A REPORT ON THE STRATEGIC STOCK ASSESSMENT SURVEY OF THE RIVER ESK CATCHMENT 1994 WITH PARTICULAR REFERENCE TO SALMONIDS.

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Front Cover : The source of the River Esk.

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1. SUMMARY

Salmon populations in the River Esk are increasing in density in the main river and are also widening their geographical distribution.

Trout production occurs mainly in the tributaries where year class strength fluctuates widely. This may be due to variations in environmental conditions, notably drying up of streams.

Acid rain no longer causes severe mortalities, but some areas remain fishless in the upper reaches as the streams are isolated from other fish populations which could repopulate them.

The productivity of the system remains low due to the geological nature of the catchment. Liming activites have limited merit as a means of increasing production.

2. INTRODUCTION

The NRA under the Water Resources Act 1991, has a responsibility to maintain, improve, and develop fisheries. To accomplish this, baseline data on the populations of fish present in North West region is required.

The stock assessment task group has identified a number of key areas for the application of stock assessment data:

1. To assess long term change.

2. To help conserve fish species.

3. To evaluate stocking programmes, habitat and water quality improvements.

4. To assess or predict the impact of activities which the NRA or other organizations may have on fish populations.

5. To comment on the fisheries implications of developments when the NRA is a statutory consultee to planning authorities.

This report forms one part of the third year of a triennial survey programme for the South West Cumbria, and South Cumbria catchments. It is the first extensive survey of the River Esk catchment, but some reference will be made to data from previous years.

3. DESCRIPTION OF STUDY AREA

3.1. SITE SELECTION

A total of 34 sites were selected throughout the River Esk catchment. All sites were chosen at approximately 1km distances apart, where access was possible and were representative of the area of river immediately around the site.

3.2. OBSTACLES

Obstacles, for example weirs and waterfalls, can act as important factors affecting the distribution of fish within a catchment (Gardiner 1990). Figure 1 shows the weirs and waterfalls known to exist within the catchment.

3.3. WATER QUALITY

The spring 1994 water quality survey on the River Esk, found good water quality class 1A at Cropple How and on Whillan Beck. The main river at Wha House Bridge was class 3, due to low diversity / abundances of fauna. (Appendix 1).

4. METHODS.

All the sites sampled in 1994, were fished using either an Electracatch pulsed DC control box, powered by a 1.5KW Honda generator, or an Electracatch Backpack unit using smoothed DC output.

For all sites, the team fished once through in an upstream direction for around 50m, without stop nets.

All fish were collected except where numbers of minor coarse fish (minnows, bullheads, stickleback and stoneloach) were so high as to make accurate netting impossible, without inordinate effort. In these cases an abundance category was assigned, Appendix 2d.

A number of other details were recorded, including temperature, conductivity, water level, velocity, general habitat details and the team's specific tasks.

Measurements of site length and widths at 10m intervals were recorded, Appendix 2a.

Target fish (salmonids and major coarse fish species) were anaesthetised when necessary using phenoxyethanol and then measured to the nearest 0.5cm (rounding down). Where the number of fish in any age class appeared to be in excess of 100, a sub sample of about this number was measured.
For each target species and age class (salmonids only), a minimum density (number of fish caught divided by the area fished, multiplied by 100) per 100m^2 was calculated. This information is tabulated in Appendix 2b.

Figure 1 : Known Obstacles to Migratory Fish in the River Esk Catchment 1994.

5. RESULTS BY SUB-CATCHMENT

5.1. LOWER ESK

5.1.1. Description of sites

This reach covers the main river at Cropple How (site 1950) and prior to the confluence with Linbeck (1951). The river is wide,(about 15 metres) and fast flowing. The edges are shallow during the summer and small gravel bars exist. The middle of the river is quite deep. The river is lined with deciduous trees and drains agricultural land.

5.1.2. Results

Both sites scored class D for salmon fry. For salmon parr PTC Linbeck scored class D, but parr were more abundant at Cropple How scoring class B.

Both sites scored class D for trout fry. Trout parr scored class D at Cropple How, but were absent at PTC Linbeck.

5.1.3. Discussion

The fry were caught mainly in the sides of the sites where cover was provided in the shallow areas with smaller cobbles. The middle of the river was often deep, fast flowing and with no substrate cover. The higher number of salmon parr found at Cropple How were caught in the larger stones positioned to create a dam for a ford. This was an artificial creation and was not representative of the whole river. As a result only a small section was fished.

5.2. MIDDLE ESK

5.2.1. Description of sites

The river in this reach is tree lined and wide during high flows, but utilises only the deeper areas during summer. The substrate at King George Bridge (1952), Below the Railway (1952.5), Boot Church (1953) and Penny Hill Farm (1955) consisted of large cobbles. Instream cover was lacking in the middle of the river.

The substrate at Whahouse (1956) and Brotherilkeld (1958) was larger consisting of large boulders throughout the river bed.

5.2.2. Results

Salmon fry are absent from the middle river sites except for below the Railway and Boot Church which scored class D. Salmon parr were more widespread, but were absent at Wha House. All other sites scored class D, except below the railway which scored class B.

Trout fry were present at class D densities at all sites except for Brotherilkeld. Trout parr were absent at the two lowest sites (King George Bridge & below the Railway) and scored class D at the rest of the sites.

5.2.3. Discussion

The large density range of class D is quite deceptive in this instance as salmon were only present in low densities, for example 2.61 fry/100 m^2 at Boot Church. The situation is similar for >0+ salmon. As a result there is little difference between sites that are class D for salmon and those where salmon are absent. The exception to this is below the Railway which had a riffle section at the top of the site which provided salmon habitat and a corresponding increase in salmon densities.

Trout fry were not as sparse as salmon fry, but were still not vastly abundant. At some sites the low conductivity of the water reduced the effectiveness of the gear and fry were observed escaping. However, they would not have increased the density substantially had they all been captured. Trout parr were only present in low densities perhaps due to the fast flows present, at these sites, especially in time of spates.

5.3. UPPER ESK

5.3.1 Description of sites

Site 1959 is accessable to migratory fish, but sites 1960, 1961 and 1962 are above a series of impassable falls. At site 1959 the substrate size was large with huge rocks deposited in the river bed, the flow was fast.

At the sites above the falls substrate varied with large cobbles, gravel and boulders. The river drained wetland and mountainside.

5.3.2. Results

Salmon were absent from all sites. Trout fry and parr both scored class D at site 1959, but this represented only 2 fry and 1 parr.

The sites above the waterfalls had no trout present. No fish of any species were seen escaping. Invertebrates were seen in very low quantities at the two lower sites.

5.3.3. Discussion

The habitat at site 1959 was very hostile to fish, with little cover and fast flows. Cover was available in the shallow margins, but few fish were found. Productivity at this site would be low with low invertebrate densities as inferred in the NWC class 3 downstream. This could cause density dependent mortality due to lack of food resources.

The sites above the waterfall were devoid of fish. It could be hypothesised that the resident fish in this area were killed during acid flushes in the eighties which caused mortalities of adult fish in the main river downstream. If all fish were killed then repopulation of the area would not be possible as migratory fish are unable to ascend the falls and spawn under any circumstances.

5.4. LINGCOVE BECK

5.4.1. Description of sites

Lingcove Beck is of a similar nature to the Upper Esk which it joins above the impassable falls upstream of site 1959.

5.4.2. Results and Discussion

As with the Esk in this region no fish at all were found in this beck. The situation with regard to absence of fish is the same as the Esk.

5.5. UPPER TRIBUTARIES

5.5.1. Description of sites

Scale Gill (site 1958.5) is fast flowing cascades and pools made up of large boulders, providing good instream cover. Hardknott Ghyll (site 1974) was surveyed above waterfalls. The substrate was bedrock and boulders with small patches of gravel. This created pools and cascades. Both becks drain sparsely vegetated steep upland, but have some mixed deciduous trees within the riparian zone.

5.5.2. Results

Salmon fry were absent from Scale Gill, but salmon parr scored class D, as did trout fry and parr.

Salmon were absent from Hardknott Ghyll. Trout scored class D for fry and class C for parr.

5.5.3. Discussion

Salmonid densities in Scale Gill were low. However, fish were present here and not in the main river adjacent.

It is unlikely that any migratory fish can ascend the falls on Hardknott Ghyll. This is supported by the absence of salmon and the presence of >1+ trout. The pools and cascades would provide good cover for larger trout. Sea trout do spawn in Hardknott Ghyll below the falls, but this area was not surveyed.

5.6. MIDDLE TRIBUTARIES

5.6.1. Description of sites

The two un-named tributaries (sites 1975 & 1975.5) at Wha house that were sampled were of a similar nature, i.e. about 1.5 metres wide, draining improved pasture, of medium flow with a gravel and silt substrate. However, at site 1975.5 the substrate undulated with large sea trout redds cut in the previous winter.

Stony Beck (site 1971), Whillan Beck (sites 1966, 1967 1968) and Birker Beck (site 1976) were all of a similar nature consisting of large boulders and bedrock. The flow was fast creating cascades and pools. The top site of Whillan Beck (1968) is above impassable waterfalls.

Blea Tarn Beck (site 1964) and Eel Tarn Beck (sites 1969 & 1970) both flow through improved pasture land. They are both about 1.5 metres wide with a medium flow and substrate dominated by gravel and small cobbles.

Stanley Force Beck (sites 1979 & 1980) drains moorland. The substrate was angular cobbles and flow was of medium velocity. Access to migratory fish may be hindered by a stepped culvert under the road close to the confluence with the main river.

5.6.2. Results

Site 1975, the un-named tributary at Wha House was devoid of salmonids.

Salmon were absent at Site 1975.5. Trout fry and parr both scored class C.

Salmon were absent from the top site of Whillan Beck (1968) and Stony Tarn Beck (1971). Salmon fry scored class D in the bottom of Whillan Beck (1966 & 1967) and at Birker Beck (1976). Salmon parr scored class D at the bottom of Whillan Beck, class B at the middle of Whillan Beck and class C at Birker Beck. Trout fry scored class D for the five sites in this paragraph. Trout parr were absent from sites 1966 and 1968 on Whillan Beck and scored class D at site 1967. Stony Tarn Beck (1971) scored class C and Birker Beck class B.

No salmon were found in Blea Tarn Beck or Eel Tarn Beck. Trout were absent from the upper site on Eel Tarn Beck. Trout fry scored class B in Blea Tarn Beck and class A at the lower site on Eel Tarn Beck. Trout parr scored class B in Eel Tarn Beck, site 1969 and class C in Blea Tarn Beck.

Salmon were entirely absent from Stanley Force Beck. Trout fry scored class D and parr scored class C and B at the upper and lower sites respectively.

5.6.3. Discussion

The silt deposition at site 1975.5 appeared to be seasonal, collecting on the dense patches of weed. At spawning time the gravel is clean and many sea trout spawn there. (Blf. J. Muir pers. comms). The habitat was suitable for spawning and fry, but not so much for parr due to the substrate size. Fry were not as abundant as they should have been considering the amount of redds cut. This is possibly due to a number factors. It may be that fry survival is low due to lack of cover availability, or alternatively, the great number of redds being cut in the same small stream may lead to overcutting of redds, where a female cuts a redd which overlaps a redd cut by an earlier female. The eggs laid in the first redd may then become exposed and wash out or die.

The fast flowing water over boulders in Whillan Beck and Birker Beck was suited to salmon, but also provided some suitable habitat for trout within the pools. Waterfalls leave much of Whillan Beck and Birker Beck inaccessible to salmon and sea trout, thus losing a substantial area of potential production for migratory fish. The habitat at the top site on Whillan Beck would have been expected to produce more trout than caught. Similarly low levels of trout were caught immediately downstream of Burnmoor Tarn in a recent electrofishing survey carried out by the Institute of Freshwater Ecology (J. M. Fletcher pers. comms.). It is possible that the population was severely reduced during the acid flushes during the eighties. Anglers report frequently catching trout up to 3/4 lb prior to the period of increased acidification.

Blea Tarn Beck and Eel Tarn Beck are small with only medium flow speeds. The habitat is more suited to trout, hence the absence of salmon. It is thought that the top site on Eel Tarn Beck had dried up in the summer of 1994 resulting in no fish being present. It is possible that as the stream dried up the fish migrated downstream resulting in high densities of fry at the lower site.

Although salmon are absent from Stanley Force Beck it is possible that this is due to the habitat being unsuitable due to medium flows. It would appear that access is not hindered too greatly as the trout that are present consist of 0+ and 1+ year classes, older fish were not found, implying that the fish are perhaps sea trout progeny and not entirely resident trout.

5.7. TRIBUTARIES ABOVE STANLEY FORCE

5.7.1. Description of sites.

Birker Beck (site 1977) and Highford Beck (site 1978) above Stanley Force drain moorland and a small amount of improved pasture. Both sites are fast flowing with large boulder substrate creating pools. Highford Beck was open, whereas Birker Beck was tree lined.

5.7.2. Results

Salmon were absent. Trout fry scored class D at both sites and trout parr scored class A at both sites.

5.7.3. Discussion

No migratory fish were present as Stanley Force is a total barrier.

The sites scored class A for trout >0+ because the population consisted of many age classes.

5.8. LOWER TRIBUTARIES

5.8.1. Description of sites

Linbeck Gill drains Devoke Water, an upland Tarn surrounded by moorland. The site on the lower reaches (site 1981), prior to the Esk, has a steep gradient resulting in fast flows and large substrate size. These cascades and pools were tree lined with lots of submerged moss present. Immediately upstream of the site the stream climbs and access to migratory fish is limited to this small stretch .

Stainton Beck also drains moorland, in the lower reaches it flows through improved pasture . Unlike Linbeck Gill access to migratory fish extends almost to the top of the system. At both sites flow was fast, substrate size large and the banks tree lined. Cover was available in riffles and deep pools scoured under tree roots.

5.8.2. Results

Salmon were found in class D densities at Linbeck Gill (site 1981) and the lower site on Stainton Beck (1983). They were absent from the upper site on Stainton Beck (1984).

All three sites scored class D for trout fry. Linbeck Gill also scored class D for trout parr, but Stainton

Beck scored class C and class A for the lower and upper sites respectively.

5.8.3. Discussion

Salmon do not migrate very far up Stainton Beck and are present only in low densities in these tributaires. Trout are more plentiful especially >0+ at the upper site on Stainton Beck. Here, half of the >0+ fish are >1+. This may imply that a large proportion of the population of trout are resident despite the accessability to migratory fish.

Figure 2 : 0+ Salmon Densities in the River Esk Catchment.

