught in the Bells Burn (site 51) and Plashetts Burn (site 25) (appendix 2). Using the information obtained, histograms of stone loach length frequency were divided into year classes, (Fig. 7) and the mean length for age estimated in the different systems (Table 6). As explained in Appendix 1, no fry were sampled since they were difficult to catch because of their small size.

Comparatively few stone loach were caught in the Whickhope system but from the size range of those caught, it appeared that the 1+, 2+ and 3+ year classes were represented (Fig. 7). In comparison, no stone loach older than 2+ were sampled from the Plashetts system, and the density of this year class was very low. Possibly the Plashetts Burn acts as a nursery ground for stone loach from the main N. Tyne.

Of the four river systems in which stone loach were found, growth appeared to be fastest in the N. Tyne (u) (Table 6). 1+ stone loach were significantly larger than fish in any of the other systems (student's t-test $p = 0.02$), and 3+ loach were significantly larger than fish in the Kielder system (student's t-test $p = 0.001$). Growth of fish in the Kielder and Whickhope systems was very similar (Table 6) and slightly better than growth in the Plashetts Burn.

4. Biomass estimates

Length/weight regression equations were calculated for the trout, salmon, stone loach and eel (appendix 3). Data were pooled from all sites except for the trout where sufficient measurements were taken to permit a separate length/weight relationship to be established for each system. The regression

TABLE 6. Estimated mean length for age in July 1978 & July 1979 for stone loach in the Kielder basin. Values are length in cm ± s.e. Sample number shown in parentheses.

Year Sampled	River system	Mean length ± s.e. (cm)			
		1+	2+	3+	*4+
1978	Whickhope	6.38 ± 0.18 (13)	8.98 ± 0.40 (5)	10.65 (2)	
	Plashetts	6.10 ± 0.10 (53)	8.74 ± 0.13 (15)	-	
	Kielder	6.35 ± 0.18 (8)	8.73 ± 0.07 (86)	10.64 ± 0.06 (38)	12.60 (3)
	N. Tyne (u)	6.91 ± 0.13 (18)	9.96 ± 0.07 (135)	11.04 ± 0.07 (17)	12.48 ± 0.17 (4)
1979	N. Tyne (m)	6.16 ± 0.005 (133)	8.14 ± 0.005 (105)	10.20 ± 0.09 (5)	
OVERALL MEAN		6.23	9.03	10.71	12.53

* No otoliths were read from 4+ fish. The existence of this year class has been assumed from the length frequency data.

Fig. 7 Length frequency distribution -stone loach (July 1978)

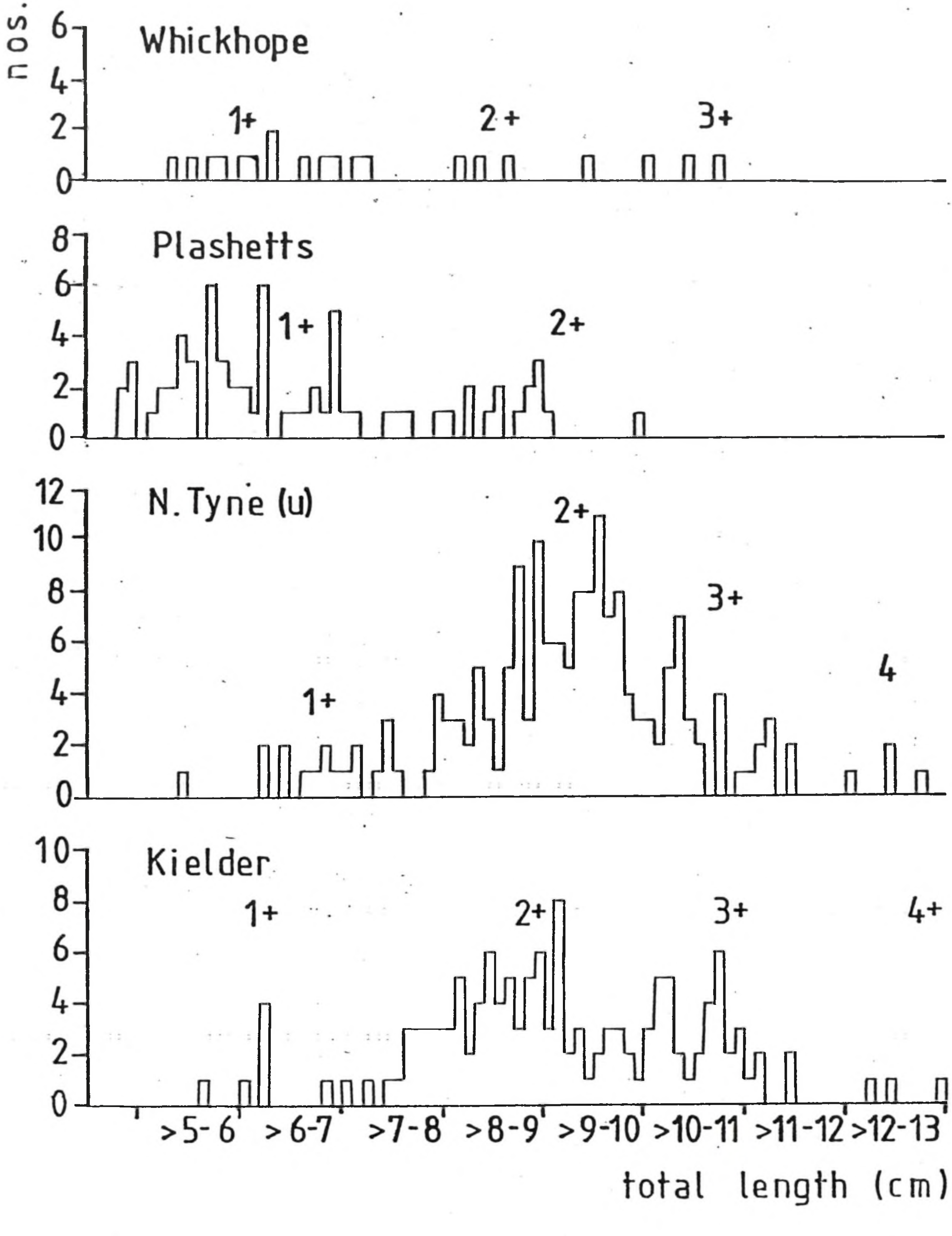
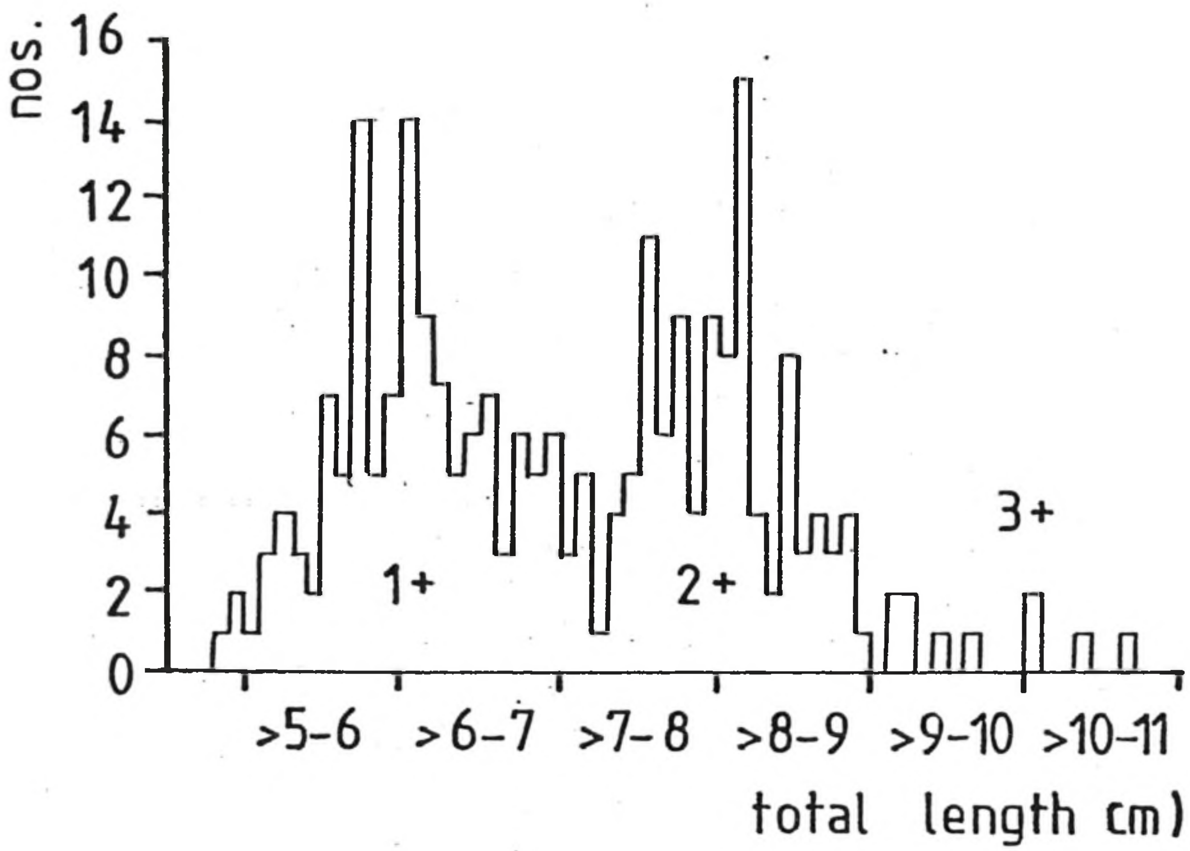


