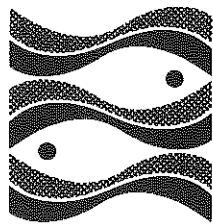


SERIES A (Freshwater) No. 26

1985



**IRISH FISHERIES  
INVESTIGATIONS**

**An Roinn Iascaigh agus Foraoiseachta  
(Department of Fisheries and Forestry)**

**H. A. DAUOD, T. BOLGER and J. J. BRACKEN**

**STUDIES ON THE MINNOW *PHOXINUS PHOXINUS*  
(L.) FROM AN UPLAND IRISH RESERVOIR SYSTEM**



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# Studies of the minnow *Phoxinus phoxinus* (L.) from an upland Irish reservoir system.

by

H. A. DAUOD, T. BOLGER and J. J. BRACKEN  
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## ABSTRACT

The paper deals with the population structure and biology of the minnow, *Phoxinus phoxinus* (L.), in the Roundwood Reservoir system. A total of 4,342 minnow were taken during the study period from three locations, 2,796 fish were used to calculate the age distributions and 3,013 were examined for gut contents. The age data, determined from the otoliths, showed that there are five age classes present. The mean length at the end of the first year (O-Group fish), was 3.41 cm, at the end of the second year (I-Group fish) it was 5.32 cm and 6.68 cm at the end of the third year (II-Group). Only thirteen minnow were found to be older than three years. The breeding season is later than normal and peaks in August and September. Sexual maturity is reached by the majority in their second year and all older fish are mature. Egg diameters were shown to be smaller than for fish from mid-land Irish waters. In the North and South Lakes the dominant food organisms were found to be chironomid and trichopteran larvae, molluscs and Cladocera. The diet of the fish from the Vartry River contained more ephemeropteran nymphs. Seasonal differences in the diet are noted. The influence of the minnow on the associated fish species is discussed. An account of the distribution of the minnow in Ireland is included as an Appendix.

## INTRODUCTION

In recent years catches of brown trout, *Salmo trutta* L., taken on rod and line in the Roundwood Reservoir system, Co. Wicklow, have shown a serious decline. A large scale investigation commenced in 1982 to examine the possible causes of this decline. Unfortunately, no previous biological monitoring had been carried out in the study area. The results of littoral and benthic sampling of the macroinvertebrates from both reservoirs could not therefore be compared with the earlier years when angling returns were good.

An extensive gill-netting and beach seine sampling programme was carried out during 1983 and revealed that large numbers of brown trout, minnow, *Phoxinus phoxinus* (L.) and three-spined stickleback, *Gasterosteus aculeatus* L., were present. Once again it was not possible to compare these data as no previous studies had been undertaken. As both reservoirs are oligotrophic and are subjected annually to severe water level fluctuations it was felt that both of the latter species could play an important role in the food chain either as competitors for a limited food supply or as food for the trout. This paper deals specifically with the minnow and describes the structure of the populations, their reproductive cycles and feeding habits within each lake.

The current state of knowledge on the distribution of the minnow in Irish waters is summarised in an Appendix.

## MATERIALS AND METHODS

The two reservoirs, which lie approximately 200m a.s.l., are known as the North Lake and South Lake. Both are controlled by Dublin Corporation and supply potable water to part of Dublin City. The South Lake, which is the larger of the two (surface area: 165.52ha), was constructed in 1866. Increased demand led to the construction of the North Lake (surface area: 122.62ha) which came into operation in 1922. The location and physical parameters of the lakes are listed in Table 1.

The Vartry River enters the North Lake. It is a moderately flowing trout stream with the same chemical parameters as the two lakes. A number of small feeder streams enter both lakes and are used by the trout and minnow as spawning areas. All of these streams dried out during the summer months of 1983 and 1984.

The geology of the area is Middle Cambrian Rock underlying a granite based boulder clay. Rainfall is high. The annual average precipitation for the 1951-1980 period was 1,216 mm. (Figures supplied by Meteorological Service). December shows the highest average rainfall at 148 mm, while the lowest values occur in June each year at 63 mm.

Five species of fish occur in the system, brown trout, the minnow, the three-spined stickleback, *Anguilla anguilla* (L.), the freshwater eel and *Noemacheilus barbatulus* (L.), the stone loach.