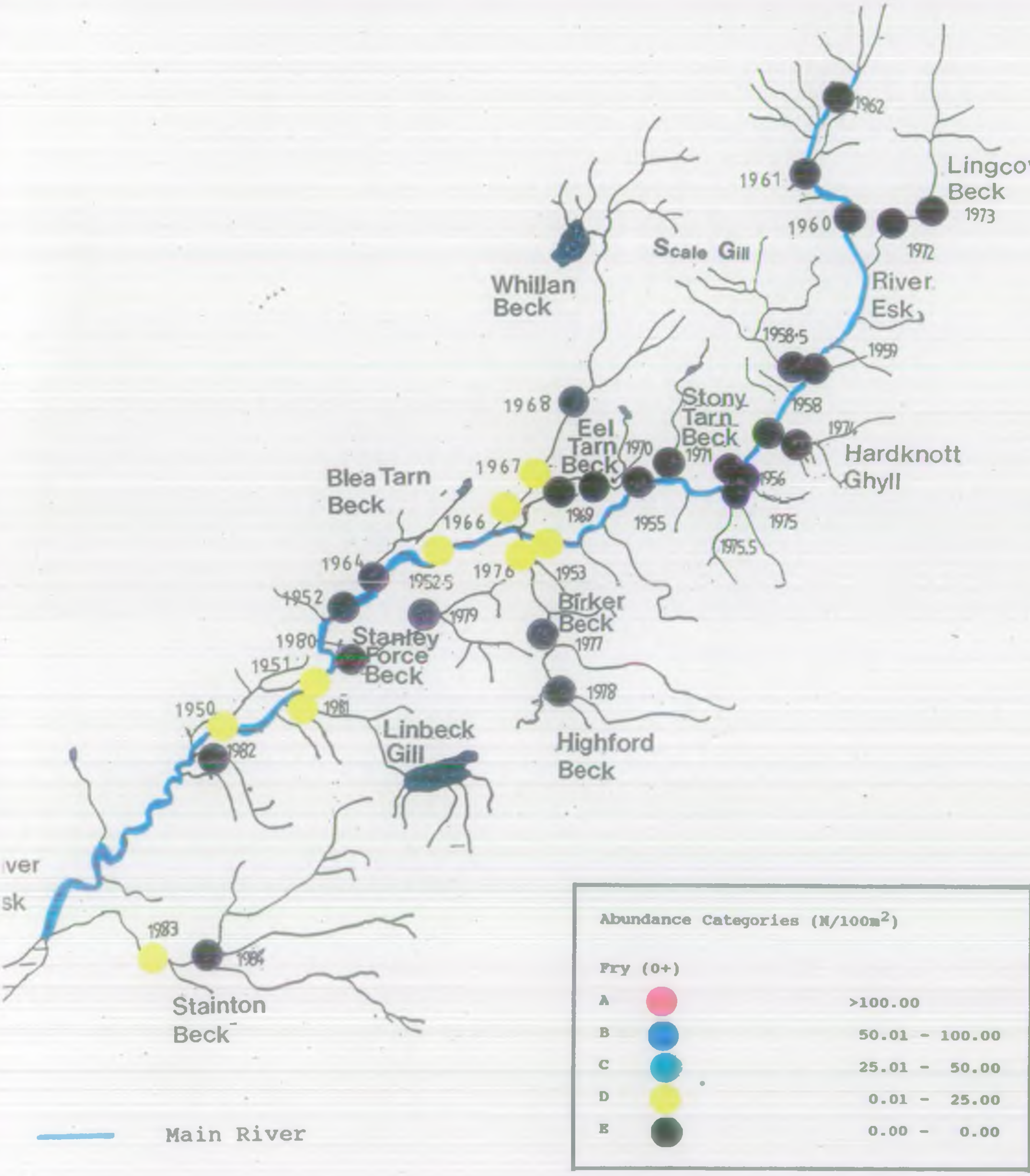

Figure 3 : Salmon Parr (>0+) Densities in the River Esk Catchment.

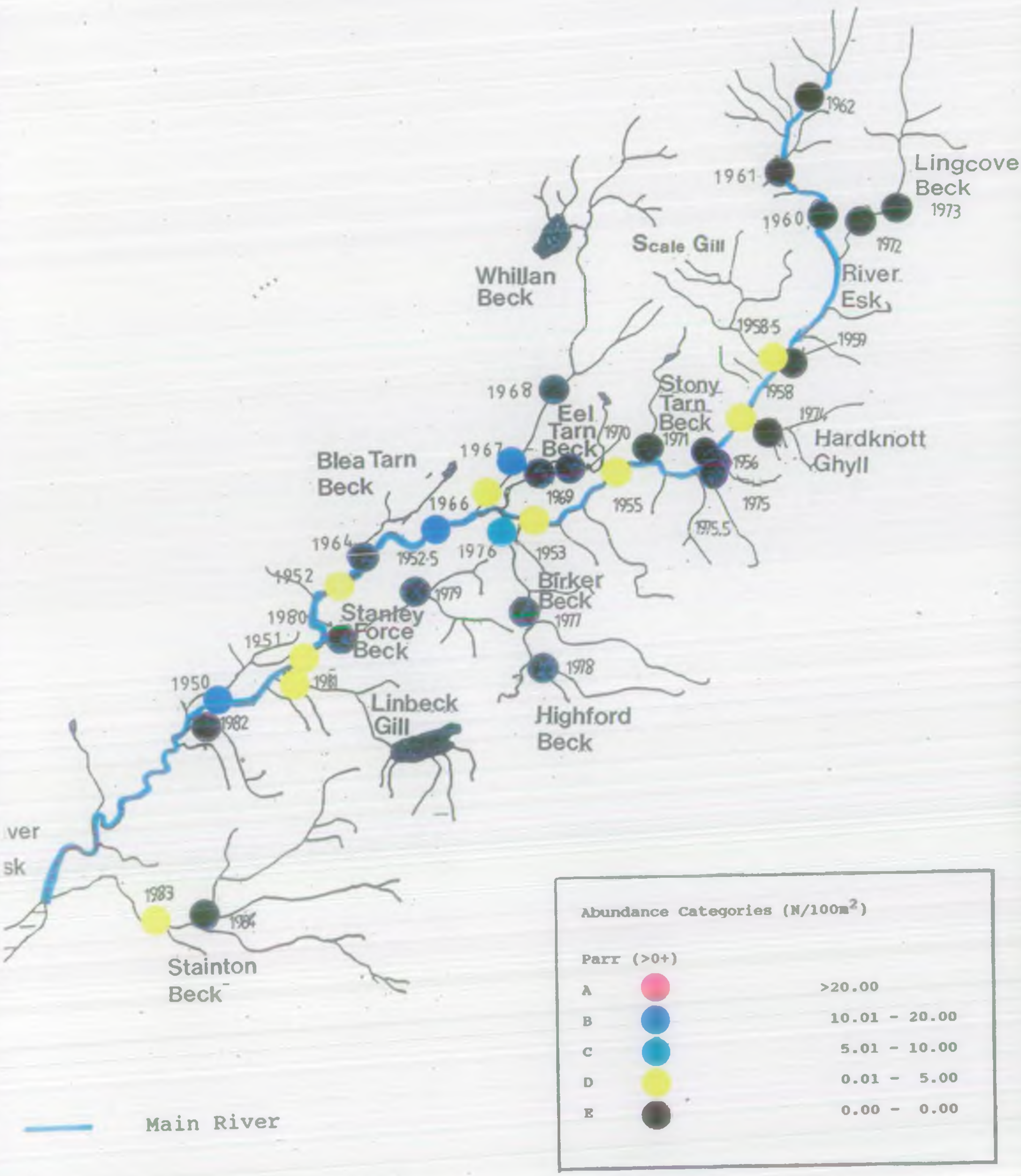

Figure 4 : 0+ Trout Densities in the River Esk Catchment.

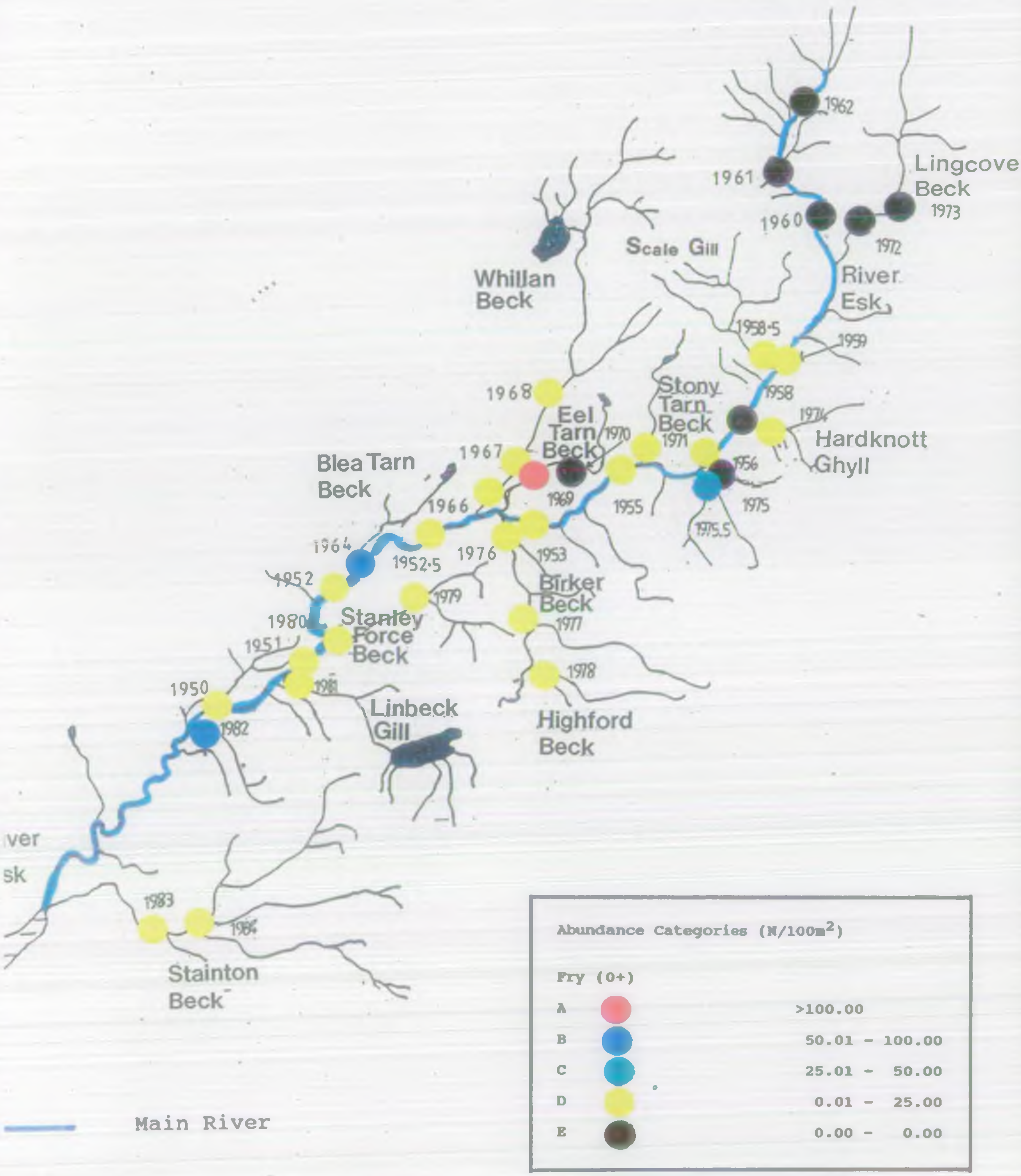

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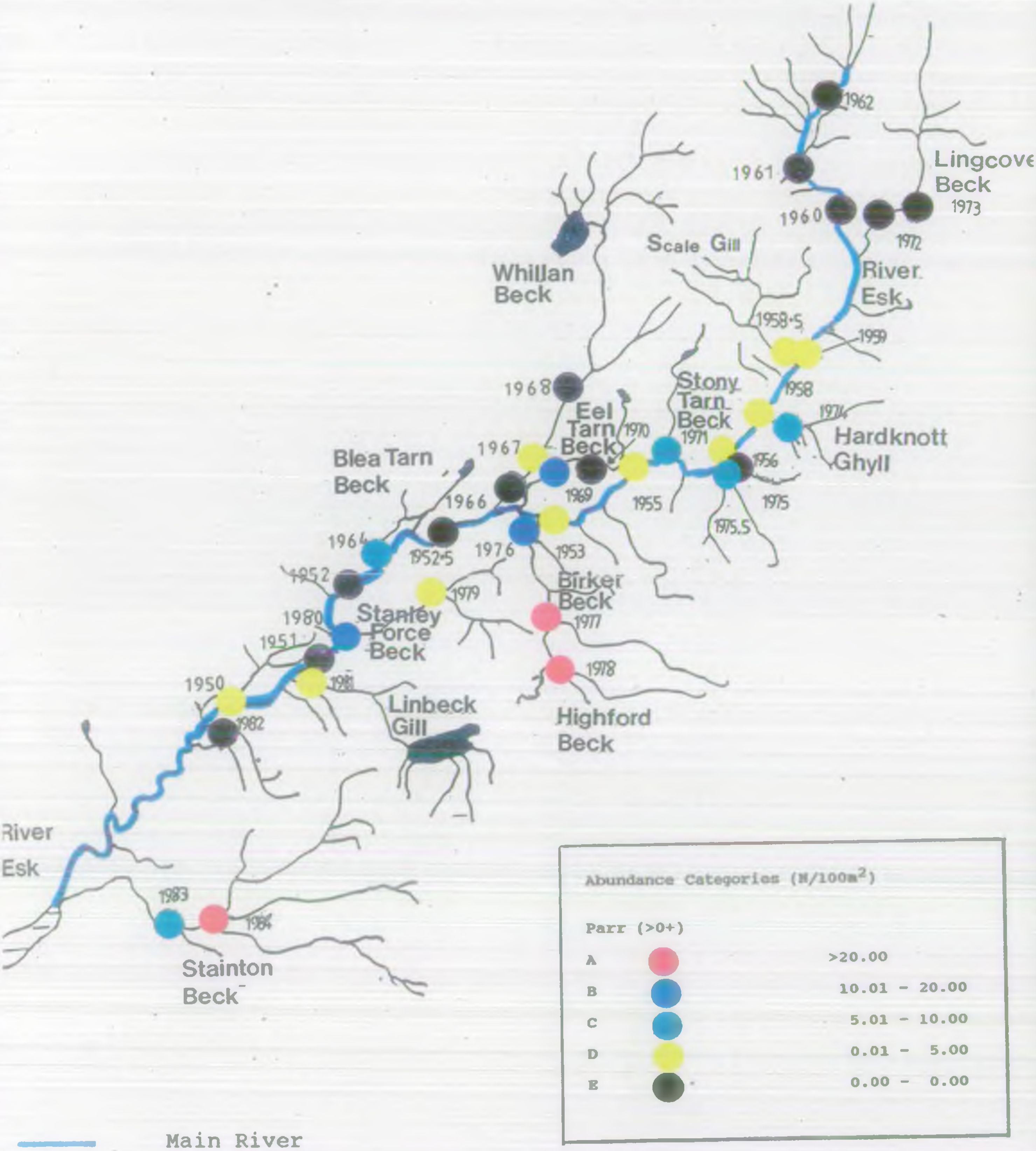
Figure 5 : Trout Parr (>0+) Densities in the River Esk Catchment.



