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Observations on some factors influencing the migration of smolts of salmon (*Salmo salar* L) and migratory trout (*S. trutta* L) in a chalkstream

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INTRODUCTION

Several studies have been published on migration of smolts of Atlantic salmon (Allen 1944, Berry 1932, 1933, Bull 1932, White 1939 and White and Huntsman 1938) which attempted to identify the environmental conditions responsible for initiating the downstream journey, and a considerable 'folklore' exists on the subject. The findings of the above authors are summarised in Table I. It is generally accepted that rainfall and increased discharge are involved, and the results of the majority of these studies bears out this assumption. All the observations were made on stream systems fed by surface run-off, which experienced more or less frequent changes in water level and discharge, with associated changes in chemistry and turbidity, due to falls of rain or melting snow. No studies had been made on the situation in streams fed by groundwater, which experience fewer and far less extreme spate conditions, and some of which support considerable runs of salmon and migratory trout. Therefore, during an exercise in which smolts were being trapped and marked on the River Piddle, a chalkstream in Southern England, to provide adults of known origin for physiological experiments, the opportunity was taken to study the influence of physical factors on smolt migration.

Site and Methods

The River Piddle and its tributaries rise in the chalk ridge of central Dorset, and flow for most of their length over chalk. The last 10 km of the main river length of 35 km flows over Bagshot beds, a mixture of clay, sand and gravel, and it receives some surface run-off in the lower reaches. The total area of the catchment is 182 km^2, of which 155 km^2 lies on chalk. The estuary, together with that of the River Frome, forms an arm of Poole harbour.

The smolts were captured in a net based on the eel fyke net design, which effectively 'sieved' the majority of the flow of the stream, and was set in the outflow of the mill pool at North Mill, Wareham, at the extreme limit of tidal influence. The net was fished between April 2 and April 17, and on

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April 24 and 25, 1974 for an average of $12\frac{1}{2}$ hours per day, and in 1975 between March 29 and April 22 for an average of 15 hours per day. The hours fished were varied, to identify and exploit the peak times for migration. The smolts were removed from the cod-end of the net at least hourly, and either marked immediately and released, or held in floating cages and marked later. All salmon and migratory trout smolts were marked by liquid nitrogen freeze branding (Piggins 1972). During the 1974 experiment, spot water-temperature readings were taken several times daily. Discharge was continuously recorded by the Wessex Water Authority at a gauging weir 1 km upstream. No tributaries entered the river between this weir and the netting site.

During the 1975 experiment, in addition to the above data, water temperature was continuously monitored with a battery-operated thermistor temperature recorder, and turbidity with a light-extinction suspended solids recorder. Turbidity readings are quoted as ppm of a calibration standard, which on checking corresponded fairly closely to gravimetrically determined suspended solids. Continuous records of barometric pressure and rainfall, and daily totals of solar radiation were made available by the staff of the Freshwater Biological Association Laboratory 5km to the West. The daily totals for solar radiation, quoted as cal/m^2/day, were measured with a Kipp recorder.

Results

1974

Although during the period of observations in this year no significant rainfall fell on the catchment, and the stream flow was gradually falling from about 2.65 m^3/Sec on April 2 to 1.95 m^3/Sec on April 25, 440 salmon smolts and 98 trout smolts were captured. The migratory stimulus for the salmon appeared to be high water temperature and bright sunlight, the majority of smolts being captured between 1300 and 1700 on hot, sunny afternoons, with water temperature exceeding 12°C. On the 8 afternoons on which the water temperature reached this level, an average of 34 smolts was recorded, whereas on the 7 afternoons on which the temperature did not reach 12°, the average was less than 5.

Trout smolt activity was more evenly spread throughout the period, but with a definite peak of movement in the early hours of darkness (2100-2400).

1975

The results for 1975 are summarized in Fig 1, showing daily totals of salmon and trout smolts, rainfall and solar radiation, and daily maxima of hourly discharge, turbidity and water temperature. A total of 1428 salmon and 303 trout smolts was captured.

Between the start of the observations (March 29) and day 13 (April 10), there persisted a spell of very cold wether, with E winds and frequent snow showers. The water temperature did not rise above 9°C, and very little smolt activity was observed. The only significant movement was on day 5, when a minor increase in discharge and turbidity caused by 6.5 mm of rain initiated a small run of trout (17) and a few salmon (10) smolts, between 2200 and 0100 hours. Up to the end of day 13 only 36 salmon and 41 trout had been captured.

