IONTAOBHAS TAIGHDE BRADAN na h-EIREANN IONCORPORTHA

(THE SALMON RESEARCH TRUST OF IRELAND INCORPORATED)

Sponsored by Arthur Guinness Son & Co. Ltd. and
the Minister for Agriculture and Fisheries

ANNUAL REPORT

No. XVIII

FOR THE YEAR ENDED 31st DECEMBER 1973

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REPORT FOR THE YEAR ENDED 31st DECEMBER 1973

The Report is set out in the following Sections:

FOREWORD	5
STAFF	6
INSTALLATIONS	6
RAINFALL AND WATER TEMPERATURES	8
REARING OF SALMONIDS OF KNOWN PARENTAGE	10
EXPERIMENTAL REARING TECHNIQUES	14
FISH MOVEMENTS	17
SMOLT TAGGING AND MARKING	27
RECAPTURES FROM TAGGING OF WILD SMOLTS	27
RECAPTURES OF REARED FISH	27
ULCERATIVE DERMAL NECROSIS (SALMON DISEASE)	31
EFFICIENCY OF ROD FISHING	32
SPONSORED RESEARCH	33
ACKNOWLEDGEMENTS	34

APPENDICES

I.	THE RESULTS OF SELECTIVE BREEDING FROM KNOWN GRILSE AND SALMON PARENTS	35
II.	A STUDY OF THE AVAILABILITY OF ORGANIC NUTRIENTS IN LOUGH FURNACE IN RELATION TO THE POPULATION OF *NEOMYSIS INTEGER*	40
III.	SUMMARY OF THE REPORT ON DIURNAL FLUCTUATIONS OF THE ZOOPLANKTON IN LOUGH FEEAGH	47

Foreword

AIMS AND OBJECTIVES

The overall objective of the Trust, founded in 1955, is to carry out fundamental research into factors which govern the development of stocks of salmon and sea trout in Irish waters. A primary aim is to study the question of whether grilse and salmon constitute genetically distinct stocks and to this end, the Trust has embarked upon a selective breeding programme, in which the progeny of various stocks or "races" of salmon are reared to the smolt stage. This work has been extended to include sea trout and other salmonids.

This work has also led to study in detail of rearing techniques, including food and feeding methods, and ancillary improvements in marking and release of reared smolts. Incidence of certain diseases during the rearing period has been shown to be a major factor affecting the success of artificial rearing and the study of this is now being pursued.

In order to assess the viability of these reared fish, it was necessary to be able to trap and count all returning adults, and to this end, the Trust has constructed trapping facilities for both upstream and downstream migrants on the two routes into and out of Lough Feeagh. These installations also allow accurate census work to be carried out on the wild populations of salmon, sea trout and eels. Annual variations in spawning escapement, rod fishing efficiency, smolt production, smolt survival to the adult stage and kelt survival have been established by this means, since 1970. **Information of this nature is the essential basis for rational management of Irish Salmon Fisheries.**

In addition to the above, research of a more general biological nature has formed part of the Trust's programme, including biological productivity surveys, experiments on artificial restocking, competition and predation, as well as research work on peat silt pollution.

R. V. H. LEVINGE, Chairman

STAFF

No changes were made in the permanent staff of the Trust during 1973 but in the absence of Mr. P. Mulchrone on sick leave, for a period of almost six months, Mr. T. O'Boyle was employed as a temporary Field Assistant.

Mr. P. Guerin (University College, Cork) was given vacation employment during the period 1st July to 30th September, when apart from routine daily work as relief assistant, he also made a collection of salmon and sea-trout scales from rod-caught fish from the Newport and Burrishoole river systems.

The first session of a second training course in fish rearing and management was held in December, 1973. Mr. Randall Boyd (University of Edinburgh) and Mr. Roscoe Wright (Trout farm, Somerset, England) were sponsored by the Atlantic Salmon Research Trust and Mm. Patrick Danel and Gilles Euzenat were sponsored by the Association pour la Protection et Preservation des Saumons de Bretagne.

INSTALLATIONS

Excavation work for the new Laboratory at Furnace, replacing the old building at Treanlaur, was commenced in September, 1973, and by the end of the year, the contractors had made good progress in the construction, having reached the stage of completing the roofing. The Laboratory, designed by Messrs. Taylor & Veale, Architects, Castlebar, Co. Mayo, is expected to be finished by mid-1974. The construction is being financed with the aid of a grant from the Atlantic Salmon Research Trust, London. The ground plan is shown in Fig 1.

A new store shed and workshop, constructed by the Trust's employees, were completed at Furnace during 1973.

A shelter was built over the upstream trap on the Mill Race at Furnace during the year, in order to give protection against inclement weather during the counting, tagging and release operations at the trap which hitherto have been carried out in the open. The lifting mechanisms for the false floor, the upstream hecks and the inscale shutter work from pulleys on an angle-iron framework. With provision of powerful electric lighting, the trap operations have been much simplified by night and in bad weather conditions. The wall bordering the right bank of the resting pool below the trap was raised by some 2' 6" and capped with concrete. This has prevented fish from crossing the wall in high flood conditions and becoming stranded when the flood water receeded, as has happened occasionally in the past.

The roof over the downstream trap at Furnace was extended to cover the entire area of the trap chambers and two translucent sheets were inserted in the roof over the tagging area to facilitate operations in the winter months.

Small, low walls of concrete blocks and plasterwork were constructed beside the overflows from the range of circular rearing ponds on the left bank of the Mill Race. These prevent splashing onto the concrete platform and the adjoining County Road. The north wall of the release pond constructed in 1972 was raised by 9" to prevent flooding from the Mill Race at very high water levels.

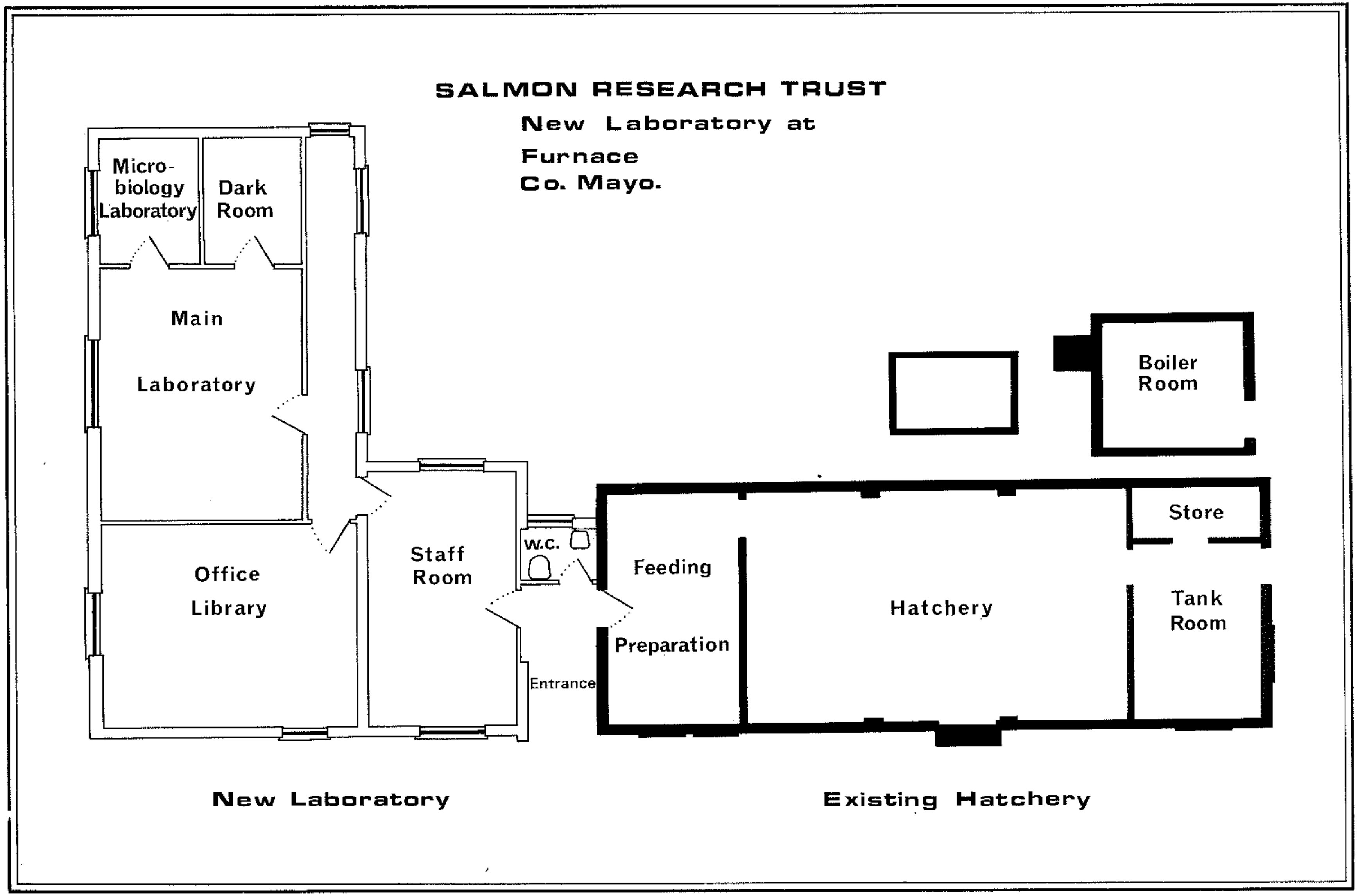


FIG. 1
Sketch plan of new laboratory and existing complex at Furnace. (The Microbiology laboratory will be used for fish disease investigations).

Rainfall and Water Temperatures

Precipitation was slightly above normal in 1973, at 108% of the average for the past five years. This was in contrast to the past two years which were marked by relatively dry summers. The total rainfall measured in 1973 at Furnace was 1468·7 mm (57·8") and the monthly totals over the past five years are shown in Table I below, for the purposes of comparison:—

TABLE I

MONTHLY RAINFALL AT FURNACE (in mm) FOR THE YEARS 1969/73

MONTH		1969	1970	1971	1972	1973
January	...	140·1	68·2	130·1	109·7	171·5
February	...	98·6	267·0	134·3	98·4	149·9
March	...	62·7	141·9	90·0	139·8	70·7
April	...	84·7	150·2	33·8	140·8	77·9
May	...	57·1	44·1	59·6	141·2	115·9
June	...	110·4	57·3	114·7	92·4	63·6
July	...	43·1	128·1	51·2	49·8	64·7
August	...	79·3	116·1	77·1	69·3	164·0
September	...	63·3	175·6	86·3	12·9	94·3
October	...	105·7	225·2	112·1	59·7	107·7
November	...	187·6	199·8	211·9	191·9	240·1
December	...	178·3	82·1	73·2	169·5	148·4
Totals (mm)		1,210·9	1,655·6	1,174·3	1,275·4	1,468·7
Totals (ins.)		47·7	65·2	46·2	50·2	57·8

January and February were relatively wet months, compared with recent years, whilst March was dry, especially during the period of kelt descent at the end of the month. Similar conditions prevailed during April but May was wetter than usual. Summer rainfall was adequate for fish migration during June and July and above normal for August, but very heavy rainfall was experienced in November, when during the last days of the month, over 5" of rain fell in 4 days.

The water temperatures in the Mill Race, shown in Fig 2, followed much the same pattern as in 1972, with slightly warmer winter temperatures but slightly cooler conditions in the summer. Another cold spring resulted in water temperatures below 10°C until late May but an average of 5°C was maintained during January, February and March. The summer temperatures reached a maximum of only 18°C on three occasions whilst the mean summer value was 15°C. This would appear to be due to the frequency of small floods during the summer when the maximum water temperatures corresponded with the periods of low water levels. Only very slight (less than 2°C) diurnal variations were noted in the summer of 1973, compared with values up to 5°C in 1972. Water temperatures began to fall steadily from mid-September but had not fallen below 7°C by the end of December.

The water levels in the Mill Race are shown in Fig 2 where the most noticeable feature is the number and amplitude of the fluctuations from the beginning of June onwards. This is explained partly by the rainfall, which occurred in heavy downpours followed by dry conditions and partly by the increased

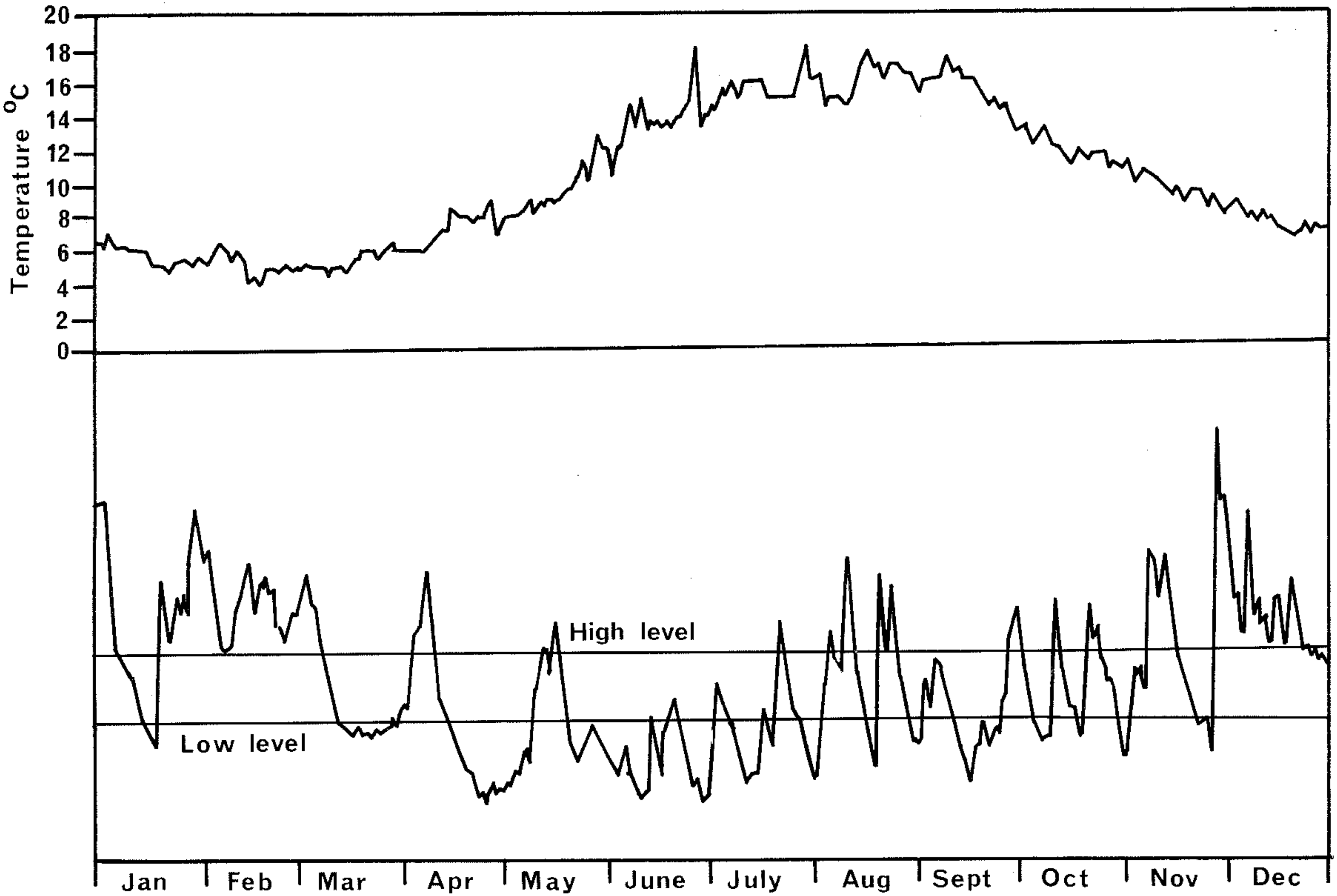


FIG. 2
Water temperature (top) and water levels (bottom) in the Mill Race in 1973.

drainage through the Mill Race and the Salmon Leap, when water levels now fall much more rapidly than in the past.

There was adequate water for fish migration during every month of the year with only two fairly prolonged periods of low water, in late March and late April. The heavy rainfall at the end of November resulted in the highest flood recorded over the past thirteen years, when the screens of the Mill Race fish fence were over-toppd by some 9" and had to be removed for three days.

