PAPER NO.4

THE ASSESSMENT OF THE FLOW REQUIREMENTS FOR UPSTREAM MIGRATION OF SALMONIDS IN SOME RIVERS OF NORTH WEST ENGLAND

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SUMMARY

Automatic fish counters operating on the resistivity principle have been used for several years in North West England to investigate the flow requirements for upstream migration of salmon and migratory trout. The data obtained have confirmed that during summer months most fish movement occurs in the higher range of the available flows, but the migration flow range varies from year to year, depending on prevailing river levels. Of the other environmental variables measured, only water temperature and incident light intensity appear to have any direct association with fish movement.

Information on migration flow ranges has been used in conjunction with computer simulations of the effects of abstraction proposals on historical flows to assess the implications of these proposals for migratory fish.

1. INTRODUCTION

During the 1960's and early 1970's the demand for water for industrial and domestic supply increased rapidly in the North West of England, and the need to develop additional sources of supply became increasingly urgent. Attention was focused on rivers as potential sources of supply, several of which supported important fisheries for salmon (Salmo salar L.) and migratory trout (Salmo trutta L.). There was concern that significant abstractions of water from these rivers could have a deleterious effect on the fisheries unless adequate safeguards were incorporated into the schemes. Most of the rivers concerned were within the area of the Lancashire River Authority (LRA), and the Fishery Department of that Authority took a very active interest in the problems of water resources development and fisheries. In 1974 the LRA was absorbed into the North West Water Authority (NWWA), but work on the water requirements of migratory fish has continued to the present day.

2. THE FLOW REQUIREMENTS OF MIGRATORY FISH

The water requirements of migratory fish within rivers have been discussed by Stewart (1969). There are two basic requirements for the maintenance of a migratory fish stock. Firstly, there is a minimum quantity of water required for fish to survive. At very low flows salmon are inactive and do not attempt to migrate upstream. The second requirement is for adequate availability at appropriate seasons of the year of those higher flows which are needed to allow upstream migration of fish to the spawning areas. Successful salmon angling is also dependent on the occurrence of flows in these higher ranges. To minimise the potentially damaging effects of a water abstraction scheme on a fishery it is essential that account should be taken of these basic requirements.

At the time that water resource development became an urgent matter in North West England, no quantitative information was available on these flow requirements. The LRA therefore embarked on a programme of installation of automatic fish counters in the principal salmon rivers of the area with the primary aim of monitoring upstream migration of fish in relation to river flows. This work was continued by the NWWA after 1974, and there are now 11 counters in operation on 8 different rivers throughout Lancashire and Cumbria. All these rivers are either already used for water supply or are being considered for inclusion in water resource development.

All of the counters operate on the resistivity principle. The first counters installed by the LRA were of the tube type originally described by Lethlean (1951). Subsequently open channel counters were developed by the LRA and the NWWA, and most recent installations have been wide gap strip counters on purpose-built weirs, compounded to cover a wide range of river levels. (Lawson, 1975 and Bussell, 1978). In addition to fish count and water level, some of the installations also monitor other environmental variables, in particular water temperature and incident light intensity, but air temperature, water conductivity, barometric pressure and dew point have been recorded at some sites. Size differentiation is incorporated into some counters, with fish longer than 50 cm being classed as salmon and smaller fish as migratory trout. Because of the large amount of data which the counters generate, computer systems for processing, storing and analysis have had to be developed.

3. ANALYSIS OF RESULTS

The simultaneous recording of fish movement and environmental variables makes it possible to investigate the relationships between migratory behaviour of fish and both specific values of, and changes in, environmental factors. The initial analysis of results was carried out by the LRA and reported by Stewart (1969, 1973, 1975). Where river flow

requirements for migration were concerned it was established that there were relationships between river discharge per unit of river width and fish movement. At flows of 2.4 Ml/d per m. of width or less, salmon were inactive and no upstream movement was observed. Stewart regarded this as an absolute survival flow. At a flow of 7.25 Ml/d per m. width, upstream migration commenced and reached a peak of intensity at a mean flow of 17.3 Ml/d/m. At higher flows, migration was reduced. Angling for salmon became successful at a flow of 25.4 Ml/d/m.

More recent analyses have been directed towards identification of other environmental variables which might influence upstream migration and towards more detailed investigation of the relationships between fish movement and river flow at individual counter sites.

A major problem in the analysis of data from fish counters is the absence of information on the numbers of fish available at any point in time to move over the counter. Early attempts to use multiple regression analysis and principal components analysis to look for association between numbers of fish moving and environmental variables gave very inconclusive results, largely because of the lack of this essential information on fish availability. The difficulties that this problem causes were acknowledged by Peters, Farmer and Radford (1973), who used data from counters on the Rivers Leven and Lune in their attempt to model the upstream movement of salmonids. In view of the impossibility of obtaining reliable information on the numbers of fish waiting downstream of the counters it was concluded that further attempts at sophisticated methods of analysis such as multiple regression and principal components analysis were not worthwhile. Recent analysis has therefore consisted of inspection of simple tabulations of numbers of fish moving against observed values of environmental variables, measured at hourly intervals. Particular attention has been directed towards determining those water levels, and hence flows, at which fish

movement takes place at individual sites, and also the year-to-year variation in flows used for migration. This of course is the essential information needed for assessing the potential impact of water resources proposals. Some of the other environmental variables have also been examined, and there is evidence that there is a preferred water temperature range, and that during the summer months most fish movement takes place at night, except in times of high flow when the water is turbid. However, no direct relationships have been detected between fish movement and air temperature, water conductivity, barometric pressure and dew point.