6. OVERVIEW

The Esk is a spate river receiving an annual average rainfall of up to 3500 mm in the upper reaches (Derwent and Cumbria Coast Catchment Management Plan Consultation Report 1994). The geology of the Esk catchment is made up of Granite Intrusions and Borrowdale Volcanic Series. These igneous rocks do not wear easily and as a result the conductivity of the river water is of a similar magnitude to rain (Diamond *et al* 1992). The primary producers, algae and bacteria, require nutrients from the water to survive. If these are not available the contribution of energy passed on by the primary producers to the next trophic level in the food chain is small. As a result the invertebrate fauna is sparse. This production discussed above is termed autochthonous, as the energy is produced within the river.

River systems also have allochthonous energy contributions, i.e. from outside the river. The most plentiful source of which is deciduous tree leaves. In some studies these contribute up to 75% of the energy in a river system (Fisher & Likens 1972). Although the main river is tree lined, the upper reaches of the main catchment are barren moorland with exposed crags, so leaf input will be severly limited. It is also possible that leaves which do enter the system are washed away relatively quickly and do not have time to decompose and be utilised by the invertebrate fauna as a food source.

As a result the invertebrate food available to salmonids becomes a limiting factor for their survival.

6.1. SALMON

6.1.1. Salmon Distribution

Eskdale is a narrow V-shaped valley. It has a limited area of valley floor, with the main river draining the majority of low lying land. The tributaries come down steeply from the mountains and have relatively short reaches across the valley floor before joining the main river. Many of the tributaries, and the main river in its upper reaches, flow over waterfalls and become so steep they are impassable to migratory fish. The area accessible to migratory fish is shown in Appendix 4.

The area utilised by salmon is limited to this area, which consists of the main river and short reaches of tributaries. However, not all the tributaries are used and salmon were not found in the main river above Brotherilkeld (1958) and were not found in substantial densities upstream of site 1952.5 (below the railway). Salmon parr were found in Scale Gill despite being absent in the main river in this area.

6.1.2. Salmon Productivity

In an effort to determine the productivity of the Esk system in terms of salmon parr, the densities of parr found at each site combined with the width data collected were used to calculate a figure for parr production over a number of "reaches." The choice of the length of these reaches was based on comparable widths at all sites where accessibility to adult salmon was observed by the presence of juveniles of this species.

Tributaries were grouped together for major tributaries to allow their importance to be assessed, in terms of the total production of each sub catchment. The figures are tabulated below.

TABLE 1: ESTIMATED SALMON PARR PRODUCTION USING MEAN DENSITIES AND WIDTHS OVER SUB CATCHMENT LENGTH.

Sub Catchment	Length (km)	Mean Width (m)	Mean Parr Density nos/100m2	Parr Production (nos)
R.Esk				
Lower	3.5	15.1	6.88	3636
Middle	9.0	9.86	0.90	799
Upper tribs	0.75	2.94	1.91	42
Middle tribs	2.4	* Values not meaned		264
Lower tribs	2.0	* Values not meaned		237
TOTAL				**4978**

* These values were calculated for the individual streams prior to entry in to this table. This ensured that the figure was not biased by areas of poor production.

It can be seen that the majority of the salmon production occurs in the Lower Esk. This 3.5 km section represents nearly three quarters of the total parr production for the whole system whilst the tributaries barely contribute to the production at only 11% of the total.

Assuming a 50% over winter mortality of parr to smolts and a 10% marine mortality of smolts to returning adults, (Mills 1989, Shearer 1994), the number of returning adults for 1996 (assuming all fish return as grilse) can be estimated at 250 fish from the parr present in 1994.

6.1.3. Comparison with Historical Survey data

Historical surveys were undertaken on the River Esk although to a smaller extent in the period 1981-89. The results of these surveys are tabulated in Appendix 6.

A summary of the changes in salmonid productivity is shown in Tables 2-3 below. As data for a number of years was available and comparisons between years are complex (Appendix 6, Graphs 1-3), two historic surveys were selected (both 5 years apart) for detailed examination.

It should be noted that the comparisons tabulated below relate to only 9 repeated sites fished in all three surveys, compared to a total of 34 sites sampled in 1994.

TABLE 2: A BREAKDOWN OF THE NUMBER OF SITES FALLING IN EACH DENSITY CLASS FOR SALMON FRY, WITH REFERENCE TO HISTORICAL DATA.

Density Class	Year 84	89	94	Class Shift '89-94
A	**0**	**0**	**0**	**0**
B	**0**	**0**	**0**	**0**
C	**0**	**0**	**1**	**+1**
D	**3**	**6**	**4**	**-2**
E	**6**	**3**	**4**	**+1**

TABLE 3: A BREAKDOWN OF THE NUMBER OF SITES FALLING IN EACH DENSITY CLASS FOR SALMON PARR, WITH REFERENCE TO HISTORICAL DATA.

Density Class	84	Year 89	94	Class Shift since 1989
A	**0**	**0**	**0**	**0**
B	**0**	**1**	**1**	**0**
C	**1**	**2**	**1**	**-1**
D	**3**	**3**	**5**	**+2**
E	**5**	**3**	**2**	**-1**

Since the 1989 survey salmon fry have been lost from one site, but densities have improved to score class C at one site. However, the reverse has occurred for parr with Class D increasing by two sites, as a result of a site gaining fish (previously class E) and a drop in a previously class C sites.

Overall class E sites for salmon parr have reduced in numbers since surveying began in the early eighties, indicating an increase in the geographical range of salmon in the catchment. This corresponds with an improvement in water chemistry experienced in both the Esk and the neighbouring Duddon catchment (Diamond *et al.* 1989) and is similar to the current salmon situation in the Duddon catchment (McCubbing 1994).

Fry densities at Cropple How (1950) have increased compared to historical surveys. As this area of river produces a substantial number of smolts, in comparison with the rest of the system, an increase in the densities of salmon fry and parr in this area is significant in terms of potential smolt production.

6.1.4. Comparison with Salmon Redd Counts

TABLE 4: SALMON REDD COUNTS FOR THE RIVER ESK, 1980-1993.

Year	Count	Year	Count
1980	2	1987	57
1981	2	1988	64
1982	4	1989	131
1983	2	1990	76
1984	6	1991	64
1985	90	1992	37
1986	*	1993	*

* No counts due to high flows during spawning period

The acid flushes that caused fish mortalities in the early eighties are reflected in very low redd counts during this period. Counts increased to 90 in 1985. Since 1987 counts have been comparable except for 1989, when a larger amount of redds were counted.

Redd counts can be used as a coarse indication of adult salmon returning to the system when added to fish exploited prior to spawning. Each salmon redd will generally relate to two salmon and from this a population estimate of 12 - 273 salmon can be made in the period 1980-1993.

Salmon were found in all areas where redds have historically been counted but also in areas where redds were not counted. This suggests that the actual number of spawning salmon will be above that estimated from redd count data alone.

6.1.5. Juvenile Salmon Production versus Adult Returns.

As in many cases an accurate value for the adult run of migratory salmonids is not possible and has had to be based on a predicted exploitation rate from rod returns with reference to redd count data. These methods have inaccuracies involving the calculations required thus making a true population estimate difficult.

TABLE 5: DECLARED ADULT SALMON ROD AND LINE CATCH RETURNS FOR THE RIVER ESK, 1962-1993.

YEAR	ROD CATCH	YEAR	ROD CATCH
1962	35	1978	9
1963	73	1979	28
1964	22	1980	15
1965	*	1981	15
1966	*	1982	7
1967	*	1983	4
1968	22	1984	2
1969	16	1985	38
1970	9	1986	43
1971	6	1987	25
1972	8	1988	51
1973	0	1989	11
1974	12	1990	21
1975	6	1991	48
1976	23	*1992*	*190*
1977	42	1993	37

* - Data unavailable
1992 - This is the figure quoted in the Annual Fisheries Statistics. However, it is incorrect as it includes an unknown quantity of fish caught in the Border Esk, Scotland. For completeness the figure was included, but shall not be considered in the following calculations.

Annual salmon rod catch fluctuates widely between years ranging from 9 to 51. The catches in the early eighties were exceptionally low partly due to "in river" mortality of adults as a result of acid flushes. Possible reasons for the variance in catch include, changing angler effort (partly weather driven in this spate river), and it seems large variations in juvenile productivity and therefore presumably adult returns. Such a situation has been highlighted for sea trout by Elliot (1993).

Typical exploitation rates for anglers catches are shown to vary from 20-40% of the available stock, (McCubbing 1993). An average explotation of 25% can be used to back calculate an estimate for original stock levels, but as not all salmon will run the river during the fishing season and will therefore be available for capture a degree of underestimate will occur using this methodology. From 1962 - 1993 data this will give a range of returning adult salmon of 8 - 292 salmon and a mean of 89. 1993 data estimates a minimum return of 148 salmon in this year.

Although there are inaccuracies involved in all adult fish estimates it is likely that the declared catch back calculation method will be the most inaccurate. This is largely due to seasonal fluctuations in angler effort (between and within catchments) and under recording of catch.

From the three methods of assessing population (parr production, redd counts & rod catches), it is likely that the adult salmon population currently fluctuates around 200 fish. If this were the case the average rod exploitation of stock may be between 15 and 20% in recent years. Considering the historical variation in juvenile production this lower level of exploitation (than in other Cumbrian rivers) is probably benificial in order to preserve the population at its present level.

6.2. TROUT

6.2.1. Trout Distribution

Trout were distributed more widely than salmon. Resident trout were found above some waterfalls, for example Stanley Force on Birker Beck. Notably trout parr were almost absent from the lower river.

6.2.2. Trout Productivity.

Trout productivity can only be measured as that for resident and migratory trout together as it is not possible to determine visually which juvenile fish originate from which parents. However, as a comparison to the salmon parr production data, a table of trout 1+ parr production for all sites (accessible to migratory fish and inaccessible) has been included below.

TABLE 6: ESTIMATED 1+ TROUT PARR PRODUCTION USING MEAN DENSITIES AND WIDTHS OVER SUB CATCHMENT LENGTH.

Sub Catchment	Length (km)	Mean Width (m)	Mean Parr Density nos/100m2	Parr Prodn (nos)
R.Esk				
Middle	9.0	9.86	0.97	861
Upper	2.0	9.4	0.65	122
Upper Tribs	0.4	5.0	3.72	74
Middle Tribs	6.35	* Value not meaned		1204
Lower Tribs	4.5	* Value not meaned		1659
Above S. Force	2.8	3.15	12.18	1074
TOTAL				4994

* These values were calculated for the individual streams

prior to entering in this table. This ensured that the figure was not biased by areas of poor production.

It is very difficult to determine what this production of parr may represent in terms of Sea Trout smolts as the percentage of migratory versus resident trout is not known. However, all fish above Stanley Force would be resident brown trout.

In contrast to the salmon the majority of trout production (80%) is in the tributaries and only 20% in the main river.

To calculate the potential returning sea trout adults the fish from above Stanley Force can be ommitted. In the surveys three age classes were found. It is possible that sea trout smolt as 2+ and 3+ fish. Only one scale sample has been received from anglers on the Esk in 1994. This fish had smolted as a two year old. To more accurately assess the adult production more scale samples are required to discover the proportions of fish smolting at each age. If it is assummed that half the fish go as 2+ and the other half as 3+, using the the same freshwater mortality as for salmon, but a 15% smolt survival rate (D. Evans pers. comms.) then the number of new recruits to the adult sea trout returning population would be 220 fish.

For the size of the river this is a very low level of recruitment to the adult stock. A large sea trout population may thus only be being maintained due to high kelt survival rates and therefore numerous repeat spawning events.

6.2.3. Comparison with Historical Survey data

As for salmon, historical data exists for a limited number of sites on the River Esk catchment, (9 in common with the 1994 survey).

The tables below show the distribution of sites across the density classes in two historic and the current survey. In addition there is a comparison of 1994 data with 1989.

TABLE 7: A BREAKDOWN OF THE NUMBER OF SITES FALLING IN EACH DENSITY CLASS FOR TROUT FRY, WITH REFERENCE TO HISTORICAL DATA.

Density Class	Year 84	89	94	Class Shift since 1989
A	0	0	0	0
B	0	0	0	0
C	1	1	0	-1
D	7	8	9	+1
E	1	0	0	0

TABLE 8: A BREAKDOWN OF THE NUMBER OF SITES FALLING IN EACH DENSITY CLASS FOR TROUT PARR, WITH REFERENCE TO HISTORICAL DATA.

Density Class	Year 84	89	94	Class Shift since 1989
A	0	1	0	-1
B	4	5	1	-4
C	2	1	1	0
D	3	2	5	+3
E	0	0	2	+2

Trout fry densities have decreased from class C to class D at Boot Church (site 1953) between 1989 - 1994. However, the main river is not a substantial production area for trout parr when compared to the tributaries.

Parr densities have decreased with class A's and B's being replaced by more class D's and sites where parr were absent.

6.2.4. Comparison with Sea Trout Redd Counts

TABLE 9: SEA TROUT REDD COUNTS FOR THE RIVER ESK, 1980-1993.

Year	Count	Year	Count
1980	19	1987	124
1981	21	1988	257
1982	19	1989	355
1983	12	1990	93
1984	19	1991	110
1985	56	1992	84
1986	*	1993	87

* No Counts due to high flows

Large numbers of adult sea trout were killed in the acid flushes of 1980 and 1983 (Robinson 1984). This would include fish of several sea age classes and as a result the spawning population in the years following these events would consist of largely new recruits to the spawning stock. As annual recruitment to adult stocks is currently shown to be low, this may account for the low redd counts until 1987 as the population was slowly regenerating.

Redd counts were high for a period in the late eighties, probably contributing to the high densitites of parr found in the 1989 survey. After this, sea trout follow a similar decline as seen in other Cumbrian rivers resulting in the lower densities of juveniles found in the 1994 survey.

Assumming that there are two fish per redd and adding the rod caught fish which were unable to spawn, a population estimate varying from 51 - 731 adult sea trout in the period 1980-1993 can be reached.

6.2.5. Juvenile Production versus Adult Returns

TABLE 10: DECLARED ADULT SEA TROUT ROD AND LINE CATCH RETURNS FOR THE RIVER ESK, 1976-1991.

