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RECENT DEVELOPMENTS IN AUTOMATIC FISH COUNTERS FOR SALMON RIVERS

by

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INTRODUCTION

Estimating the abundance of a fish stock is the first and most important step in evaluating its status and in assessing the long and short term effects of fishing upon it. For many commercially important fish species, abundance estimation may be undertaken only by indirect means. Furthermore, even where it is possible to ascribe confidence limits, they are sometimes so great as to seriously compromise the making of management decisions.

Accurate stock assessment is potentially more achievable for salmon than for other fish species. Stocks, which may have been spread over wide areas of sea during the marine phase of the life cycle, separate at spawning times into discrete 'homing units' which are specific to particular catchments or parts of catchments. Here, in the relatively confined surroundings of the river, the potential exists to count individual fish. However, until the development of the automatic fish counter, the scope for counting migrant salmon was restricted to those few sites where it was possible to operate a trap or counting fence.

In this paper, current developments in the technology of automated counting are reviewed. The emphasis of the paper is overwhelmingly on the resistivity method because it is currently the only technique which is sufficiently reliable for widespread application. Nevertheless, the high civil engineering costs associated with the construction of Crump weirs (Crump 1952), which are often necessary to support effective resistivity counter electrode arrays, serve to keep alive interest in other approaches. Thus, brief reference is also made to acoustic techniques and to other methods of deploying resistivity counter electrodes.

BRIEF HISTORY OF FISH COUNTING RESEARCH IN THE UK

The development of automatic fish counting methods began in 1949 (Lethlean 1953) with the construction of the first tube resistivity counter by the North of Scotland Hydro-Electric Board (NSHEB). During the 1960s and 1970s, research programmes were undertaken by both the Department of Agriculture and Fisheries for Scotland (DAFS, now SOAFD) and the Ministry of Agriculture, Fisheries and Food (MAFF) into the reliability of both sonar and electrical counters.

The sonar counters tested included the Bendix sonar counter (Fig. 1) which had been developed for use in rivers in the western USA and Canada to count Pacific salmon of various species, and a sonar counter developed at Birmingham University (Fig.2). The Bendix sonar array proved to be unsuitable as a counting method for Atlantic salmon as fish could pass through gaps in the 'sound curtain' and escape detection. In addition, it was found that the level of background noise in a natural river channel usually resulted in false counts being recorded. Research into the operation of the Birmingham sonar counter was continued for a number of years as the system was developed but, eventually, it was considered to be too unreliable to merit further investigation.

The electrical counters examined included two types of resistivity counter, the NSHEB counter and the Sharkey counter (Marine Electrics Ltd., Killybegs, Donegal, Eire) used under two different detection formats, i.e. tube (Fig. 3) and strip (Fig. 4) and the Delta-V counter, also developed by Sharkey, which aimed to detect the electrical output of the muscles of actively swimming fish. Research on all these methods continued for a number of years. The Delta-V counter proved to be too unreliable to be considered as an effective counter; the small electrical signals produced by swimming fish were swamped by background 'noise'. Of the resistivity methods, the NSHEB counter proved to be the more reliable but, as it was felt desirable to avoid using tube counters except in fish passes because of their liability to blockage and their inhibition of the upstream migration of salmon, research was concentrated on the performance of strip resistivity counters. In this format, the NSHEB counter proved to be more reliable than the Sharkey counter.

FISH COUNTER RESEARCH ON THE NORTH ESK

During the late 1970s and 1980s, fish counter research undertaken by DAFS concentrated on the reliability of the NSHEB Mark 8 resistivity counter (Dunkley and Shearer 1982) and on the swimming behaviour of fish as they crossed a Crump weir (Dunkley and Shearer 1989). In 1980, a purpose built counting weir was constructed in the North Esk at Logie Mill, 5.8km from the sea (Brown 1981). The river channel here is approximately 42m wide, straight for 800m, of uniform cross section and well-contained at all flood levels by a high natural bank on the north side and by a flood bank on the south side. Recorded flows for the river in the three years immediately preceding installation ranged between 2 and 270m^{3}s^{-1}.

As financial constraints precluded the construction of a concrete weir, an alternative design was developed using trench sheeting foundations embedded in the river bed gravel to which triangular steel supports were fixed, the supports isolated from the trench sheeting using neoprene seals. Glass-reinforced plastic deck sections were fixed to the steel supports using nylon bolts. Stainless steel electrodes (50mm x 3mm) were mounted in chases moulded at 450mm centres into the GRP deck sections and fixed with epoxy resin adhesive and stainless steel screws. The most upstream electrode was fixed at 150mm downstream from the crest. Care was taken to ensure that the electrodes were insulated from any of the steel support structures, which had all been coated with an epoxy-resin based paint. As all of the construction components were pre-fabricated, much of the work was done off-site.

The weir takes the form of a three-channel, two-stage compound Crump weir with a low central section with a crest height of 200mm above the upstream bed level and flank sections with crests 425mm above the upstream bed level. The flank sections are each 17.3m wide and the central section is 6.07m wide. The sections are separated by timber and GRP cutwaters. All cabling to the electrodes is carried under the weir using pipework ducts. Connections to the far flank (relative to the instrument cabin) and central channel electrodes are made inside the hollow cutwaters while connections to the near flank section are made in an inspection pit set into the near bank. A steel CCTV platform spans the central channel and allows monitoring of the central or flank channels using CCTV cameras in weather housings and infra-red lights for night time work. Access to the platform is by way of a cable car system which spans the whole river.