The usual meteorological records of air temperatures, rainfall, sunshine and barometric pressure were kept throughout the year.

Rearing of Salmonids of known parentage

The grilse used in the rearing work described below were part of the annual return for each year, derived from smolts. They are thus a selected strain from known grilse parents since 1963, and with known grilse parents and grand-parents since 1967.

(a) Grilse ova hatched in 1971

No. of ova, December 1970	84,650
Remaining stock at 31/12/71	20,184
No. of 1+ smolts released in 1972	4,362
Mark: Brand "B" or "7" and adipose fin clip	
No. of parr remaining, June 1972	3,373
No. of parr remaining, January 1973	3,106
No. of 2+ smolts released, April 1972 ... ... (88·2% survival over 2nd year)	2,974
Mark: Brand "X" and adipose fin clip	

These fish were again subject to "fungus" disease during the winter of 1972/73, as in previous years and as before, the major part of the losses occurred during December and January. The incidence of the disease was much less marked in February and March, when only 0·3% was recorded as affected when the fish were branded during the period 24-27 March. After three weeks in the release pond, however, the disease suddenly flared up again, causing a loss of almost 100 smolts in three days. The smolts were "flushed out" of the release pond, in the hope that the brackish water of Lough Furnace would inhibit the further spread of the disease. Although the total of smolts released is given above as 2,974, it would be wise to assume an effective total of about 2,700, following this outbreak of disease. A similar pattern in the occurrence of the disease was seen in 1971 and to some extent in 1972.

The average size of these smolts was 158 mm, ranging from 141 mm to 188 mm and only 13 "giant" smolts (over 25·0 cm) were recorded.

(b) Grilse ova hatched in 1972

No. of ova, December 1971	61,600
Remaining stock at 31/12/72	23,314
No. of 1+ smolts released in 1973	2,505
Mark: Brand "O" and adipose fin clip	
Remaining 1+ parr, April 1973	19,242
Remaining 1+ parr, December 1973	8,508

The pattern of rearing losses in 1973 followed almost exactly that of the past four years, in that mortalities were normal until mid-April, when the 1+ smolts were removed. Thereafter, until mid-July, heavy losses were experienced among the 1+ parr resulting in approximately 50% mortality of the stock. The signs of this disease epidemic have been described fully in previous Reports but as in previous years, many of the dead fish were unblemished externally and showed no microscopic evidence of disease internally. Samples were again examined by the Fish Pathology Section of the Veterinary Research Laboratory of the Department of Agriculture & Fisheries and again, as in previous years, cultures of *Aeromonas liquifaciens,* showing disc sensitivity to the usual antibiotics, were the only results of the examination. No signs of viral infection were found. A variety of treatments, including chloramphenicol, furazolidone, oxytetracycline and potentiated sulphonamide were given, without effect. It now seems unlikely that this epidemic can be ascribed solely to haemorrhagic septicaemia arising from infection with *A. liquifaciens* and the annual scale of losses of 1+ parr (which have cost at least 5p each to produce) is such as to warrant a full-scale research project on the aetiology and treatment of the epidemic.

The measures proposed in 1972 for the possible prevention of a recurrence of this epidemic were carried out from April, 1973, without effect.

The following table shows the losses experienced over the year among this group of fish: —

TABLE II

Stock at 31/12/72	23,334	
Losses in January	643	
„ „ February	470	
„ „ March	474	
„ „ April	1,637	1+ smolts released (2,505)
„ „ May	2,589	
„ „ June	4,944	
„ „ July	1,101	9,218 1+ parr retained for rearing
„ „ August	139	to 2+ smolts, from mid-July
„ „ September	27	
„ „ October	99	
„ „ November	34	
„ „ December	104	8,568 1+ parr remaining at 31/12/73

After July, losses reduced to a low level, with slight increases during October and December, due to outbreaks of "fungus" disease. This disease was manifested in the pectoral and caudal regions of the fish, as in every year since 1969, and in December was confined largely to precocious male parr with developing testes. It should be reiterated that the epidemics of early summer, the "fungus" disease of winter and spring and U.D.N. of adult fish in the winter all appeared for the first time in 1969, although there may well be no actual relationship between the three.

The 1+ smolts were few in number (12·5% of the population) but were fairly well-grown fish, with an average size of 13·5 cm.

The survival of the 1+ parr retained for rearing to the 2+ smolt stage was 92·9% and they had reached an average size of 15·1 cm by the end of the year.

(c) Grilse ova hatched in 1973

No. of ova, December 1972	128,600
No. of ova, February 1973	80,000
(after transfer of quantity to commercial hatchery)	
No. of fry, July 1973	31,435
No. of parr, December 31st, 1973	18,034

Ova were laid down during December, 1972 in two separate groups, comprising approximately 64,000 each of the progeny of grilse derived from 2+ smolts and those from 1+ smolts. By February 8th, the losses in the 2+ grilse group were 1·9% whilst those in the 1+ grilse group were 4·5%, so that there was a distinct difference in early viability, as well as in size of ova and fecundity of the females, as noted in *Ann. Rep. XVII*. At this stage, the hatchery stock was reduced to 80,000 by transfer to the commercial hatchery.

Some ova were eyed by mid-January and the first hatching was observed on February 9, although this process was not complete until mid-March.

Six groups of 4,000 ova each were used in a trial of warmed water during late incubation and early feeding and these have been reported on separately in the Experimental Rearing Techniques Section (p 14).

Mortality over the year was severe, as may be seen by reference to Table IV below, where the survival of 18,034 parr by December 31st represents only 22·5% of the original stock. This is the worst result yet recorded for the first year's rearing, but follows the general pattern of the past three years, compared with the years 1967-69:—

TABLE III

Year	Survival at end of first year
1967	60·0%
1968	48·0%
1969	63·7%
1970	25·7%
1971	23·8%
1972	37·9%
1973	22·5%

This illustrates the degree to which disease has become endemic and drug resistant in the rearing station since 1969. In 1973, the proportion of infertile ova was much the same as in earlier years, as was that due to washing and shocking in January and February. During hatching, in March, there was a noticeable increase in the proportion of dead ova and incompletely hatched alevins, which has been noted before, when water temperatures show no increase at this time, over the mid-winter values. Incubation proceeded normally throughout April but when early feeding was well-established by mid-May, the fry suffered an epidemic of bacterial gill disease which was largely refractory to treatment with furanace. As a consequence, half the stock in the hatchery had died by the end of the month and fairly heavy losses persisted into June.

A further outbreak of disease, tentatively diagnosed as a resistant form of furunculosis, occurred in September when the casualties were mostly confined to the larger specimens of 0+ parr, derived from the warm water treatment in the February-May period. A small proportion of the losses were attributable to "fungus" disease, from September onwards.

There were approximately 4,000 large-grade parr averaging 96·5 mm in length and 14,000 small-grade parr, averaging 62·5 mm in length, at the end of the year. Approximately 65% of the large-grade fish were derived from parents which were 2+ smolts. Table IV (below) shows the survival from a stock of 80,000 ova, expressed as monthly losses, totals and percentage survival: —

TABLE IV

	Stock	Losses	% Survival
Original Stock	80,000	—	—
December 1972	78,262	1,738	97·8
January 1973	76,922	1,340	96·2
February	73,769	3,153	92·2
March	69,365	4,404	86·7
April	66,950	2,415	83·7
May	37,417	29,533	46·8
June	31,435	5,982	39·3
July	29,004	2,431	36·3
August	26,332	2,672	32·9
September	21,561	4,771	26·9
October	19,530	2,031	24·4
November	18,733	797	23·4
December	18,034	699	22·5

(d) Swedish sea trout hatched in 1972

No. of parr remaining December 31, 1972	:	6,177
No. of parr remaining June 1, 1973	:	5,762
No. of parr remaining December 31 1973	:	1,981

Only very light losses were experienced in this group of fish until early June, when some signs of fungus disease appeared. During the ensuing three months, approximately 2,500 deaths were recorded, largely composed of well-grown, unblemished fish and, as for the salmon parr, no form of antibiotic treatment was effective.

When the disease subsided amongst the large-grade fish in early September, this batch was moved to a release pond, where they fed and grew very well. In early December, however, the combination of the highest flood yet experienced and an exceptionally high tide resulted in the release pond being completely covered by the water of Lough Furnace and 956 of these fish escaped. The population at the end of the year comprised 918 large-grade fish, which had grown from 8·3 cm to 19·4 cm over the year and 1,063 small-grade, which had grown from 6·8 cm to 16·5 cm in the same period. All of these fish were marked in mid-December (cold-brand and adipose fin-clip) ready for release as 2+ smolts in 1974.

(e) Hatchery operations in 1973

It was intended to continue selecting two types of grilse parents (1+ and 2+ smolts) for hatchery stocks in the 1973/74 season but the small number of reared fish available coupled with a severe outbreak of U.D.N. made it necessary to pool the remaining healthy parents into one stock.

The first female fish was stripped on November 27, over a week earlier than any fish heretofore, followed by a further six on November 30. All of the resulting ova were lightly eyed by December 31 at an average incubation temperature of 6·5°C. Stripping continued until December 20, when these later fish were slow to ripen.

A total of 90,080 ova was obtained from 20 females, the values for fecundity being almost the same as those obtained in 1972:—

TABLE V

Number of female fish	:	20
Number of fluid ounces produced	:	573
Number of ova produced	:	90,080
Number of ova per fish	:	4,504
Number of fluid ounces per fish	:	29 (0·82 litres)
Number of ova per fluid ounce	:	157 (5528 litre)
Average weight of fish (—per litre)	:	5·75 lbs. (2·61 kg)
Number of ova per pound weight	:	783 (1725 kg)

The size of the ova varied between 139 and 189 per fluid ounce, as measured after they had been allowed to swell in water for over 30 minutes.

EXPERIMENTAL REARING TECHNIQUES

(a) Warmed water for incubation and early feeding

Although this installation was restarted in December, 1972, a pump failure occurred after two days and there was a month's delay until a replacement pump arrived. This proved to be the wrong type of pump and yet another delay of a month occurred before the installation was set working on February 16.

As a result of several small faults in the apparatus, it proved impossible to maintain continuously a temperature of 10°C (±1°C), later increased to 12°C and an interesting feature of this first experiment was the apparent facility with which alevins and young fry adjusted to sudden drops in water temperature to 6·5°C and one increase to 20°C.

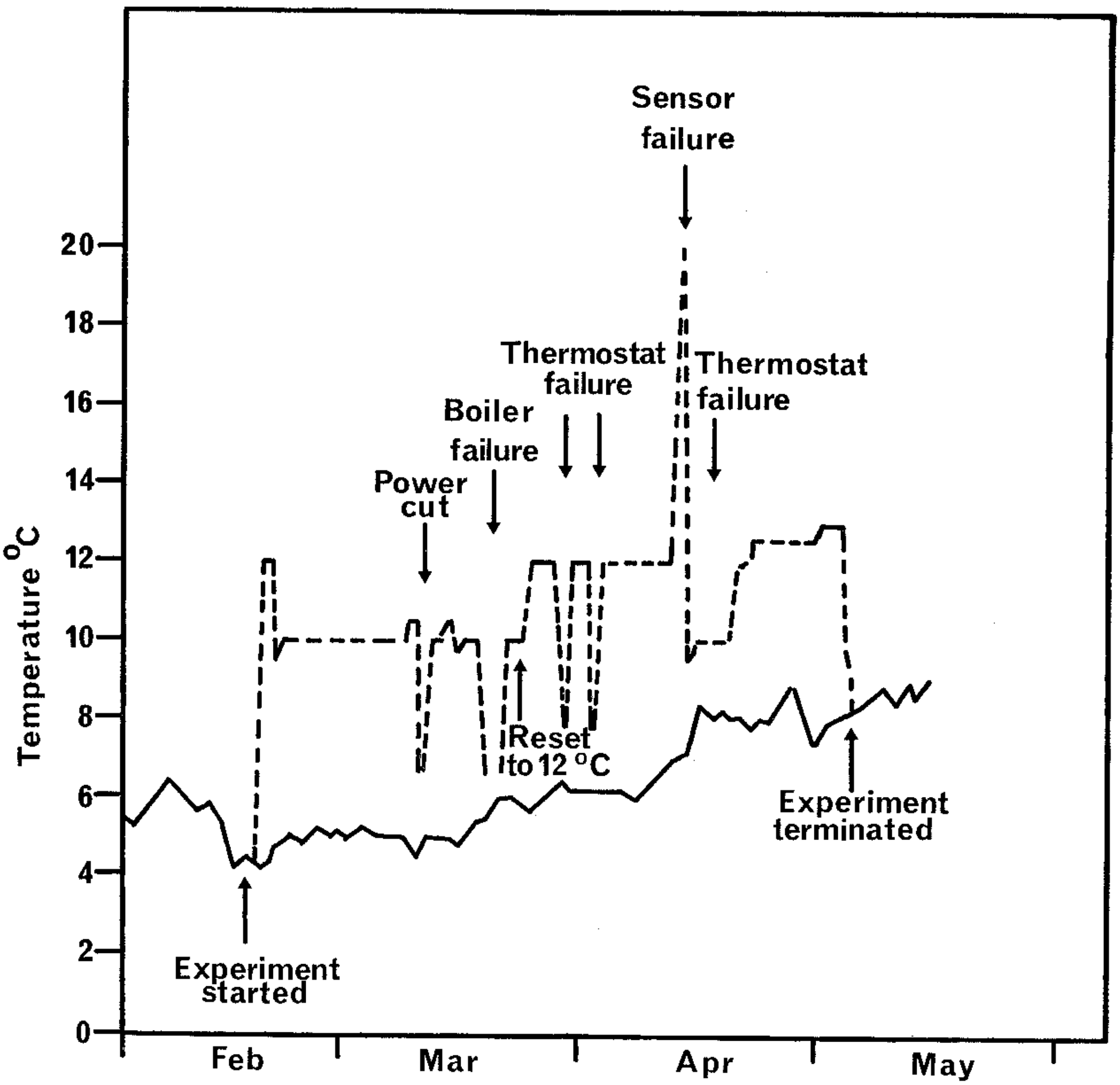
The lower temperatures were due to two failures of the heat exchanger thermostat, which caused a gradual cooling and to four failures in the mains electricity supply, when the cooling was more rapid. The power failures were aggravated by the provision of an automatic safety switch in the electrical circuit, which cut out if power failure occurred only momentarily, the switch having then to be reset manually. A sensor failure occurred overnight on April 12, resulting in a temperature increase to 20°C for seven hours. Apart from a slight increase in mortality in one batch, this had no apparent ill effect.

When all the thermostat and sensor systems were working correctly, the apparatus maintained the pre-set temperature to within the limits of ±1°C, but a constant cyclical variation within these limits was apparent from the thermographic records. The first batch of 4,000 ova was supplied with warmed water on February 18, this being the most advanced batch of ova in the hatchery and was hatching vigorously within two days. Four other batches were set going on February 23, of which one had been observed to contain alevins which were having difficulty in emerging from the egg shells. Hatching was complete in this batch within 36 hours. A sixth and final batch was changed to warm water on March 8 where difficult hatching had again been noted.

Apart from infertile ova (lacking embryos) which were removed in early March, losses were very light until the appearance of gill disease in mid-April, after the fry had been feeding for three weeks. By this time, the two most advanced batches (ova fertilised on December 5, 1972) were feeding strongly and were relatively unaffected by the disease. In the remainder, the disease seemed to have been intensified by the warm water and losses were severe. Over the period from mid-February to early May, total mortality was 21·2% in the least affected and 77% in the worst affected batch.

By early June, there was a noticeable difference in size between fry reared at ambient water temperatures (average length 27·5 mm) and those subjected to

FIG 4
Ambient water temperature (full line) and heated water temperatures (broken line).



warmed water treatment (average length 34·0 mm). The experimental fish were fully twice as heavy as the controls, with a complete absence of "pin-heads".

There was no evidence of mortality from supersaturation of the warmed water with air, and little physical evidence (floating food or faeces) of the occurrence of this phenomenon, but regular monitoring of this feature is planned for 1974. More conclusive results will emerge from a longer-term experiment but the severe fuel shortage in December, 1973, made it impossible to begin experimental work at the green ova stage. Figure 4 shows the temperatures at which the warmed water was maintained, the reasons for the fluctuations and the ambient water temperature.