YEAR	ROD CATCH
1976	165
1977	*411*
1978	155
1979	47
1980	115
1981	85
1982	27
1983	27
1984	19
1985	80
1986	45
1987	129
1988	93
1989	21
1990	39
1991	33
1992	*199*
1993	59

1977 & 1992 Include data from the Border Esk due to mis reporting on catch return forms.

Sea trout rod catches also fluctuate, but not in line with salmon. Catches were high in the late seventies and 1980. Only in 1987 were catches as high recently. The average catch since 1981 (excluding 1987) has been 47. If the angler exploitation was 7% as estimated for the river Ehen, (McCubbing 1994), this would give an estimate of

271-2357 returning adult sea trout in the period 1976-1993 and a mean of 1017 fish.

This estimate is well above that predicted from the redd count method of estimation. It is possible that the most accurate population figure would be the redd count estimate as this takes account of all successful spawning adults, includes fish that were caught and unable to spawn and is also a minimum estimate. Should this be the case, then exploitation levels of sea trout are well above those on other rivers in Cumbria. For example, in 1993 exploitation would represent some 25% of the calculated potential spawning stock.

6.2.6 Early Summer Droughts and Trout Production.

In Table 6 it can be seen that 80% of trout production is in the tributaries and only 20% in the main river. Of this 80%, 21% of the production is above Stanley Force in a self sustaining resident population.

The remaining trout in the tributaries are presumably a mixture of sea trout progeny and resident brown trout.

After hatching trout fry show weak territorial behaviour with fish mainly dying due to environmental factors. For example, starvation, predation and adverse environmental conditions. These factors cause density independent mortality. As the fry age there is a critical period between 33-70 days old when mortality becomes density dependent and fish which have not got a territory die (Elliott 1994).

If there is a drought early in the summer when the 0+ trout are still small, the available area of the stream is reduced. As the numbers of fish initially remain the same, this increases the density of fish and in turn the density dependent mortalities increase.

The early summers of 1992 and 1993 were dry which may account for the low parr densities found in the 1994 survey.

If a stream dries up entirely then the fish may be stranded in pools initially, which may dry up later leaving all fish dead. Also fish are more vulnerable to Heron predation when stranded in pools, which would reduce numbers. If the upper reaches become dry first then the fish may be able to move downstream retreating with the water. If the stream does not entirely dry up and the carrying capacity of the lower reaches are sufficient, then these fish from the upper reaches may survive. It is possible that this may have occurred in Eel Tarn Beck. The upper site (1970) was fishless, but the lower site (1969) scored class A for trout fry and class B for trout parr. It is possible that the stream has dried up this year and perhaps last year.

Some spawning areas are close to the main river, as in the un-named tributary near Wha House. If these streams dry up, the fish that are present may drop into the main river. If this occurred, and production originating from the tributaries was high, then this would account for the continued high returns of adult fish to the tributary spawning grounds. Evidence of this in the form of trout parr in the main river is limited in this survey.

Therefore, if the fish do not drop into the main river and die when the stream dries up in years of less rainfall, then the spawning in these areas will be fruitless. As it is not possible to predict rainfall in the spring following spawning, it is not possible to predict whether a years spawning will be successful or not. Further study is necessary to determine the success of spawning in these shallow tributaries, especially considering the 80% contribution to production from the tributaries.

6.2.7. Upper Esk Restoration

During the early eighties SO_2 emmissions, mainly from coal burning power stations, produced rain fall with such low pH that it became acidic. When this rain fell on land which drained over sedimentary rocks, which were easily weathered the acidity was buffered by Calcium particles in the rocks and the pH raised. However, when the rain fell on land which drained over hard igneous rocks, the chemical composition of the water was relatively unchanged. This is the case on the River Esk. It is likely that if the water was acidic enough to kill adult fish "in river" further downstream as seen in the mid eighties then trout at the source of the river would suffer severe acid stress and not survive either, leaving the area fishless.

When a reach of river loses its fish population, migration of fish into this fishless reach, (mainly from upstream areas, but also from downstream), will occur. This would not be a conscious reaction from the fish, but a normal phenomena, for example, due to downstream displacement in high flows. (Crisp & Hurley 1991a) However, when fish arrived in the unpopulated area, (providing the cause of the fish loss has gone) they will repopulate the area.

The Upper Esk area (main river and Lingcove Beck) is isolated from any areas of water with fish present and inaccessible to migratory fish, due to large waterfalls. Therefore the only possibility for establishing a fish population comes from introduction of resident brown trout preferably progeny from a similar subcatchment of the Esk.

The nutrient poor land which is drained by the Upper Esk will result in very low productivity in the river. The invertebrate fauna was very sparse at the time of fish surveying, so the density of trout that the river could suppport at present will be very low. However, current trends in water quality show that conditions are improving in the Esk and the neighbouring Duddon, which could result in improved abundancies of invertebrates and fish in the catchment.

There would be no benefit to the sea trout fishery of the Esk if a resident trout population was established above impassable waterfalls. However, the National Rivers Authority has a responsibility to maintain, improve and develop fisheries. Prior to the 1960's a brown trout population existed in this area (Robinson 1984) and on conservation grounds a man made restoration may merit investigation.

6.3. TOTAL PRODUCTIVITY.

An attempt in this study has been made to determine the total productivity of the system as well as a total productivity on a site by site basis. The methodology used is described in appendix 11.

Whilst acknowledging the possible flaws in the methodology used for determining the total productivity classes, some interesting results are obtained.

From fig 6 it can clearly be seen that over half the sites fall into class D, but that a fifth are fishless. Most of these fishless sites are in the upper catchment above falls where repopulation is not possible. The sites which score class B for productivity are those above Stanley Force falls which have high densities of resident trout.

Class D covers quite a wide range of densities and many sites score class D, had only a few fish present.

TABLE 11: TOTAL PRODUCTIVITY CLASSES FOR THE RIVER ESK, 1994.

Class	1994 Nos of sites	1994 % of Total
A	0	0
B	2	6
C	7	20.5
D	18	53
E	7	20.5

Figure 6 : Total Salmonid Production in the River Esk Catchment.

Main River

TABLE 12: TOTAL PRODUCTIVITY CLASSES (OF NINE COMPARATIVE SITES) - HISTORIC DATA.

Class	1984 % of total	1989 % of total	1994 % of total	% Shift since 1989
A	0	0	0	0
B	22	45	11	-34
C	45	33	22	-11
D	33	22	67	+45
E	0	0	0	0

Total productivity in the Esk system has dropped considerably (at comparitive sites) since the historic surveys in the eighties, with a 45% increase in class D sites. The reduction is mostly in sites previously exhibiting class B densities. Salmon densities have been increasing whilst trout densities have been decreasing.

Historically salmon would have been affected to a greater degree by the acidic water chemistry than trout. Trout may therefore have utilized a niche normally populated by salmon in the lower main river sites. In these sites and in Birker Beck the trout densities dropped through the eighties as the salmon densities increased and the population re-instated itself. It is likely that salmon in the lower Esk will continue to dominate over trout now that the water has an increased pH (Rosseland *et al.* 1986a).

6.4. THE ACID RAIN FACTOR

Considerable time and resources were spent on trying to establish the effects of acid deposition on the fisheries of the Cumbrian Esk and River Duddon in the 1980-87 period, following a mortality of fresh run adult migrants in the River Esk in 1980 and again in 1983. The results were written up and published as a report to the Department of the Environment entitled, Acidification of Surface Waters in Cumbria and South Pennines. This report established a number of important conclusions that are relevant to this study.

1) The results of 130 monitored sites, established that acidification had taken place in the 20 years prior to the study (i.e. pre 1980)

2) A substantial number of the most acid sites were either fishless or had abnormally low densities of salmonids.

3) The fisheries of the Duddon and Cumbrian Esk had declined in the period 1966-1980, although since 1984 a continual improvement in fish densities has been apparent.

4) Large scale agricultural liming as undertaken in the 1960's was percieved to have improved the fisheries of the Cumbrian Esk and Duddon during that period, although evidence was anecdotal.

5) Small scale instream liming was shown to have very mixed results at the two test sites (Tarn Beck - River Duddon and Fisher Beck - River Esk).

6) Large scale catchment liming in 1986/87 with 3,000t of lime had an immediate buffering effect on the Esk at Cropple How, although longer term studies have yet to establish a benefit to the fishery from this course of events.

This report was followed up by continued research on the effects of liming the Esk catchment as the liming exercise was repeated in 1987/88. In comparison no large scale liming over and above normal agricultural practice was undertaken on the Duddon catchment.

Work by Diamond *et al* (1992), showed that the continued experimental work on liming, whilst showing a decrease in soluble aluminium ions in the River Esk, failed to establish an increase in either pH or conductivity when compared to the River Duddon, Appendix 9.

Invertebrate life was shown to improve during the 1980's on both catchments and it was concluded that the benefits of liming to such a large extent were low and that natural reductions in the acidity of rainfall were likely to play a much greater part in the overall improvement in water quality found on both systems.

Water quality in the Esk and Duddon systems has improved due to the increased awareness of the causes and effects of acid rain. To avoid acidification of our upland rivers it is neccessary to minimise the emmisions which cause the acid rain to form. The major source of SO_2 is coal burning electricity generating stations. Current phasing out of these old stations combined with scrubbing of gas emmissions, has and is reducing SO_2 emmissions, probably resulting in the observed improvements in water quality.

The Duddon Catchment has higher total salmonid productivity than the Esk, with a higher percentage of class A and B sites and a lower percentage of class D and E sites (Table 13). This further iterates the conclusions of Diamond et al. (1992) that liming has had little beneficial effect on the Esk catchment, and that the improvements in both catchments are due to the changes in water quality, derived from less acidic rainfall.

TABLE 13 : COMPARISON OF PERCENTAGE TOTAL SALMONID PRODUCTIVITY CLASS BETWEEN ESK (1994) & DUDDON (1993)

CLASS	ESK	DUDDON	COMPARISON
A	0	9	+9
B	6	31	+25
C	20.5	25	+4.5
D	53	31	-22
E	20.5	3	-17.5

7. CONCLUSIONS

[1] Nutrient input into the catchment is low and limits the production of invertebrates and subsequently fish.

[2] The area of catchment accessible to migratory fish is limited to the valley floor and short reaches of tributaries.

[3] Above impassable waterfalls there are often good populations of resident brown trout. However, in some areas fish populations are absent. It is hypothesised that these areas have suffered severe acid stress, resulting in fish mortalities. These areas are not able to repopulate due to their isolation.

[4] The majority of salmon production is in the lower main river, with only 20% in the tributaries. In comparison, 80% of trout production is in the tributaries.

[5] Comparisons with historic survey results for the main river show a modest increase in salmon densities and a drop in trout densities. This is the main area of salmon production and an area of little significance to trout production.

[6] Salmon are also increasing their geographical range with improvements in water quality.

[7] Trout densities fluctuate historically, perhaps due to environmental variations in the tributaries.

[8] The calculated exploitation rate of salmon by rod and line is low, but of sea trout is high.

[9] Recruitment of sea trout to the 1996 spawning stock will be relatively low.

8. RECOMMENDATIONS

Salmon populations are currently increasing their geographical range and densities are stable or possibly increasing. For these reasons no attempt to manage this resource is deemed required at this time.

Trout year classes appear to fluctuate widely in the tributaries which will give varying recruitment to the adult sea trout spawning stock. It is possible that much of this variation is a result of streams drying up in the early summer months.

Special attention should be taken to applications for land drainage in areas which drain into streams containing trout populations. Further investigation is needed into the fate of juveniles caught in streams which are subject to early summer low flows, to discover whether they die in situ or survive by migrating downstream.

The Upper Esk area which is currently devoid of fish would benefit from introduction of brown trout, preferably the progeny of Esk fish. This would be for conservation reasons and would not benefit the rod fishery.

In order to gain a further understanding of the complex structure of the sea trout population it would be benificial to know the proportion of fish which smolt as two year olds and how many as three year olds. This can be acheived by reading scales collected from rod caught fish. Scales can also give information on age class strengths and the number of repeat spawners in the adult population. Collection of such data should be deemed a priority.

9. REFERENCES

Crawshaw, D. H., Diamond, M., Prigg, R. F., Cragg-Hine, D. & Robinson, J. F. (1989). Acidification of Surface Waters in Cumbria and South Pennines. *North West Water : Final Report to Department of Environment, Research Contract PECD7/10/89.*

Crisp,D. T. & Hurley, M. A. (1991a). Stream channel experiments on the downstream movement of recently emerged trout, *Salmo trutta* L. and salmon, *Salmo salar* L.: Effect of four different water velocity treatments upon dispersal rate. *J. Fish Biol.* **39**, 347-362.

Derwent and Cumbria Coast Catchment Management Plan Consultation Report. (1994). *National Rivers Authority, North West Region.*

Diamond, M., Prigg, R. F., Winder, L. & Cragg-Hine, D. (1992). Acid Waters in North West England : The Effect of Liming Agricultural Land on the Chemistry and Biology of the River Esk, North West England. *National Rivers Authority : Final Report for the Department of the Environment Research Contract PECD 07/10/89.*

Elliott, J. M. (1992). Sea Trout in England and Wales. *National Rivers Authority, Fisheries Technical Report No. 1.*

Elliot, J. M. (1993). *Quantitative Ecology and the Brown Trout.* Oxford University Press. 285 pp.

Fisher, S. G. & Likens, G. E. (1972). Energy flow in Bear Brook, New Hampshire : an integrative approach to stream system metabolism. *Ecol. Monogr.* **43**, 421.

Gardiner, R. (1990). Tweed Juvenile Salmon and Trout stocks. *Tweed Foundation Symposium. May 1989.*

Mills, D. (1989). *Ecology and Management of Atlantic Salmon.* Chapman and Hall. 351 pp.

McCubbing, D. J. F. (1993). A Report on the Strategic Stock Assessment Survey of the River Leven Catchment 1992 with particular reference to salmonids. *NRA/NW/FTR/93/8.*

McCubbing, D. J. F. (1994). A Report on the Strategic Stock Assessment Survey of the River Duddon Catchment 1993 with particular reference to salmonids. *NRA/NW/FTR/94/4.*

McCubbing, D. J. F. (1994). A Report on the Strategic Stock Assessment Survey of the River Ehen with particular reference to the restoration of the River Keekle. *NRA/NW/FTR/94/8A.*

Robinson, J. F. (1984). A Review of Land Use, Farming & Fisheries in the Esk & Duddon Valleys. *North West Water, Rivers Division, October 1994.*

Rosseland, B. O., Skogheim, O. K. & Sevaldrud, J. N. (1986a). Acid deposition and effects in Nordic Europe. Damage to fish populations continue to apace. *Water, Air and Soil Pollution,* **30**, 65-74.