With the shift of wind to the west on day 14 (April 11) and rapidly rising water temperatures, there started a period of much increased smolt activity which persisted, with fluctuations, until the end of the experiment on day 25 (April 22). For two days there was a fair degree of activity, with an average of about 30 salmon smolts each day, mainly during the afternoon, and about 20 trout each day. On day 17 (April 14), about 10 mm of rain caused a minor spate and increase in turbidity, initiating a major run of smolts of both species. Hourly figures for smolts, rainfall, discharge, turbidity and water temperature are shown in Fig 2. Activity was mainly at night, coinciding with peaks in turbidity. A further small amount of rain (4 mm) the next day initiated another major run that night, also shown in Fig 2. It must be stressed that the increases in discharge (2.6 m^3/Sec to 3.2 m^3/Sec) and turbidity (up to 22 ppm suspended solids) were very small indeed compared with spate conditions in a surface-water fed stream.

For two days thereafter the numbers of migrating smolts was small, despite afternoon conditions considered conducive to a major run of salmon - presumably most immediately 'available' fish had migrated during the spates. For the last 5 days of observations large runs of salmon smolts occurred each afternoon, but only small numbers of trout smolts were recorded. Hourly figures for the last 2½ days are shown in Fig 3, representing the typical non-spate afternoon migration situation.

Small increases in turbidity each weekday night varying between 2300 and 0400 hours, apparent in the second and third nights on Fig 3, failed to stimulate any movements. These increases in turbidity are believed to have been caused by gravel washing activity in extraction undertakings several km upstream. Changes in barometric pressure did not appear to influence migration.

Thus two sets of very different conditions initiated large scale migrations of salmon smolts.

1) Slightly increased discharge and turbidity following heavy rain, on two consecutive nights.

2) High water temperature or possibly increasing water temperature above 11°C, and bright sunshine, between 1400 and 1900 hours.

Trout smolt movements were more evenly spread, with spate conditions greatly increasing activity.

Discussion

Although large numbers of smolts of both salmon and migratory trout migrated during spate conditions at night, the number of occasions on which enough rain fell to produce such conditions were few - only for one period of 2 days during 44 days of observations did these conditions occur. The majority of smolts migrated at times when the generally recognised stimuli were not operating. High water temperature has been indicated as being an effective stimulus by White (1939), but in that case migration took place almost entirely at night. The movement of large numbers of salmon smolts during the brightest part of sunny days, in very clear water, is surprising. The stimulus to migrate was not merly temperature, as high water temperatures commonly persisted long after the numbers of fish had dropped in late afternoon (Fig 3). Nor were bright conditions per se effective, as indicated by the failure of high levels of solar radiation to induce migrations at low water temperatures (days 11 and 12, Fig 1). Possibly increasing temperature above about 11°C provided the stimulus.

No reference could be found elsewhere to differences between the behaviour of the smolts of salmon and migratory trout, except that Berry (1932) and Menzies (1936) report that trout may migrate earlier, sometimes by several weeks. In this study the trout smolts behaved in a similar manner to the salmon smolts in most of the studies summarized in Table 1.

Thanks are due to Mr Ian Farr and Mr Paul Henville of the Freshwater Biological Association, and the Wessex Water Authority, for providing some of the data on physical conditions.

Summary

Movements of smolts of salmon and migratory trout were studied using a fixed net at the tidal limit on a chalkstream. Water temperature, turbidity, discharge, barometric pressure and rainfall were continuously recorded. Daily totals of solar radiation were available. Two very different sets of conditions were found to stimulate migration. The findings are summarized thus :-

1) Following heavy rain, large numbers of smolts of both species migrated, associated with increased flows and turbidity, mainly at night. This is consistent with findings elsewhere, but because spate conditions occur infrequently in groundwater-fed streams, less than 25% of the total salmon smolts captured were recorded at such times.

2) At other times, large numbers of salmon smolts migrated on hot, bright afternoons. Movements were much reduced by dusk. Very little movement occurred with water temperatures less than 10^{o}C, and most smolts were recorded above 12^{o}C.

3) Migratory trout smolts ran in small numbers at all water temperatures recorded during the study, larger numbers being recorded at higher temperatures. More activity took place after dark.

4) Increases in turbidity on weekday nights between 2300 and 0400 hours, due it is believed to gravel washing activities upstream, failed to stimulate any movement.

5) The movement of large numbers of salmon smolts during bright sunlight in clear water has not been recorded elsewhere. Both high water temperature and bright light conditions are necessary to initiate migration.