Fig. 7 Length frequency distribution - stone loach (July 1979)

N. Tyne (m)



equations were used to obtain a biomass estimate for each site (Table 7).

Weight of minnows, sticklebacks or lampreys were not collected during the survey. Biomass estimates for minnows were obtained by applying a length/weight regression equation from data collected elsewhere by D.T. Crisp (Appendix 4). The contribution of sticklebacks and lampreys to the biomass total was ignored, both occurred fairly infrequently and generally in low numbers. Biomass estimates for minnow fry and stone loach fry were also not made.

The biomass estimates varied considerably from site to site, the highest being recorded on the N. Tyne system. At most stations the greatest contribution to the total biomass was made by the trout, with the exceptions of sites 24 and 39 where the stone loach were very numerous, sites 55 (i) and 57 where the population of eels was large, and site 52 where the weight of minnows was quite considerable.

Should a follow-up study be made after completion of the Kielder reservoir, Table 7 provides a means whereby the fish populations can be directly compared on a before and after basis. It has been shown that year classes of salmonids can vary in strength but that given stable environmental conditions, the total weight of fish in a stream generally remains constant plus or minus approximately 25% (Egglishaw & Shackley, 1977).

5. Estimation of the number of juvenile salmon that will be landlocked by the Kielder reservoir.

Two age groups of juvenile salmon were sampled in the survey, salmon fry (0+) and salmon parr (1 - 2+). From their estimated densities an attempt was made to calculate the total number of salmon that were likely to be landlocked by the Kielder dam (Tables 8 & 9).

TABLE 7. Biomass data

T_1 = trout fry
T_2 = older trout
S_1 = salmon fry
S_2 = older salmon

SL = stone loach
M = minnow
ST = stickleback
L = lamprey

• = minimum estimate

i) Biomass data collected July 10-25 1978

River system	Biomass g m^{-2}							
	Site no.	$T_1 + T_2$	$S_1 + S_2$	SL	M	E	Total	Species excluded
Whickhope	1	0.845	-	0.221	0.796	0.139	2.001	
	2	4.823	-	-	-	0.994	5.817	
	3	1.732	-	-	-	-	1.732	
	6	1.969	-	-	-	1.645	3.614	
	4	9.030	-	-	-	1.860	10.890	
	5	-	-	-	-	1.338	1.338	
	10	0.993	0.188	0.377	0.825	2.117	4.500	
Lewis	12	1.614	-	0.011•	0.006•	1.040	2.671	
	13	3.426	0.495	-	-	0.927	4.848	
	14	2.577	-	-	-	0.660	3.237	
	15	0.029	-	-	-	0.274	0.303	
	16	0.858	-	-	-	0.150	1.008	
	17	0.051	-	-	-	1.511	1.562	
	57	2.507	-	-	0.012	2.380	4.899	
	19	0.410	-	-	-	-	0.410	
	20	1.610	-	-	-	1.141	2.742	
	23	0.248	-	-	-	-	0.248	
Plashetts	24	1.158	0.265	6.545	-	-	7.968	
	25	2.852	0.142	2.152	1.871	1.071	8.088	
	26	16.605	-	-	0.193	0.959	17.757	

Table 7. (continued)