Shearer, W. M. (1984a). The natural mortality at sea for North Esk Salmon. *International Council for the Exploration of the Sea. C.M.1984/M:24.*

APPENDIX

Appendix	1	Water Quality in the Esk catchment 1994.
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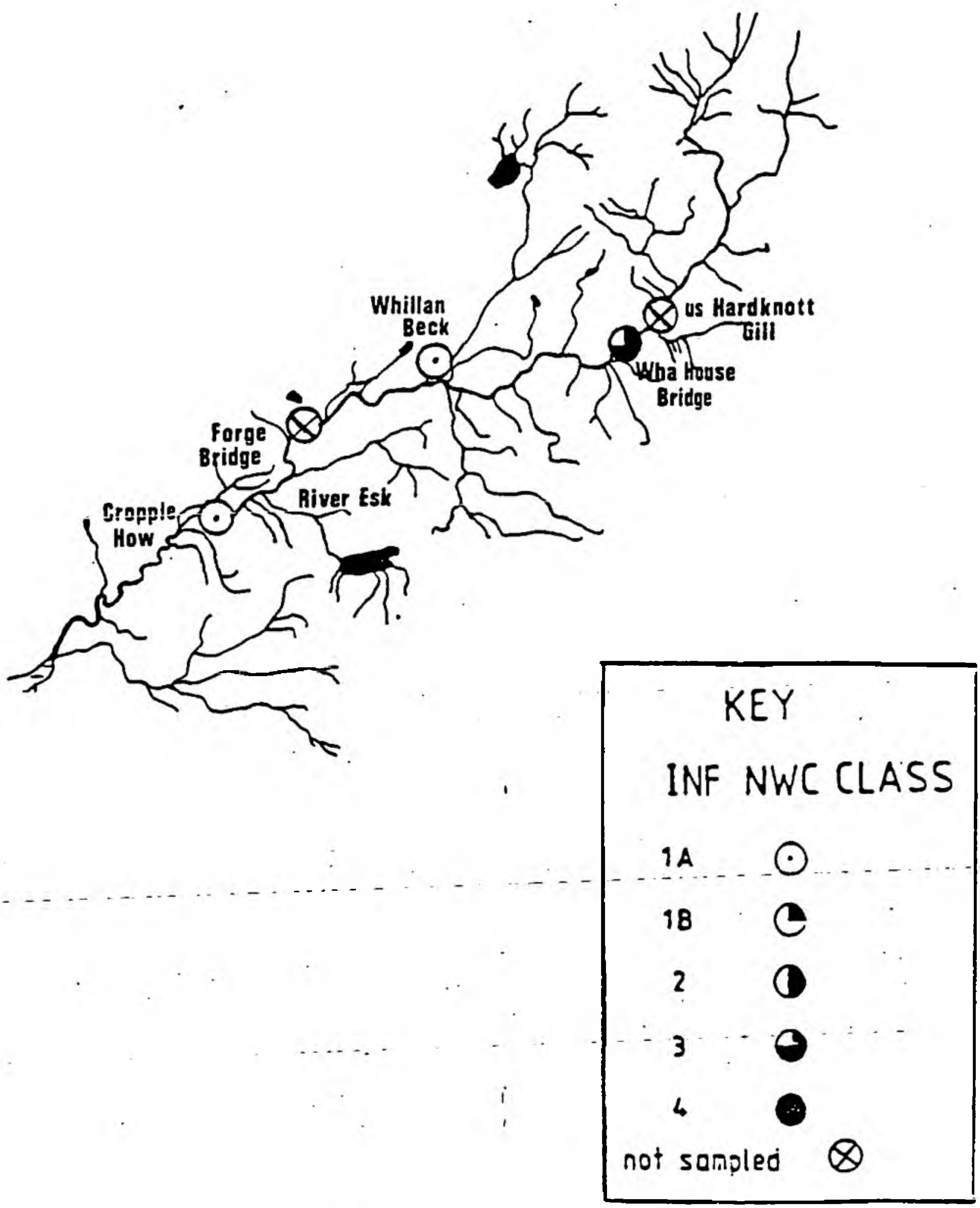
Appendix 1 : Water Quality in the River Esk Catchment. Spring 1994.



Appendix 2a : Site Reference Data

site nos	Site Name	Tributary	Date	NGR	Site Width (mean)	Site Length	Area of Site
950.00	Cropple How		13/10/94	SD132-978	15.80	40	632
951.00	PTC Linbeck		28/09/94	SD146-987	14.40	40	576
952.00	King George Bri		29/07/94	SD148-996	6.40	50	320
952.50	Below Railway		19/10/94	NY164-002	9.88	40	395
953.00	Boot Church		22/09/94	NY176-002	11.40	50	570
954.00	U/S Footbridge		01/01/94	NY177-002			
955.00	Penny Hill Fm T		10/08/94	NY190-009	10.20	50	510
956.00	D/S Whahouse Br		10/08/94	NY204-009	9.90	40	396
958.00	Brotheritke		28/09/94	NY212-013	11.40	50	570
958.50	U/S confluence	Cowcove Gi	19/10/94	NY215-023	2.94	42	123
959.00	U/S Cowcove D/S		19/10/94	NY217-023	9.40	30	282
960.00	Scar Lathing		23/09/94	NY224-047	8.00	50	400
961.00	Great Moss		23/09/94	NY218-052	6.00	50	300
962.00	Dow Crag		23/09/94	NY223-061	8.00	50	400
963.00	Footbridge	Un-named	01/01/94	SD138-987			
964.00	D/S Layby nr Pu	Blea Tarn	10/08/94	NY153-001	1.10	50	55
965.00	Spout House Far	Blea Tarn	01/01/94	NY158-002			
966.00	Beckfoot Statio	Whillan Be	28/07/94	NY169-006	6.30	50	315
967.00	Boot	Whillan Be	22/09/94	NY176-012	5.40	50	270
968.00	Gill Bank	Whillan Be	22/09/94	NY181-019	4.40	50	220
969.00	Hollins Campsit	Eel Tarn B	28/07/94	NY178-009	1.30	40	52
970.00	Paddock Wray	Eel Tarn B	28/07/94	NY185-007	1.00	50	50
971.00	YHA	Stony Tarn	28/07/94	NY194-010	2.00	50	100
972.00	Throstle Garth	Lingcove B	23/09/94	NY231-043	4.00	50	200
973.00	Pianet Knott	Lingcove B	23/09/94	NY235-044	4.00	50	200
974.00	Hard Knott Ghyl	Un-named	28/07/94	NY212-012	5.00	50	250
975.00	Wha House Farm	Un-named	28/07/94	NY203-008	1.00	50	50
975.50	PTC Esk	Un-named B	10/08/94	NY204-007	1.90	50	95
976.00	PTC Esk	Birker Bec	12/08/94	SD174-002	3.50	50	175
977.00	Whincop Bridge	Birker Bec	12/08/94	SD176-988	3.60	45	162
978.00	Birkerthwaite F	Highford B	12/08/94	SD177-979	2.70	50	135
979.00	Cattle Grid	Stanley Fo	29/07/94	SD158-992	3.50	50	175
980.00	PTC Esk	Stanley Fo	29/07/94	SD148-988	2.10	50	105
981.00	Road Bridge	Linbeck Gi	29/07/94	SD140-982	10.20	50	510
982.00	Cropple How	Un-named	11/08/94	SD127-976	0.80	25	20
983.00	Broad Oak	Stainton B	11/08/94	SD074-946	4.30	50	215
984.00	PTC Samgarth Be	Broadoak B	11/08/94	SD121-946	3.10	50	155

Appendix 2b : Salmonid densities in the Esk Catchment 1994

site nos	Site Name	pop dens of 0+ salmo	pop dens of 1+ salmo	pop dens of 0+ Trou	pop dens of 1+ Trout	pop dens of >1+ trou
1,950.00	Cropple How	25.92	10.07	5.01	0.00	0.40
1,951.00	PTC Linbeck	20.37	3.68	4.21	0.00	0.00
1,952.00	King George Bridge	0.00	1.49	1.17	0.00	0.00
1,952.50	Below Railway	11.79	11.34	11.32	0.00	0.00
1,953.00	Boot Church	2.61	0.42	10.78	0.34	1.98
1,954.00	U/S Footbridge					
1,955.00	Penny Hill Fm Track	0.00	0.92	13.50	2.55	1.48
1,956.00	D/S Whahouse Bridge	0.00	0.00	3.76	0.95	0.31
1,958.00	Brotheritke	0.00	1.65	0.00	0.99	0.88
1,958.50	U/S confluence Esk	0.00	1.91	1.51	0.00	2.04
1,959.00	U/S Cowcove D/S Fall	0.00	0.00	1.32	0.65	0.00
1,960.00	Scar Lathing	0.00	0.00	0.00	0.00	0.00
1,961.00	Great Moss	0.00	0.00	0.00	0.00	0.00
1,962.00	Dow Crag	0.00	0.00	0.00	0.00	0.00
1,963.00	Footbridge					
1,964.00	D/S Layby nr Pub	0.00	0.00	77.88	6.78	0.00
1,965.00	Spout House Farm					
1,966.00	Beckfoot Station	5.33	3.00	2.36	0.00	0.00
1,967.00	Boot	4.82	18.35	2.07	2.07	2.32
1,968.00	Gill Bank	0.00	0.00	2.53	0.00	0.00
1,969.00	Hollins Campsite	0.00	0.00	139.66	14.32	0.00
1,970.00	Paddock Wray	0.00	0.00	0.00	0.00	0.00
1,971.00	YHA	0.00	0.00	7.45	7.45	2.51
1,972.00	Throstle Garth	0.00	0.00	0.00	0.00	0.00
1,973.00	Pianet Knott	0.00	0.00	0.00	0.00	0.00
1,974.00	Hard Knott Ghyll	0.00	0.00	2.23	3.72	2.01
1,975.00	Wha House Farm	0.00	0.00	0.00	0.00	0.00
1,975.50	PTC Esk	0.00	0.00	49.01	3.93	1.32
1,976.00	PTC Esk	5.33	5.40	18.08	11.71	0.00
1,977.00	Whincop Bridge	0.00	0.00	24.13	16.09	4.64
1,978.00	Birkerthwaite Fm	0.00	0.00	6.89	8.27	14.85
1,979.00	Cattle Grid	0.00	0.00	2.12	4.26	0.71
1,980.00	PTC Esk	0.00	0.00	21.28	17.73	0.00
1,981.00	Road Bridge	1.10	3.23	8.77	3.28	1.23
1,982.00	Cropple How	0.00	0.00	55.87	0.00	0.00
1,983.00	Broad Oak	2.61	1.11	22.51	6.93	1.75

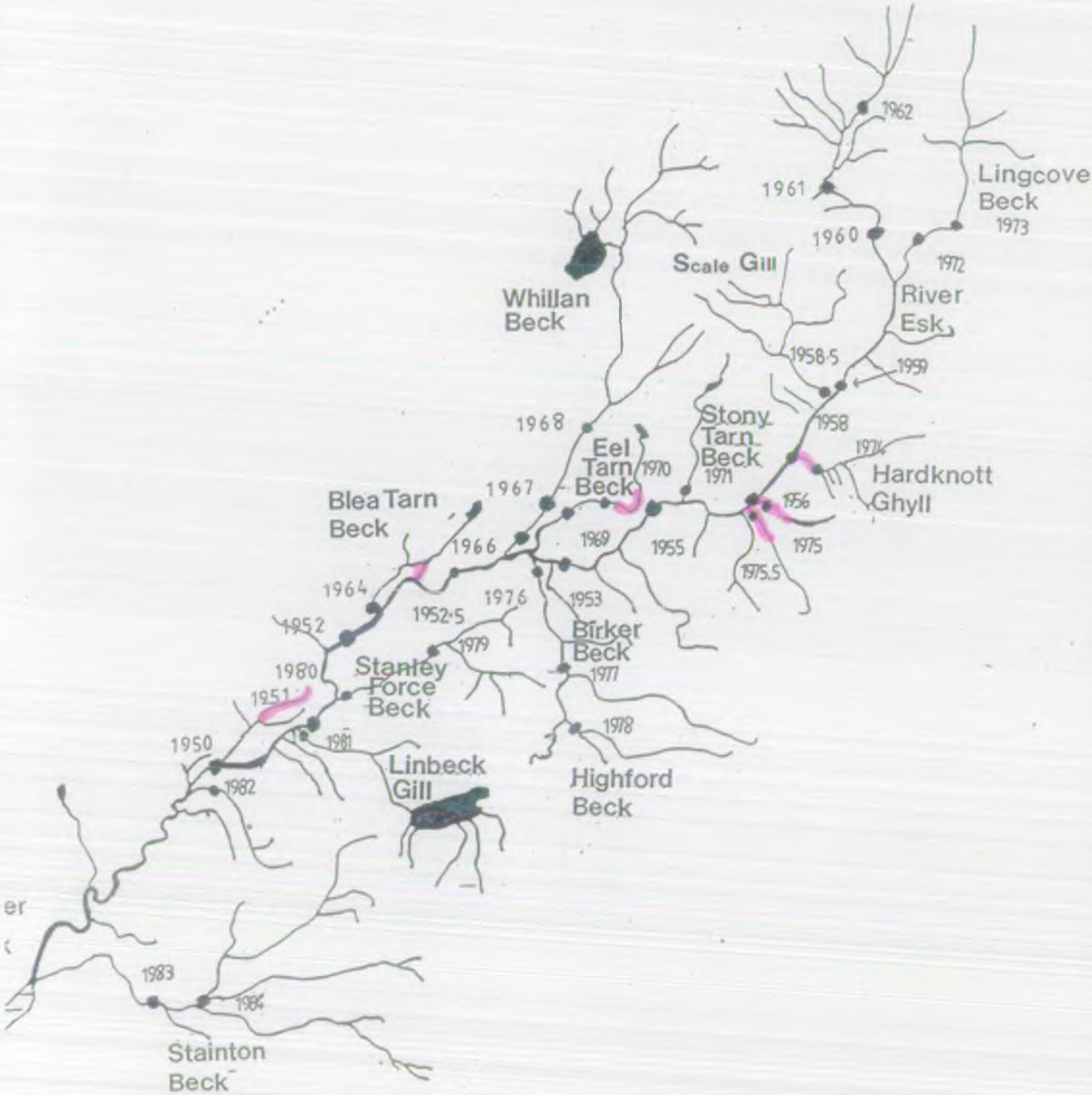
Appendix 2c : Major Coarse Fish Species Densities.