(b) Marking Techniques

(i) Cold branding

The brand marks used for reared smolts in 1972 proved to be less successful than earlier marks, when read on returning grilse in 1973. The marks were '*Z*', '*7*' and '*B*', of which '*Z*' was most easily recognisable, '*7*' was difficult to distinguish from '*Z*' and '*B*' was often blurred. Altogether, almost 20% of the brands were classed as doubtful and had to be checked against scale-reading for batch identification.

The branding tools used in the years 1971 and 1972 differed from those used in 1970 which gave highly successful marks on returning grilse. The former are mounted on solid brass handles whilst the latter are mounted on hollow copper tube handles which it is thought may give a colder tip temperature. A new series of branding tools have been designed for use in 1974, having copper tube handles and larger (3/8th" diameter) branding tips.

It should be noted that there were 13 examples of fish in 1973 which had easily discernable brand marks after 2 years in the sea, either as small spring fish or as previously spawned grilse.

(ii) Tagging

With increasing experience of using Floy tags on upstream-migrating reared grilse, the degree of tag loss lessened in 1973, with only some 5% of fish recorded with tag scars, during a period of up to six months after application. In addition, of 18 previously-spawned grilse recorded in 1973 which were tagged as grilse in 1972, only 5 had lost their tags over the intervening year. Some of these tags were difficult, but not impossible to read, due to fading and algal growth.

The comparison of the tags mounted on double wire attachments with those having a double polyethylene thread attachment was continued in 1973, using salmon kelts. Of 115 kelts tagged with double wire tags, there were 18 recaptures (15·7%), compared with 32 recaptures (21·2%) from 151 kelts bearing polyethylene thread tags. This confirms results obtained in 1970 and 1971 where the thread gave slightly better results but reverses the result in 1972 where the double wire attachment was the more successful. The comparison is to be continued in 1974 but it would appear that polyethylene thread is to be preferred, on the grounds that it gives equally good results and is just as easy and slightly cheaper, in use.

Smolt tags with thread attachments were used again in 1973 for sea trout kelts and gave a satisfactory return of 39·9%.

Only 40 wild salmon smolts were tagged (for demonstration purposes) in 1972, using double thread attachments and two recaptures (5%) were made as grilse in 1973.

FISH MOVEMENTS

This section deals with the results of census work on upstream and downstream migrants, 1973 being the fourth year in which a complete count was possible, following construction of the Salmon Leap installations in 1969.

(a) Upstream

(i) Salmon and grilse

The first small spring fish was recorded moving upstream on April 18 and was followed in May by 10 further specimens, two of which were reared fish. No two-sea-winter fish were seen in June but 12 small summer fish were noted in July. The small spring fish total was less than that of 1972 but the overall escapement of 2-sea-winter fish was almost exactly the same. The earliest fish (April 18) was stimulated to move upstream when the water temperature in the Mill Race increased from 6·5°C to 8°C over a period of two days.

During April and May, the resting pool below the Mill Race trap was fished frequently by one or more otters. From the evidence of scales found on rocks etc., at least 6 small spring fish were killed in this way.

The first wild grilse appeared on May 19 and was followed by 117 fish in June, including 42 at the Salmon Leap, although water levels were lower than was thought to be the minimum required. (See Fig. 3).

Grilse ran steadily throughout July in the Mill Race, with a moderate flood on July 19 bringing about a run of 107 fish on that day at the two traps. This run quickly tailed off at the Salmon Leap but continued at the Mill Race until August 10, when a high flood resulted in a count of 129 grilse at the two traps. Further floods were experienced in the latter half of August and the total for the month was 588. Water levels were low throughout September until the 26th, when a moderate flood brought about a heavy run of grilse at the Salmon Leap, with almost as good numbers at the Mill Race. Despite a succession of floods in October and November, the numbers of ascending fish were relatively small, indicating that when water levels are adequate for upstream movement throughout the summer, the vast majority of the grilse (97%) leave Lough Furnace by the end of September. It was interesting to note that the bulk of the grilse movement occurred on the rising flood and fell away at the height of the floods.

The current trend of increasing numbers of grilse, allied with a low count of two-sea-winter fish is illustrated by the comparison of the three five year averages for the Mill Race escapement: —

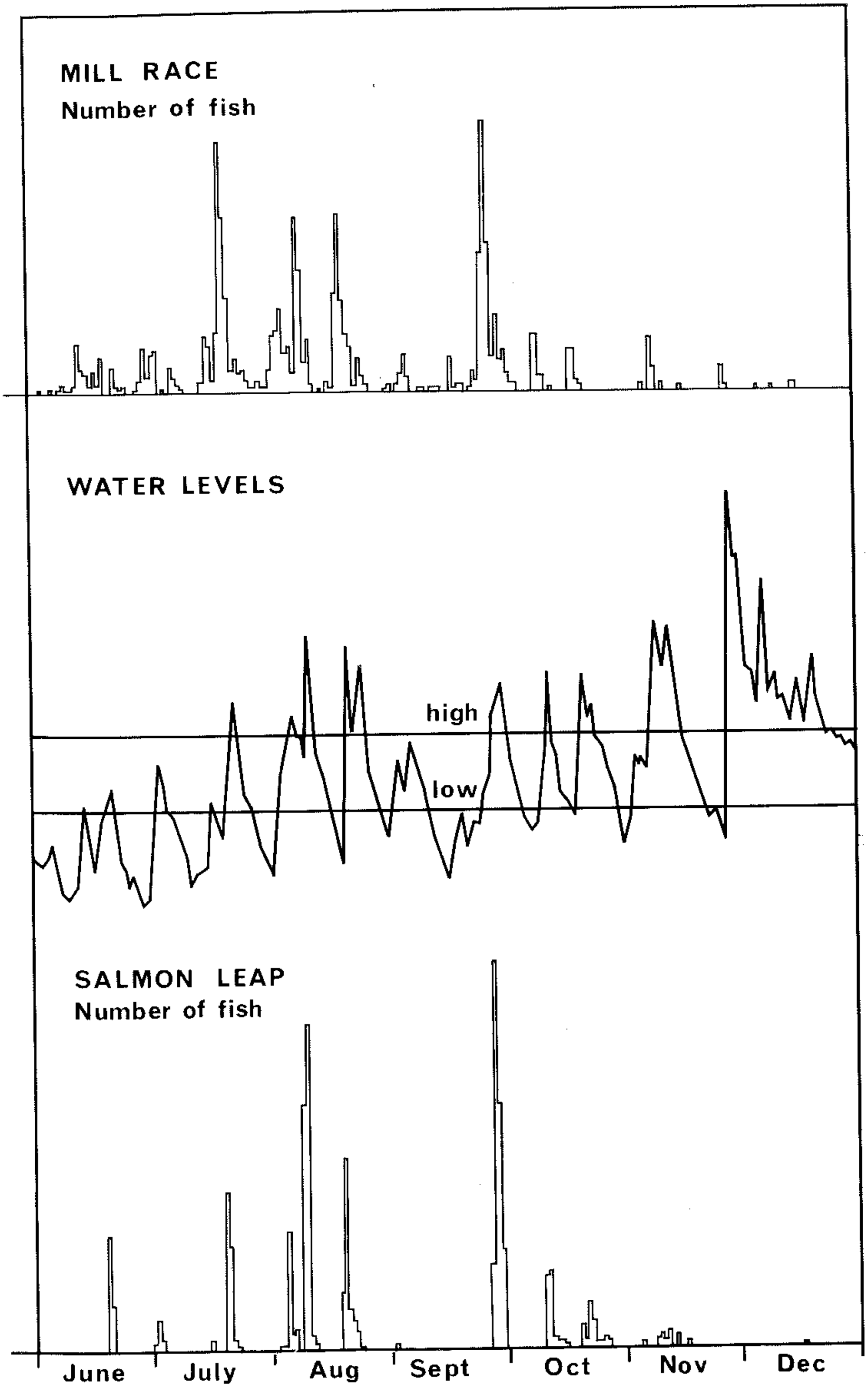
TABLE VI

	2 Sea winter-fish	Grilse
5 year average 1959-63	17	233
5 year average 1964-68	6	321
5 year average 1969-73	5	756

Table VII gives the comparative escapements of wild salmon and grilse through both traps for the years 1970 to 1973: —

TABLE VII

	Mill Race		Salmon Leap		Total	
Year	Salmon	Grilse	Salmon	Grilse	Salmon	Grilse
1970	0	468	0	620	0	1,088
1971	4	354	1	386	5	740
1972	3	1,024	18	345	21	1,369
1973	15	954	8	722	23	1,676


MILL RACE
Number of fish
WATER LEVELS
high
low
SALMON LEAP
Number of fish
June
July
Aug
Sept
Oct
Nov
Dec
FIG 3

In a year of adequate water levels and a succession of floods, the respective totals at the two traps were much more nearly similar than in 1972.

The total of 1,676 wild grilse counted through the traps is the largest to date and confirms that the technique of trapping, counting and releasing smolts is not having a deleterious effect.

Table VIII compares the monthly percentages of wild grilse counted through the Mill Race trap only, over the past few years, with the average values for the two five-year periods 1960-64 and 1965-69.

TABLE VIII

	1960-64	1965-69	1970	1971	1972	1973
June	16·8	11·6	8·1	2·8	7·2	9·4
July	24·2	18·9	16·0	16·7	6·2	26·0
August	34·4	29·8	27·1	11·9	32·5	31·4
September	13·8	21·4	43·6	35·6	0·2	22·6
October	3·3	10·4	3·6	22·3	42·7	7·7
November	4·2	3·3	1·3	10·2	9·9	2·4
December	3·3	4·6	0·3	0·5	1·3	0·5

As can be seen, there was a shift in emphasis of the main run in 1973, when the proportion in July increased whilst that of October decreased, by comparison with the past two years. The trend observed from comparison of two five year averages with the average for the past four years is still that of reduced numbers in June and July and increased numbers in August, September and October, as is shown in Table IX: —

TABLE IX

	1960-64	1965-69	1970-73
	%	%	%
June and July	41·0	30·5	23·1
Aug., Sept. and Oct.	51·5	61·6	70·3
November and December	7·5	7·9	6·6

For comparison with the results from the Mill Race trap, the monthly proportions of the run at the Salmon Leap are given in Table X, where it can be seen that fluctuating water levels have a more pronounced effect: —

TABLE X

	1970	1971	1972	1973
June	3·5	6·2	10·7	5·8
July	7·5	8·2	4·8	12·1
August	19·9	6·2	40·0	39·5
September	60·9	26·8	0·2	29·3
October	6·7	42·7	35·0	11·1
November	1·4	9·6	8·3	2·1
December	0·1	0·3	1·0	0·1

To summarise, the run of wild grilse in 1973 was the best recorded to date and included an improved proportion of early running fish which were able to move upstream into Lough Feeagh without delay, due to adequate water levels throughout the summer period.

(ii) Sea Trout

There was a further improvement in the count of sea trout through the trap in 1973, when the total of 2,844 represented an increase of 27·8% over the total of 2,205 in 1972. The large smolt run in 1972 gave rise to a heavy run of finnock (0+ sea years) later in the same year and the further increase in 1973 can be attributed in part to the survivors of these finnock plus the 1+ sea years maiden sea trout derived from the 1972 smolt run. In addition, the 1973 sea trout smolt run was even larger than in 1972 so that the finnock component of the 1973 smolts must also have contributed to the increased number of returning sea trout. Finnock were not as much in evidence in the Mill Race trap as in 1972 due to the prevailing high water levels in 1973, when small finnock can escape through the bars of the fish fence.

The totals for returning sea trout counted through both traps over the past four years are as follows: —

TABLE XI

Year	Mill Race	Salmon Leap	Total
1970	885	359	1,244
1971	889	518	1,407
1972	1,799	426	2,225
1973	1,596	1,248	2,844

For comparison with the run through the Mill Race only, in earlier years, the three 5-year averages are as follows: —

TABLE XII (Mill Race only)

Year	Total
1959-63	1,548
1964-68	1,345
1969-73	1,344

The timing of the upstream movement of sea trout in 1973 reverted more nearly to that of the years prior to 1969, when over 80% of the run was counted in June and July. From 1969 to 1972 there was a decreased proportion noted in July and/or an increase in August, where this seems to have been due to relatively lower water levels in June and July.

The monthly proportions of the run for the past four years are shown (in percentages) in Table XIII, drawn from the pooled monthly totals from both traps: —

TABLE XIII

	1970	1971	1972	1973
June	19·6	13·2	4·0	12·8
July	44·2	32·9	62·2	60·4
August	13·8	11·6	18·7	13·8
September	14·2	17·3	0·1	5·5
October	5·2	19·0	10·6	4·5
November	2·4	5·5	4·0	2·7
December	0·6	0·5	0·4	0·3

(iii) Spawning escapement to Lough Feeagh

(a) Salmon

TABLE XIV

	Wild		Reared
Counted through traps	1,666	+23	91
Rod catch on Lough Feeagh	90		1
Taken for hatchery use	114		63
Escapement	~~1,462~~	1485	27
Potential spawning stock	~~1,489~~	1522	—

Over the period 1963-1973 the sex ratio for grilse entering Lough Feeagh has been found to be 55 females to 45 males on average, ranging from 60:40 to 50:50 females to males.

(b) Sea Trout

TABLE XV

Counted through traps	2,844
Rod catch on Lough Feeagh	453
Escapement	2,391

Note that between 800-1,000 of these sea trout were finnock (0+ sea years) of which perhaps 200-300 will spawn. No accurate sex ratio has been determined for sea trout but it is suggested that the proportion of females may be as high as 75%.

This spawning escapement refers only to Lough Feeagh and its tributaries but some salmon and a fair number of sea trout are known to spawn in the tributary streams of Lough Furnace, below the traps.

The following table shows the spawning escapements of wild salmon and sea trout into Lough Feeagh, since 1970:—

TABLE XVI

	1970	1971	1972	1973
Wild Salmon	1,011	552	1,256	1,489
Sea Trout	1,017	1,249	1,883	2,391

DOWNSTREAM

(i) Salmon Smolts

The pattern of salmon smolt migration was much the same in 1973 as in 1972 in that the first smolts were seen in the traps on April 7, following a high flood and as the water temperature began to increase from 6°C. Relatively few (272) smolts were counted in April, with 90% of the run occurring in May, especially during the peak from May 5-17 when over 2,000 were counted on May 14. Water levels were low during April and early May but during the flood in mid-May, it was confirmed that larger numbers of downstream migrants use the Salmon Leap passage at high water levels.

The total of 11,282 smolts represents a 20% decrease in numbers compared with the average for the past three years, which cannot be ascribed to a poor year-class for the parent grilse (1970) run. As may be seen below, the sea trout smolts did not decrease in numbers, so that adverse climatic factors are unlikely to be responsible. The "fungus" disease described among reared smolts was also noted in a number of specimens of wild smolts during the 1973 run, so that it is possible that this disease may have accounted for part of the decrease in numbers.

Table XVII gives the annual totals of salmon and sea trout smolts for the past four years, when complete census has been possible:—

TABLE XVII

Year	Salmon Smolts	Sea Trout Smolts
1970	14,637	3,228
1971	13,915	2,961
1972	14,081	5,465
1973	11,282	6,071

(ii) Survival of salmon smolts

The salmon smolt run in 1972 was 14,081 and there were 1,676 wild grilse counted through the traps in 1973. A further 110 grilse were caught by rod-anglers on Lough Furnace so that the total survival may be said to be 1,786 grilse from 14,081 smolts, or 12·7%. This is the best survival rate recorded over the past four years of complete census.

The figure of 10·9% survival from smolt to grilse in 1971/2 has now been increased to 11·0% by the addition of 13 specimens of 2-sea-winter fish, returning in 1973.

In tabular form, the results for salmon smolt survival over the past four years are as follows:—

TABLE XVIII

	Smolt numbers	Returning salmon	% Survival
1969	12,000-14,000 (estd.)	1,288	9·2-10·7
1970	14,637	811	5·5
1971	13,915	1,534	11·0
1972	14,081	1,776	12·6

(iii) Sea trout smolts

The sea trout smolt migration began on March 26 and ended three months later on June 26 with a pronounced peak from May 5-17, as for the salmon smolts, when 85% of the run was counted. The total of 6,071 represents an increase of 11·1% over that of 1972, itself a record, although the large run in 1973 was not followed by a heavy finnock run, as in 1972.