Originally, three NSHEB Mark 8 counters were used, one connected to each weir channel. Transient recorders were employed to capture the electrical signals detected and dump them at a slower rate to a chart recorder. Good results were obtained after extensive calibration trials but frequent and time consuming manual recalibrations to compensate for changes in the conductivity of the river water, several times each day, were required to maintain a constant level of accuracy. Even so, numerous false counts resulting from the effects of wind-driven waves washing over the weir or, in winter, large quantities of ice passing downstream were recorded and had to be eliminated from the record by reference to the analogue chart recorder output. Consequently, research effort was concentrated on automating the processing of signal information and compensating for changes in the river water conductivity.

The electrical signal detected by a resistivity counter as a fish passes over the electrode array approximates to a single cycle of a sine wave. Detailed study of the electrical waveforms detected during the passage of fish over the Logie weir indicated that the many characteristics of the entire signal waveform had to be utilised if an accurate count were to be obtained, particularly if spurious counts due to the passage of ice, flood-borne debris, wind-driven waves etc. were to be rejected. The data collected at Logie were used by a Scottish electronic development company to develop the microprocessor-based 'Logie' counter.

In its fully-developed form, the 'Logie' counter automatically monitors and compensates for environmental changes and can count fish in up to 4 channels simultaneously (there are two models of the Logie counter, the 1700A which is a single channel counter and the 2100A which may contain up to 4 counting channels for use with compound weirs or in multi-channel situations). The counter employs an algorithm to compare the form of a received signal with that of a stored fish signal, only counting those signals where comparison is good. The algorithm used is deliberately not too complex as few signals generated by fish approximate to perfect sine waves.

An automatic self test routine, in which a 'dummy fish' is inserted into each counter channel in either direction every 30 minutes, effectively recalibrates the instrument at half-hourly intervals. An optional conductivity meter module, cell and cable may be retro-fitted allowing modification of the signal processing algorithm not only for changes in bulk resistance but also specifically for changes in water conductivity. The counter is routinely fitted with relay contacts (to operate chart drives, data loggers, cameras etc.), analogue output for recording signal waveforms using a chart recorder and a serial printer port to allow printing of detailed count information (date, time, channel, direction and signal size) using a standard computer printer. Waveform data can also be recorded by a microcomputer directly from the counter as digital information. To allow for the different swimming behaviour of ascending and descending fish (Dunkley and Shearer 1989) separate upstream and downstream operating thresholds are standard and user-selectable. The installed RAM in the counter may store up to 2048 counts before downloading is necessary but this may extended to 65536 by the installation of extra RAM. The counter may be controlled either via a 4x4 hexadecimal keypad on the front panel of the instrument or via the RS232 port using a computer either directly or, using a modem, via the telephone network. Data transmission rates are selectable between 300 and 2400 baud.

In validation experiments using CCTV and time lapse video recording, the Logie counter on the Crump weir at Logie on the North Esk has been found to operate with a high degree of accuracy. When counts recorded by the counter were compared with fish seen which should have been counted, the correlation coefficient was 0.99 for both upstream (Fig. 5) and downstream counts (Fig. 6).

The 'Logie' counter is now in successful operation in Scotland, England, Ireland, Spain and Canada.

SALMON STOCK ASSESSMENT IN THE NORTH ESK

Development of the 'Logie' counter continues as more information becomes available on the performance of the instrument under different conditions. Nevertheless, the counter has proved to be an invaluable tool in the stock assessment programme being carried out on the North Esk salmon population. It is important to realise that in the North Esk, as elsewhere, a counter on its own cannot provide all the information necessary to assess the structure of a salmon population. Rather, it is one of the most important tools used in an integrated research programme.

The North Esk, although a small river with a catchment area of about 732 km^2, is one of the major salmon producing rivers in Scotland and supports important net and rod fisheries. All net fisheries in the river are located downstream of the counter and are operated by one fishing company. Full access to the catches taken by net below the counter is provided to SOAFD and all fish so caught are examined daily and the entire catch on one or two days per week, depending on the time of year, is sampled to provide data on age, length, weight and sex. The entire catch in the major rod fishery below the counter is also sampled. Detailed counts of any removals from the lower river of dead or diseased fish or fish removed for broodstock for the District Salmon Fishery Board's hatchery are also kept. Thus, the net upstream counts at Logie plus all the removals from downstream of the counter provide data on the numbers of fish entering the North Esk, their times of movement, the biological characteristics of the various stock components which ascend the river and the levels at which they are exploited. These data have been collected since 1981. The total numerical strength of the stock entering the river each year has varied between 8076 in 1990 and 18594 in 1988 (Figs. 7-16). In order to allocate counts and catches to the same spawning stocks, the year is considered to run from 1 December to 30 November of the following year. The lowest monthly totals were usually recorded in January each year. In most years, the biggest single monthly record of entrants was recorded in July; the largest catches were generally also recorded in this month. In 1989, however, the largest single monthly total was recorded in October, after the net fishing season had finished.