Site nos	Site Name	Tributary	Eels	Pike	Dace	Perch
				Density per 100m2		
1,950.00	Cropple How		101-200	0.00	0.00	0.00
1,951.00	PTC Linbeck		101-200	0.00	0.00	0.00
1,952.00	King George Bridge			0.00	0.00	0.00
1,953.00	Boot Church		1-10	0.00	0.00	0.00
1,954.00	U/S Footbridge					
1,955.00	Penny Hill Fm Track			0.00	0.00	0.00
1,956.00	D/S Whahouse Bridge			0.00	0.00	0.00
1,958.00	Brotheritke		11-50	0.00	0.00	0.00
1,960.00	Scar Lathing		0	0.00	0.00	0.00
1,961.00	Great Moss		0	0.00	0.00	0.00
1,962.00	Dow Crag		0	0.00	0.00	0.00
1,963.00	Footbridge	Un-named				
1,965.00	Spout House Farm	Blea Tarn Beck				
1,966.00	Beckfoot Station	Whillan Beck		0.00	0.00	0.00
1,967.00	Boot	Whillan Beck	1-10	0.00	0.00	0.00
1,968.00	Gill Bank	Whillan Beck	0	0.00	0.00	0.00
1,969.00	Hollins Campsite	Eel Tarn Beck		0.00	0.00	0.00
1,970.00	Paddock Wray	Eel Tarn Beck		0.00	0.00	0.00
1,971.00	YHA	Stony Tarn Beck		0.00	0.00	0.00
1,972.00	Throstle Garth	Lingcove Beck	0	0.00	0.00	0.00
1,973.00	Pianet Knott	Lingcove Beck	0	0.00	0.00	0.00
1,974.00	Hard Knott Ghyll	Un-named		0.00	0.00	0.00
1,975.00	Wha House Farm	Un-named		0.00	0.00	0.00
1,976.00	PTC Esk	Birker Beck		0.00	0.00	0.00
1,977.00	Whincop Bridge	Birker Beck		0.00	0.00	0.00
1,979.00	Cattle Grid	Stanley Force		0.00	0.00	0.00
1,980.00	PTC Esk	Stanley Force		0.00	0.00	0.00
1,981.00	Road Bridge	Linbeck Gill	11-50	0.00	0.00	0.00
1,982.00	Cropple How	Un-named		0.00	0.00	0.00
1,984.00	PTC Samgarth Beck	Broadoak Beck		0.00	0.00	0.00
1,983.00	Broad Oak	Stainton Beck		0.00	0.00	0.00
1,978.00	Birkerthwaite Fm	Highford Beck		0.00	0.00	0.00
1,975.50	PTC Esk	Un-named Beck		0.00	0.00	0.00
1,964.00	D/S Layby nr Pub	Blea Tarn Beck	51-100	0.00	0.00	0.00
1,959.00	U/S Cowcove D/S Fall		0	0.00	0.00	0.00
1,958.50	U/S confluence Esk	Cowcove Gill	0	0.00	0.00	0.00
1,952.50	Below Railway		1-10	0.00	0.00	0.00

Appendix 2d : Minor Coarse Fish Abundances in the Esk Catchment 1994

site nos	SITE NAME	Stoneloach	Bullhead	Minnow	Stickleback
1,950.00	Cropple How	0	0	0	0
1,951.00	PTC Linbeck	0	0	0	0
1,952.00	King George Bridge	0	0	0	0
1,952.50	Below Railway	0	0	0	0
1,953.00	Boot Church	0	0	0	0
1,955.00	Penny Hill Fm Track	0	0	0	0
1,956.00	D/S Whahouse Bridge	0	0	0	0
1,958.00	Brotheritke	0	0	0	0
1,958.50	U/S confluence Esk	0	0	0	0
1,959.00	U/S Cowcove D/S Fall	0	0	0	0
1,960.00	Scar Lathing	0	0	0	0
1,961.00	Great Moss	0	0	0	0
1,962.00	Dow Crag	0	0	0	0
1,964.00	D/S Layby nr Pub	0	0	0	0
1,966.00	Beckfoot Station	0	0	0	0
1,967.00	Boot	0	0	1-10	0
1,968.00	Gill Bank	0	0	1-10	0
1,969.00	Hollins Campsite	0	0	0	0
1,970.00	Paddock Wray	0	0	0	0
1,971.00	YHA	0	0	0	0
1,972.00	Throstle Garth	0	0	0	0
1,973.00	Pianet Knott	0	0	0	0
1,974.00	Hard Knott Ghyll	0	0	0	0
1,975.00	Wha House Farm	0	0	0	0
1,975.50	PTC Esk	0	0	0	0
1,976.00	PTC Esk	0	0	0	0
1,977.00	Whincop Bridge	0	0	0	0
1,978.00	Birkerthwaite Fm	0	0	0	0
1,979.00	Cattle Grid	0	0	0	0
1,980.00	PTC Esk	0	0	0	0
1,981.00	Road Bridge	0	0	0	0
1,982.00	Cropple How	0	0	0	0
1,983.00	Broad Oak	0	0	0	0

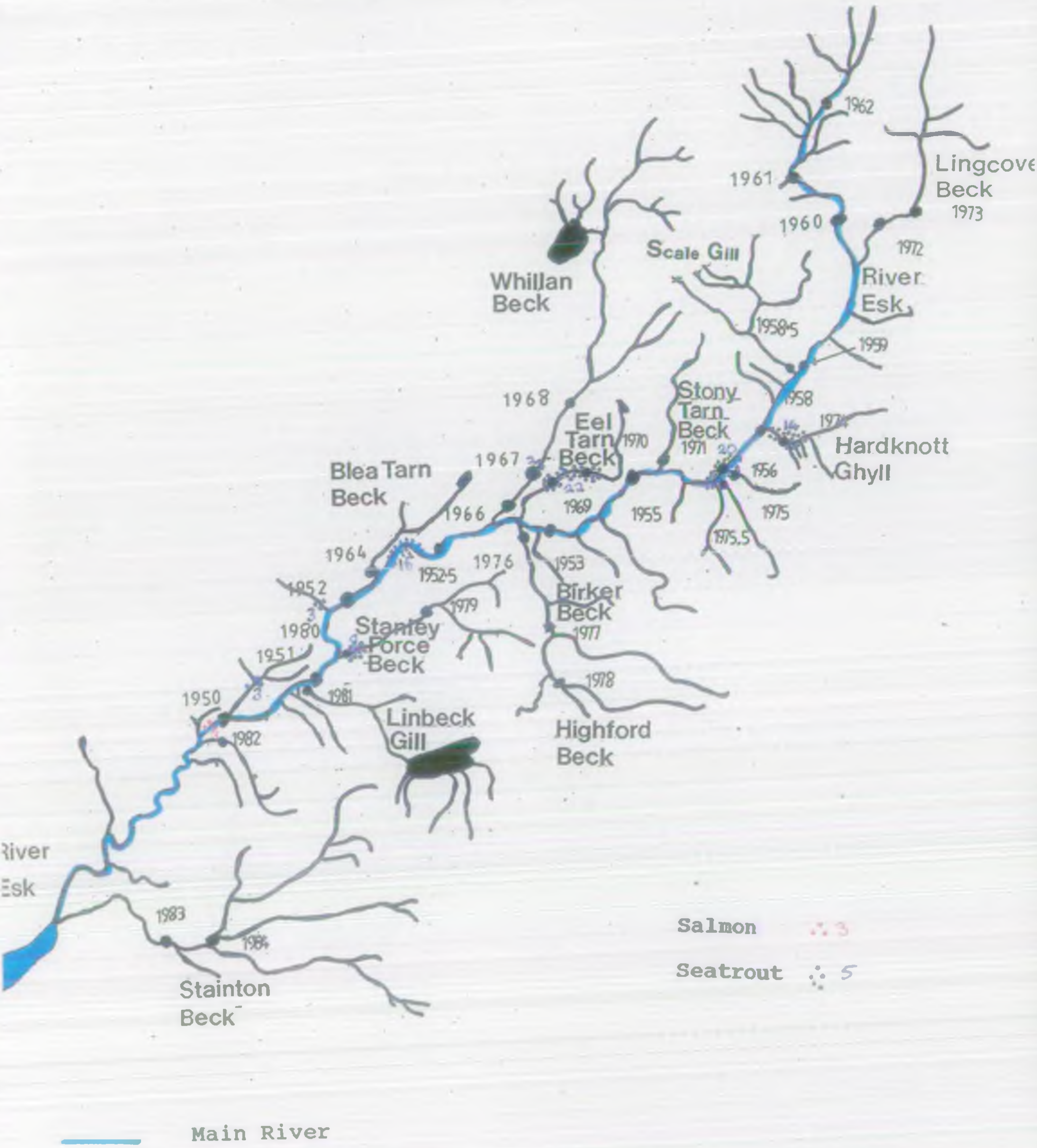
Appendix 3 : Streams which have dried up or suffered low flows in 1994.



Streams which dried up or suffered low flows.

Appendix 4 : Area accessible to migratory fish.

Appendix 5 : Salmon and Seatrout Redd Counts 1993/94.



APPENDIX 6 : HISTORICAL SURVEY RESULTS. 1981 - 1989.

ss0 = Salmon 0+ density (N/100m2)
ss1 = Salmon >0+ density (N/100m2)
st0 = Trout 0+ density (N/100m2)
st1 = Trout >0+ density (N/100m2)

Year 1950 Cropple How

	ss0	ss1	st0	st1	TP
1981			3.7	0.6	1.3
1982	3.6	0.9	3.2	0.4	2.7
1984	0.7	5.9	5.3	3.2	10.3
1986	16.2	7.1	6	1.4	12.9
1987	21.9	1.09	4.5	2.1	8.5
1988	17.2	11.1	2.9	2.5	17.6
1989	1	12.1	4.2	1.3	14.4
1994	25.92	10.07	5.01	0.4	16.7

Year 1952 King George Bridge

	ss0	ss1	st0	st1	TP
1981	1.5	0.0	2.6	2.3	3.1
1982	1.0	2.6	2.3	0.5	3.8
1984	0.3	0.6	1.0	2.3	3.2
1986	6.1	3.3	11.1	2.2	8.9
1987	13.1	2.6	4.9	3.8	10.0
1988	8.0	0.8	13.3	0.8	5.9
1989	11.6	0.5	7.8	2.9	7.3
1994	0.0	1.5	1.2	0.0	1.7

Year 1953 Boot Church

	ss0	ss1	st0	st1	TP
1981			5.7	5.1	6.2
1982			4.1	2.3	3.1
1984			6.5	13.9	15.2
1986	0.4	0.9	6.1	9.7	11.9
1987			4.9	5.3	6.3
1988	0.2	0.6	8.0	4.1	6.3
1989	2.3	0.9	31.2	12.5	20.1
1994	2.6	0.4	10.8	2.3	5.4

Year 1955 Penny Hill Farm

	ss0	ss1	st0	st1	TP
1981			1.4	4.3	4.6
1982			1.5	7.0	7.3
1984			8.1	14.0	15.6
1986			4.8	11.8	12.8
1987		0.3	5.8	13.3	14.8
1988			8.5	9.0	10.7
1989			9.4	18.9	20.8
1994		0.9	13.5	4.0	7.7

Year 1956 Wha House

	ss0	ss1	st0	st1	TP
1981			0.6	1.7	1.8
1982			0.6	0.9	1.0
1984			0.6	2.5	2.6
1986			3.4	5.7	6.4
1987		0.2	3.3	4.1	5.0
1988			4.2	5.1	5.9
1989			0.9	5.7	5.9
1994			3.8	1.3	2.0

Year 1966 Whillan Beck

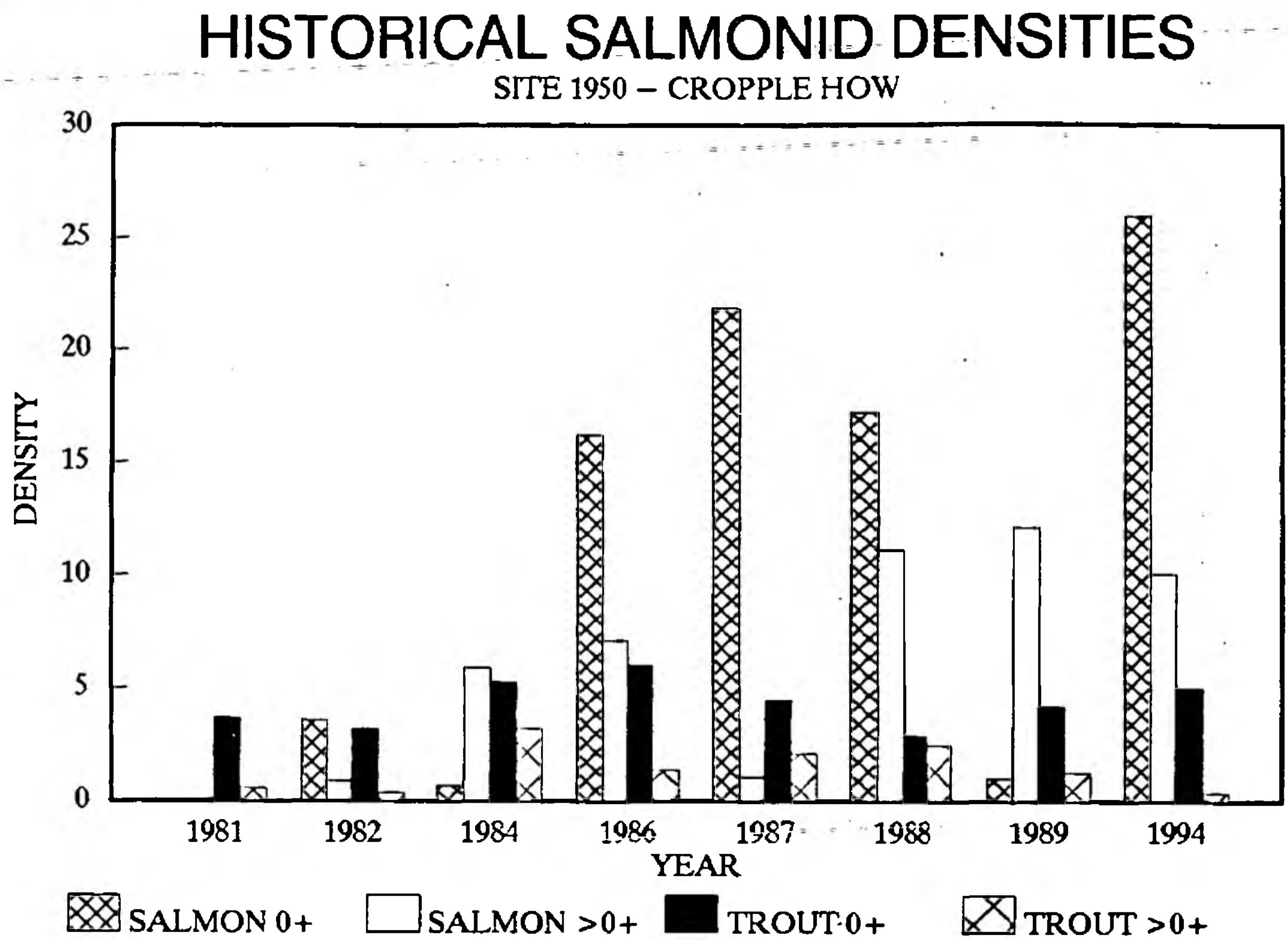
	ss0	ss1	st0	st1	TP
1981	0.7	0	1.2	1.5	1.9
1982	0	1.9	3	1.6	4.1
1984	0	2.6	5.2	6.5	10.1
1986	1.1	2.6	0	4	6.8
1987	2.9	2.4	0.5	0.5	3.6
1988	3.5	5.1	2.9	4.9	11.3
1989	17.2	9.6	2.2	13.4	26.9
1994	5.33	3	2.36	0	4.5