The reasons for this increase in sea trout smolt production over the past two years are not known but may become apparent with continuing study and comparison of future trends in the production of both salmon and sea trout smolts.

(iv) Kelts: 1972-73 spawning season

(a) Salmon

TABLE XIX

	Counted through traps
November 1972	3
December 1972	80
January 1973	149
February 1973	32
March 1973	133
April 1973	17
May 1973	2
Total	416

comprising 361 females: 55 males.

As in 1972, the wild salmon kelt total was evenly divided between the two traps and tagging commenced on December 30, 1972. Only 266 kelts were adjudged healthy enough to tag, the remaining 150 having been released owing to moderate or severe "fungus" infection.

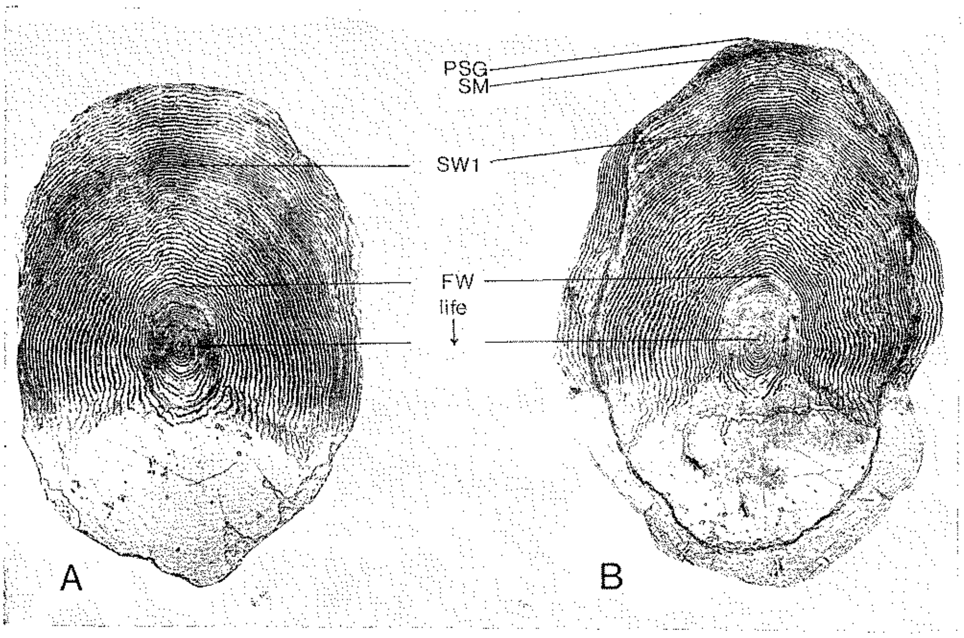
Survival to the previously-spawned grilse stage in the summer of 1973 was good, with a total of 50 recaptures (18·8%) from the 266 tagged kelts. Those tagged with double polyethylene thread attachments gave a better return (21·2%) than those with double wire attachments (15·7%).

There were 8 recaptures out of the total of 50 from drift nets operating in coastal waters from northern Co. Donegal as far south as Mason Island on the north shore of Galway Bay. Two recaptures were made south of the home river in 1973, where this is the first occasion in the past 16 years when returning fish are known to have strayed south of Clew Bay. A further recapture from the Connemara drift nets was reported but the tag was not available for checking.

Two recaptures were made in estuary nets operating in the Newport River which is separated by only a narrow neck of land from that of the Burrishoole (home) river.

One recapture of a fish tagged as a grilse kelt was made off S.W. Greenland on 27/8/73 in a position 65°30'N, 53°28'W. Two other examples of Greenlandic recaptures were noted in *Ann. Rep. IX* (1964) from a similar position, near Kangamiut. These fish were "long-absence" grilse kelts which spend 12-15 months in the sea, returning in the April/May period of the year following that of descent as kelts. The evidence for this type of kelt behaviour was presented in *App. IV of Ann. Rep. VIII* (1963). Photomicrographs of the scales of the fish when taken are shown in Plate I.

PLATE I



Comparison photomicrographs of scales taken from:
A: grilse kelt, tagged 3 March, 1973; B: same fish, on recapture off S.W. Greenland, 27 August, 1973.
FW life: freshwater life. SW1: first winter in the sea. SM: spawning mark. PSG: post-spawning growth, on return to the sea.

The known spawning escapement in 1972 was 1,256 wild fish which may be assumed to have comprised 691 females and 565 males, taking a sex ratio of 55 females to 45 males, as has been found in earlier determinations. The total number of kelts counted down through the traps was 416 (33·1%) from the escapement of 1,256 but the total of kelts which were in a healthy condition was only 292 (23·2%). This was an improvement over the previous year when 16·3% survived to the healthy kelt stage.

Female fish constituted the bulk of the well-mended kelts, only 2% of the male spawners surviving to this stage, compared with 39·4% of the females.

Comparable survival rates over the past three years (calculated from the escapements in the preceeding years) are shown in percentages in Table XX: —

TABLE XX

Survival from total escapement by sex			Survival as:	
Year	Females	Males	Total kelts	Healthy kelts
1971	50·1	7·7	40·0	33·1
1972	26·0	2·0	22·1	16·3
1973	39·4	2·0	33·1	23·2

Previously spawned fish constituted a total of 39 (including 1 long-absence previously-spawned grilse) out of 1,666 wild fish counted up through the traps in 1973. If it is assumed that approximately 900 of these fish were females, previous spawners comprised 4·3% of the total female population.

The average absence period for the 37 short-absence fish counted back through the traps was 184 days, which was rather less than the average (200 days) for the previous two years. Individual absence periods ranged from 92 to 273 days.

The average growth increment was 6·5 cm (2·5 ins), compared with 6·2 cm in 1972 and 6·4 cm in 1971.

There was a slight tendency for returning fish to ascend the route they had used when moving downstream as kelts, in that a larger proportion of the kelts tagged at the Salmon Leap were recaptured there, rather than at the Mill Race.

(b) Sea trout

The earliest sea trout kelts were noted on November 2, 1972, and the run continued until late May, with a distinct break in February between the earlier, dark kelts and the bright, well-mended kelts which ran later. Only 59 fungused kelts were seen in the earlier part of the run, constituting 2·7% of the total of 2,149 kelts. Of these, 935 were counted at the Mill Race and 1,214 at the Salmon Leap and of the total, 854 were over 30 cm in length whilst 1,295 were finnock kelts of under 30 cm fork length. For the first time since census records have been available from both traps, the count of kelts down (2,149) has not exceeded the count of sea trout up in the preceeding summer (2,225).

In 1971 and 1972, there was a 25% discrepancy in these figures, due, it was suggested, to small upstream-migrating finnock being able to squeeze through the bars of the Mill Race fish fence and trap heck. This was proved, in 1973, when a second upstream heck, having bars at ½" spacing, was installed upstream of the original heck with 1¼" spaced bars. A number of finnock were able to pass through the first heck but were stopped by the second.

In the summer of 1972, however, the bulk of the finnock migration occurred during very low water conditions in July, when it is thought that only a small proportion were able to swim over the fish fence sill and through the bars of the fence. In consequence, the count of finnock through the trap was much more nearly complete than in years when high water conditions prevailed.

Sea trout kelt tagging began on December 30, 1972, and in all, 669 fish of over 30 cm in length were tagged with dark green, rectangular plastic tags (15 x 4 mm), using double polyethylene thread attachments. There were 267 recaptures (40·0%) during the following summer, made up of 97 out of 243 (40·0%) from the Mill Race and 170 out of 426 (40·0%) from the Salmon Leap. The figure of 40% recaptures may be compared with 30% in 1972 and 37% in 1971.

An extraordinary feature of these recaptures is that only one was taken by a rod angler in Lough Furnace, the remainder having been recorded in the trap catches. One further tagged fish was taken by a rod angler in Lough Feeagh after having been checked through the trap 12 days previously. A recapture was reported from Stranraer, Wigtownshire, Scotland of a sea trout bearing one of our tags and weighing 1 lb $10\frac{1}{2}$ ozs but unfortunately, the tag had been lost from the letter before it was received by the Trust. Only one tagged sea trout was recorded moving downstream as a kelt which had not been checked moving upstream, by December 31, 1973.

In a summer of adequate water levels for upstream migration, it appears that some selectivity of route may exist, in that a slightly greater proportion (32%) of fish tagged at the Salmon Leap returned to fresh water by this route than did those tagged at the Mill Race (23%).

The averages for growth increment and absence period in the sea are shown in Table XXI for comparison with results from 1971 and 1972, as well as the average for the period 1960-66.

TABLE XXI

Year	Growth Increment (cm)	Absence period (days)
1960-66 (average)	4·0	99
1971	3·8	155
1972	4·2	124
1973	4·3	113

(c) Recaptures of fish tagged prior to the 1972-73 season

(i) Salmon

Only one recapture of a long-absence, previously-spawned grilse occurred in 1973, bringing the total recapture rate of 1971/72 tagged kelts to 21·6%. Details of the fish are as follows:—

No. H267 tagged 19/1/72. Length 58·3 cm.
Recaptured 21/7/73. Length 76·0 cm (female).

(ii) Sea trout

The recapture of 132 tagged sea trout kelts in 1972 was increased to 149 by 17 kelts with tags that had been missed in the upstream traps. A further 6 fish were noted in the upstream run of 1973 which had not been seen as fresh fish or kelts in the preceding season, where it is fair to assume that these fish were "wanderers" and had not returned to the home river system in 1972. The known overall recapture rate from 510 kelts tagged in 1971/72 was increased therefore to 155 (30·4%). Although the proportion of tags missed in the upstream traps in 1972 showed a decrease over that of 1971, the true survival rate was likely to have been of the order of161 out of 510 (31·6%) as fresh fish in the first summer after release.

Of 95 kelts bearing 1971/72 tags, checked downstream in 1972/73, there were 39 recaptures as fresh fish (41%) in the summer and autumn of 1973.

Further recaptures were made in 1973 of sea trout kelts tagged in the 1970/71 season, including:—

3 as fresh fish, after recorded as kelts in 1972/73.
2 as kelts, not having been recorded previously.
7 as kelts, after recorded as fresh fish in 1972.

(d) Silver Eels

Water conditions were adequate for eel migration throughout the autumn of 1973, when the first fish were seen in the Salmon Leap trap in late August. The bulk of the run occurred in late September and October and the overall catch was 62% up on that of 1972. It might be that a proportion of the eels that failed to migrate in the dry autumn of that year, did so in 1973. Details of the catch are as follows:—

	Mill Race	Salmon Leap	Total
August	—	296	296
September	801	1,014	1,815
October	569	1,560	2,129
November	336	498	834
December	—	13	13
	1,706	3,381	5,087

The total catch was estimated to weigh 900 lbs (409 kg).

(e) Autumn migrating trout

The total of 2,606 autumn migrating trout in 1973 represented an improvement on that of 1972 (2,124) but was not as high as in 1970 and 1971. The proportion of these fish suffering from "fungus" disease increased markedly in 1973, when 90 specimens were noted with the disease, to a greater or lesser degree. This is the same disease as that which afflicts yearling salmon in the rearing ponds and which is now endemic in the river system. Details of the run of autumn trout are as follows:—

	Mill Race	Salmon Leap	Total
August	—	65	65
September	114	430	544
October	258	614	872
November	229	422	651
December	253	221	474
	854	1,752	2,606

90 diseased = 3·45%

SMOLT TAGGING AND MARKING

The marks used on two categories of reared salmon smolts in 1973 were as follows: —

Type of fish	Number	How marked
2+ grilse smolts	2,974	Brand mark 'X' + adipose fin-clip
1+ grilse smolts	2,505	Brand mark 'O' + adipose fin-clip
Total reared smolts	5,479	

RECAPTURES FROM TAGGING OF WILD SMOLTS

Only 40 wild salmon smolts were tagged in 1972 for demonstration purposes but there were 2 recaptures (5%) as grilse in 1973: —

No. 2118: tagged 17/5/72: length 13·0 cm: recaptured 21/10/73: length 67·0 cm, male.

No. 2130: tagged 23/5/72: length 15·0 cm: recaptured 21/10/73: length 63·0 cm, female.

There were two further recaptures as maiden sea trout from the tagging of 500 wild sea trout smolts in 1971. This gives an overall recapture rate of 3·6%.

Details: —

No. 1323: tagged 21/5/71: length 17·5 cm: recaptured 1/10/73: length 32·0 cm, female.

No. 1417: tagged 24/5/71: length 18·0 cm: recaptured 4/8/73: length 45·5 cm, female.

RECAPTURES OF REARED FISH

As stated in the foreword, one of the primary aims of the Trust was to study the question as to whether grilse and salmon constitute genetically distinct stocks. Work under this heading has been in progress since 1960 and the results to date are discussed in detail in Appendix I to this Report.

The return of reared smolts released in 1972 was disappointingly low as grilse in 1973, after the very high recapture rates recorded in 1972. Only 100 maiden fish (92 grilse and 8 two-sea-winter fish) were noted in 1973, the low recapture rate being attributable to deaths from disease at the smolt and immediate post-smolt stages.

The returning fish in 1973 may be divided into the following categories: —

(i) 2+ smolts, grilse parentage, released in 1972, branded 'Z'. Smolt total: 3,544. Returns as maiden grilse: 55 : 1·55%.

(ii) 1+ smolts, reared grilse parentage, released in 1972, branded '7'. Smolt total: 2,656. Returns as maiden grilse: 24 : 0·92%.

(iii) 1+ smolts, wild grilse parentage, released in 1972, branded 'B'. Smolt total: 1,706. Returns as maiden grilse: 13 : 0·76%.

(iv) 2+ smolts, grilse parentage, released in 1971, branded 'V'. Smolt total: 7,653.

Returns as maiden grilse: 527 : 6·87%.
Returns as small spring fish: 3 : 0·045%.
Returns as small summer fish: 3 : 0·045% = 6·96%.

(v) 1+ smolts, grilse parentage, released in 1971, branded 'H'.
Smolt total : 1,567.

Returns as maiden grilse: 62 : 3·96%.
Returns as small spring fish: 1 : 0·06%.
Returns as small summer fish: 1 : 0·06% = 4·08%.

(vi) Previous spawners: 17 : from 2+ smolts, grilse parentage, released 1971, branded 'V'.

The maiden grilse returning in 1973 were derived largely from the grilse year-class which returned in 1969, which was the most successful group until 1972, so that any selective breeding factor present was nullified by the disease which appeared among the smolts whilst they were in the release ponds.

Again, 1972/73 was a good year for survival of wild smolts to the grilse stage, so that adverse conditions in the sea were not responsible for the decline in the survival rate of reared smolts. This result further underlines the necessity for rapid disease diagnosis and control in salmon rearing operations, because mortality at the smolt stage represents a complete waste of effort for up to two years.

The 117 recaptures were made in the following ways:—

97 in the Mill Race trap
7 in the Salmon Leap trap
9 by rod-fishing on Lough Furnace
3 in coastal drift-nets
1 in estuary drift net.

The 9 rod-caught specimens represent only 8% of the total rod-catch on Lough Furnace, from which it appears that reared grilse were affected to at least the same degree as wild grilse by the poor angling conditions in 1973.

The results for the freshwater angling on Lough Feeagh were worse than usual for reared fish, in that only 1 specimen was caught out of 74 "available" by October 12. As has been reported previously, reared grilse which have passed their homing point at the Mill Race, seem disinclined to settle down in Lough Feeagh and seldom make any worthwhile contribution to the rod-catch on that lake.

The usual "multiple return" habit of these grilse was noted again in 1973, in that of 75 fish passed through the upstream traps by October 19, 52 (69%) migrated back down the Salmon Leap, below which they were released, and re-appeared in the upstream trap on the Mill Race. After October 19, all reared grilse were held for hatchery parent stock, effectively putting a stop to this behaviour.