The dominant aquatic macrophytes in both lakes were *Eleocharis palustris* R. and S., *Ranunculus flammula* L., *Polygonum amphibium* L., *Littorella uniflora* Asch., *Mentha aquatica* L., *Hydrocotyle vulgaris* L., *Utricularia intermedia* Hayne and *Ranunculus* sp. In the Vartry River the dominants were *M. aquatica*, *U. intermedia* and *Ranunculus* sp.

**Collecting Methods**

The lake minnow were sampled by means of a 4mm mesh beach seine which was 18.55m in length, made up of two wings, each 6.2m in length and varying from 2.0m to 0.5m in depth and a central bag approximately 6.0m in length and varying in depth from 2.0m at either side to 2.6m in the centre. Samples were taken on one day each month in both lakes from April to September during 1983 and 1984. Different locations were fished on a random basis each month (c.f. Fig. 1). No attempt was made to catch minnow during the quiescent phase (October to March).

River samples were taken by electro-fishing. The first sample was taken in October 1982. Only two samples were taken during 1983 (June and September) but the programme was extended to monthly samples (April to October) in 1984.

A total of 2,380 fish were caught in the North Lake, 1,421 in the South Lake and 541 in the Vartry River.

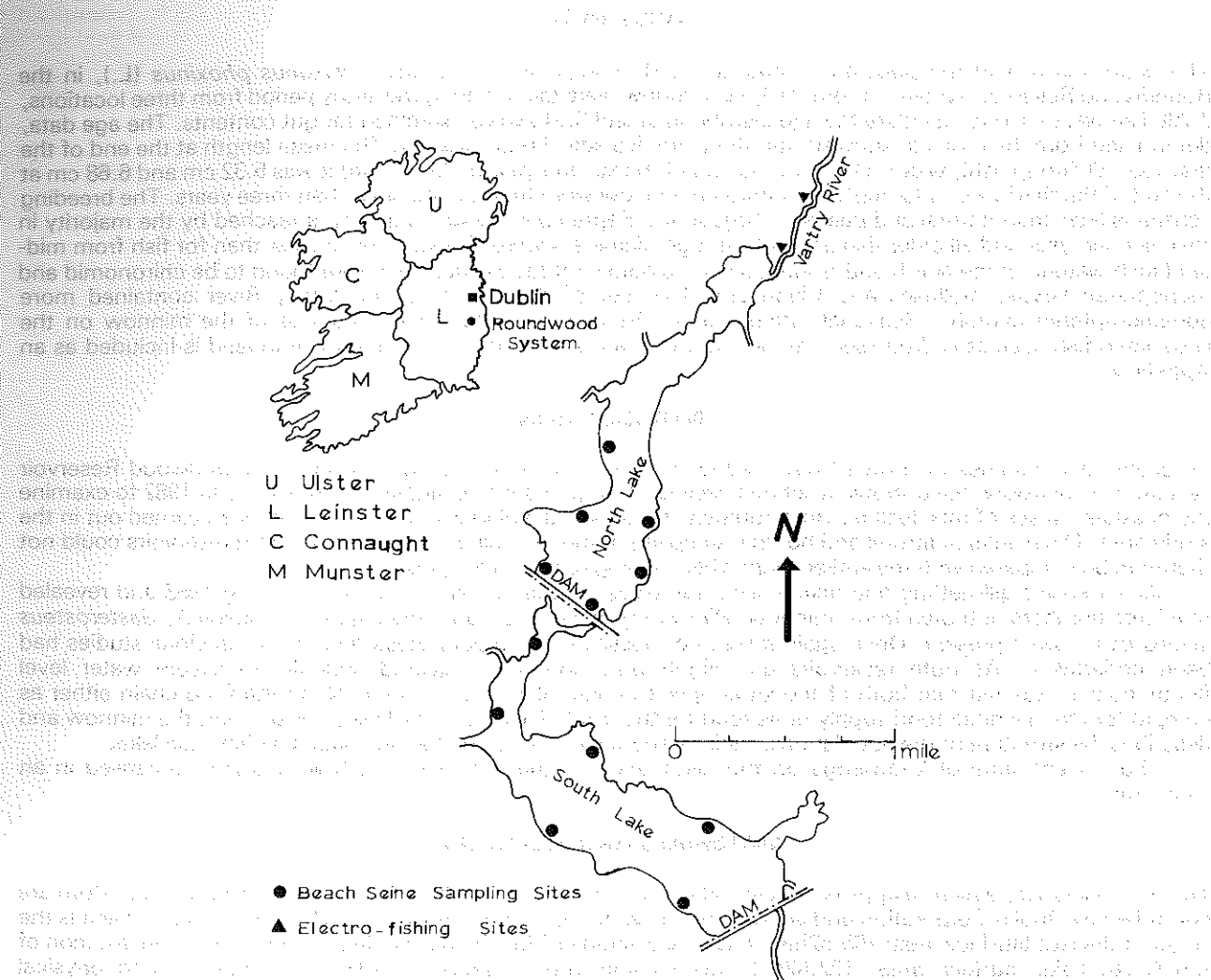


Figure 1. Roundwood Reservoir showing sampling stations.

**Measurements**

All fish were measured from the tip of the snout to the fork of the caudal fin. The numbers measured, aged and examined for gut contents are listed in Table 2.

**Age Determinations**

Initially two ageing methods were compared. Scales were removed from above the lateral line in the caudal peduncle and mounted on glass slides. Otoliths, from the same fish, were removed, placed in xylol and examined under a microscope. There was excellent agreement in the age data obtained by both methods. The otoliths were extremely clear and easy to read and this method was subsequently used.

**Gut Examination**

The gut contents of 1,437 minnow from the North Lake, 1,078 from the South Lake and 498 from the Vartry River were examined. Each gut was opened from mouth to vent and the food contents examined.

The gut contents from the minnow at the three locations at Roundwood were assessed using both their frequency of occurrence and numerical percentage composition. A third method, percentage composition by 'bulk' was also used. It was considered desirable to use these three measures because, as Cailliet (1976) has stressed, each method investigates different things about the feeding habits of the same fish. The numerical importance (expressed as percentage by number) and frequency of occurrence (the proportion of the guts containing a specific prey item) reflect the process of selection used by the fish in its feeding behaviour by pointing out how many prey items and how often a certain prey species was selected but tell little about the energy content the fish gained from the item. On the other hand, the volumetric importance (percentage composition by volume or weight) of a prey item indicates more about the nutritional importance of the prey item.