Year	1976.0 Stony Tarn Beck				
	ss0	ss1	st0	st1	TP
1981			2.9	6.0	6.6
1982			13.3	16.7	19.4
1984		0.4	39.0	18.8	27.0
1986	2.4	5.2	4.8	10.8	17.4
1987	0.3	1.4	5.8	10.4	13.0
1988	0.5	0.8	6.8	7.0	9.3
1989	6.0	1.9	10.8	13.7	19.0
1994	5.3	5.4	18.1	11.7	21.8

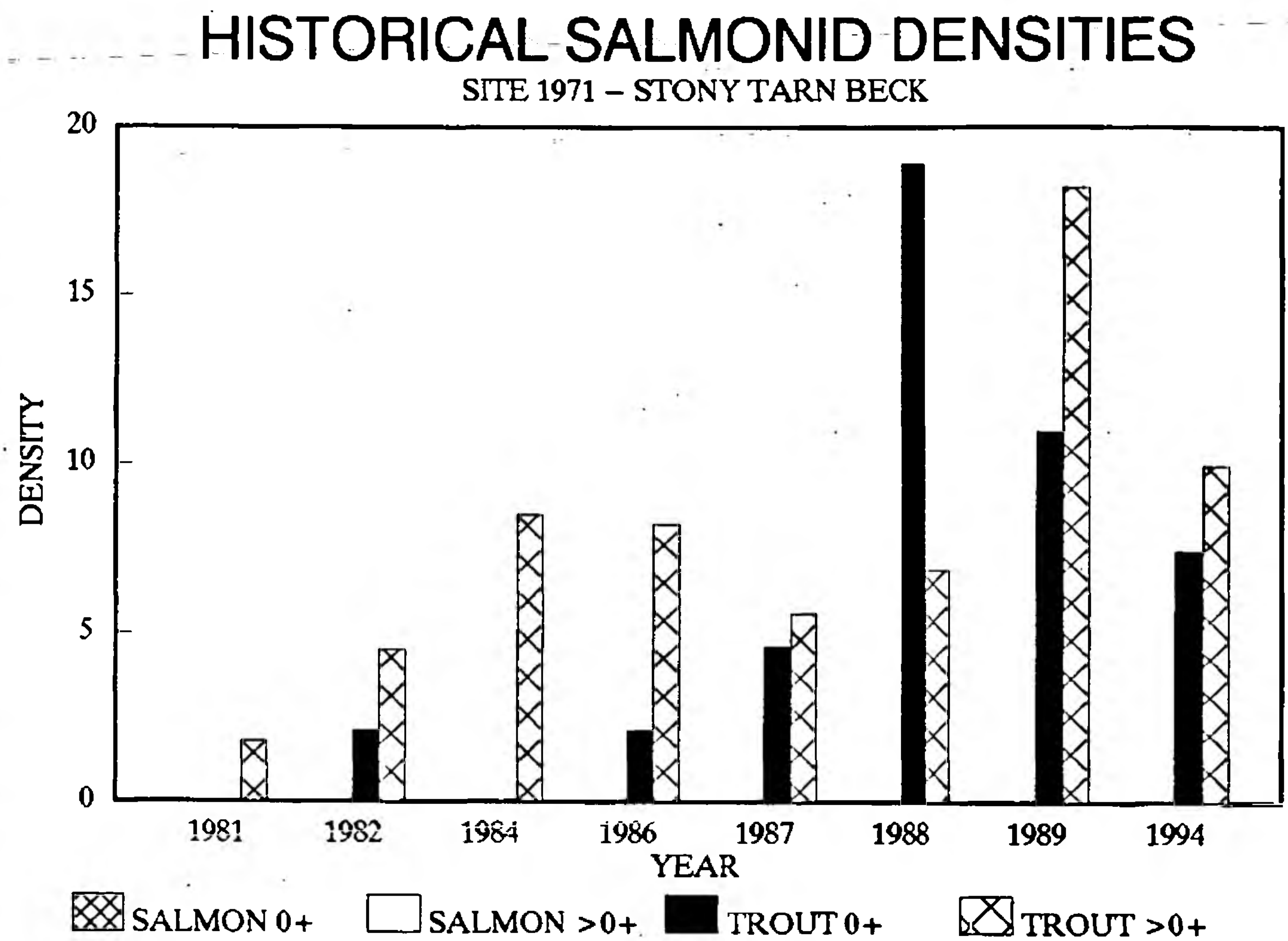
Year	1971.0 Birker Beck				
	ss0	ss1	st0	st1	TP
1981			0.0	1.8	1.8
1982			2.1	4.5	4.9
1984				8.5	8.5
1986			2.1	8.2	8.6
1987			4.6	5.6	6.5
1988			18.9	6.9	10.7
1989			11.0	18.2	20.4
1994			7.5	10.0	11.5

Year	1981.0 Linbeck Gill				
	ss0	ss1	st0	st1	TP
1981			9.0	9.0	10.8
1982	3.8	1.5	24.1	9.0	16.1
1984	0.8	4.2	14.1	16.7	23.9
1986	3.3	26.2	24.7	19.7	51.5
1987	20.8	9.6	17.2	9.6	26.8
1988	7.9	10.8	17.3	13.6	29.4
1989	2.7	6.8	5.4	24.4	32.8
1994	1.1	3.2	8.8	4.5	9.7

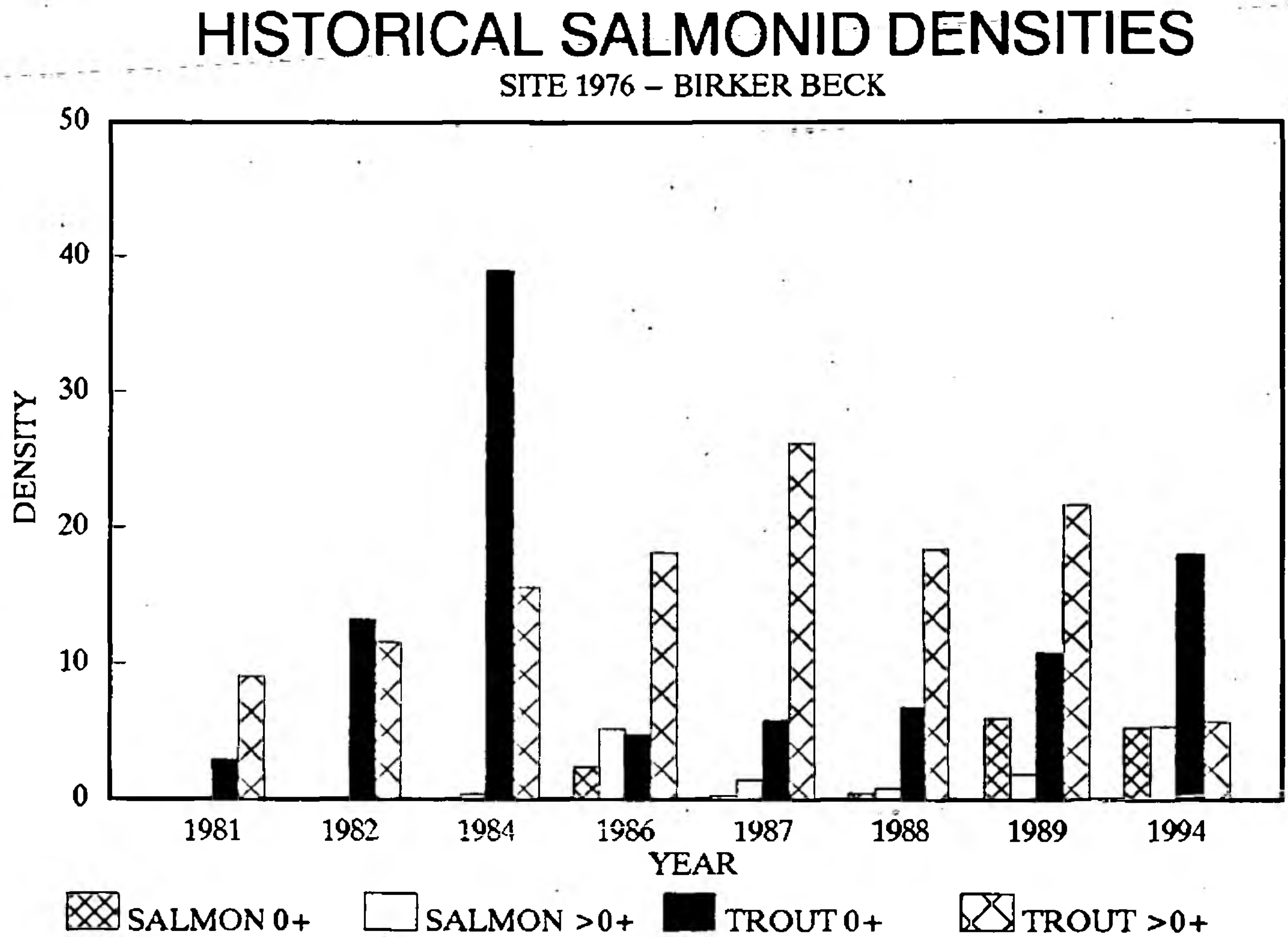
Graph 1 :


HISTORICAL SALMONID DENSITIES
SITE 1950 – CROPPLE HOW
DENSITY
30
25
20
15
10
5
0
1981
1982
1984
1986
1987
1988
1989
1994
YEAR
SALMON 0+
SALMON >0+
TROUT 0+
TROUT >0+

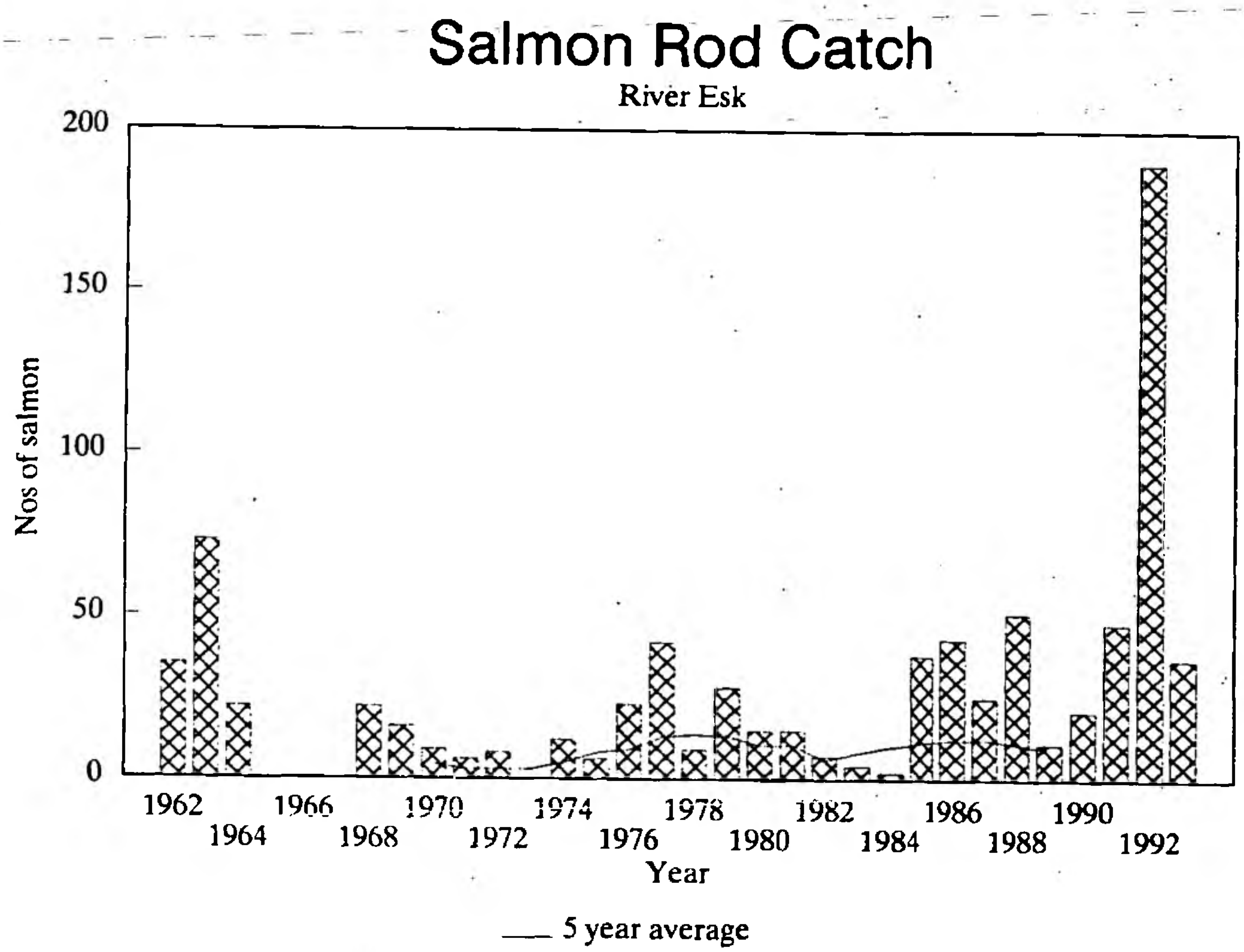
Graph 2 :


HISTORICAL SALMONID DENSITIES
SITE 1971 – STONY TARN BECK
DENSITY
20
15
10
5
0
1981
1982
1984
1986
1987
1988
1989
1994
YEAR
SALMON 0+
SALMON >0+
TROUT 0+
TROUT >0+

Graph 3 :