The percentage sea age distribution of the salmon entering the North Esk has changed over the period 1981-1990 (Fig. 17). The proportion of the stock returning to freshwater after three winters at sea declined from about 6% in 1981 and 1982 to less than 2% in 1985. In 1986, 3SW salmon comprised about 3.5% of the total returning adult stock but this sea age group has since declined to about 1.5% in 1990. At the start of the time series, 2SW salmon accounted for more than half of the returning stock but had declined to about one-third by 1990. Conversely, 1SW salmon have increased in importance from about 43% in 1981 to 61% in 1990, and exceeded 70% in both 1988 and 1989. Previous spawners have remained at a low level throughout, never exceeding 1% and exceeding 0.5% in only five of the ten years for which data are available.

Because the amplitude of the signal made by a fish passing the detection electrodes is related to its size, the potential exists for sub-dividing the counts recorded into size classes and, potentially, sea age groups. Some progress has been made in this area and investigations have shown that whereas the counter does not provide detailed length information in an absolute sense, the sizes of the signals may be used to separate counts into groups. It remains to be demonstrated whether these groups correspond to sea age classes.

Further trials are in progress to determine whether the modern signal processing techniques used by the 'Logie' counter extend its application to 'non-Crump weir' situations, allowing the instrument to be used more widely than is possible at the moment.

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Dunkley, D.A. and Shearer, W.M. 1982. An assessment of the performance of a resistivity fish counter. ***Journal of Fish Biology* 20, 717-737.**

Dunkley, D.A. and Shearer, W.M. 1989. Swimming height of Atlantic salmon *Salmo salar* L., crossing a Crump weir. ***Aquaculture and Fisheries Management* 20, 193-198.**

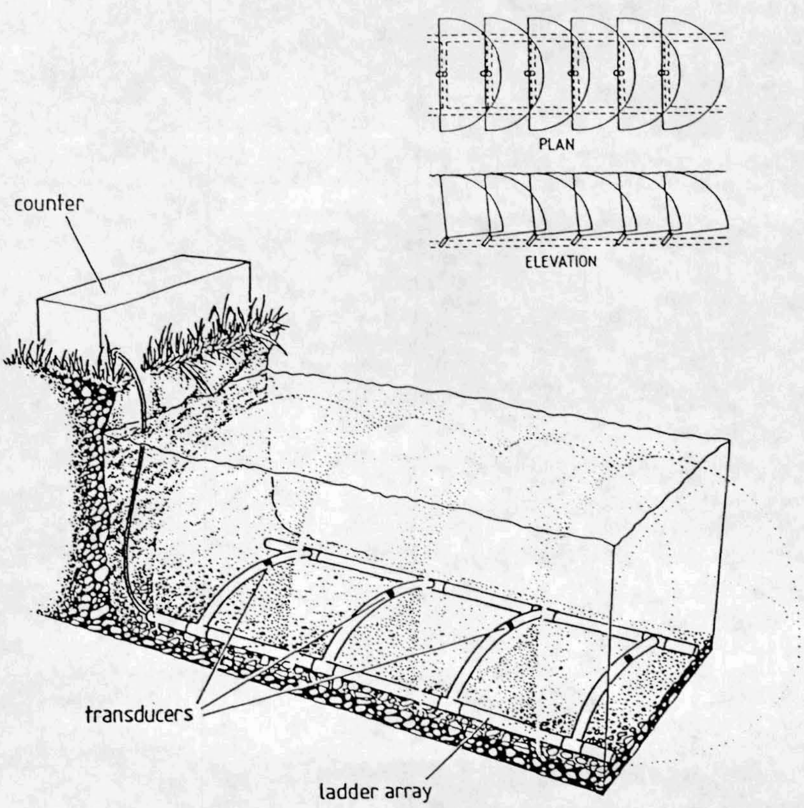

Figure 1. Bendix sonar counter. Redrawn from Hellawell (1973).

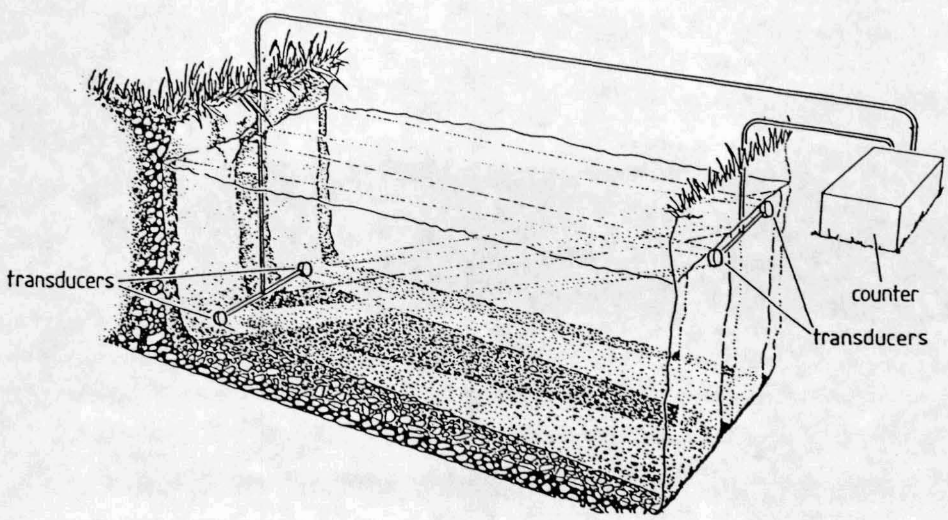

Figure 2. Birmingham University sonar counter. Redrawn from Hellawell (1973).