The volume or weight of individual food items were not measured but an estimate of the 'bulk' of the different food categories was achieved by weighing a range of individuals of each species within a given category. It was then possible to calculate weighted averages for the categories based on the overall numbers of each species found in the gut contents. The weight of a single cladoceran was taken as the basic unit and the numbers of the other categories were multiplied by appropriate conversion factors to give estimates of their 'bulk' (Table 3).

Food items were classified into twelve categories as follows: surface insects, molluscs, trichopteran larvae, trichopteran pupae, Cladocera, Copepoda, Chironomid larvae, chironomid pupae, ephemeropteran nymphs, other larvae, *Gammarus* and chance food.

**Determination of Maturity Stages**

The method described by Nikolsky (1963) was used to identify maturity stages. However, due to the small size of the fish, it was impossible to distinguish between Stages IV and V in many specimens, these are therefore treated as a single stage.

**RESULTS**

**Age Distribution**

- Five year classes were obtained as follows:
- O-Group (fish in their first year)
  - I-Group (fish in their second year)
  - II-Group (fish in their third year)
  - III-Group (fish in their fourth year)
  - IV-Group (fish in their fifth year)

The age structure from the minnow from all three locations is given in Table 4. Despite the fact that second year fish (I-Group) dominated at the three locations there were significant differences between the distributions ( $X^2 = 304.5$ ,  $p < .001$ ). The distributions were similar in both years but a greater proportion of young fish occurred in the North Lake. The dominance of I-Group fish at all locations, over the two year sampling programme, is difficult to explain but is thought to be related to the fact that the beach seine missed some of the small fish which were able to escape by swimming under stones at some sites.

**Length and Growth**

Monthly length frequency distributions for the minnow from the three locations are illustrated in Fig. 2. The distributions are broadly similar with modal frequencies all in the 5-6 cm range. The recruitment of young fish into the populations of each lake is indicated by the presence of 0-3 cm fish in August 1983. No such peak was evident in the 1984 data.