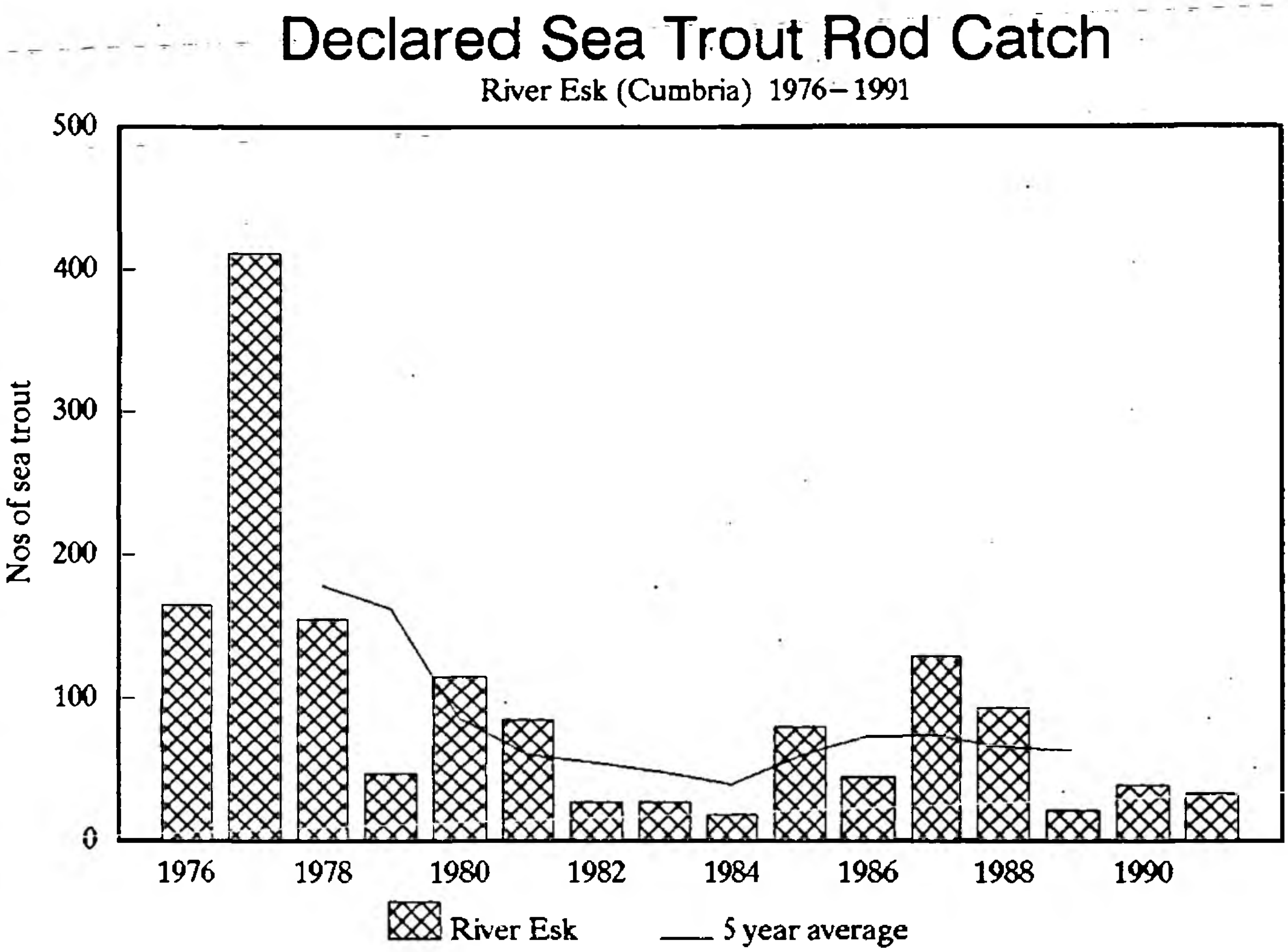

HISTORICAL SALMONID DENSITIES
SITE 1976 – BIRKER BECK
DENSITY
50
40
30
20
10
0
1981
1982
1984
1986
1987
1988
1989
1994
YEAR
SALMON 0+
SALMON >0+
TROUT 0+
TROUT >0+

Appendix 7 :

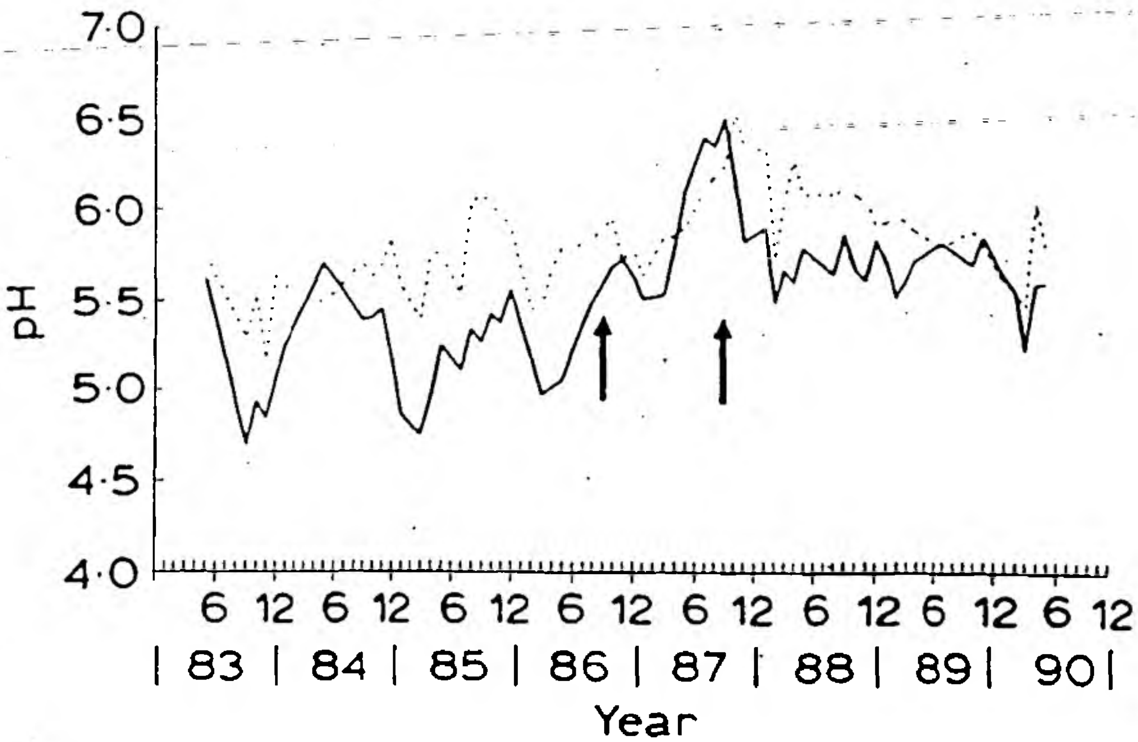


Salmon Rod Catch
River Esk
200
150
100
50
0
Nos of salmon
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
Year
5 year average

Appendix 8 :



Declared Sea Trout Rod Catch
River Esk (Cumbria) 1976–1991
Nos of sea trout
500
400
300
200
100
0
1976
1978
1980
1982
1984
1986
1988
1990
River Esk
5 year average



Time-series of predicted pH at 99 percentile flow for the Esk and Duddon continuous monitoring stations. Arrows indicate the start of the two liming periods. (– – –), Duddon; (——), Esk.

The relationship between the semi-quantitative (SQ) and quantitative (Q) results for salmonids using the arithmetic data and transformed data (Log_e n+1)

Age And Species	Arithmetic	Transformed
0+ Salmon	0+ SQ = 0.463 (+/-0.043) * Q (R^2 = 96.1%, $p < 0.0001$)	Log 0+ SQ = 0.710 (+/-0.078) * Log Q (R^2 = 89.0%, $p < 0.0001$)
>0+ Salmon	1+ SQ = 0.424 (+/-0.057) * Q (R^2 = 85.1%, $p < 0.0001$)	Log 1+ SQ = 0.661 (+/-0.059) * Log Q (R^2 = 90.0%, $p < 0.0001$)
0+ Trout	0+ SQ = 0.515 (+/-0.036) * Q (R^2 = 93.6%, $p < 0.0001$)	Log 0+ SQ = 0.800 (+/-0.037) * Log Q (R^2 = 95.2%, $p < 0.0001$)
>0+ Trout	>0+ SQ = 0.539 (+/-0.055) * Q (R^2 = 83.4%, $p < 0.0001$)	Log >0+ SQ = 0.775 (+/-0.088) * Log Q (R^2 = 86.3%, $p < 0.0001$)
1+ Trout	1+ SQ = 0.537 (+/-0.051) * Q (R^2 = 86.9%, $p < 0.0001$)	Log 1+ SQ = 0.778 (+/-0.051) * Log Q (R^2 = 87.0%, $p < 0.0001$)
>1+ Trout	>1+ SQ = 0.798 (+/-0.097) * Q (R^2 = 84.1%, $p < 0.0001$)	Log >1+ SQ = 0.839 (+/-0.083) * Log Q (R^2 = 85.3%, $p < 0.0001$)

Constant = $p > 0.05$

APPENDIX 11

Derivation of Total Salmonid Density Class

In order to create a class which related to Total Salmonid Density (i.e. all salmon plus all trout) it was necessary to rationalise the abundance categories for the two different age classes, i.e fry and parr (Table 14).

The classes are based on the assumption that 1 in 5, or 20%, of fry survive to become parr (Table 14). Thus by dividing the total fry density by 5, all densities could be related to the Abundance Class for parr.

An index for Total Salmonid Density was calculated using densities as follows :-

Index = 1/5 (Salmon 0+ + Trout 0+) + (Salmon >0+ + Trout >0+)

As this index was derived from both salmon and trout, the parr abundance categories have been doubled (Table 14).

Table 14 : Classification for Total Salmonid Density Index (N/100m2)

Class			
A		>40.00	
B	20.01	-	40.00
C	10.01	-	20.00
D	0.01	-	10.00
E		0.00	

Methodology to determine Total Salmonid Productivity

To determine if the classes are set at a realistic level, a literature search was undertaken.

Work by Elliot on a Lake District stream has shown that a range of salmonid biomass from 8.86 - 33.9g/m^2 was recorded over a 25 year period. Similar work by Brynildson *et al.* 1984 in the USA, and Mortenson 1978 in Holland, showed a recorded biomass in the range of 12.2 - 36.0g/m^2 and 14.1 - 33.1g/m^2 respectively. However, Elliot postulates that these results are higher than in most studies.

From data collected on weight/length relationships for salmonids, we can calculate what, in biomass terms, our classification system is telling us. Typically, salmonid parr in South Cumbria averaged 13cm in length by the end of the survey year. This would equate to a weight of 25g/fish. Thus our classification system can be shown in terms of weight production (in grammes) per 100m^2.

Class	Nos of Salmonid Units per 100m^2	Weight in grammes per m^2
A	> 40.01	>10.01+
B	20.01 - 40.00	5.01 - 10
C	10.01 - 20.00	2.51 - 5
D	0.01 - 10.00	0.1 - 2.5
E	0.00	

A class A result with a unit score of e.g. 63.7 fish would record a biomass of 15.9g/m^2. This falls within the range of Elliot's work which, as stated, gave a variation of biomass productivity higher than in most experimental results published. It is thus concluded on present knowledge that the proposed total productivity classes are acceptable.

Elliot, J. M., Crisp, D. T., Mann, R. H. K., Pettman, I., Pickering, A. D., Pottinger, T. G. & Winfield, I. J. (1992). Sea trout literature review and bibliography. *NRA Fisheries Technical Report No. 3.*

Elliot, J. M. (1993). *Quantitative Ecology and the Brown Trout*. Oxford Press 286pp

Brynildson, O. M. & Brynildson, C. L. (1984). Impacts of flood retarding structure on year class strength and production of wild brown trout in a Wisconsin coulee stream. *Winsconsin Dept of Nature Research, Technical Bulletin,* 146, 1-20.

Mortenson, E. (1978). The population dynamics and production of trout (*Salmo trutta* L.) in a small Danish stream. In *Proc. Wild Trout - Catchable Trout Symp.* ed. J.R.Moring, 151-160. Oregon: Dept Fish Wildl.

Appendix 12 : Minimum Salmonid Population Estimates in River Esk 1994.

Site Nos	Site Name	Salmon 0+	Salmon 1+	Trout 0+	Trout 1+	Trout >1+
950.00	Cropple How	13.92	4.27	2.69	0.00	0.32
951.00	PTC Linbeck	10.94	1.56	2.26	0.00	0.00
952.00	King George Bridge	0.00	0.63	0.63	0.00	0.00
952.50	Below Railway	6.33	4.81	6.08	0.00	0.00
953.00	Boot Church	1.40	0.18	5.79	0.18	1.58
954.00	U/S Footbridge					
955.00	Penny Hill Fm Track	0.00	0.39	7.25	1.37	1.18
956.00	D/S Whahouse Bridge	0.00	0.00	2.02	0.51	0.25
958.00	Brotheritke	0.00	0.70	0.00	0.53	0.70
958.50	U/S confluence Esk	0.00	0.81	0.81	0.00	1.63
959.00	U/S Cowcove D/S Fall	0.00	0.00	0.71	0.35	0.00
960.00	Scar Lathing	0.00	0.00	0.00	0.00	0.00
961.00	Great Moss	0.00	0.00	0.00	0.00	0.00
962.00	Dow Crag	0.00	0.00	0.00	0.00	0.00
963.00	Footbridge					
964.00	D/S Layby nr Pub	0.00	0.00	41.82	3.64	0.00
965.00	Spout House Farm					
966.00	Beckfoot Station	2.86	1.27	1.27	0.00	0.00
967.00	Boot	2.59	7.78	1.11	1.11	1.85
968.00	Gill Bank	0.00	0.00	1.36	0.00	0.00
969.00	Hollins Campsite	0.00	0.00	75.00	7.69	0.00
970.00	Paddock Wray	0.00	0.00	0.00	0.00	0.00
971.00	YHA	0.00	0.00	4.00	4.00	2.00
972.00	Throstle Garth	0.00	0.00	0.00	0.00	0.00
973.00	Pianet Knott	0.00	0.00	0.00	0.00	0.00
974.00	Hard Knott Ghyll	0.00	0.00	1.20	2.00	1.60
975.00	Wha House Farm	0.00	0.00	0.00	0.00	0.00
975.50	PTC Esk	0.00	0.00	26.32	2.11	1.05
976.00	PTC Esk	2.86	2.29	9.71	6.29	0.00
977.00	Whincop Bridge	0.00	0.00	12.96	8.64	3.70
978.00	Birkerthwaite Fm	0.00	0.00	3.70	4.44	11.85
979.00	Cattle Grid	0.00	0.00	1.14	2.29	0.57
980.00	PTC Esk	0.00	0.00	11.43	9.52	0.00
981.00	Road Bridge	0.59	1.37	4.71	1.76	0.98
982.00	Cropple How	0.00	0.00	30.00	0.00	0.00
983.00	Broad Oak	1.40	0.47	12.09	3.72	1.40
984.00	PTC Samgarth Beck	0.00	0.00	4.52	7.10	10.97