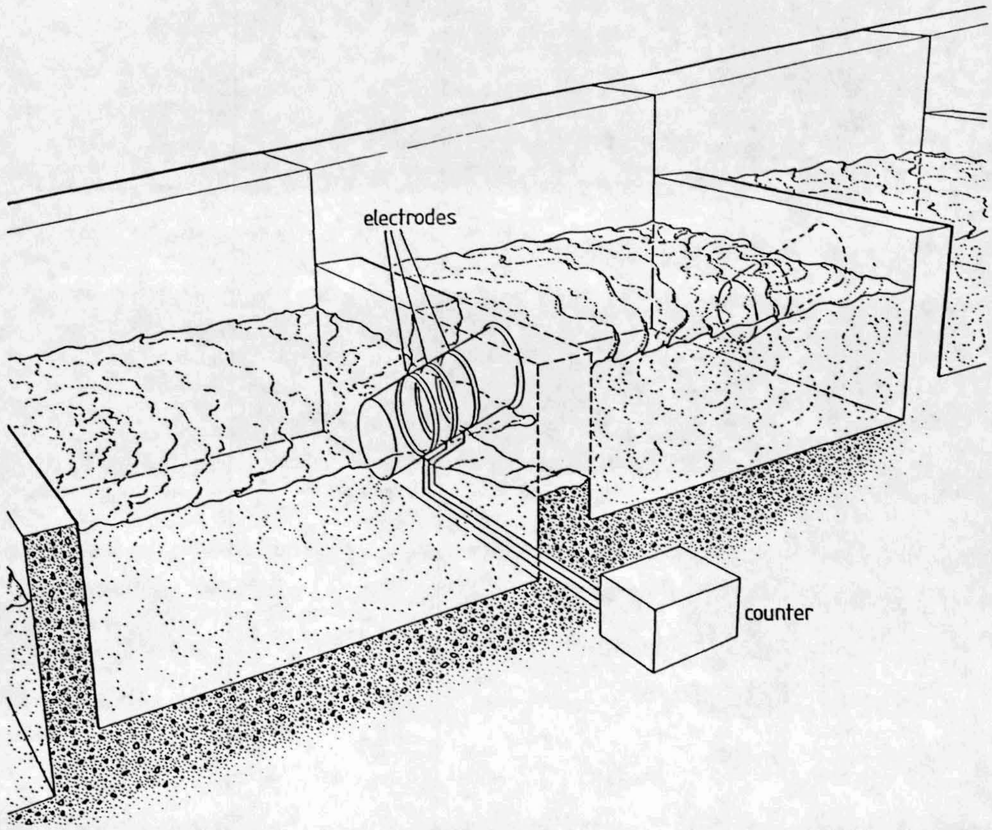

Figure 3. Resistivity counter electrode array in tube-counter format.

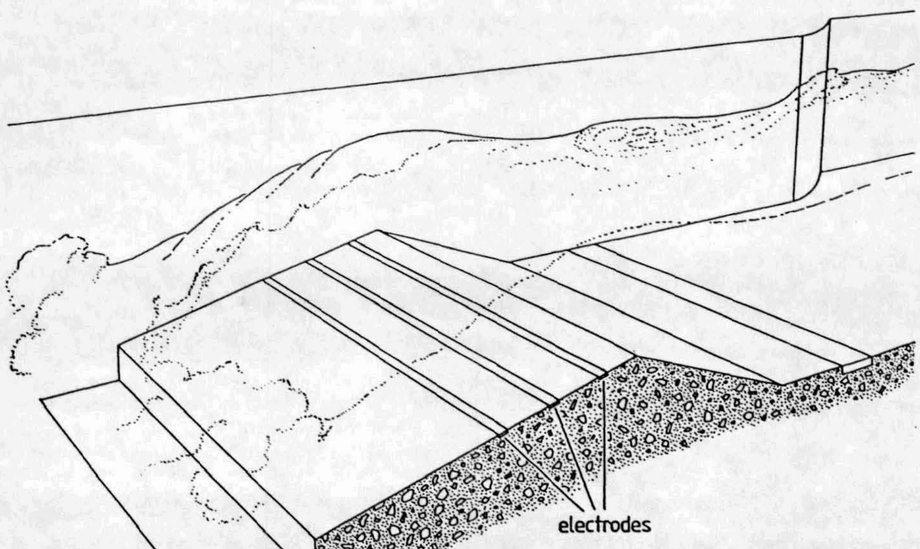

Figure 4. Resistivity counter electrode array in strip counter format. The electrodes are fixed to the downstream face of a Crump weir.