The average lengths of fish from particular age groups did not usually differ between sites. However, river minnow, in their second year (I-Group), were significantly larger ( $F = 8.975$ ,  $p < .01$ ) than those from the two lakes (Fig. 3). This may reflect a bias in the sampling method used rather than a real difference.

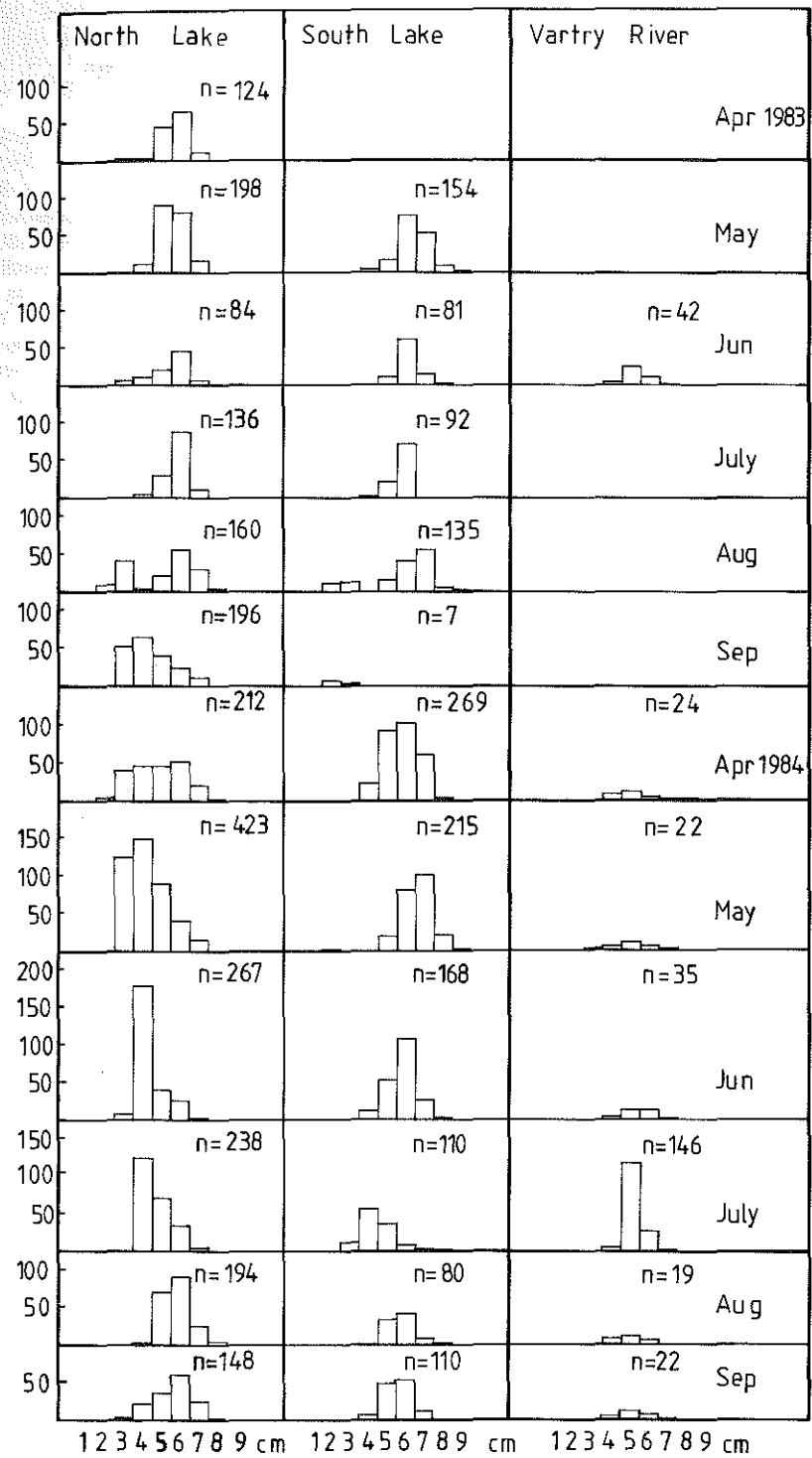


Figure 2. Numbers of fish in cm length groups (rounded downwards).