It should be noted that even when ample water existed for fish movement up the Salmon Leap throughout the summer and autumn, the reared grilse returned to the Mill Race, by a factor of 14:1. The comparable figures for wild grilse were 9:7. A number of reared grilse exhibited highly developed homing behaviour, in that they selected a very small side stream, some thirty yards from the Mill Race proper for their ascent into fresh water. This side stream is fed by a 9" pipe from the Mill Race but also carries the outflow from the rearing ponds and on several occasions it was by no means unusual to see 10-15 reared grilse held up in the pool below the outflow of the 9" pipe and pond water. Four other specimens moved into the release ponds during floods and two of them were stranded there before grids were installed.

As in 1972, some reared smolts whose parents and grandparents are known to have been grilse, returned as small spring-fish and small summer fish (2-sea-winter fish). In 1973, there were 8 such recaptures, 6 derived from 2+ smolts (3 spring fish, 3 summer fish) and 2 from 1+ smolts (1 spring fish and 1 summer fish). Recaptures as small summer fish from grilse parentage smolts were recorded prior to 1972 (27 recaptures in all) but the 8 spring fish in 1972 and the 4 in 1973 were the first examples of this behaviour pattern.

Various explanations of this behaviour can be postulated, including alterations in sea migration and feeding habits brought about by as yet unknown oceanographical changes, from which it would follow that the sea absence habit must be genetically plastic and capable of being influenced by the environment. Alternatively, the 2-sea-winter habit may be recessive in character becoming more prominent with continued in-breeding of grilse. The fact that small summer fish derived from grilse parentage smolts were recorded in earlier years proves that grilse return from grilse smolts is not inevitable. A 2-sea-winter habit is more likely however, from smolts of the corresponding parentage (See Table XXIII). No attempt was made to retain the 2-sea-winter reared fish for hatchery parent stock in 1973, due to current difficulties experienced from disease, including U.D.N.

Summary

The returns in 1973 reverted to the levels recorded in 1971, considerably below those of other years since 1968, due, it is thought to disease at the smolt stage.

Smolt type	1968	1969	1970	1971	1972	1973
2+ grilse	4·41	5·20	3·04	1·27	7·00	1·55
1+ grilse	2·91	4·02	1·25	1·65	4·08	0·85

The total of reared fish recaptures now stands at 2,762, starting in 1962, as follows:—

TABLE XXII

Year	Smolts released	No. recaptured
1962	8,000	12
1963	9,420	51
1964	4,787	19
1965	6,630	33
1966	9,764	62
1967	10,250	194
1968	14,260	490
1969	17,317	654
1970	16,636	312
1971	10,219	136
1972	10,237	682
1973	7,906	117

Excluding the previous spawners, these fish can be divided into the following categories:—

TABLE XXIII

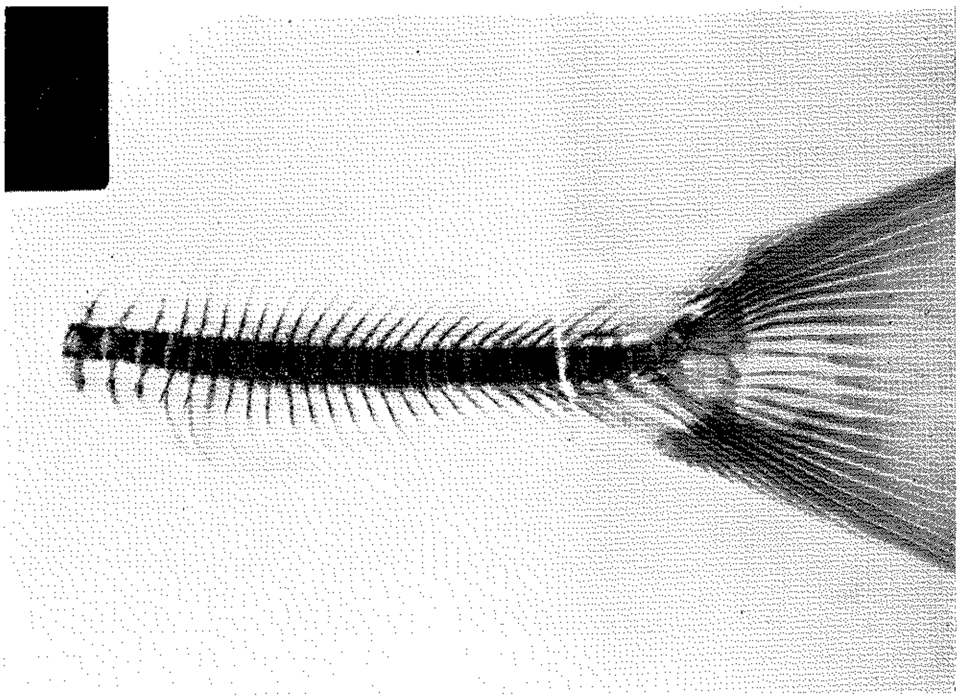
Smolt parentage	Returned as grilse	2-sea-winter fish*	Pre-grilse
Spring fish	183 (87%)	27 (13%)	0
Grilse	2,290 (98%)	43 (2%)	4
Spring fish X Grilse	147 (96%)	6 (4%)	0

* Includes both small spring and small summer fish (2 and 2+ sea age groups).

The sex ratios of returning grilse were almost exactly those recorded in 1972. The grilse from 1+ smolts gave a ratio of 68 females to 32 males whilst those from 2+ smolts were 60 females to 40 males. The overall return was not large enough to permit significant conclusions to be drawn for sex ratios and size of each sex by month of return but there was a tendency for males to be more numerous in the last three months of the year. In 1973, the average sizes of the two sexes in the two smolt year-classes were similar, as opposed to earlier years when males were larger: —

	1+ smolt grilse	**2+ smolt grilse**
Males	64·2 cm	63·7 cm
Females	62·2 cm	64·3 cm

PLATE II



X-Ray positive of distal portion of the vertebral column of a grilse showing the "stumpy tail" deformity. Note the biconcave disc appearence and compaction of the ventabrae. The fracture occurring close to the origin of the caudal fin rays was caused after death, during preparation of material.

The foreshortening of the caudal peduncle in some fish (see Plate II) resulting in a decrease in overall average length, first noted in 1972, was noted again in 1973 when 10% of the maiden grilse exhibited this feature, this being the same proportion as in 1972. The larger grilse reached a length of 72 cm, weighing almost 10·0 lbs (4·5 kg). The average length of the complete sample of maiden grilse was 63·5 cm and the mean coefficient of Condition for rod-caught fish was 1·05.

The time of appearance of trap-caught reared smolts differed only slightly from that of the wild fish, with a reduced proportion in September and an increased proportion in November.

TABLE XXIV

	Wild fish %	Reared fish %
June	9·4	2·2
July	26·0	30·4
August	31·4	37·0
September	22·6	13·0
October	7·7	7·6
November	2·4	8·7
December	0·5	1·1

ULCERATIVE DERMAL NECROSIS (Salmon Disease)

(a) 1972-73 spawning season

The incidence of U.D.N. among kelts, as adjudged from slightly and heavily fungused fish increased again in 1973, although the onset of the disease was delayed until mid-December, 1972. Thereafter, and particularly during January, a high proportion of "marked" kelts was seen in the traps although the proportion of heavily-fungused, moribund kelts was rather less than in the preceding season. Many of the lightly-marked kelts were tagged and three survived to spawn for a second time in 1973. All traces of infection had disappeared by mid-March, somewhat earlier than in 1972.

As in 1972, the male fish were badly affected, when only four were healthy enough to tag, compared with 262 females. The full results for percentage infection of kelts by monthly totals is given in Table XXV below, with comparative results for the three preceding years: —

TABLE XXV
Percentage U.D.N. infection in downstream migrating salmon kelts

	1969/70	1970/71	1971/72	1972/73
November	0	20	10	0
December	70	58	40	32
January	70	55	69	78
February	20	7	30	8
March	0	5	0	0·7
April	0	0	7	0
	—	—	—	—
% total run	21	21	32	37

Infection among sea trout did not appear until early December and had disappeared by mid-February, with a total incidence of 59 out of 2,149 (2·7%), compared with 4·8% in 1972.

Juvenile trout, with external signs exactly the same as those of "fungus" disease appeared in the downstream traps in late December. Thereafter, the incidence of infected fish was 10% in the months of January and February, declining to 3% in March. Very occasional specimens of salmon and sea trout smolts were seen with fungal "waistcoats", in the pectoral fin region.

(b) 1973/74 spawning season

Only 7 salmon were seen in the upstream traps in December, 1973, and 4 of these exhibited skin lesions and white patches on the heads and bodies.

Deaths occurred among hatchery parent salmon in holding ponds from November 17 onwards and despite treatment with Malachite Green every two days, over 50% of the stock of fish for the experimental hatchery had died by December 19, without having been stripped. Even heavier mortalities were experienced among the stock for the commercial hatchery, where two-thirds of the females died from UDN and fungus infection before stripping.

Infected kelts appeared in the downstream traps from December 11 onwards and by the end of the month, every kelt was marked to some degree. The overall incidence of infection for the month was 78%, including both ripe grilse and kelts, compared with 32% in December, 1972.

Marked sea trout were noted as early as November 5 and the timing and degree of infection resembled that of 1971, in contrast with the late, light infection experienced in 1972. The incidence of infection was 23% in November and 27% in December, although the worst of the disease appeared to have passed by the end of December.

A similar situation obtained with juvenile trout migrating downstream, when signs of "fungus" disease were noted from November 4 and the incidences of infection were 24% for November and 22% for December. This was a very considerable increase over that found in 1972 (5·5%).

Thus, the early onset and severity of UDN and "fungus" disease in late 1973 indicated that the infection has by no means run its course and it is probable that considerable losses will be experienced from this cause for some years to come.

EFFICIENCY OF ROD FISHING

Records now exist of the rate of exploitation of stocks of wild and reared salmon, as well as sea trout, by rod fishing (fly only) since 1970. Accurate assessments can be made for Lough Feeagh but the unknown factor of the numbers of salmon and sea trout spawning in the streams flowing into Lough Furnace render it necessary to make an estimate of the minimum overall rate of exploitation. The maximum rates are correct, since they assume no spawning in the Lough Furnace tributaries but tentative correction values for Lough Furnace salmon have been included, where these are probably slightly over-estimated, since only one stream is used to a minor extent by spawning salmon. Salmon derived from reared smolts are treated separately in Table XXVI below, which gives the comparative values for the years 1970-72. Due to the difficulty of forming a reliable estimate of the numbers of sea trout which spawn in the Lough Furnace tributaries, no attempt has been made to define the overall exploitation rates of sea trout for the complete fishery system. It should be noted that 591 sea trout were caught on Lough Furnace during 1973, some of which were obviously destined to spawn in the Lough Feeagh tributaries. (See frontispiece for geography of Burrishoole River System.)

TABLE XXVI

WILD SALMON				
Lough Feeagh	**1970**	**1971**	**1972**	**1973**
"Available" wild fish by October 12	961	546	1,033	1,572
Rod catch	72	33	118	89
Rate of exploitation of stock	7·5%	6·0%	11·4%	5·7%

Loughs Feeagh and Furnace	1970	1971	1972	1973
Total stock of wild fish	1,352	790	1,373	1,676
After estimated correction for Lough Furnace residents	1,502	890	1,523	1,876
Total rod catch of wild fish	309	75	335	190
Maximum rate of exploitation	22·9%	9·5%	24·4%	11·3%
Minimum rate of exploitation	20·6%	8·4%	22·0%	10·1%

REARED SALMON

Lough Feeagh

"Available" fish by October 12	216	66	385	74
Rod catch	5	3	10	1
Rate of exploitation of stock	2·3%	4·5%	2·6%	1·4%

Loughs Feeagh and Furnace

Total stock	312	136	682	113
Total rod catch	45	11	83	10
Rate of exploitation of stock	14·4%	8·1%	12·2%	8·8%

(Note the low exploitation rate of reared salmon, compared with wild salmon, in Lough Feeagh.)

SEA TROUT

Lough Feeagh

"Available" fish by October 12	1,194	1,246	1,977	2,699
Rod catch	225	158	342	453
Rate of exploitation of stock	18·8%	12·7%	17·3%	16·8%

Summary

Conditions for rod fishing were poor during the 1973 season, when the continuous succession of floods in June, July and August (see Fig. 3) are thought to have contributed to an "unsettled" condition in the fish, when little, if any, "free-rising" activity was observed. The exploitation rates for salmon, in particular, were only half those of 1972 and but for good catches at the end of the season, would have been much lower. Sea trout, particularly the smaller specimens, were less affected by the adverse conditions and the exploitation rate for Lough Feeagh was only slightly lower than that for 1972.

SPONSORED RESEARCH

Mr. M. Parker, B.A. (Mod.) of Trinity College, Dublin, continued his research on the organic nutrients in Lough Furnace in respect of *Neomysis integer* and has contributed an account of some of his results in Appendix II to this Report. Mr. Parker received a supplementary grant from the Trust towards the cost of travel and accommodation and was allowed laboratory space and other facilities for his studies.

Mr. J. K. Field has submitted a summary of the work he carried out on the plankton of Lough Feeagh in 1972 and this is published as Appendix III to this Report.

GENERAL

Dr. Went and Dr. Piggins attended meetings of the Salmon Research Group held in London in May and November. Dr. Piggins accepted an invitation to become a full member of this Group in December. The April meeting was followed by a visit to Vortex Ltd. of Stow-on-the-Wold, Glos., where new types of fish rearing equipment were inspected. Dr. Piggins made two advisory visits overseas during 1973; the first at the request of the Highland Trout Co., Argyllshire and the second to the Lessees of the Aroy River, in Norway. He has undertaken also to advise on the construction of hatchery facilities for the owners of the Erriff River, Co. Mayo.

Dr. Went and Dr. Piggins made a study tour of salmon research and management projects in France and Spain, during June. This tour was facilitated by the kind co-operation of Dr. R. Vibert, Director, Scientific Research Centre, Biarritz, M. Jacques Arrignon, Engineer-in-charge, 1st Fishery Region, Compiègne and Señor Juan Jesus Molina, Head of the Provincial Icona at Oviedo.

Dr. Piggins attended the meetings of the Anadromous and Catadromous Fish Committee of the International Council for the Exploration of the Sea, held in Lisbon from October 2-5 and afterwards attended a meeting of the Scientific Advisory Committee of the International Atlantic Salmon Foundation, at Frederickton, N.B., Canada.

Dr. Went and Dr. Piggins also attended the London Conference of the Salmon and Trout Association, in November.

ACKNOWLEDGEMENTS

The Committee expresses its appreciation to the Minister for Agriculture and Fisheries, and to the staff of his Department for their valuable assistance during 1973.

APPENDIX I

THE RESULTS OF SELECTIVE BREEDING FROM KNOWN GRILSE AND SALMON PARENTS

D. J. Piggins

INTRODUCTION

The question of whether the sea absence period of maiden salmon was governed by heredity or was due to the influence of the environment solely, was one of the primary objectives of the work of the Salmon Research Trust of Ireland, begun in 1957 and which has continued to the present day. In the text which follows, two-sea-winter fish have been given the abbreviation '*2SW*' and grilse are referred to as '*G*' for purposes of convenience in discussing parentage, etc. of smolts.

MATERIALS AND METHODS

Smolts were reared artificially in conventional, circular ponds to the 1+ and 2+ years stages, from eggs derived from wild parent fish initially, whose sea absence period was determined by scale reading, before stripping. In the early years, much had to be learned about the basic techniques of rearing viable smolts and considerable improvements were made in the diet, feeding methods, marking and release techniques and disease control, before significant returns of grilse and salmon were obtained. Recapture rates did not exceed 1·0% of the smolts released until 1967, when returning grilse were themselves the progeny of "reared" grilse which had returned in 1963. This element of selective breeding is thought to be a major factor in the improved recapture rates (up to 7·0%) of later years, allied with the technical improvements noted above. Since 1971, parent fish for selective breeding have been third-generation grilse and the first fourth-generation fish are due in 1975.

The breeding of selected stocks has been confined to the grilse strain, due to the paucity of two-sea-winter fish in the experimental river system. A reasonable stock existed until about 1963, although most were caught in a commercial drift net which operated in the brackish water of Lough Furnace. There followed a pronounced recession in the stocks of small spring fish which appears to have been a cyclical phenomenon, fairly general throughout Ireland as a whole, followed by some slight improvement in the early 1970's. The presence of UDN in the system has effectively prevented these more recent stocks from being held for stripping from perhaps April, until early December.