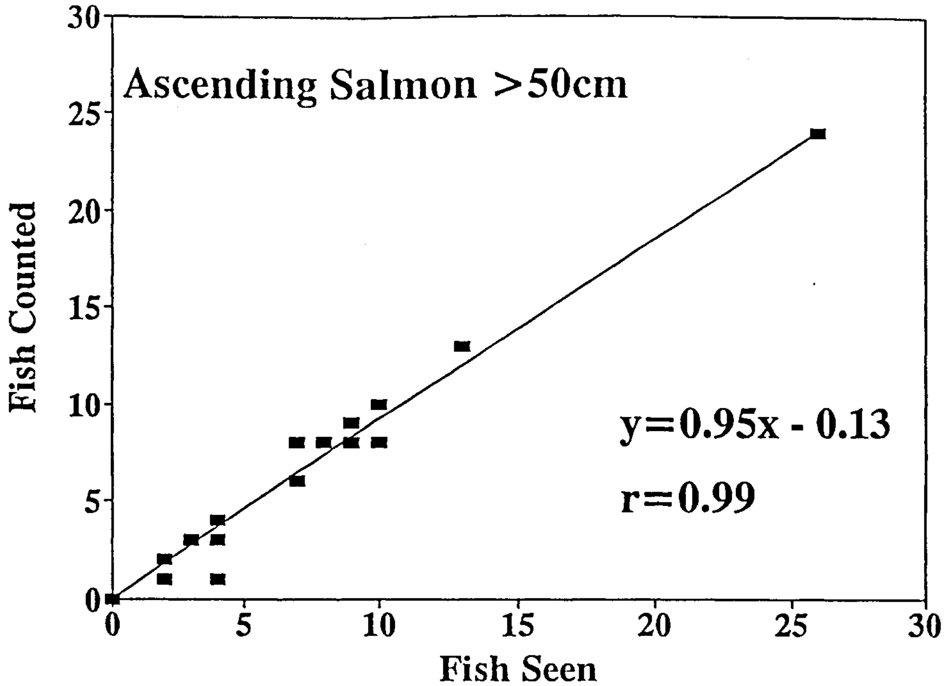

Figure 5. Relationship between ascending salmon counted by the 'Logie' counter and salmon seen using CCTV surveillance equipment during the same time period.

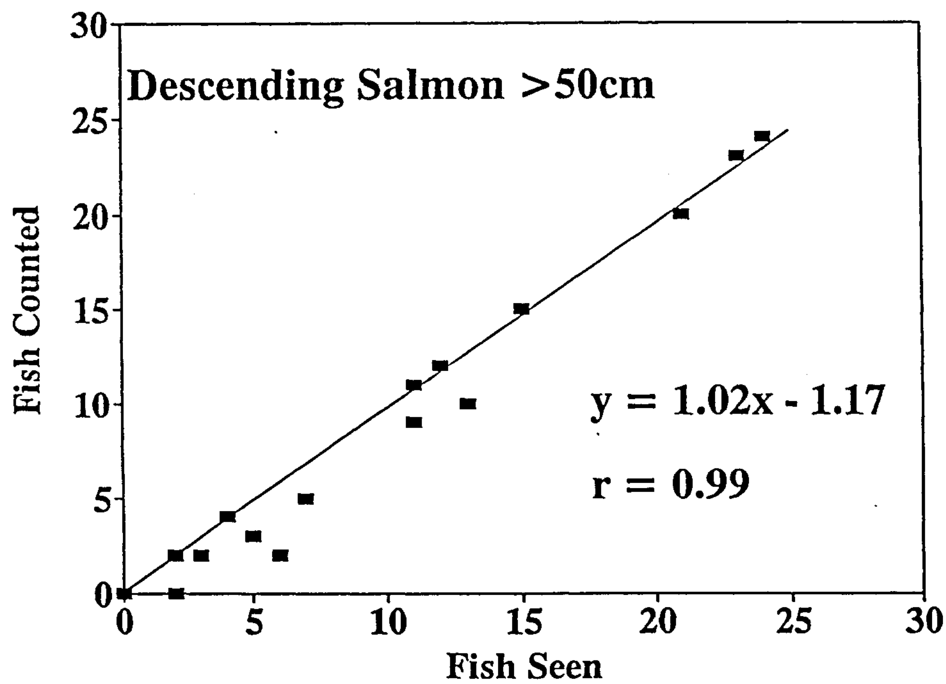

Figure 6. Relationship between descending salmon counted by the 'Logie' counter and salmon seen using CCTV surveillance equipment during the same time period.

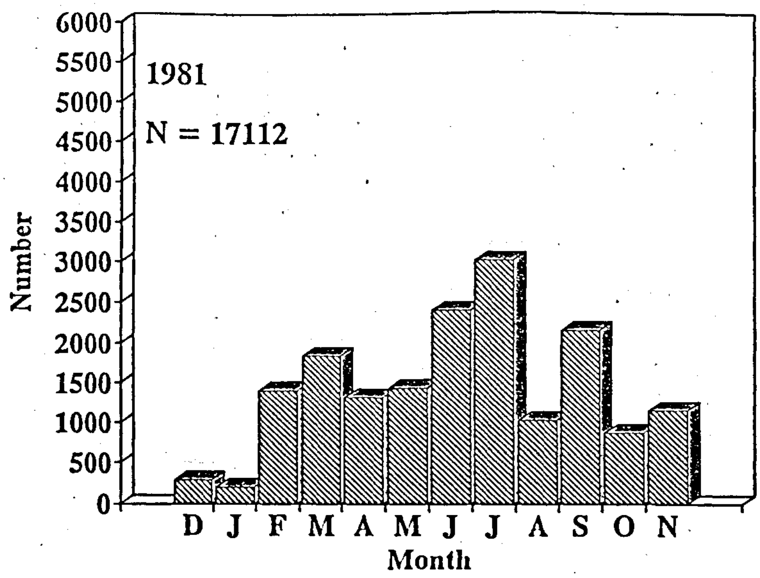

Figure 7.

Salmon stock entering the North Esk each month.