To illustrate the year-to-year variation which occurs in the flows used by fish for migration, data from a counter installed in the fish pass at Forge Weir on the River Lune for the period June to August for each of the years 1974 to 1979 are presented in diagramatic form in Fig.1. The counts are of fish > 50 cm, some of which would be large migratory trout. Generally the mean value of the flows at which fish movement was recorded exceeded slightly the mean river flow for the period, but there was considerable variation in the migration flow range from year to year, depending on the flows actually available. In 1979 the mean migration flow was actually less than the mean available flow, but the river level was consistently high for much of the summer.

Fig.2 summarises the data for the 6 year period. The frequency distribution of numbers of fish moving against flow (represented by water level) is displaced to the right of the distribution of available flows (levels), the modal value for the former being equal to a flow of $7.2\ m^3s^{-1}$ and for the latter $3.1\ m^3s^{-1}$. The mean migration flow was $9.8\ m^3s^{-1}$, compared with a mean river flow of $7.2\ m^3s^{-1}$, and the flow range covering the major part of fish migration (mean migration flow $\pm$ 1 Std. Dev.) was $3.0\ m^3s^{-1}$ to $27.0\ m^3s^{-1}$. The long-term average daily flow (ADF) for the Lune at Forge Weir is $33.2\ m^3s^{-1}$ so the summer migration flow range was approximately 10-82% ADF.

Also in Fig. 2 the number of fish moving at a particular water level divided by the number of times that particular water level occurred has been plotted against water level. This gives an indication of the flows actually preferred for fish migration. It is obvious that the flow at which most fish movement was actually recorded is significantly less than the preferred flow. This is because the preferred higher flows only occur for relatively short periods.

4. USE OF INFORMATION ON FISHERY FLOW REQUIREMENTS IN ASSESSMENT OF ABSTRACTION PROPOSALS

The approach adopted by the NWWA in recent years has been to use mathematical modelling to simulate the effects which the proposed abstraction rules would have had on historical flows and then to determine to what extent the availability of flows used by fish for migration would have been affected if the abstraction had actually been taking place. Where data for the river concerned have been available, these have been used in deciding on the appropriate migration flow ranges. For example, the majority of fish moving over the counter on the lower reaches of the River Derwent (West Cumbria) during the period May to October 1979-1981 did so when the flow was in the range 245-2400 Ml/d (approximately 10-100% of the long term ADF). According to historical records, flows in this range occurred on average for 100 days during this period of the year, which is the one during which most migratory fish enter the river. Simulations of a proposed regulation/abstraction scheme showed that the availability of flows in this range during May to October would be reduced on average by only one day, and it was concluded that the proposals would be unlikely to have any significant effect on fish migration.

Where abstraction proposals have been examined for rivers where no direct information on migration flows is available, the flow/width relationships determined by Stewart have been used to predict the range of flows likely to be of importance for salmon migration. The validity of extrapolation from Lancashire to rivers in other areas has been questioned, but where it has been possible to check the relationships against data from elsewhere, reasonably good agreement has been found. For example, the width of the River Derwent in the vicinity of the fish counter is 35m. On the basis of Stewart's flow/width relationship one would predict a commencing migration flow of 253 Ml/d, which agrees closely with the observed value of 245 Ml/d. The use of simulation modelling also enables recommendations for abstraction rules to be made which minimise the impact on critical flow ranges. During the period 1977-1978 a detailed appraisal was carried out on four possible major water resources developments. Some of the proposals involved unsupported abstractions at higher flows, (i.e. unsupported by releases of stored water) but with abstraction at lower flows supported by releases of stored water. An important aspect of the abstraction rules was the "prescribed flow", i.e. the flow at which unsupported abstraction had to cease. Obviously this flow should be set high enough to ensure that flows would not be reduced below the survival flow requirement. Secondly, to ensure that a natural sequence of flows should be maintained it was recommended that only a proportion of the flow above the prescribed flow should be abstracted, and a factor of 50% was suggested and used in simulations. A migration flow range was estimated for the appropriate points on each of the rivers concerned and simulations were carried out for different values of prescribed flow to determine the one which resulted in a minimum impact on availability of migration flows whilst still permitting a realistic abstraction. This approach is feasible because abstraction of

50% of the flow in excess of the prescribed flow, up to the capacity of the abstraction pumps, results in a reduction of very high flows (above the range normally used for migration) down into the migration range, to compensate for the loss of migration flows at the bottom of the range, and with an appropriate prescribed flow, these can cancel out. To give an example, the estimated migration flow range in the River Eden at Staingills, Cumbria, is 1050-2600 Ml/d, and over the period 1967-1976 flows in this range occurred on average for 45 days per annum during the period May-October. Simulations using these historical data but with abstraction of 50% of the excess flow above a prescribed flow of 500 Ml/d were carried out, and these showed a reduction in the availability of migration flows during this period of the year of from 45 to 28 days. However, when the simulation was re-run with the prescribed flow increased to 900 Ml/d, the loss of availability of migration flows was reduced to only 3 days.