Spring fish parentage smolts were released every year from 1960 to 1969 inclusive, and smolts derived from crossing 2SW females with G males were released in 1965 and 1966. Grilse parentage smolts have been released in every year up to the present. It should be noted that all 2SW fish employed in this breeding programme were wild fish and no second generation 2SW stock has been produced, as yet. The earliest eggs were obtained from the Blackwater River in Co. Cork, followed by native stocks until 1967, when eggs of Scottish origin were obtained.

RESULTS AND DISCUSSION

In the following discussion of the results, the returning maiden fish have been divided into grilse and 2SW fish, without making any distinction between small spring fish and small summer fish (2 and 2+ sea age groups). It should be noted, however, that small spring fish derived from G-parentage smolts have appeared only since 1972, when the remainder were small summer fish, as determined by the somewhat arbitrary technique of scale-reading. The reason for this is unknown but a possibility exists of the emergence to a greater degree of recessive characters in the grilse strain, with continued in-breeding. Only one large spring fish has been recorded in these experiments, when it was derived from a 1+ smolt of 2SW parentage, released in 1957. The sea migration pattern of artificially reared smolts of 2SW parentage is thought to be normal for that element of the population which develops into 2SW fish, in that two tagged specimens were recaptured off Greenland, in 1970.

The results are set out in numerical form in Tables I and II and some interesting relationships have become apparent.

Firstly, the overall recapture rates of 2SW smolts have been lower than those of G smolts by a factor of approximately 1 : 4 where this may be explained on three counts. The 2SW smolts (as noted above) have been the progeny of wild parents, with no element of "line-breeding" in their genetic make-up, as has been the case for G smolts since 1963. Secondly, there were no 2SW smolts released in the years 1970-72, when almost 900 returns accrued from G smolts and thirdly, the longer sea absence period involved in returns as 2SW fish may result in less good natural recapture rates.

There seems little doubt that 2SW smolts give rise to a greater proportion of 2SW fish than do G smolts, by a factor of over 7 : 1. A similar factor is operative when 1+ 2SW smolts are compared with 1+ G smolts (8 : 1) and as between 2+ 2SW smolts and 2+ G smolts (almost 8 : 1). It is apparent from Table II however, that 2SW smolts have consistently produced more grilse than 2SW fish, even though the proportion of the latter has been higher than for G-parentage smolts. This is thought to be due to an overriding effect of a grilse environment on the genetic traits of 2SW fish.

It would appear that 1+ smolts produce a higher proportion of 2SW fish than 2+ smolts, irrespective of parentage, when in the cases of all three types of smolts produced, a factor of approximately 3 : 1 appears to operate in favour of 1+ smolts producing 2SW fish. It should be noted too, that the overall recapture rates from 1+ smolts are less than those from 2+ smolts, for all three smolt types.

Those smolts which were the result of crossing 2SW females with G males were intermediate in all respects between the two "pure lines". They produced a higher proportion of 2SW fish than did G smolts but less than was the case for 2SW smolts and the 1+ smolts produced almost three times as many 2SW fish as did the corresponding 2+ smolts from the same egg year-class. The results for the overall recapture rates for this group are not strictly comparable in that they refer to only one generation, which was reared at a time when techniques were fairly well advanced and thus take no account of the low recapture rates experienced for the other two groups in the early years of the experiment.

Thus, the results from the selective breeding programme would appear to indicate that a definite hereditable factor is involved in returns of maiden fish as grilse or two-sea-winter fish. This hereditable factor seems capable of being influenced by the environment however, in that 2SW parentage smolts produced more grilse than two-sea-winter fish, under the conditions of these experiments. It is possible too, that artificial rearing may reinforce or even superimpose a grilse-type return habit on a recessive 2SW parentage. This seems unlikely to be due to an artificial emphasis being placed on fast-growing smolts, since the fastest growing smolts (1+ yrs at release) have produced more 2SW fish than have 2+ smolts, irrespective of parentage. It is possible that an extra year of smolt life allows more time for any environmental influence to be exerted on the genetically controlled physiological basis of the sea absence period.

The results from one experiment involving "hybrids" between 2SW fish and grilse support the concept of an hereditable factor being involved.

One further facet of the grilse-salmon relationship, unconnected with the selective breeding experiments, has emerged from census work on the wild salmon population, allied with tagging of well-mended kelts. It had become apparent by 1961 that a small proportion of grilse kelts spent one year or more in the sea, before returning for a second spawning, as opposed to the majority which spent only 4-8 months away, returning in the same year as that of descent as kelts. Kelts of 2SW fish were found invariably to spend one year or more away at sea before returning for a second spawning.

These findings were confirmed and expanded in 1968 and a number of further examples of this behaviour have been noted since that time. These "long-absence" grilse kelts appear to undertake an aberrant migration route in the sea, in that three tagged specimens have been recaptured off S.W. Greenland. These fish were known to have been grilse on their first return from the sea, since the kelt scales were preserved at tagging. It is presumed that no maiden grilse undertake the migration to S.W. Greenland that is made by 2SW fish but the "instinctive" mechanism to do so appears to be present in a small proportion of them, as kelts. Whether this is the result of chance reaction to oceanographical conditions, or passive "following" of other kelts or whether it represents an emergence of a dormant hereditable factor is impossible to decide at the present time.

SUMMARY

1. Smolts of known grilse and two-sea-winter fish parentage have been reared, released and recaptured since 1960.

2. Within the environment of the Trust's operations the major proportion of the returns from reared smolts has occurred as grilse, irrespective of parentage.

3. Smolts of two-sea-winter fish parentage types have produced a greater proportion of two-sea-winter fish in the returns than have grilse-parentage smolts.

4. One-year-old smolts of both parentage types have produced more two-sea-winter fish than have two-years-old smolts of comparable parentage.

5. The results of one experiment involving smolts derived from crossing two-sea-winter females with grilse males were intermediate in character between the two "pure lines".

6. A small proportion of wild grilse kelts appear to change their sea migration pattern at the kelt stage and undertake a two-sea-winter fish type migration to S.W. Greenland, involving a sea-absence period of one year or over.

TABLE I

DETAILS OF ANNUAL RELEASES OF SMOLTS AND RECAPTURES AS MAIDEN FISH

Year of smolt release	Smolt parentage	Smolt age	Smolt total	Recaptured as : Grilse	2SW fish
1960	G	1+	258	—	—
	2SW	1+	534	—	1
	2SW	2+	961	—	1
1961	G	1+	1700	2	—
	G	2+	2700	9	2
	2SW	2+	3600	—	2
1962	G	1+	560	—	—
	G	2+	8345	49	2
	2SW	1+	515	—	—
1963	G	1+	82	—	—
	G	2+	2240	8	—
	2SW	1+	556	1	2
	2SW	2+	1919	5	—
1964	G	2+	3290	19	—
	2SW	2+	3340	8	—
1965	G	1+	898	—	—
	G	2+	4180	37	—
	2SW × G	1+	1082	9	1
	2SW	2+	3514	11	6
1966	G	1+	307	4	1
	G	2+	4600	43	1
	2SW	1+	243	2	2
	2SW × G	2+	5100	138	5
1967	G	1+	3260	95	5
	G	2+	6300	278	5
	2SW	2+	4700	105	6
1968	G	1+	4649	183	4
	G	2+	3285	423	6
	2SW	1+	4503	18	4
1969	G	1+	5200	64	1
	G	2+	6127	181	—
	2SW	2+	5310	33	3
1970	G	1+	4547	76	7
	G	2+	5672	57	1
1971	G	1+	1567	62	2
	G	2+	6670	608	6
1972	G	1+	4362	37	N/A
	G	2+	3544	55	N/A

TABLE II

TOTAL SMOLT RELEASES BY SMOLT TYPE, SHOWING OVERALL RECAPTURES AND RECAPTURES ACCORDING TO PARENTAGE TYPE

Smolt type and age	Smolt total	Overall No.	Recapts. %	Recaptured as : Grilse No.	2SW No.	% 2SW of total
2SW 1+	6351	30	0·47	21	9	30
2SW 2+	23344	180	0·77	162	18	10
G 1+	27390	543	1·98	523	20	3·7
G 2+	63953	1790	2·80	1767	23	1·3
2SW × G 1+	1032	10	0·92	9	1	10
2SW × G 2+	5100	143	2·80	138	5	3·5

APPENDIX II

A STUDY OF THE AVAILABILITY OF ORGANIC NUTRIENTS IN LOUGH FURNACE IN RELATION TO THE POPULATION OF NEOMYSIS INTEGER

M. Parker, Trinity College, Dublin

Since September, 1972, work on the ecology of *Neomysis integer* in Lough Furnace and on the relevant physio-chemical characteristics of the lough has been carried out on a regular basis. A synopsis of the results to date, with some more detailed information about temperature, salinity and oxygen concentrations near the outflow from the Mill Race, is presented here.

1. THE POPULATION BIOLOGY OF NEOMYSIS INTEGER

Between September, 1972, and October, 1973, *N. integer* has been more or less evenly distributed around the shores of the lake and very rare in the open waters. The mode of behaviour is epibenthic and no evidence of diurnal migration has been obtained. Samples of the population have been taken monthly at the Yellow River and at the Mill Race. The population structure is similar to that described by Mauchline (1971) for *Neomysis* in Loch Etive (Argyll), though on average the Furnace Mysids are smaller and the females carry fewer eggs. Growth, as estimated by weight/length data, is close to isometric. These parameters are being followed further at present, attempts are being made to estimate the size of the population, and certain aspects of the physiology of *Neomysis* are being investigated. It is hoped that with these data the productivity of *N. integer* may be estimated.

2. VERTICAL DISTRIBUTION OF SESTON

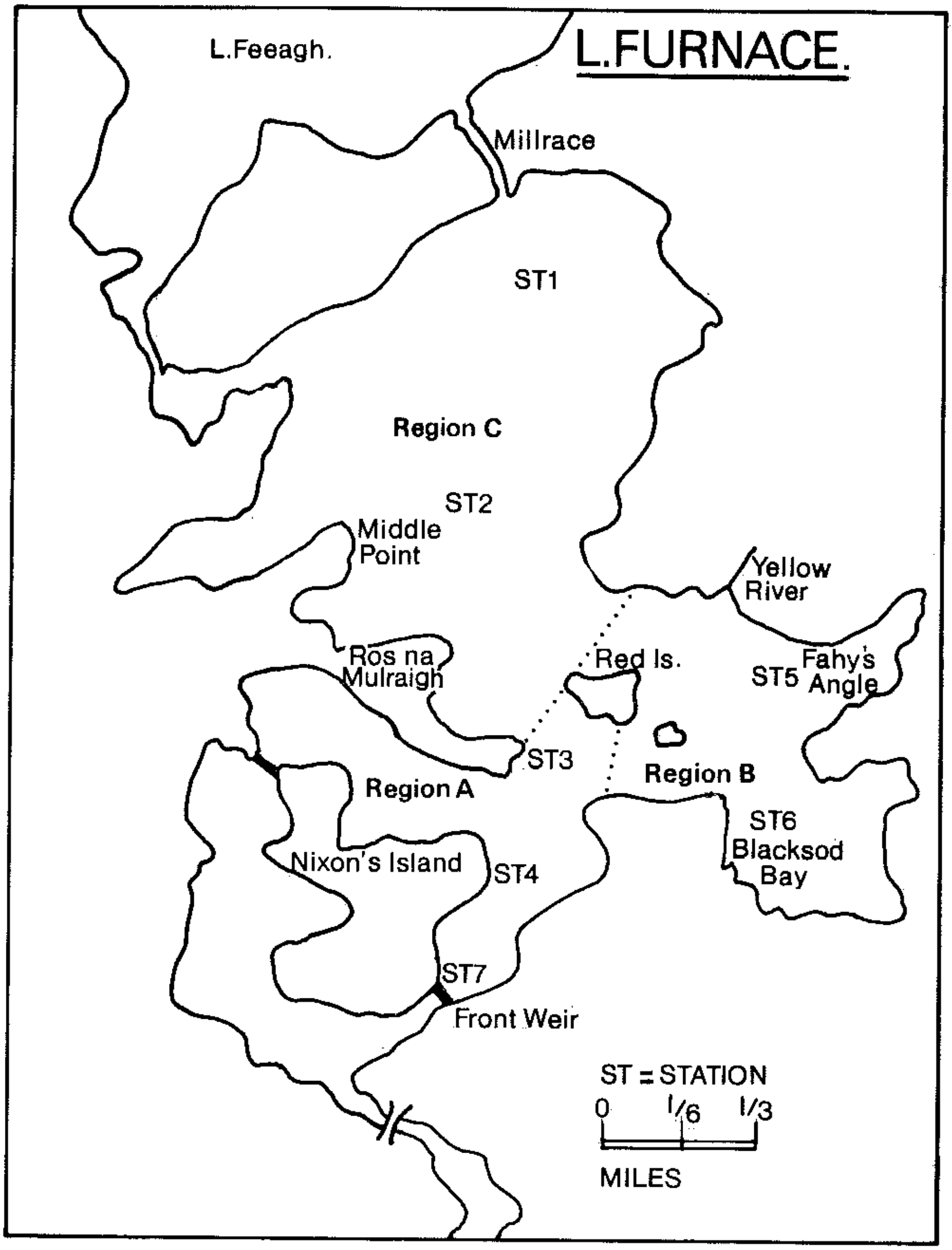
Water samples for gravimetric analysis of seston were taken at intervals during the year at stations I, II, IV (Fig. 1) at 1 metre intervals down to 6 metres and at 2 or 3m intervals below that. These were filtered first through Watman GF/C glassfibre filters to remove particulate material, then through 0·025 u pore size "Millipore" filters to remove colloids. The dry weights of the materials retained were then measured.

The results indicate that 1 to 2mg/litre of particulate material is present in the surface waters and that this rises unevenly to 5 to 7mg/1 below the halocline. Within 1 to 2m of the bottom there is a massive rise in the quantity of particulate material. Colloidal materials are present in quantities larger than those of particulate material by a factor of about 10 (between 0 and 20mg/1 of colloids above the halocline; 30 and 70mg/1 below it). Data on colloids in natural waters are sparse, and these figures are high in comparison with most published results, which generally refer to ocean water. However, the ratio of colloids to particles is similar to that found by Sharp (1973) who, using a filtering technique for colloids but assaying organic carbon found ratios of between 2 and 10 in oceanic water.

This work continues on a regular basis.

FIG. 1

Lough Furnace, showing sampling stations and regions.



3. VERTICAL DISTRIBUTION OF CARBOHYDRATES IN PARTICULATE, COLLOIDAL AND DISSOLVED FORM

Water samples from the same stations and depths as described above were collected and filtered to separate the particulate, colloidal and soluble fractions. These were assayed using the Dubois technique (Dubois *et al.* 1963, Strickland and Parsons 1968).

Preliminary results suggest that from variable but generally high figures (up to 0·9 mg/1 glucose - equivalent during a plankton bloom last spring) at the surface the quantities of particulate carbohydrate material fall unevenly to a low point (0·1 to 0·2 mg/1) around the bottom of the halocline and then rise slowly again towards the bottom of the lake (to as much as 0·5mg/1). The ratio of particulate carbohydrate material to total weight of particulate matter falls sharply between the surface and the halocline and remains at a constant or very slightly increasing figure below that. Indications are that the combined colloidal and dissolved fraction may contain up to 5mg/1 of carbohydrates in the surface waters, but at 2-3m this falls below 0·5mg which approaches the limit of the sensitivity of the assay technique.

It is hoped that the sensitivity of the technique will shortly be enhanced.

4. PHYSICAL CHARACTERISTICS OF THE WATERS OF LOUGH FURNACE

A study of the variations in temperature, salinity and dissolved oxygen concentration with depth at 7 stations in Lough Furnace has been in progress for over a year. The results from the most northerly station are presented here in some detail and may be taken as fairly typical for Region C in the Lough (Fig. 1).