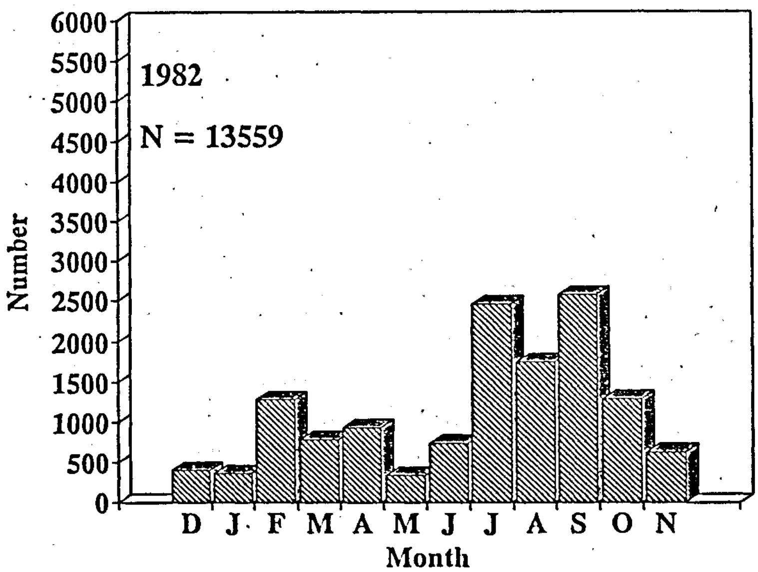

Figure 8.

Salmon stock entering the North Esk each month.

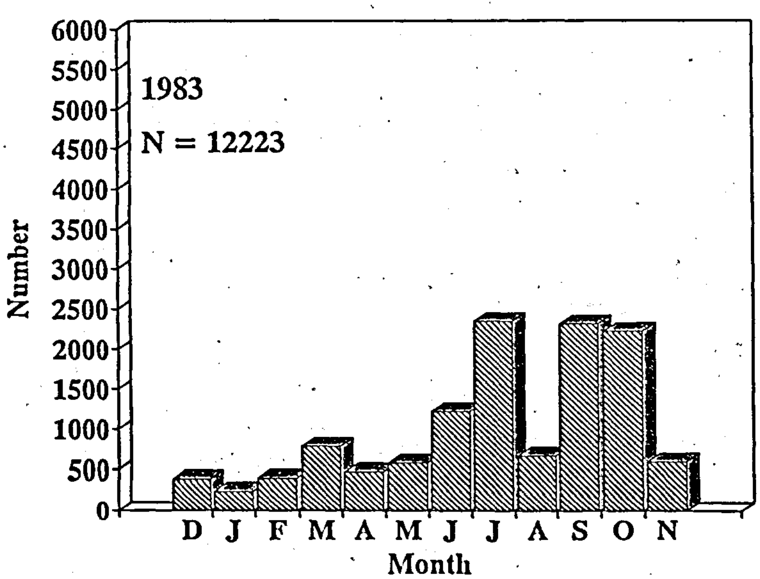

Figure 9.

Salmon stock entering the North Esk each month.

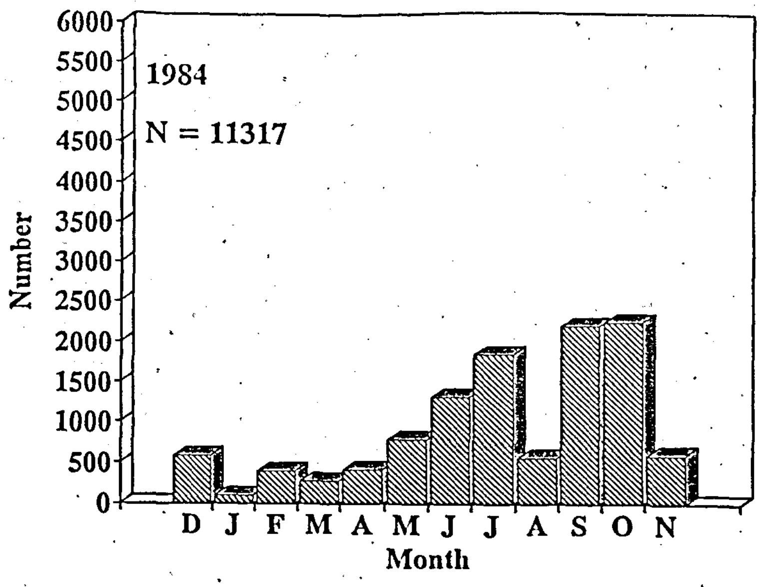

Figure 10.

Salmon stock entering the North Esk each month.

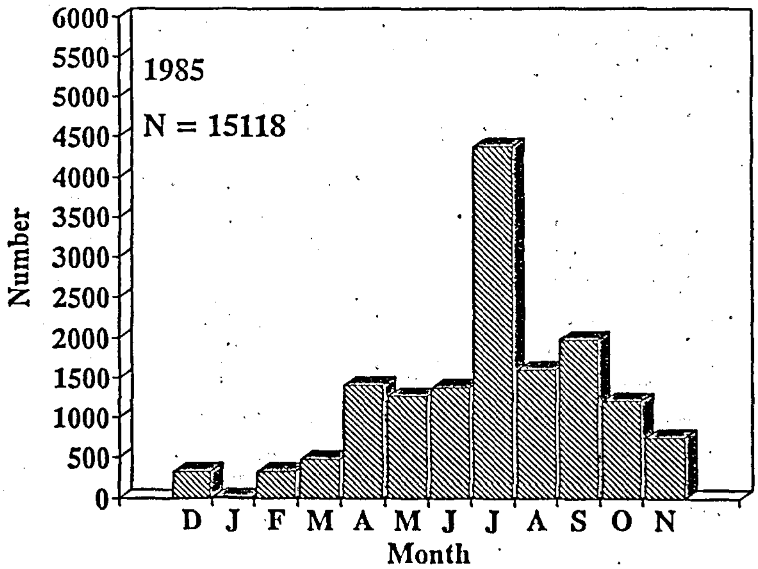

Figure 11.