River system	Biomass g m^{-2}							
	Site no.	$T_1 + T_2$	$S_1 + S_2$	SL	M	E	Total	Species excluded
Belling	28	12.170	-	-	-	1.060	13.230	
	29	2.556	-	-	-	-	2.556	
	30	3.239	-	-	-	-	3.239	
Kielder	42	2.405	0.016	0.622	0.892	0.218	>4.153	ST
	41	0.477	0.302	0.816	0.067	1.400	3.062	
	40	3.759	2.903	1.236	-	1.476	9.374	
	39	1.318	0.619	1.375	0.052	0.003	>3.367	L
	38	5.190	0.426	0.879	-	0.666	7.161	
	32	6.439	-	0.307	-	1.113	7.859	
	37	5.162	-	0.917	-	0.094	6.173	
	34	2.556	-	-	-	-	2.556	
	35	1.889	-	-	-	0.347	2.236	
	43	4.683	-	-	-	-	4.683	
N. Tyne (u)	46	3.170	0.992	0.755	0.164	0.487	>5.568	L
	45	15.584	2.028	3.563	0.645	1.403	>23.223	L
	44	3.983	-	3.179	-	-	>7.162	L
	49	13.111	-	1.207	-	-	>14.318	L
	48	8.520	-	-	-	-	8.520	
	47	20.991	-	-	-	-	20.991	
	51	14.477	-	5.491	1.611	2.114	23.693	
	50	-	-	-	-	2.400	2.400	
N. Tyne (m)	52i	-	0.144*	2.909	4.132	0.299	>7.484	L
	52ii	0.085	0.300	2.411	0.126	-	>2.922	ST, L

ii) Biomass data collected July 9 - 12 1979.

River system	Biomass g m^{-2}								
	Site no.	$T_1 + T_2$	$S_1 + S_2$	SL	M	E	L	Total	Species excluded
N. Tyne (m)	52i	0.056	0.758	0.512	1.663	0.191	0.259+	3.439	
	52ii	0.420	0.724	0.277	2.710	2.344	-	>6.475	L
	53	0.236*	1.149	0.553	0.036	1.214	-	3.188	
	54	0.004*	0.182	0.760	0.009	2.417	-	>3.372	L
	55i	0.141*	-	2.055	1.278	4.225	n.e.	>7.699	ST,L
	55ii	0.028*	0.194*	n.e.	n.e.	n.e.	-	>0.222	all non salmonids
	55iii	0.025*	-	1.127	0.071	-	-	1.223	
	56	0.024	0.221	0.237	0.006	-	-	>0.488	L
	57	0.822*	0.958	0.483	0.041	13.287	-	>15.591	L
	58	4.828	1.965	0.834	1.372	2.569	-	11.568	
Whickhope	59	2.444	-	0.011*	-	0.557	-	3.012	
	60	3.759	-	-	0.019	3.963	-	>7.741	L
N. Tyne (u)	51	7.543	0.107*	4.042	-	4.802*	-	>16.494	ST,L
	51b	9.698	0.188*	0.922	-	1.177*	-	11.985	
	51c	10.498	-	-	-	2.893*	-	13.391	

+ = total lamprey biomass for site measured by volume

n.e. = not estimated

A minimum and maximum value have been applied to the final total of salmon fry because of lack of data on the main N. Tyne (Table 8). No salmon fry were caught in the 1979 survey therefore the estimates are based on fry densities measured at site 52 in 1978. Site 52 was somewhat atypical of the 10 km. of the N. Tyne above the dam since it consisted of shallow riffles separated by islands. The site was chosen since it was one of the few places at the time where fish could be caught without the use of boats. The density of salmon fry measured here was probably high compared to surrounding reaches of river since a previous study on the Tyne (Carling, unpublished) suggested that riffles between islands were one of the most popular spawning places for salmon. The fry density estimated at this site was therefore only appled to similar island-riffle reaches of Tyne to arrive at a minimum total of 26,809 fry. The maximum total was obtained by deriving a possible fry density for the rest of the Tyne. On the Kielder Burn, sites 41 and 40 represented a pool and riffle respectively, and there was a 3-fold difference in salmon fry densities, the greatest number being found in the riffle (Appendix 1). Assuming a similar disparity on the Tyne between island riffle-reaches and the rest of the river, the fry density measured in site 52 was divided by 3 and applied to the rest of the Tyne.

More data were available for the calculation of numbers of salmon parr, and the estimate of the number of parr likely to be landlocked is 11,567 (Table 9).

Using data collected elsewhere, the number of smolts that will be produced from this number of fry can be predicted. A July density of 0.1 - 0.2 fry m^{-2} on the River Wye would give a smolt density of 0.013 - 0.025 m^{-2} (Gee et al, 1978) i.e. 46,781 fry in 368,033 m^2 (0.127 fry m^{-2}) may produce between 4,800 and 9,200 smolts. However, Symons (1979) criticises Gee's data as possibly containing some confusion between fry movement and mortality. He attempts to review the literature on juvenile

Table 8. Estimation of the number of salmon fry that will be landlocked by Kielder Water

River system	Site no.	Estimated salmon density (no. m^{-2})	Mean width of site (m)	Length of river like site (m)	Area of river containing fish at same density (m^2)	Area rep. by fishing %	Est. no. of salmon in the total area
Plashetts	24	0.107	3.2	450	1,427	6.7	153
	25	0.097	4.2	250	1,050	13.4	102
Kielder	38	0.209	4.9	1,000	4,930	2.7	1,030
	39	0.323	8.3	1,900	15,827	2.0	5,112
	*40	0.639	10.5	2,700	32,981	2.0	14,050
	*41	0.213	13.9				
	42	0.012	13.9	1,250	17,413	3.7	209
N. Tyne (u)	45	0.281	4.0	400	1,612	13.3	453
N. Tyne (m)	52	0.228	25.0	1,000	25,000	1.1	5,700
				Total	105,240		26,809 Minimum
N. Tyne (m)		0.076			262,793	-	19,972
				Total	368,033		46,781 Maximum

* Site 40 and 41 combined since the sites were close together, one being totally pool, the other riffle.

Table 9. Estimation of the number of salmon parr that will be landlocked by Kielder Water.