(a) The regions of the Lough

Lough Furnace (de Burgh and Smart, 1968) north of the two weirs, falls naturally into three regions. The first extends from the Weirs to Ros na Mulraigh (Region A, Fig. 1) and is shallow (2-5m) with occasional deep pits (down to 7m). Though it is tidal (at least from midtide to spring tide) it acts as a very long sill; obvious tidal effects are damped down by the time they reach Ros na Mulraigh, and incoming salt water forms a bottom layer. The area of Blacksod Bay and Fahey's Angle (Region B, Fig. 1) is mainly shallow (3-5m). Here there is a stable situation with salt water forming a shallow bottom layer. This region is separated from Region C, the main body of the lake, by the Red Island and the sand bank that has formed at the mouth of the Yellow River. Region C is comparatively deep, ranging from 13 metres at station II to 15 at station I and to a maximum of 21·5m below the Mill Race. Tidal effects in this region are negligible (6-12"); floods of fresh water cause far greater changes in the height of the lake water.

(b) Salinity at Station I

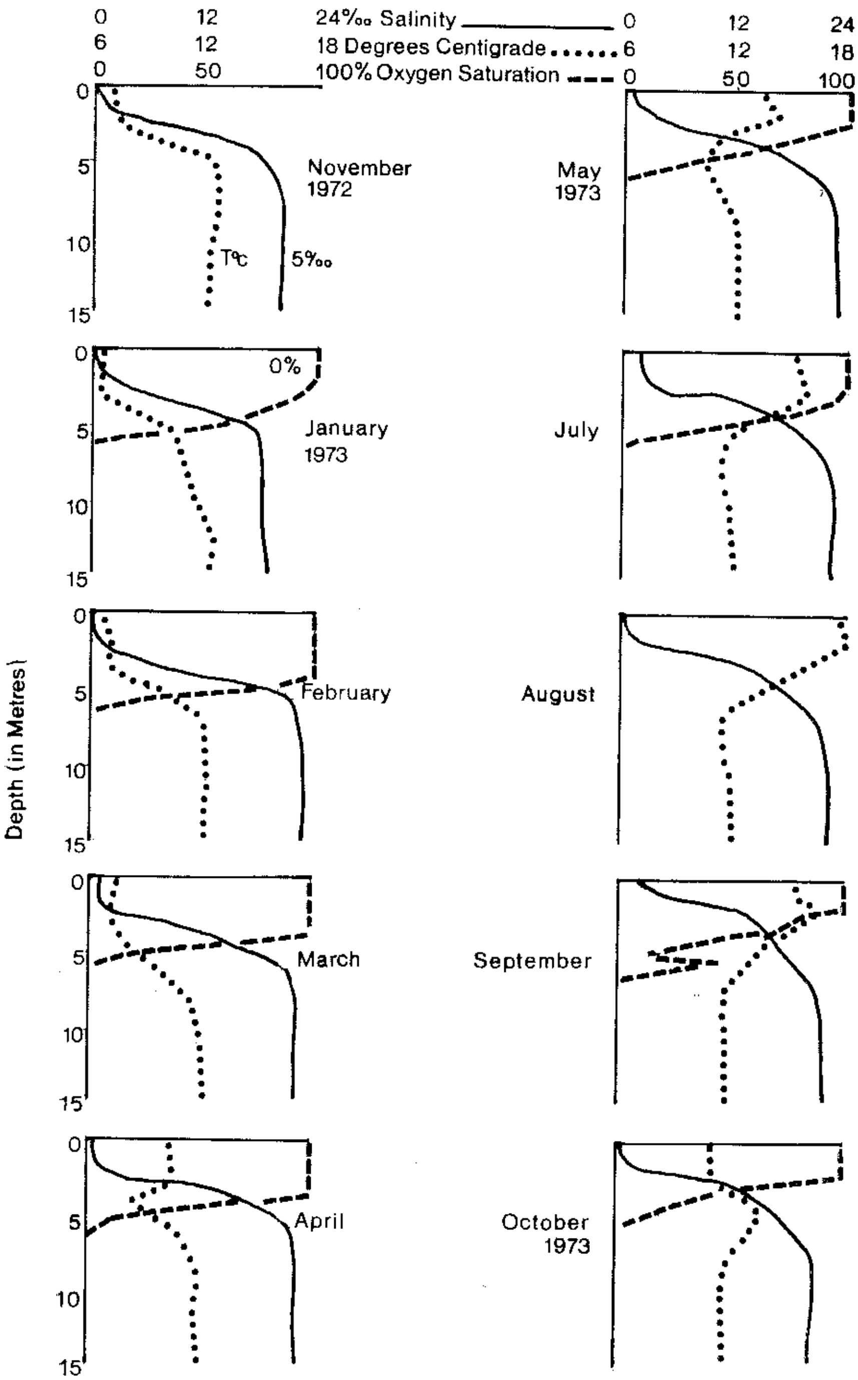
A layer of fresh or nearly fresh water 0·5 to 3m in depth lies on the surface at all times of the year (Fig. 2). The depth of this layer varies with the amount of rainfall. Below this, extending to between 6 and 8m there is a halocline. The salinity rises to 22·5‰ at 8m in summer and is then constant to the bottom. The shape of the halocline varies as the year progresses, but as yet there is no explanation for this. At all times of the year, salt water at maximum salinity is found below 8m, though in winter the salinity reduces to about 20‰.

(c) Dissolved Oxygen at Station I

The surface layers are always fully saturated with oxygen. During the winter months the waters are fully saturated to 4m depth, but then there is a sharp oxycline, and at 6m the waters are totally anoxic. The oxycline tilts during the

FIG. 2

Monthly Salinity, Temperature and Oxygen Profiles for Station 1.



summer (oxygen concentration falling off at one metre from the surface), though the depth at which the waters become totally anoxic remains at 6m throughout. An extraordinary, and as yet unexplained, maximum occurred at around 5m in September.

(d) Temperature at Station I

In the summer, the surface waters are warm, reaching 18°C. In the winter the surface temperature falls to around 6°C. The deep saline waters maintain a temperature of 12°C during the winter which falls slightly to about 11·8° during the summer. In winter and summer there is a marked thermocline reaching to about 6m, but in the winter temperature increases with depth, while in the summer the reverse occurs. In spring and autumn a minimum and maximum respectively can be seen to occur, at first at the top of the halocline, but moving downwards as the season progresses.

(e) Discussion

The presence of salt water in the lake, and its marked stratification, makes for an unusually stable system. The specific gravity of the waters increases from 1·000 on the surface to 1·010 or more at the bottom, and this is due almost entirely to the changes in salinity. Against such a gradient, the relatively small range of temperature changes seems unlikely to cause sufficient changes in density to result in convection in the deeper waters, though convection probably does occur in the surface layer of fresh water. The generally weak surface currents in Lough Furnace appear to cut down eddy conduction except, again, in the first few metres. One result of this stable situation can be seen in the complete absence of oxygen below 6m, though the fact that the depth and shape of the oxycline varies with the season suggests a limited amount of mixing in the upper waters. Another result of it is the curious temperature structure of the lake. If, as has been suggested, convection is insignificant in the lough, conduction would be the only method left open for large scale heat transfer; in other words, the lough would be behaving more like a solid than a fluid.

This situation can be modelled by the equation used by Kelvin* to describe heat transfer in the earth or any large solid body when heated by a source (such as the sun) whose effective temperature varies regularly over a long time scale (1 year). The temperature curves in Fig. 3 were generated by solving this equation for Lough Furnace. While these figures do not entirely coincide with those observed, they serve as a good first approximation.

* Kelvin's equation.

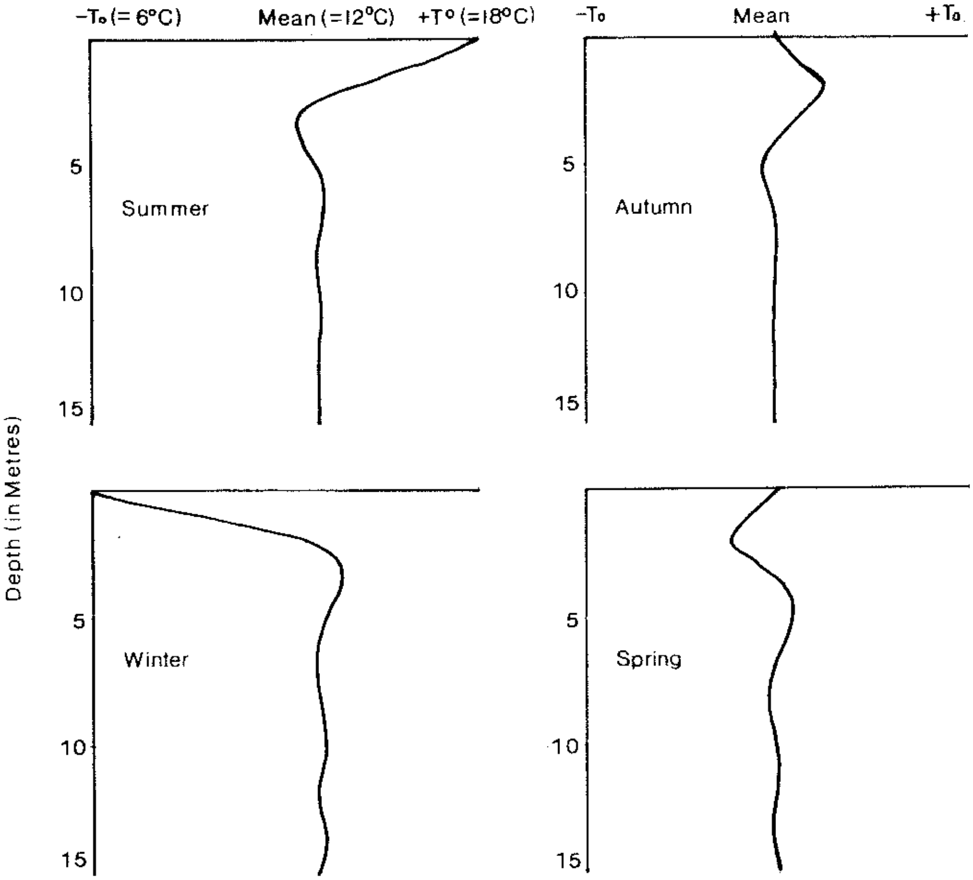
$$Tx = to.e^{-Ax}.\cos\left(\frac{2\ t\ \ n}{to} -Ax\right)$$

Where

To = Mean temperature of heat source
Tx = Temperature at depth x.
$A = \frac{n}{to}$
= Conductivity

FIG 3

Temperature Profiles generated by solving Kelvin's Equation for Lough Furnace.



(f) Possible Implications: Lough Furnace as a source of Brackish water

As a source of brackish water, Lough Furnace has the advantage of being an extremely stable system; at any given depth the salinity of the water is virtually constant, and at depths from 8m down fluctuations in temperature greater than 1°C do not occur. On the other hand, the lack of oxygen below 6m could be a disadvantage in fish rearing, as could the large quantities of particulate material which occur within 2m of the bottom. The optimum depth for drawing off water might be between 8 and 9m, where the salinity (20-22·5%), and temperature (11-12°C) are constant throughout the year.

The saline waters of the northern region of Lough Furnace appear to have a very slow rate of turnover. Consequently it is hard to assess the long term effects of the removal of large quantities of deep saline water upon the stability of this system. However, it seems probable that any measures which would increase the depth of oxygen penetration can only lead to an increase in the productivity of the whole Lough.

I wish to thank Dr. Piggins and the Committee of the Trust for a grant towards the cost of travel and accommodation, for laboratory space and for many other facilities; and Dr. Crane of the Department of Mathematics, Trinity College, for his assistance.

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APPENDIX III

SUMMARY OF THE REPORT ON DIURNAL FLUCTUATIONS OF THE ZOOPLANKTON IN LOUGH FEEAGH

By John K. Field

During the summer of 1972 a survey into diurnal fluctuations of the dominant species of zooplankton in Lough Feeagh was undertaken. The survey was basically similar to that of Southern and Gardiner (1932) on Lough Derg, but different sampling methods were used.

Seven series of samples were taken at approximately three hour intervals over a 24 hour period from a range of depths at a buoy moored in 27m of water. At the time of sampling eight environmental parameters were measured. Eight litre samples were pumped from each depth and concentrated a thousand fold and were later identified.

The data were analysed initially by preparing cone histograms, representing the percentage of a species at each depth. Comparisons of these data with the variations in environmental parameters were made by plotting the model depth of a species at each sampling time in a series, on graphs of each of the parameters studied (involving some 400 graphs in all, performed on an IBM 360 computer in Trinity College).

The vertical migration patterns of the following eight groups of organisms were studied : —

Cyclops strenuus, Diaptomus gracilis, Daphnia hyalina, Diaphanosomia brachyurum, Bosmina conegoni, Hydracarina, Rotifers and total zooplankton of each series.

Migration rates of ascent and descent were calculated for periods in which the organisms were exhibiting the greatest migratory distances over the largest periods of time. The results compare with Worthington (1931) in Lake Lucerne; for example, *Cyclops strenuus* juveniles descended at a rate of 17 min/m, and ascended at a rate of 60 min/m before and 5·5 min/m after dark, while in Lough Feeagh (1972) the same species descended 18 min/m and ascended 42 min/m.

The vertical migration patterns of the total zooplankton give an overall impression of the changes in migrating pattern from mid-summer to mid-autumn. It was seen that a trend from nocturnal migration (Fig. 1) in July develops into a twilight migration (Fig. 2) in late September, during which time other patterns such as midnight sinking (associated with adverse weather conditions), twilight migration, and a complex migration pattern similar to Cushing's paradigm of twilight migration (Cushing 1951) were seen. Each species was seen to have its own seasonal history where this distribution was worked out on a percentage basis. During the period of the survey, two maxima were seen, one in late June and the other in early September.

Some speculative conclusions were drawn from the data on environmental parameters when compared with varying migration patterns. Light has been