Salmon stock entering the North Esk each month.

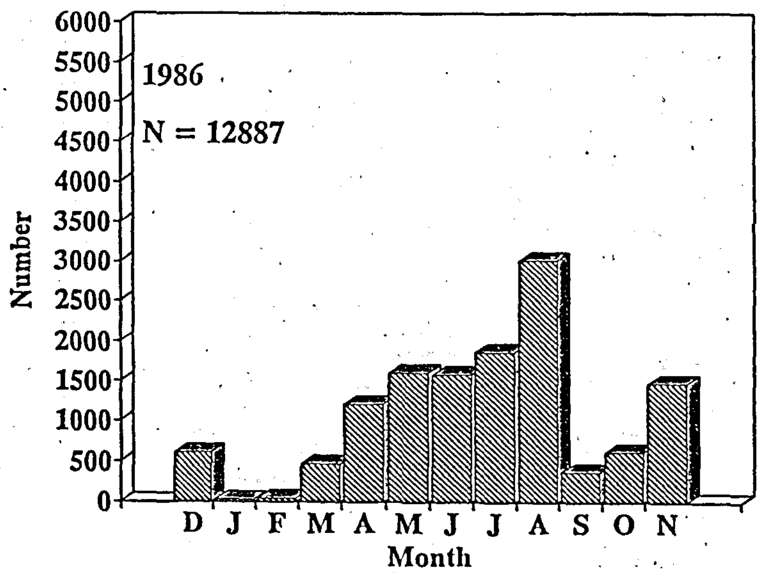

Figure 12.

Salmon stock entering the North Esk each month.

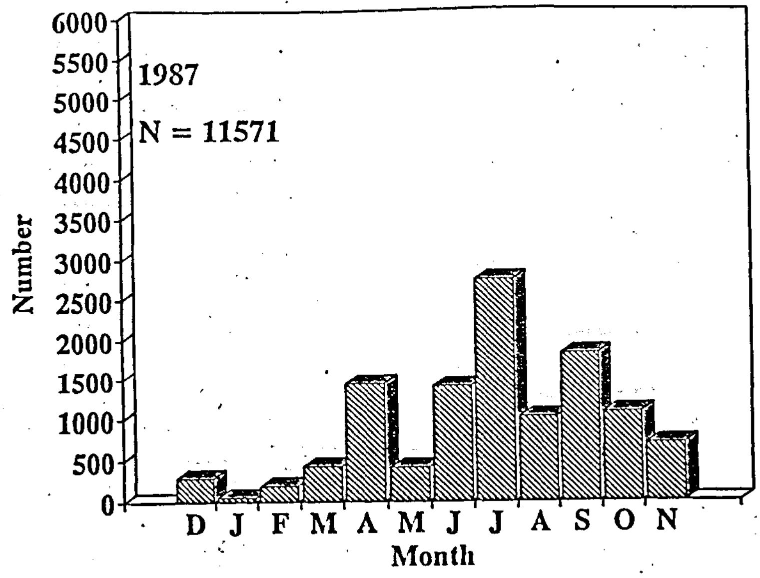

Figure 13.

Salmon stock entering the North Esk each month.

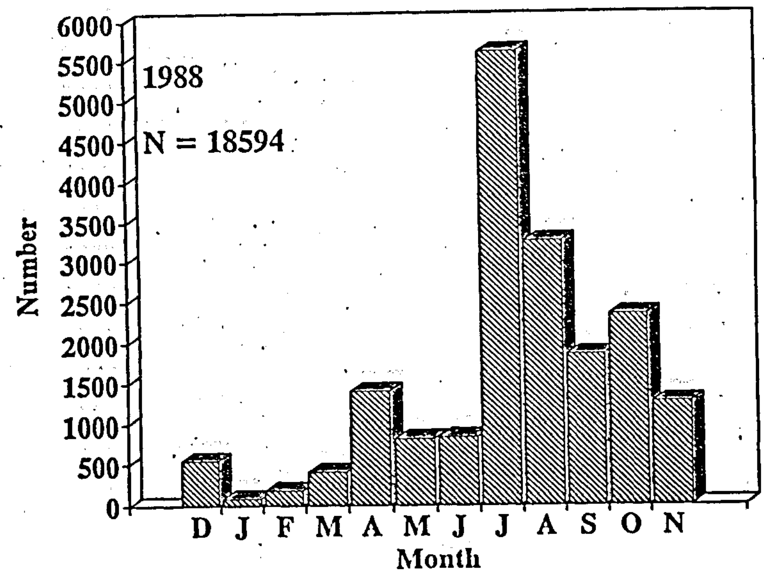

Figure 14.

Salmon stock entering the North Esk each month.