References

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AUTHOR	LOCATION	KEY FACTORS	OTHER INFLUENCES (+ stimulatory, - inhibitory)	TIMES OF MAIN MIGRATION.
Allen (1944)	Thurso R., Scotland	Rise in water level.	High temperature(+) Passage of other smolts(±)	Not recorded
Berry (1932)	R. Tay estuary, Scotland.	Rise in water level.	Stormy conditions.	Night?
Berry (1933)	R. and Loch Ness, Scotland.	Rise in water level.	E wind (-), Thundery conditions (-)	Afternoon
Bull (1932)	R. Tyne, England	Fall of rain, Rise in water level.		Night, but observations very few
White (1939)	Forest Glen Brook, Cape Breton Is.	High water temperature		Night
White and Huntsman (1938)	Apple River, Nova Scotia	Rise in water level		Dusk and night

TABLE 1. Summary of findings of studies on factors influencing migration of salmon smolts.

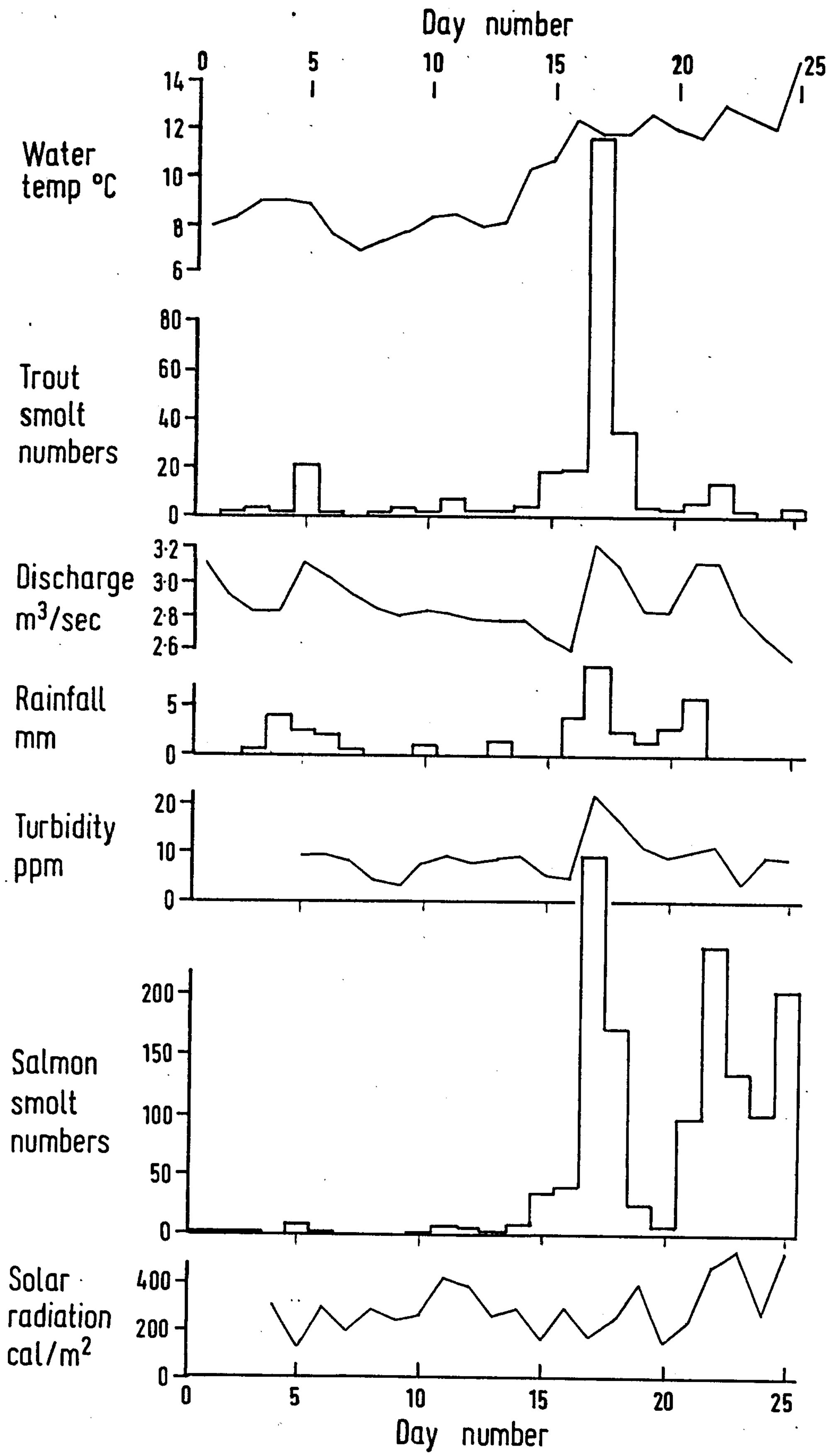

Fig 1. Daily totals of salmon and trout smolts, rainfall and solar radiation, and maxima of hourly discharge, water temperature and turbidity during the 1975 experiment. Days numbered run from 09.00 to 09.00 hours, day 1 starting on March 29.