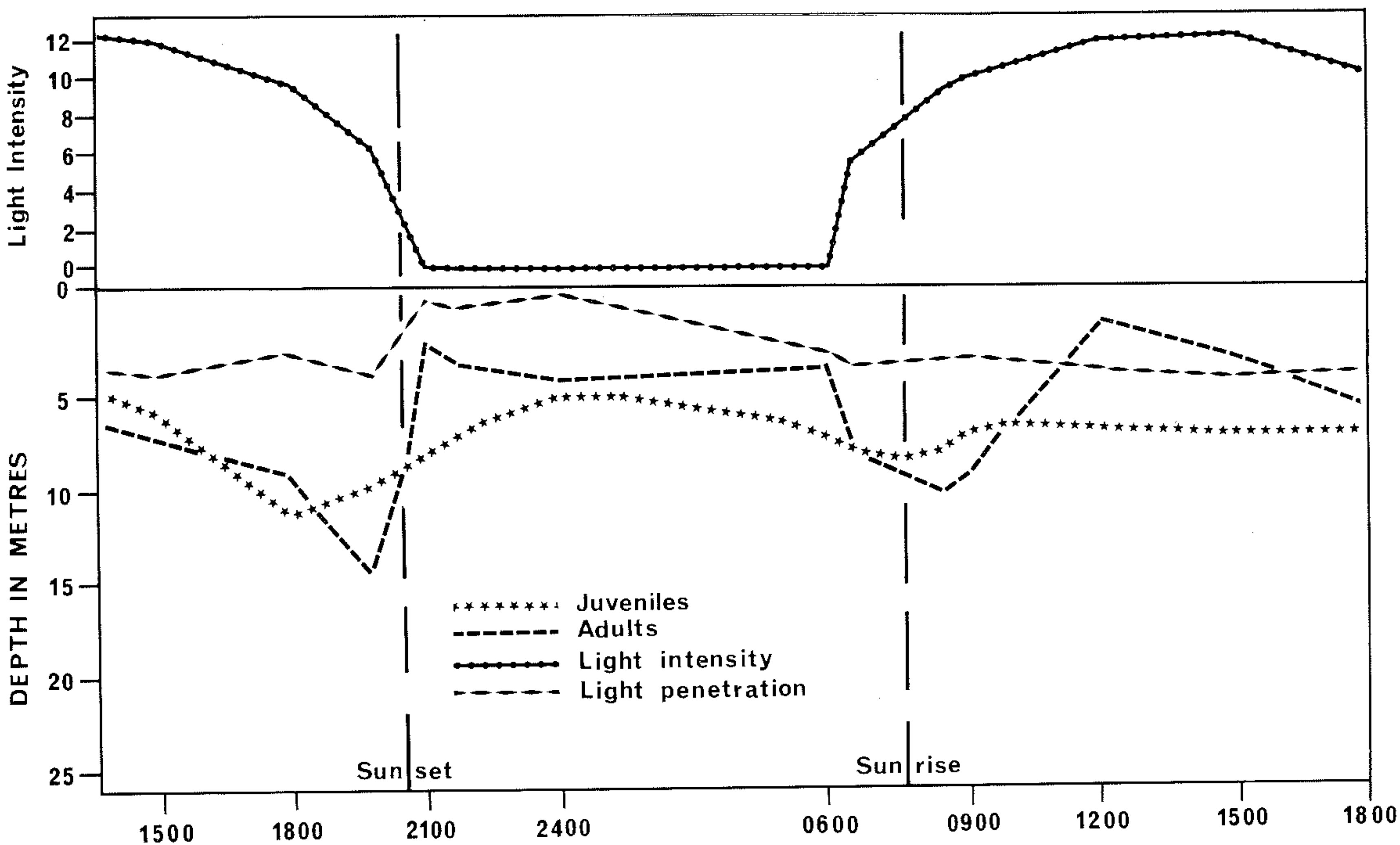

FIG. 1

Nocturnal Type Migration as shown by *Diaptomus gracilis* in Series Six

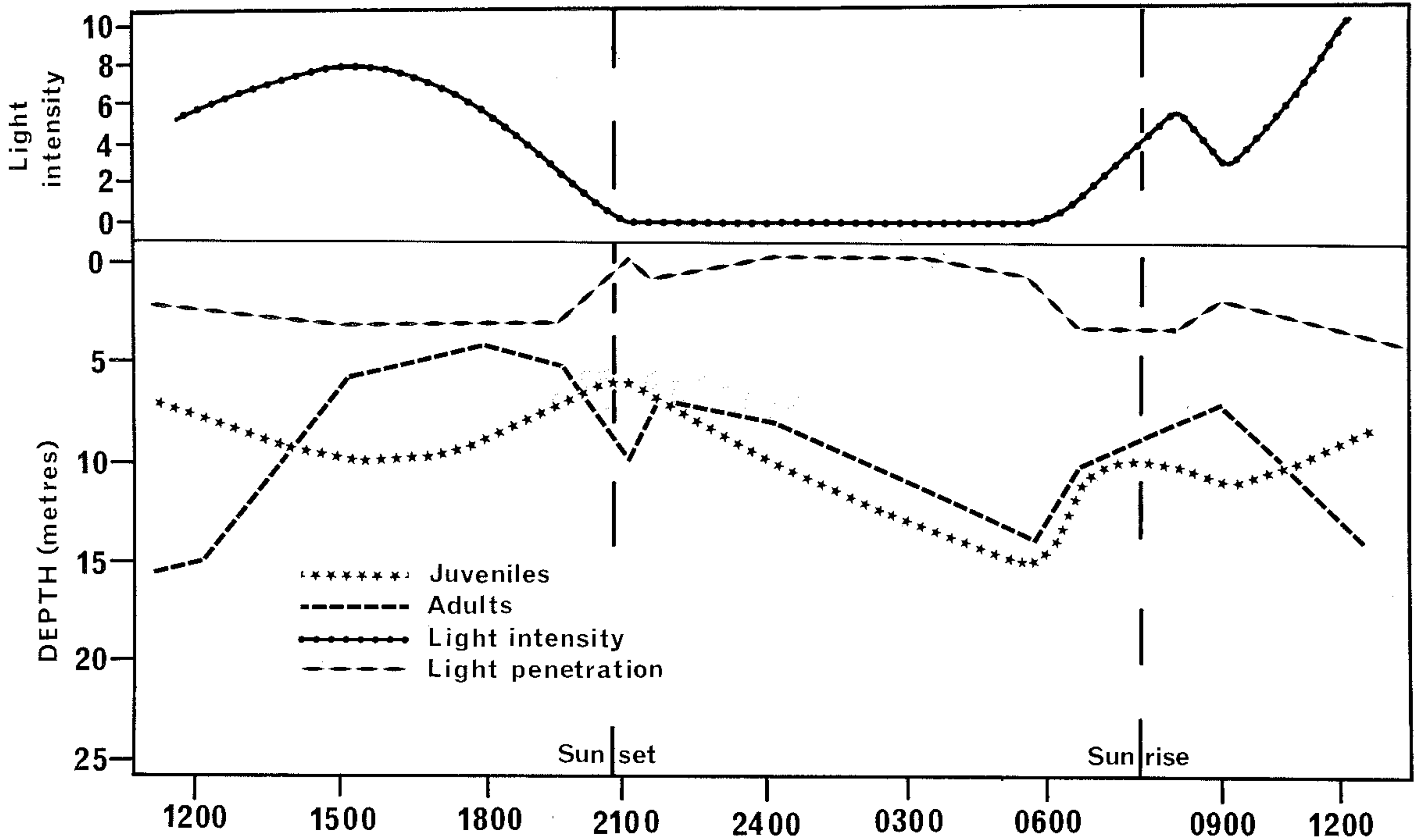

FIG. 2

Twilight Migration as shown by *Diaptomus gracilis* in Series Seven.

implicated in vertical migration either as a direct stimulus to movement or as a synchronizing factor of a pre-existing rhythm. *D. hyalina* was seen to migrate to the surface on dull cloudy days as well as at night. Another instance of the effects due to the changes of light was seen when the moon suddenly appeared one night when a general shift in the zooplankton took place towards the surface, while all other parameters remained constant.

Some evidence existed that the migration at about dawn is not initiated by light but commences before brightening of the sky. Upward movement of *D. gracilis* (Fig. 2) occurred before the light intensity was brighter than starlight and *Daphnia hyalina* moved downwards under the same conditions. Waterman *et al* (1939) also observed this phenomenon.

In general, the concentration of zooplankton in the water is higher by day when light intensity is high. Dice (1914) showed that increased illumination induced positive geotaxis in *Daphnia pulex* and when the illumination was reduced a negative geotaxis ensued. This may be an important mechanism in many species, but it is probable that the acclimatisation of the organism to a particular light intensity also plays a role, otherwise many organisms would migrate further from the surface by day than was observed e.g. *D. hyalina* in series six, never sank further than 5m (Fig. 3).

The Secchi disc extinction depth on Lough Feeagh never exceeded 4m due to the considerable amount of peat in suspension, and this factor was of great importance as it gave an estimate as to what depth light had an effect. A close correlation between this parameter and the migratory patterns was seen throughout the survey.

No true thermocline existed on Lough Feeagh during the survey, contrary to Partridge (1971), so that no correlation between water temperature and vertical migration was found. Similarly no correlation between air temperature and migratory behaviour was detected.

Atmospheric pressure is not normally associated with vertical migration of zooplankton but two sets of results in this survey did indicate a possible relationship. When pressure fell by 4 millibars during the night the plankton remained deep until sometime after sunrise, only beginning to rise when the pressure began to increase (Fig. 4). The other set of results occurred in September when the pressure rose by 4½ millibars and the modal depth dropped from seven to eight metres. These results give the impression that the zooplankton become more active and swim upwards when the pressure is increased but when a decrease takes place the organisms become less active and sink passively, as Knight-Jones and Quasi (1955) found with hydrostatic pressure.

France (1894) noted in Lake Balaton that the population tended to avoid the surface at night during a storm. In this survey the results of rough weather were anomalous in that the number of *Cyclops strenuus* taken in a set when the wind had risen to force 5 was significantly lower than in another set taken when the wind was less strong, whereas there was no recognisable effect in series four when the wind force was 6 gusting 7.

The results indicate that different species have different behavioural patterns in different lakes and at different times of the year. Minor changes in the migration pattern may occur due to environmental factors such as wave turbulence and cloud cover. Variations in pattern may also result from age and sex differences and occasionally parts of the population may break off and behave idiosyncratically.

The Crustacea and Rotifers perform considerable migratory movements during a twenty-four hour period but the range was more limited than other

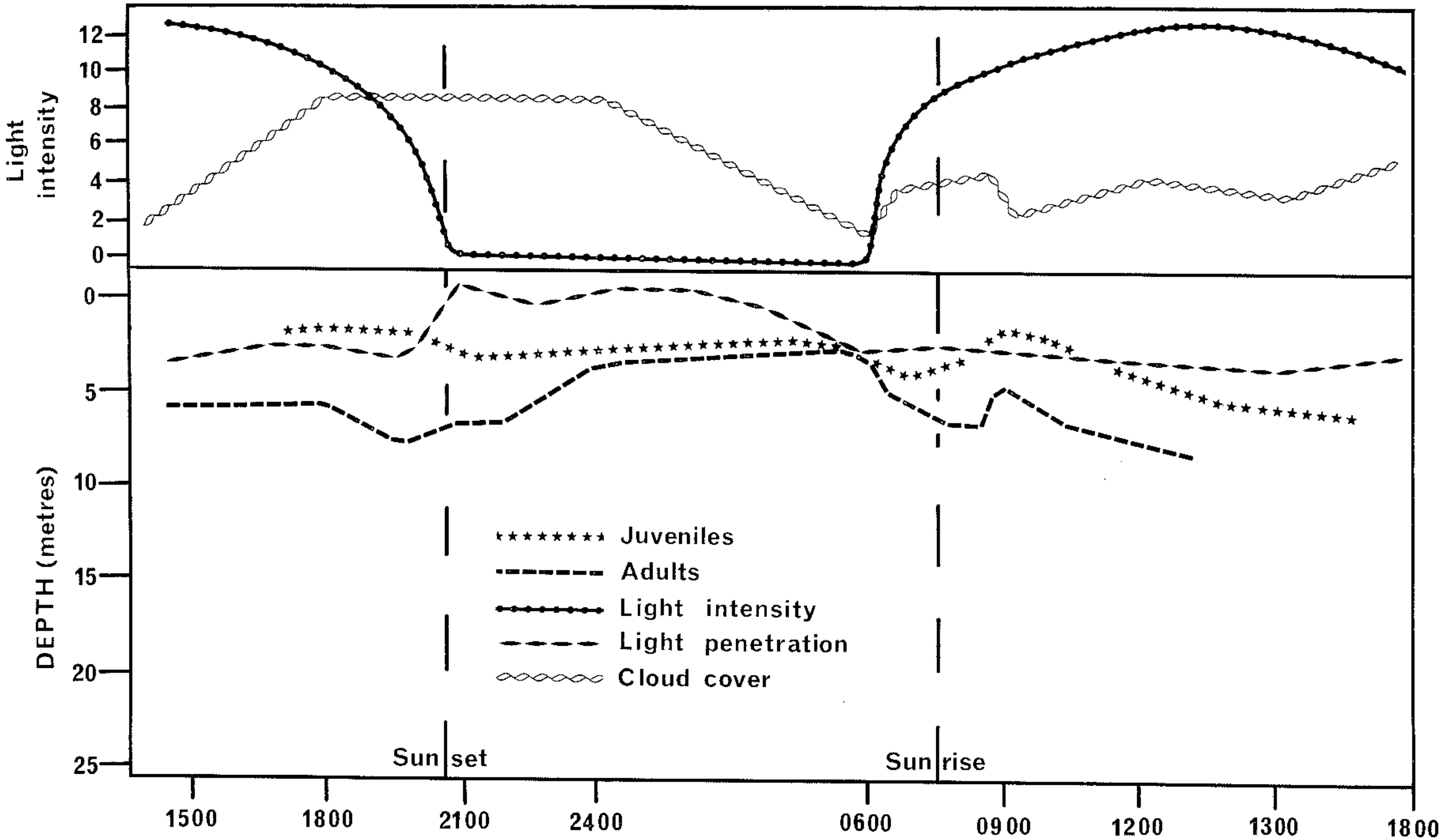

FIG 3

Migration Pattern of *Daphnia hyalinia* as shown in Series Six.

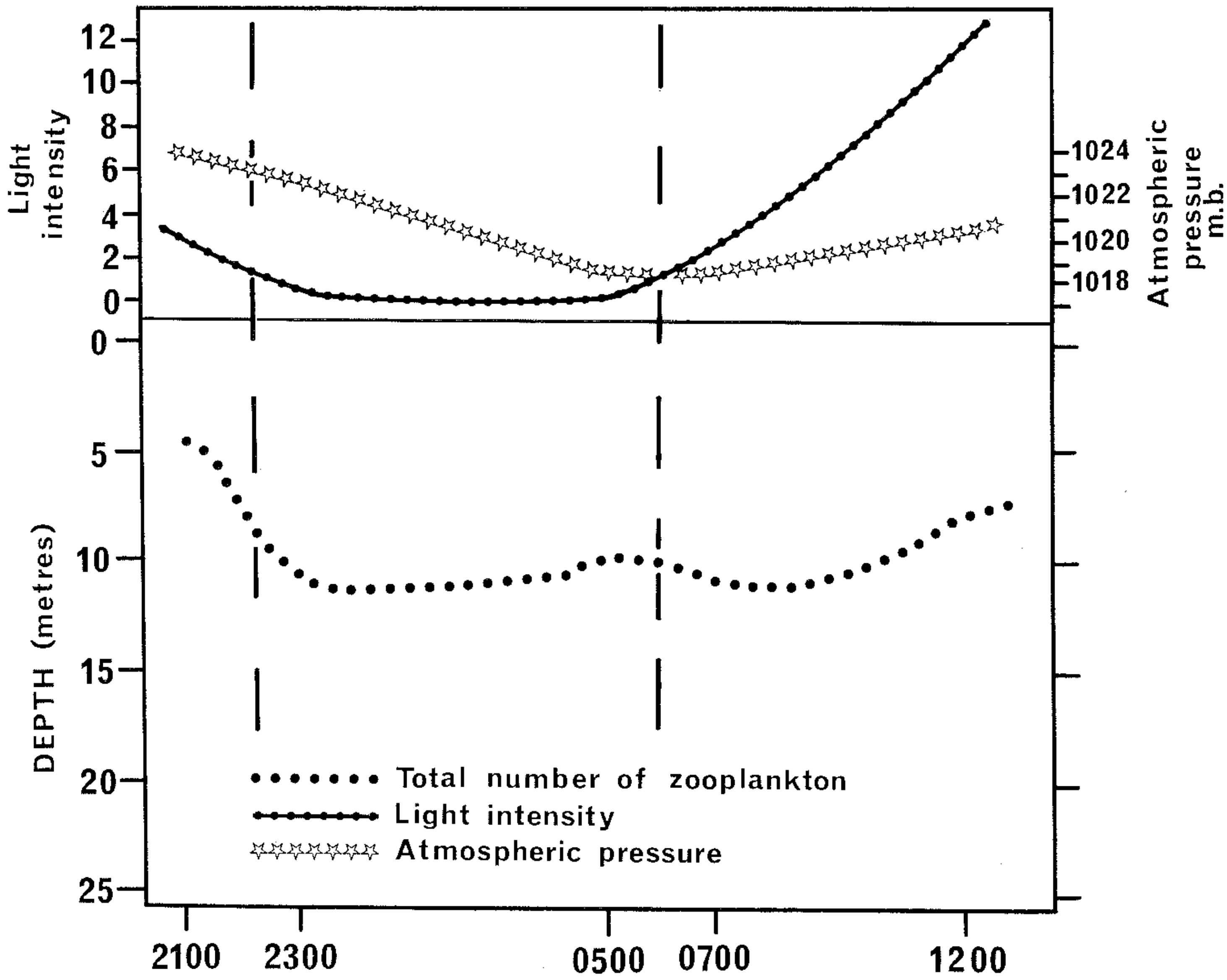

FIG. 4

Migration Pattern of the total Zooplankters in Series One showing the overall pattern of dusk sinking.

workers have found elsewhere for the same species. This may be due to the limited light penetration in Lough Feeagh.

Light appears to have the major influence on the migration pattern and results show that light penetration (Secchi disc extinction depth) is a more useful parameter than surface intensity, as it takes into account the attenuations of light.

For a more complete survey it would be desirable to sample throughout the entire year with added investigations into the phytoplankton and bacteria. It would also be interesting to know if the fish population of the lake responds in any way to the movements of the plankton.

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The complete report has been deposited in the Library of the Salmon Research Trust of Ireland.

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