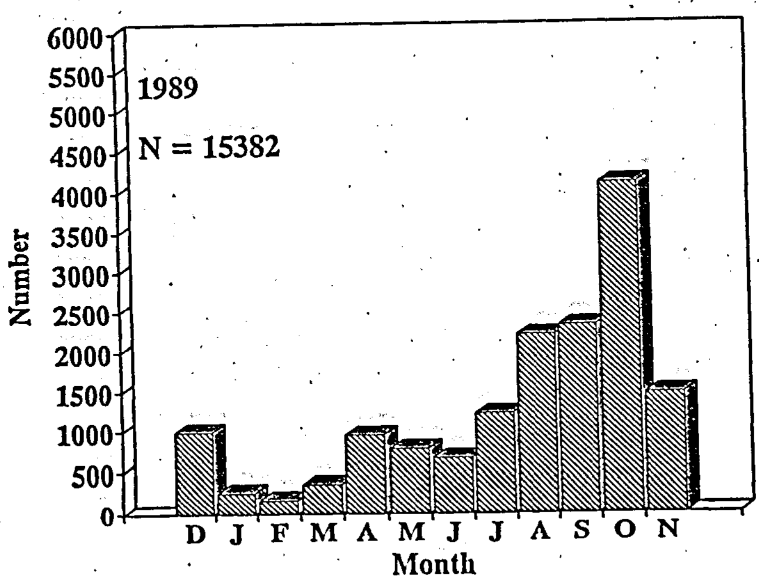

Figure 15.

Salmon stock entering the North Esk each month.

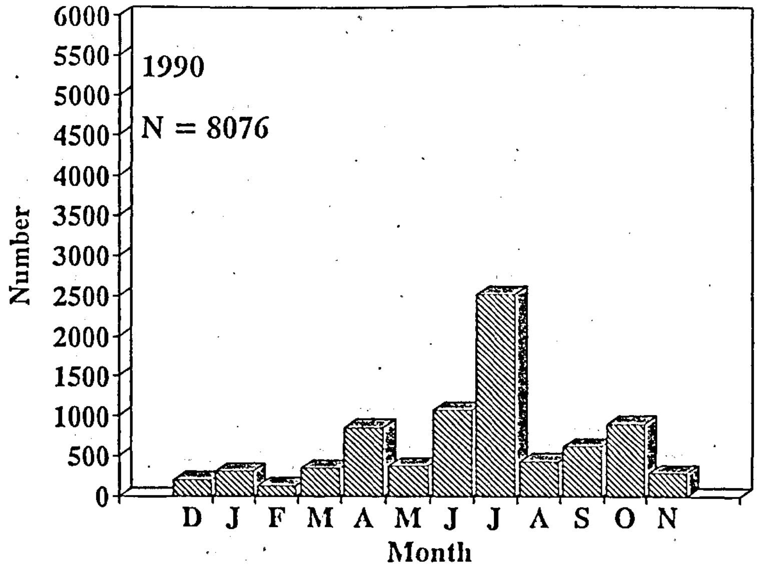

Figure 16.

Salmon stock entering the North Esk each month.

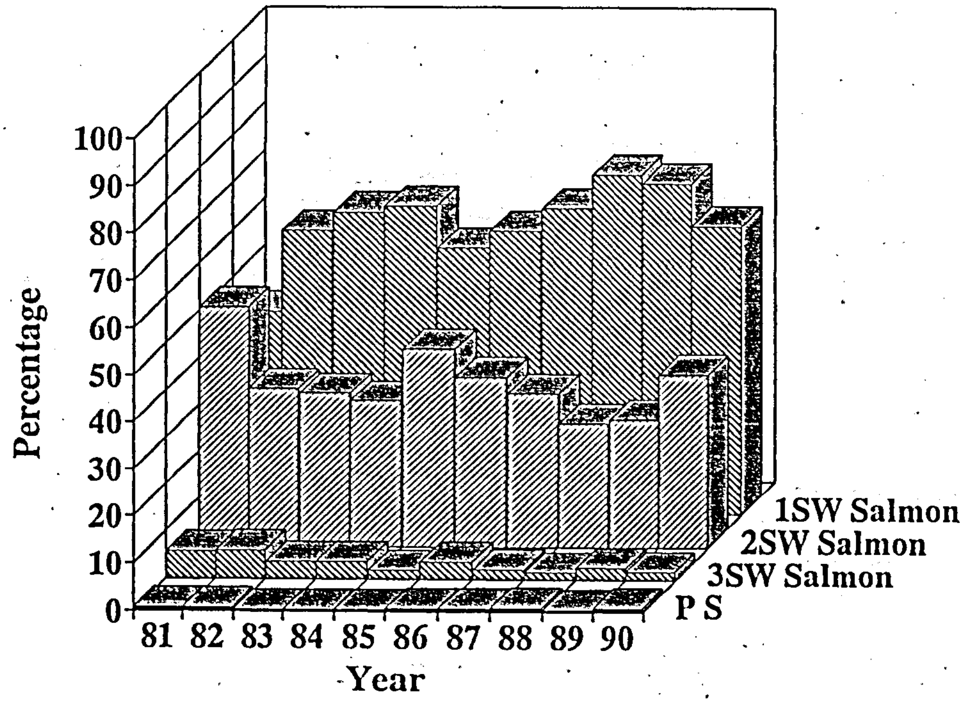

Figure 17. Percentage monthly sea age distribution of salmon stocks entering the North Esk, 1981 - 1990.