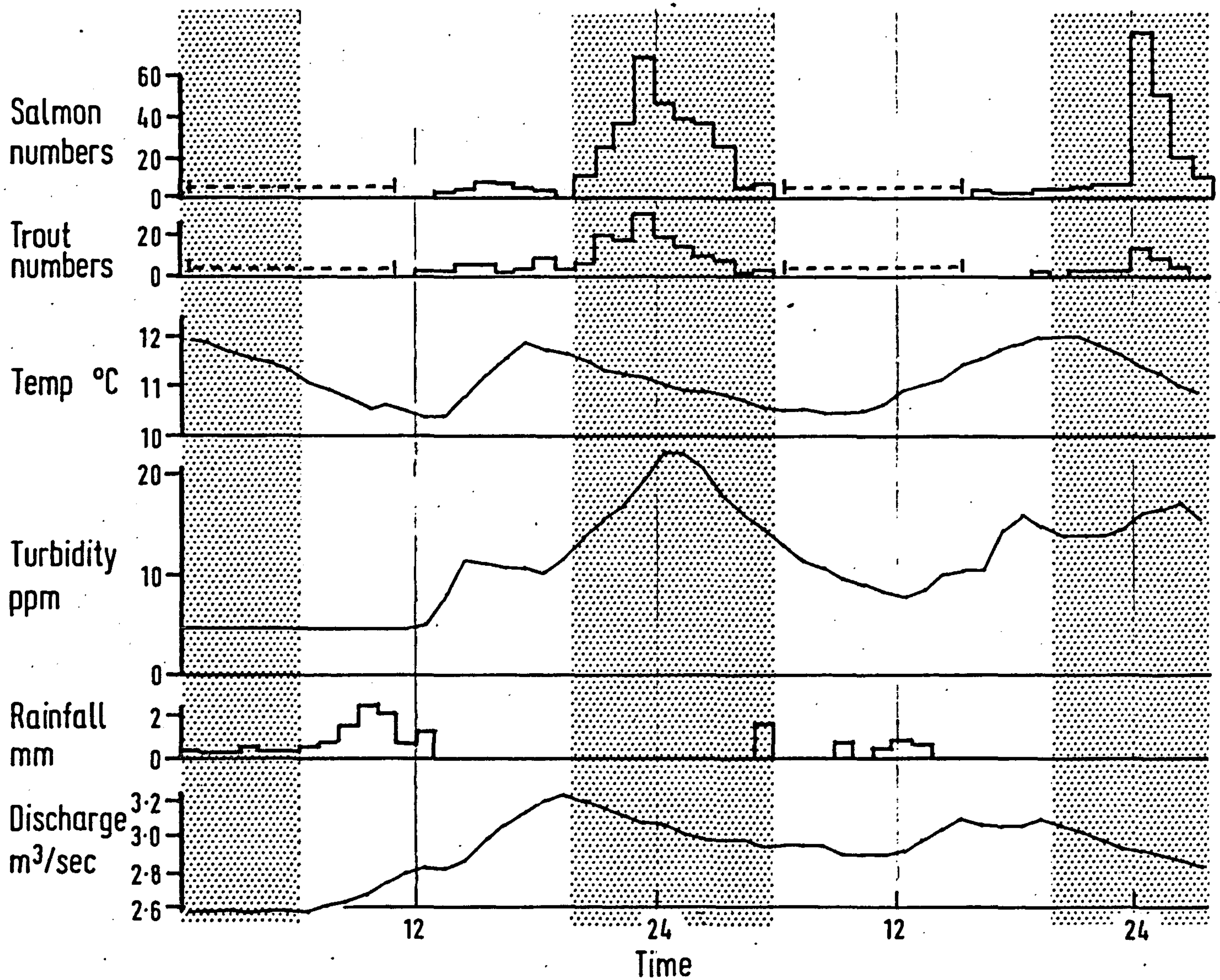

Fig 2. Hourly catches of salmon and trout smolts, and values of physical conditions, from 00.00 hours on April 14 to 04.00 hours on April 16, 1975. Shaded areas indicate hours of darkness. Dotted line on catch histograms indicate times when the net was not operating. Main movements took place at night, corresponding with peaks in turbidity.