River system	Site no.	Estimated salmon density (no. m^{-2})	Mean width of site (m)	Length of river-like site (m)	Area of river containing fish at same density (m^2)	Area rep. by fishing %	Est. no. of salmon in the total area
Whickhope	10	0.007	3.0	1,150	3,485	2.1	24
Lewis	13	0.004	11.2	900	10,107	6.5	40
Plashetts	24	0.013	3.2	450	1,427	6.7	19
Kielder	38	0.011	4.9	1,000	4,930	2.7	54
	39	0.014	8.3	1,900	15,827	2.0	222
	•40	0.081	10.5	2,700	32,981	2.0	1,336
	•41	-	13.9				
N. Tyne (u)	45	0.032	4.0	400	1,612	13.3	52
	46	0.024	4.7	1,300	6,071	2.2	146
	51	0.007	2.5	600	1,482	9.8	10
N. Tyne (m) •x•	52	0.036	25.0	1,621	40,525	1.7	1,459
	53	0.057	25.0	1,243	31,075	0.3	1,771
		0.057	15.0	3,784	56,760		3,235
	54	0.010	25.0	3,405	85,125	0.5	851
	55	0,004	20.0	649	12,980	8.4	52
	56	0.007	20.0	1,243	24,860	1.9	174
	57	0.040	18.0	1,621	29,178	1.5	1,167
	58	0.131	15.0	486	7,290	3.0	955
					365,715		11,567

* Site 40 and 41 combined since the sites were close together, one being totally pool, the other riffle.

•x• Widths for the N. Tyne (m) are estimates since only part of the river width was normally fished.

salmonid survival and using his graphs, the predicted number of smolts from 26,809 - 46,781 fry is somewhere between 2,305 and 17,254 - depending on whether survival rate is high or low.

The N.W.A. are planning to stock the Tyne with 160,000 0+ and 60,000 1+ salmon (figures provided by A.S. Champion, Fisheries Officer North N.W.A.). Both figures are considerably in excess of the estimated numbers and will thus probably adequately compensate the populations of salmon below the dam.

IV GENERAL DISCUSSION

This survey has provided information previously not available on fish distribution and density in the Kielder basin. The biomass estimates are available for comparison should any follow-up study be carried out at Kielder at a similar time of year.

As regards the numbers of migratory fish that will become landlocked by the dam, the only calculation made is for the salmon, sea trout are still an unknown quantity. The density estimates for the trout will include juvenile progeny of sea trout but it is not possible to distinguish these from brown trout progeny before smoltification.

The ultimate fate of the landlocked salmon is open to question. On the one hand, experimental work has been carried out showing that salmon smolts can feed and grow as well or better in fresh than in salt or brackish water (Saunders and Henderson, 1969), suggesting that the landlocked smolts may survive in Kielder water. There are also landlocked populations of salmon in Canada - but these have been landlocked for many thousands of years. On the other hand, smoltification is a process which involves major hormonal and behavioural changes, and smolts hindered from reaching sea water become very vulnerable to disease, parasites and predation (Thorpe and Morgan, 1978). Their osmotic capacities seem to be impaired at smoltification, and high mortality rates have been observed amongst smoltifying salmon kept in fresh water (Koch and Evans, 1959). It is the author's view that the landlocked juvenile salmon at Kielder will probably die at smoltification.

The sea trout progeny may stand a better chance of survival. Sea trout and brown trout are considered to be migratory and non-migratory forms of the same species, and sea trout prevented from migrating to the sea have been shown to grow and spawn in fresh water like typical brown trout (Frost and Brown, 1967).

The lack of salmon fry in the N. Tyne during the 1979 survey is somewhat curious. The salmon run in the autumn of 1978 was reported to be poor and possibly this together with high levels of suspended sediment in the river from the construction of the dams and the repeated incidence of poaching using potassium cyanide (cymag) may account for the absence of fry.

The gill nets were used in the N. Tyne (m) since it was thought probable that the larger fish were not being adequately sampled. The larger salmonids are less susceptible to capture by electrofishing because of their tendency to inhabit deeper and wider stretches of water - their inaccessability and mobility helping them to avoid capture. In 1978 seven fish were gill netted in 6.5 hours in one stretch of river (Appendix 5). Few fish were however gill netted in 1979 despite more intensive netting activity. The drop in catch could have been due to bad placement of the nets or possibly it reflected an actual decrease in fish density correlating with observations from rod and line fishing (A. Clarke - F.B.A.).

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Appendix 1. Fishing data

NOTES ON TABULATED DATA

The fishing data collected during the survey carried out between July 10 - 25th 1978 have been arranged in tabulated form.

The following column titles are used:-

Stream name

Site number (Site no.) Arbitrary numbers were assigned to sites for easy reference.

Ordnance survey grid reference (O.S. grid ref.)

For the full grid reference, all numbers given should be preceeded by the letters NY.

(Site gradient)

The gradients at sites were estimated by measuring the distance on the O.S. map between the nearest contour lines to the sites. The gradients are quoted as percentages and the values given in brackets.

Species

T_1	rep.	0^+ trout	Salmo trutta
T_2	rep.	brown trout older than 0^+	Salmo trutta
S_1	rep.	0^+ salmon	Salmo salar
S_2	rep.	salmon older than 0^+	Salmo salar
SL	rep.	stone loach	Noemacheilus barbatulus
M	rep.	minnow	Phoxinus phoxinus
ST	rep.	three-spined stickleback	Gasterosteus aculeatus
E	rep.	eel	Anguilla anguilla
L	rep.	brook lamprey	Lampetra planeri

Estimates were made where possible of the population density of all fish species with the exception of minnow fry, stone loach fry and lampreys. The fry were excluded for the reason that their very small size rendered them difficult to catch in a quantitative manner. Likewise it was hard to provide an accurate measure of lamprey density due to their habit of burrowing in sand and mud. This meant that the number caught depended on depth of burial rather than on efficiency of fishing.

•x• = fry present.

Area fished (m^2)

This was estimated by multiplying the length of the reach fished by the mean width. Three measurements were averaged to obtain the latter value, these were the width of the river at the top, middle and bottom of the reach.

Efficiency of fishing

This was calculated using the method of Seber and Le Cren (1967) using the following formulae:-

$$n = \frac{C_1^2}{C_1 - C_2}$$

$$p = \frac{C_1}{n} \times 100$$

where n = estimate of population

C_1 = number caught in first fishing

C_2 = number caught in second fishing

p = efficiency of fishing (%)

It is apparent from the formulae that in order to get efficiency estimates reaches had to be fished twice. Double fishings were in fact only carried out on selected sites.

The efficiency values obtained from these sites were then applied to like reaches on the same river system which had only been fished once. Where efficiencies have not been estimated but values from other sites applied, the number is shown in brackets. In a few double fishings more fish were caught in the second electrofishing than in the first. In these cases, no efficiency estimate is shown but an exclamation mark is indicated in the column.

In reaches where both 0+ trout and salmon were caught, the catches were combined for the purposes of estimating the efficiency of fishing. The same procedure was applied to catches of trout and salmon greater than 0+.

The fish densities measured should not be taken as absolute. Le Cren (1969) estimated that the 2-catch method provides densities accurate to only ± 20%.