In conclusion, information derived from fish counters on the flow requirements of migratory fish, coupled with the use of computer simulations of the effects of water resource development proposals on river flows, has proved invaluable in assessing and advising on the implications for fisheries of such proposals.

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Fig. 1 Migration flow ranges compared with available flow ranges at Forge Weir Counter, River Lune, June-August inclusive, 1974-1979.

Fig. 2 Fish movement in relation to water level at Forge Weir Counter, River Lune, June-August, 1974-1979.

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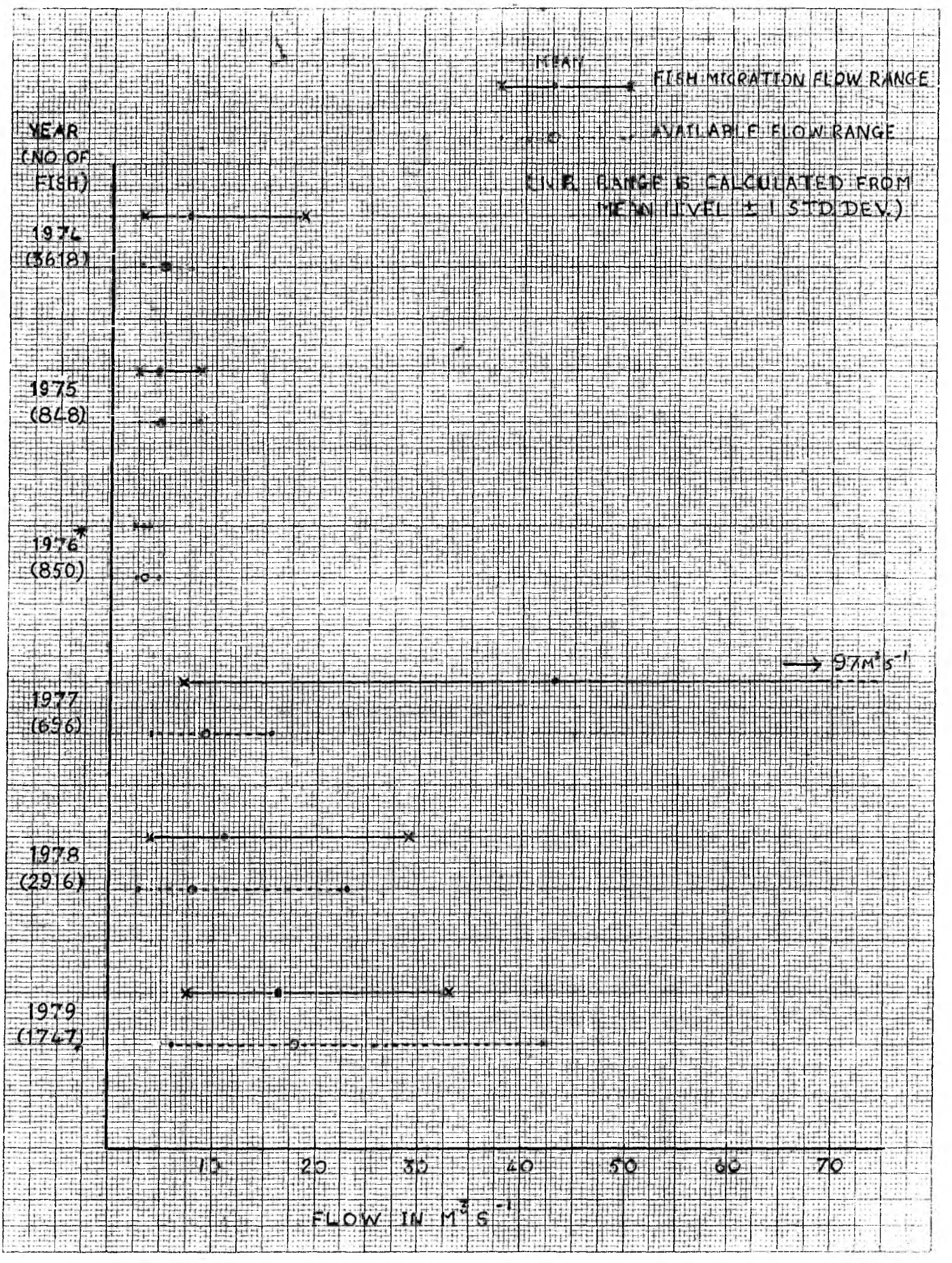

* 1976 DATA INCOMPLETE