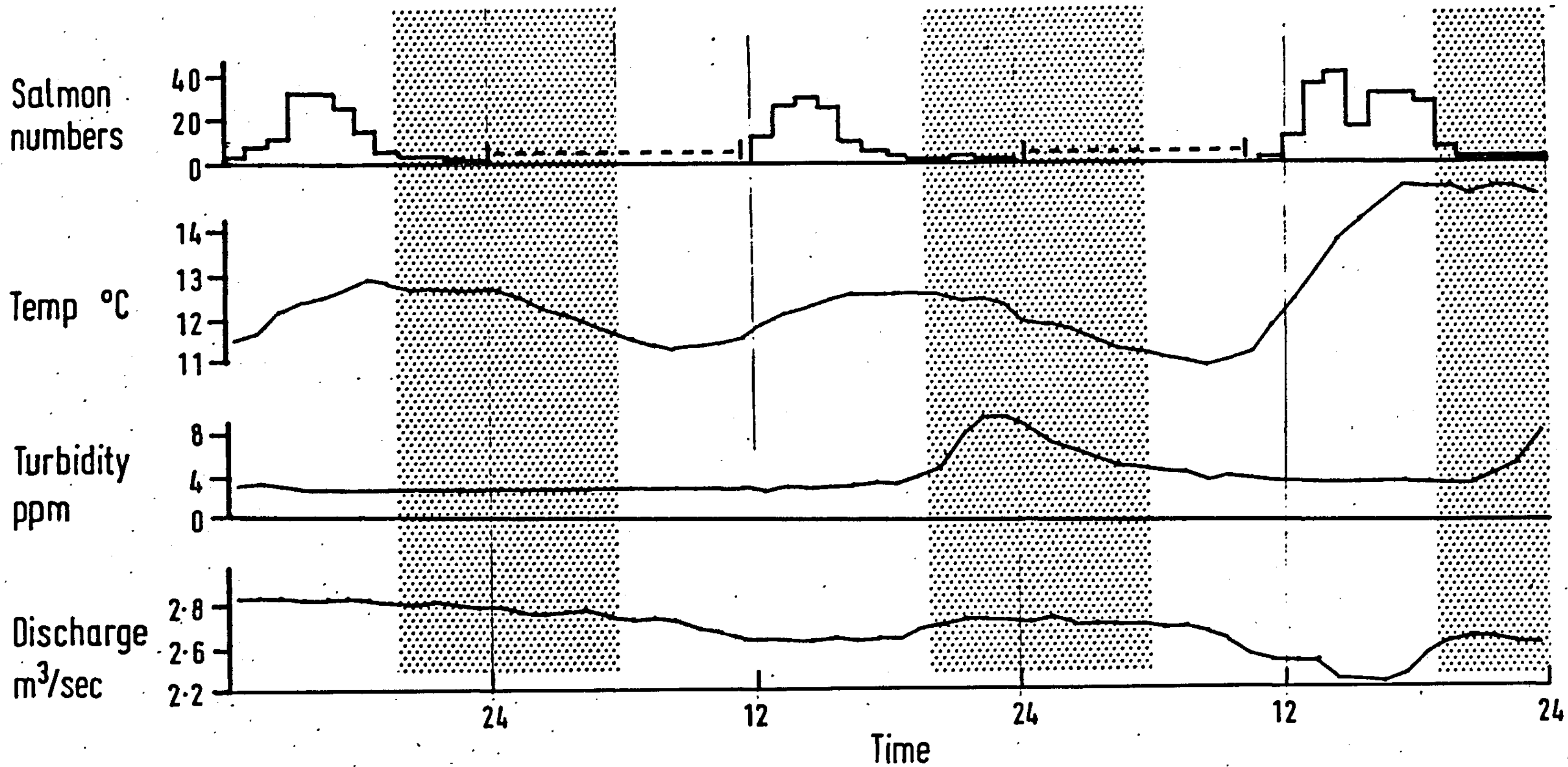

Fig 3. Hourly catches of salmon smolts, and values for physical conditions, from 12.00 hours on April 20 to 24.00 hours on April 22 1975. Shaded areas indicate hours of darkness. Dotted lines on the catch histogram indicate hours when the net was not operating. No rain fell during the period, and only 4 trout smolts were recorded. Main movements occurred during the afternoon, with very little activity persisting after dusk.