Number caught (No. caught)

The same notation is used as above i.e.

C_1 = number caught in first fishing

C_2 = number caught in second fishing

n.e. = not estimated.

Estimated population (Est. pop.)

The population was estimated by multiplying the number caught in one fishing by $\frac{100}{\text{efficiency}}$ and correcting the result to the nearest whole figure. In cases where no efficiency value was available the total number of a particular fish species caught in that reach is given.

• = minimum estimate.

Estimated population density (No. m^{-2})

This was obtained by dividing the estimated population size by the area fished. Minimum estimates are given where efficiency values were lacking and are indicated with asterisks (•).

1978 SURVEY

WHICKHOPE SYSTEM

Stream name	Site no.	O.S. grid ref. (site gradient)	Species	Area fished (m^2)	Efficiency of fishing (%)	No. caught		Est. pop.	Est. pop. density (no, m^{-2})
						C_1	C_2		
Whickhope Burn	1	682864	T_1	198.65	!	1	4	5*	0.025*
			T_2	198.65	86	7	1	8	0.041
			SL	198.65	100	8	0	8	0.040
		(1.5%)	M	198.65	91	43	4	47	0.238
			E	198.65	!	0	1	1*	0.005*
	2	662858	T_2	260.93	63	24	9	38	0.146
		(1.9%)	E	260.93	!	0	2	2*	0.008*
	3	656851	T_2	185.91	(74.50)	6	-	8	0.043
		(2.5%)							
	6	633843	T_1	103.66	75	20	5	27	0.257
		(1.5%)	T_2	103.66	!	1	3	4*	0.039*
			E	103.66	!	2	2	4*	0.039*
Little Cranecleugh	7	642863	-	35.00					
		(6.1%)							
	8	652864	-	65.00					
Binky Burn	4	659849	T_1	119.15	(75.00)	14	-	19	0.157
		(3.4%)	T_2	119.15	(74.50)	29	-	39	0.327
			E	119.15		2	-	2*	0.017*
Humble Burn	5	645834	E	97.67		1	-	1*	0.010*
		(3.8%)							
Little Whickhope	9	691845	-	166.67					
		(2.5%)							

WHICKHOPE BURN SYSTEM (Continued)

Stream name	Site no.	O.S. grid ref. (site gradient)	Species	Area fished (m^2)	Efficiency of fishing (%)	No. caught C_1	No. caught C_2	Est. pop.	Est. pop. density (no. m^{-2})
Little Whickhope (Continued)	10	691866 (2.5%)	T_2	146.51	(74.50)	4	-	5	0.034
			S_2	146.51	(74.50)	1	-	1	0.007
			SL	146.51	(100.00)	12	-	12	0.082
			M	146.51	(91.00)	86	-	95	0.648
			E	146.51		2	-	2*	0.014*
	56	686855 (3.8%)	-	126.67					

LEWIS BURN SYSTEM

Stream name	Site no.	O.S. grid ref. (site gradient)	Species	Area fished (m^2)	Efficiency of fishing (%)	No. Caught		Est. pop.	Est. pop. density ($no. m^{-2}$)
						C_1	C_2		
Lewis Burn	12	643903	T_1	544.88		2	-	2*	0.004*
		(1.2%)	T_2	544.88	(71.00)	20	-	28	0.052
			SL	544.88		1	-	1	0.002*
			M	544.88		1	-	1*	0.002*
			E	544.88	(50.00)	3	-	6	0.011
	13	634893	T_1	661.64	9.00	54	49	103*	0.156*
		(3.4%)	T_2	661.64	71.00	33	6	49	0.075
			S_2	661.64	71.00	2	0	3	0.004
			E	661.64	50.00	2	1	4	0.006
	14	629878	T_2	299.00	(71.00)	15	-	21	0.071
		(1.3%)	E	299.00	(50.00)	2	-	4	0.013
	15	608865	T_1	259.31	(70.00)	3	-	4	0.017
		(2.5%)	E	259.31	(100.00)	2	-	2	0.008
	16	595864	T_1	266.85	70.00	10	3	14	0.054
		(1.7%)	T_2	266.85	100.00	6	0	6	0.023
			E	266.85	100.00	1	0	1	0.003
Lishaw Burn	17	609856	T_1	250.20	(70.00)	7	-	10	0.040
		(1.9%)	T_2	250.20	(100.00)	5	-	5	0.020
Akenshaw Burn	57	624892	T_2	345.89	(71.00)	25	-	35	0.102
		(2.5%)	M	345.89		1	-	1	0.003
			E	345.89	(50.00)	4	-	8	0.023
	19	613897	T_1	386.04	(70.00)	3	-	4	0.011
		(2.8%)	T_2	386.04	(100.00)	6	-	6	0.016

LEWIS BURN SYSTEM (CONTINUED)

Stream name	Site no.	O.S. grid ref. (site gradient)	Species	Area fished (m^2)	Efficiency of fishing (%)	No. caught C_1	C_2	Est. pop.	Est. pop density (no. m^{-2})
Akenshaw Burn	20	594896	T_1	282.33	(70.00)	15	-	21	0.076
		(1.9%)	T_2	282.33	(100.00)	3	-	3	0.011
			E	282.33	(100.00)	4	-	4	0.014
Grains Burn	21	578906	-	25.00					
Buck Burn	22	587898	-	72.50					
Neate Burn	23	588892	T_1	128.75	78.00	22	4	28	0.219

PLASHETTS BURN

Stream name	Site no.	O.S. grid ref. (site gradient)	Species	Area fished (m^2)	Efficiency of fishing (%)	No. caught C_1	C_2	Est. pop.	Est. pop density (no. m^{-2})
Plashetts Burn	24	665897	T_1	95.00	(59.00)	36	-	61	0.642
		(1.7%)	T_2	95.00	(82.00)	1	-	1	0.013
			S_1	95.00	(59.00)	6	-	10	0.107
			S_2	95.00	(82.00)	1	-	1	0.013
			SL	95.00	(33.00)	46	-	139	1.467
	25	664903	T_1	140.28	59.00	26	11	44	0.314
		(1.7%)	T_2	140.28	82.00	17	3	21	0.148
			S_1	140.28	59.00	8	3	14	0.097
			SL	140.28	33.00	12	8	36	0.259
			M	140.28	96.00	152	6	158	1.129
			E	140.28	100.00	1	0	1	0.007
	26	661914	T_2	97.75	(82.00)	31	-	38	0.387
		(3.0%)	M	97.75	(96.00)	7	-	7	0.075
			E	97.75	(100.00)	1	-	1	0.010
	27	670924	-	27.46					
		(2.8%)							

BELLING BURN

Stream name	Site no.	O.S. grid ref. (site gradient)	Species	Area fished (m^2)	Efficiency of fishing (%)	No. caught C_1	C_2	Est. pop.	Est. po density (no. m^{-2})
Belling Burn	28	693883	T_1	74.20	(78.50)	15	-	19	0.258
		(3.0%)	T_2	74.20	(91.00)	26	-	29	0.385
			E	74.20		1	-	1*	0.013*
	29	691898	T_1	215.89	57.00	107	46	188	0.870
		(5.1%)	T_2	215.89	100.00	2	1	2	0.009
	30	694908	T_1	136.47	100.00	2	0	2	0.015
		(3.8%)	T_2	136.47	82.00	11	2	13	0.098
	31	695922	-	12.50					
		(2.4%)							

KIELDER BURN SYSTEM

Stream name	Site no.	O.S. grid ref. (site gradient)	Species	Area fished (m^2)	Efficiency of fishing (%)	No. caught C_1	C_2	Est. pop.	Est. pop density (no. m^{-2})
Kielder Burn	42	633934	T_1	640.93	(25.00)	6	–	24	0.037
		(2.0%)	T_2	640.93	(66.50)	49	–	74	0.115
			S_1	640.93	(25.00)	2	–	8	0.012
			SL	345.46	(50.50)	18	–	36	0.103
			•x•M	160.20	(67.00)	41	–	61	0.382
			ST	640.93	–	2	–	2*	0.003*
			E	640.93	(100.00)	1	–	1	0.002
	41 (pool)	644946 (1.1%)	T_1	403.10	28.00	1	4	4	0.009
			T_2	403.10	100.00	8	0	8	0.020
			S_1	403.10	28.00	24	14	86	0.213
			SL	403.10	44.00	16	9	36	0.090
			•x•M	403.10	67.00	9	3	13	0.033
			E	403.10	100.00	2	0	2	0.005
	40 (riffle)	648952	T_1	263.33	22.00	4	5	18	0.069
			T_2	263.33	33.00	15	10	45	0.173
		(1.1%)	S_1	263.33	22.00	37	27	168	0.639
			S_2	263.33	33.00	7	2	21	0.081
			SL	263.33	57.00	21	9	37	0.140
			E	263.33	100.00	5	0	5	0.019
	39	655965	T_1	321.67	(25.00)	32	–	128	0.398
		(0.6%)	T_2	321.67	(66.50	6	–	9	0.028

KIELDER BURN SYSTEM (CONTINUED)

Stream name	Site no.	O.S. grid ref. (site gradient)	Species	Area fished (m^2)	Efficiency of fishing (%)	No. caught C_1	C_2	Est. pop.	Est. pop. density (no. m^{-2})
Kielder Burn	39		S_1	321.67	(25.00)	26	-	104	0.323
			S_2	321.67	(66.50)	3	-	5	0.014
			SL	321.67	(50.50)	37	-	73	0.228
			M	321.67	(67.00)	5	-	7	0.023
			E	321.67	(100.00)	1	-	1	0.003
			L	-				-	-
Scaup Burn	38	665981	T_1	133.69	(25.00)	23	-	92	0.688
		(1.5%)	T_2	133.69	(66.50)	18	-	27	0.202
			S_1	133.69	(25.00)	7	-	28	0.209
			S_2	133,69	(66.50)	1	-	2	0.011
			SL	133.69	(50.50)	8	-	16	0.118
			E	133.69	(100.00)	1	-	1	0.007
	32	661987	T_1	255.85	(25.00)	38	-	152	0.594
		(1.3%)	T_2	255.85	(66.50)	32	-	48	0.188
			SL	255.85	(50.50)	5	-	10	0.039
			E	255.85	(100.00)	3	-	3	0.012
White Kielder Burn	37	669982	T_1	193.67	(25.00)	54	-	216	1.115
		(1.5%)	T_2	193.67	(66.50)	30	-	45	0.233
			SL	193.67	(50.50)	14	-	28	0.143
			E	193.67	(100.00)	1	-	1	0.005
Ridge End Burn	34	662959	T_1	258.50	!	1	1	2*	0.008*
		(2.4%)	T_2	258.50	100.00	9	0	9	0.035

KIELDER BURN SYSTEM (CONTINUED)

Stream name	Site no.	O.S. grid ref. (site gradient)	Species	Area fished (m^2)	Efficiency of fishing (%)	No. caught C_1	C_2	Est. pop.	Est. pop density (no. m^{-2})
Ridge End Burn	35	691972	T_2	269.97	(100.00)	3	-	3	0.011
		(6.1%)	E	269.97	(100.00)	1	-	1	0.004
White Knowes Sike	43	655964	T_1	68.46	78.00	9	2	12	0.169
		(6.1%)	T_2	68.46	75.00	12	3	16	0.234

NORTH TYNE (UPPER) SYSTEM

Stream name	Site no.	O.S. grid ref. (site gradient)	Species	Area fished (m^2)	Efficiency of fishing (%)	No. caught C_1	C_2	Est. pop.	Est. pop density (no. m^{-2})
North Tyne	46	628940	T_1	134.40	(28.50)	5	-	18	0.131
		(1.2%)	T_2	134.40	(63.00)	17	-	27	0.201
			S_2	134.40	(63.00)	2	-	3	0.024
			SL	134.40	(67.00)	9	-	13	0.100
				134.40	(38.00)	3	-	8	0.059
				134.40	(100.00)	2	-	2	0.015
			L	-					
	45	624946	T_1	213.77	20.00	37	21	185	0.865
		(0.6%)	T_2	213.77	59.00	40	18	68	0.317
			S_1	213.77	20.00	12	18	60	0.281
			S_2	213.77	59.00	4	0	7	0.032
			SL	213.77	67.00	63	21	94	0.440
			M	213.77	38.00	8	5	21	0.098
			E	213.77	100.00	1	0	1	0.005
			L	-					
	44	611955	T_1	112.00	37.00	41	26	111	0.989
		(0.6%)	T_2	112.00	67.00	12	4	18	0.160
			SL	112.00	67.00	36	n.e.	54	0.480
			ST	112.00	50.00	2	1	4	0.036
			L	-					

NORTH TYNE (UPPER) SYSTEM (CONTINUED)

Stream name	Site no.	O.S. grid ref. (site gradient	Species	Area fished (m^2)	Efficiency of fishing (%)	No. caught		Est. pop.	Est. pop. density ($no. m^{-2}$)
						C_1	C_2		
Deadwater Burn	49	605965	T_1	65.00	(41.00)	30	-	73	1.126
		(1.8%)	T_2	65.00	(92.00)	33	-	36	0.552
			SL	65.00	(70.00)	7	-	10	0.154
			L	-					
	48	611978	T_1	54.39	41.00	17	10	41	0.762
		(3.0%)	T_2	54.59	92.00	26	2	28	0.520
	47	619984	T_1	34.63	(41.00)	19	-	46	1.338
		(4.4%)	T_2	34.63	(92.00)	21	-	23	0.659
Bells Burn	51	616951	T_1	31.90	61.00	97	38	159	4.985
		(0.6%)	T_2	63.69	47.00	17	9	36	0.568
			SL	63.69	73.00	30	8	41	0.645
			M	63.69	94.00	34	2	36	0.568
			E	63,69	100.00	3	0	3	0.047
	50	598934	E	132.72	(100.00)	2	-	2	0.015
		(2.5%)							

NORTH TYNE (main)

Stream name	Site no.	O.S. grid ref. (site gradient	Species	Area fished (m^2)	Efficiency of fishing (%)	No. caught		Est. pop.	Est. pop. density ($no. m^{-2}$)
						C_1	C_2		
North Tyne (main)	52i	656903	S_1	502.97	!	19	26	45*	0.089*
"Plashetts"		(0.3%)	SL	502.97	11.00	19	17	181	0.360
Reach 1			M	245.10	25.00	115	86	456	1.860
			E	502.97	100.00	2	0	2	0.004
			L	–					
Reach 2	52ii	656903	T_1	372.40	100.00	1	0	1	0.003
		(0.3%)	T_2	372.40	100.00	1	0	1	0.003
			S_1	372.40	45.00	38	21	84	0.227
			SL	194.30	18.00	11	9	61	0.315
			M	194.30	!	8	10	18*	0.093*
			ST	372.40	100.00	3	0	3	0.015
			L	–					

1979 SURVEY

North Tyne (m)   * = minimum estimate.   •x• = fry also present.

Site name	Site no.	O.S. grid ref. (site gradient	Species	Area fished (m^2)	Efficiency of fishing (%)	No. caught C_1	No. caught C_2	Est. pop.	Est. pop. density (no./m^2)
N. Tyne (m)			T_1	380.16	33.33	3	2	9	0.024
Plashetts	52i	656903	S_2	380.16	62.50	8	3	13	0.034
Reach 1		(0.3%)	SL	380.16	64.71	17	6	26	0.069
			M	205.00	45.45	110	60	242	1.180
			E	380.16	100.00	1	0	1	0.003
			L	380.16	68.52	54	17	79	0.207
N. Tyne (m)			T_1	291.55	(33.33)	21	-	63	0.216
Plashetts	52ii	656903	T_2	291.55	(62.50)	2	-	3	0.011
Reach 2		(0.3%)	S_2	291.55	(62.50)	7	-	11	0.038
			•x• SL	291.55	(54.71)	10	-	15	0.053
			•x• M	291.55	(45.45)	230	-	506	1.736
			E	291.55	(100.00)	4	-	4	0.014
			L	291.55	(68.52)	12	-	18	0.060
N. Tyne (m)			T_1	269.24		9	-	9*	0.033*
Plashetts Bridge	53	662898	T_2	269.24		1	-	1*	0.044*
		(0.44%)	S_2	269.24	(78.57)	12	-	15	0.057
			SL	269.24	(61.91)	16	-	26	0.096
			M	269.24	(100.00)	5	-	5	0.019
			E	269.24	(77.78)	1	-	1	0.005
N. Tyne (m)			T_1	390.56		1	-	1*	0.003*
Hawkhirst	54	665886	S_2	390.56	(78.57)	3	-	4	0.010
		(0.44%)	SL	390.56	(61.91)	36	-	58	0.149
			M	390.56	(100.00)	2	-	2	0.005
			E	390.56	(77.78	4	-	5	0.013
			L	390.56	(100.00)	1	-	1	0.003

1979 SURVEY

North Tyne (m) (Continued)

Site name	Site no.	O.S. grid ref. (site gradient	Species	Area fished (m^2)	Efficiency of fishing (%)	No. caught C_1	C_2	Est. pop.	Est. pop. density ($no./m^2$)
N. Tyne (m)			T_1	230.58	!	0	2	2*	0.009*
Mounces	55i	664882	•x• SL	230.58	44.44	45	25	101	0.439
Reach 1		(0.44%)	•x• M	230.58	69.48	154	47	222	3.190
			ST	230.58	100.00 (fry)	1	0	1	0.004
			E	230.58	83.33	6	1	7	0.031
			L	230.58	100.00	1	0	1	0.004
N. Tyne (m)			T_1	432.00		9	-	9*	0.021*
Mounces	55ii	664882	S_2	432.00		4	-	4*	0.009*
Reach 2	(only fished for salmonid species)								
N. Tyne (m)			T_1	423.80		8	-	8*	0.019*
Mounces Reach 3	55iii	664882	SL	423.80	(44.44)	48	-	108	0.255
			M	423.80	(69.48)	22	-	32	0.075
N. Tyne (m)			T_1	462.86	(33.33)	3	-	9	0.019
Otterstone Lee	56	670879	S_2	463.86	(62.50)	2	-	3	0.007
		(0.44%)	SL	462.86	(64.71)	16	-	25	0.053
			M	462.86	(45.45)	2	-	4	0.010
			L	462.86	(68.52)	1	-	1	0.003
N. Tyne (m)			T_1	441.25	!	1	1	2*	0.005*
Nr. Black Hole	57	678878	T_2	441.25	!	0	2	2*	0.005*
		(0.22%)	S_2	441.25	78.57	14	3	18	0.040
			SL	441.25	61.91	21	8	34	0.077
			M	441.25	100.00	7	0	7	0.016
			E	441.25	77.78	36	8	46	0.105
			L	441.25	100.00	1	0	1	0.002

North Tyne (m) (Continued)

Site name	Site no.	O.S. grid ref. (site gradient)	Species	Area fished (m^2)	Efficiency of fishing (%)	No. caught C_1	No. caught C_2	Est. pop.	Est. pop. density (no./m^2)
N. Tyne (m)			T_1	220.62	(33.33)	8	-	24	0.109
Museum	58	654904	T_2	220.62	(62.50)	8	-	13	0.058
		(0.34%)	S_2	220.62	(62.50)	18	-	29	0.131
			SL	220.62	(64.71)	21	-	32	0.147
			M	220.62	(45.45)	82	-	180	0.818
			E	220.62	(100.00)	5	-	5	0.023
N. Tyne (u)									
Bells Burn	51a	616951	T_1	145.20	65.47	139	48	212	1.462
			T_2	145.20	66.67	33	11	50	0.841
			S_2	145.20	!	0	1	1*	0.007*
			SL	145.20	68.18	44	14	65	0.444
			ST	145.20	100.00	1	0	1	0.007
			E	145.20	!	2	2	4*	0.028*
			L	145.20	100.00	2	0	2	0.014
	51b		T_1	100.60	(65.47)	18	-	27	0.273
			T_2	100.60	(66.67)	28	-	42	0.417
			S_2	100.60		1	-	1*	0.010*
			SL	100.60	(68.18)	9	-	13	0.131
			E	100.60		1	-	1*	0.010*
	51c	613949	T_1	154.10	(65.47)	56	-	86	0.555
			T_2	154.10	(66.67)	24	-	36	0.234
			E	154.10		3	-	3*	0.019*

WHICKHOPE BURN SYSTEM

Site name	Site no.	O.S. grid ref. (site gradient)	Species	Area fished (m^2)	Efficiency of fishing (%)	No. caught		Est. pop.	Est. pop. density (no./m^2)
						C_1	C_2		
Whickhope Burn	59	693873	T_1	463.98		4	-	4*	0.009*
			T_2	463.98	(42.86)	5	-	12	0.025
			SL	463.98		1	-	1*	0.002*
			E	463.98	(70.00)	1	-	1	0.003
	60	691867	T_1	854.37	!	0	1	1*	0.001*
			T_2	854.37	42.86	7	4	16	0.381
			M	854.37	!	3	5	8*	0.009*
			E	854.37	70.00	10	3	14	0.017
			L	854.37	!	1	3	4*	0.005*

Appendix 2 Age for length of stone loach sampled in the survey

Bells Burn (site 51)		Plashetts Burn (site 25)	
Length (cm)	Age*	Length (cm)	Age*
8.10	2+	6.45	1+
8.45	2+	6.70	1+
9.45	2+	6.80	1+
9.45	2+	7.00	1+
9.70	2+	7.20	1+
9.70	2+	7.25	1+
9.70	2+	7.35	1+
9.75	2+	7.60	1+
9.75	2+	7.90	1+
9.75	2+	8.90	1+
9.80	2+	9.10	2+
9.90	2+	9.30	2+
10.20	2+	10.70	2+
10.25	2+		
10.35	3+		
10.50	2+	n = 13	
10.50	2+		
10.70	2+		
10.90	3+		
11.20	3+		
n = 20			

* Age determined from otoliths cleared in creosote.

Appendix 3. Length/weight regression equations calculated for the month of July from data collected at Kielder.

River system	n	r	p	$w = a\ l^b$ a $\pm$ s.e.	b $\pm$ s.e.
<u>Trout</u>					
Whickhope	37	0.87	0.01	0.12 $\pm$ 1.63	2.15 $\pm$ 0.20
Lewis	68	0.94	0.01	0.02 $\pm$ 1.38	2.91 $\pm$ 0.13
Plashetts	51	0.99	0.01	0.01 $\pm$ 1.18	2.93 $\pm$ 0.14
•Belling				not sufficient data	
Kielder	89	0.92	0.01	0.03 $\pm$ 1.35	2.65 $\pm$ 0.12
N. Tyne (u)	126	0.98	0.01	0.01 $\pm$ 1.14	2.98 $\pm$ 0.06
N. Tyne (m)	12	1.00	0.01	0.02 $\pm$ 0.35	2.92 $\pm$ 0.09
•x• <u>Salmon</u>	5	0.99	0.01	0.01 $\pm$ 2.10	3.26 $\pm$ 0.30
•x• <u>Eel</u>	22	0.97	0.01	0.001 $\pm$ 2.05	3.26 $\pm$ 0.20
•x• <u>Stone loach</u>	17	0.57	0.01	0.63 $\pm$ 2.46	1.05 $\pm$ 0.41

n = number of pairs of data

r = correlation coefficient

p = significance level of r

w = weight (g)

l = length (cm)

a,b = constants

• Length/weight regression equation for the Plashetts Burn was applied to estimate weights of fish caught in the Belling Burn.

•x• Data from all river systems combined.

Appendix 4 Length/weight regression equations for minnows calculated for the month of July in the Weel basin (D.T. Crisp).

Sex	n	p	$w = al^b$	
			a	b
♀	8	0.01	0.0556	2.2087
♂	7	0.01	0.0068	3.3157

n = number of pairs of data

p = significance level of correlation coefficient

w = weight (g)

l = length (cm)

a, b = constants

N.B. Since minnows were not sexed in the survey a mean was taken of the estimated male and female weight for length.

Appendix 5. Data collected from gill netting the N. Tyne (m) July 1978 and 1979.

O.S. Grid Ref. of gill net site	Date	Time set	Sp.	Catch FL	Wt(g)	Age
679878 Black Hole	25/7/78	10.00 to 16.30	T_2	21.0	110	3+
			T_2	21.3	120	2+
			T_2	22.0	155	2+
			T_2	25.2	190	3+
			T_2	26.4	250	3+
			T_2	27.8	260	4+
			T_2	31.0	325	4+
671879 Otterstone Lee	10/7/79	20.00 to 08.30	S_2	10.5	-	1+
670879 Otterstone Lee	11/7/79	09.00 to 17.00	-			
668895 Wellhaugh	11/7/79	20.00 to 09.00	S_3	71.5	-	-
			T_2	37.9	530	5+
			T_2	-	-	-

Appendix 6. Statistics about Kielder Water (source N.W.A.)

Top water level 185.16 m (607.5 ft.) A.O.D. (N)

Gross storage 200,938,000 m^3 (44,200 m.g.)

Usable reservoir storage 188 million m^3 (41,350 million gallons)

Min. Draw Down Level of 152.5 m (500 ft.) A.O.D. (N) (42,000 m.g.)

Estimated yield 900,000 m^3/day (210 m.g.d.)

Length of dam 1140 m (3750 ft.)

Max. height of Dam 51.8 m (170 ft.)

Volume of fill 4 million m^3 (5.2 million cu. yards)

Area of water surface at T.W.L. 10.87 sq. km. (2684 acres)

Length of reservoir 11.1 km (6.9 miles)

Catchment area 24,150 hectares 59,400 acres

Average annual rainfall over catchment 1370 mm (51 ins.)