Length — Weight Relationships

Tesch (1968) suggests that length-weight relationships may be affected by sex, maturity of the gonads, age and time of year. All of these factors were examined by comparing Geometric Mean Regression Coefficients of  $\log_{10}$  (weight) on  $\log_{10}$  (length) using the approximate method of Gabriel (Sokal and Rohlf 1981). With this method comparison intervals are constructed such that two regression coefficients are significantly different if and only if their 95% confidence intervals do not overlap.

The regression coefficients obtained for minnow for the three locations at Roundwood differ significantly. The coefficient for fish from the North Lake was lower than those from the other two sites:

	Coefficient	95% Comparison Intervals
North Lake	3.16	$\pm .0325$
South Lake	3.25	$\pm .0458$
Vartry River	3.43	$\pm .1366$

The length—weight relationship varied significantly among the sampling dates at the three locations (Fig. 4). The variations were most noticeable in the North Lake where the condition of the minnow fluctuated markedly in 1983. During this time the changes in condition appear to be closely related to the percentage of minnow feeding at each sampling date in both lakes (Fig. 7). A similar relationship has been noted by Bhatt (1970) while studying *Mystus seenghala* (Sykes). The length—weight relationship did vary significantly with age (Fig. 5) but not with sex or maturity stage.

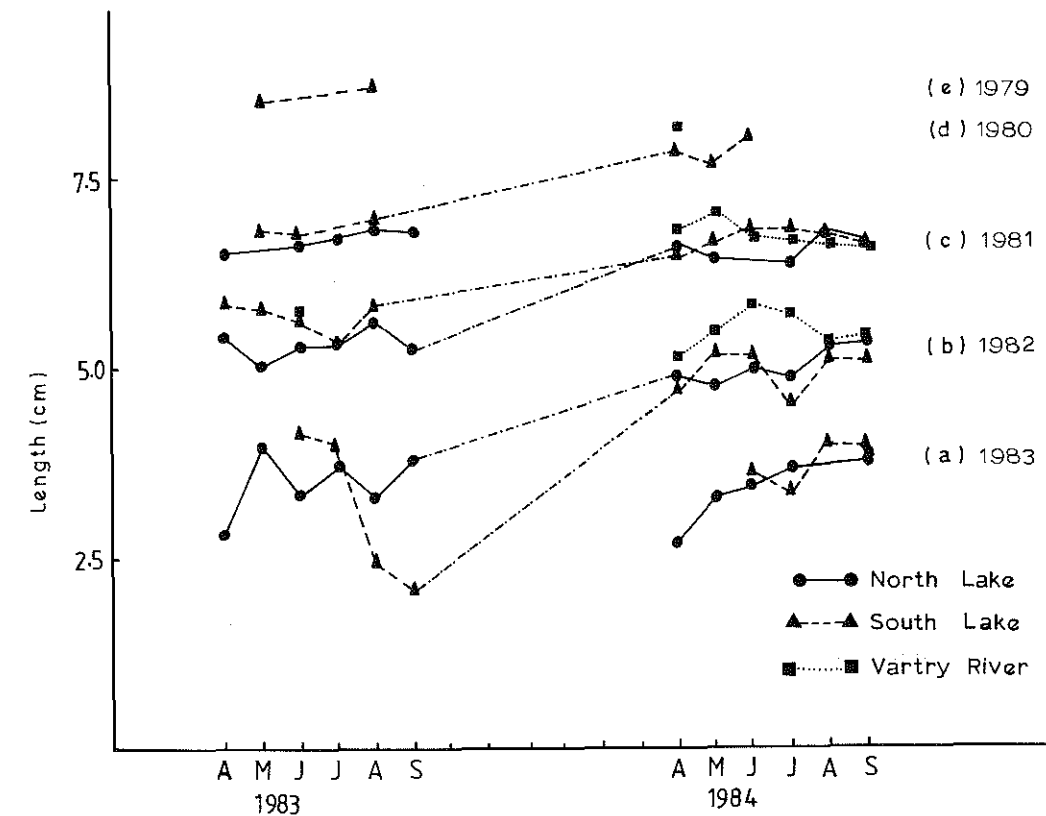


Figure 3. Mean lengths of fish of age groups indicated by year of birth in North and South Lakes and Vartry River.

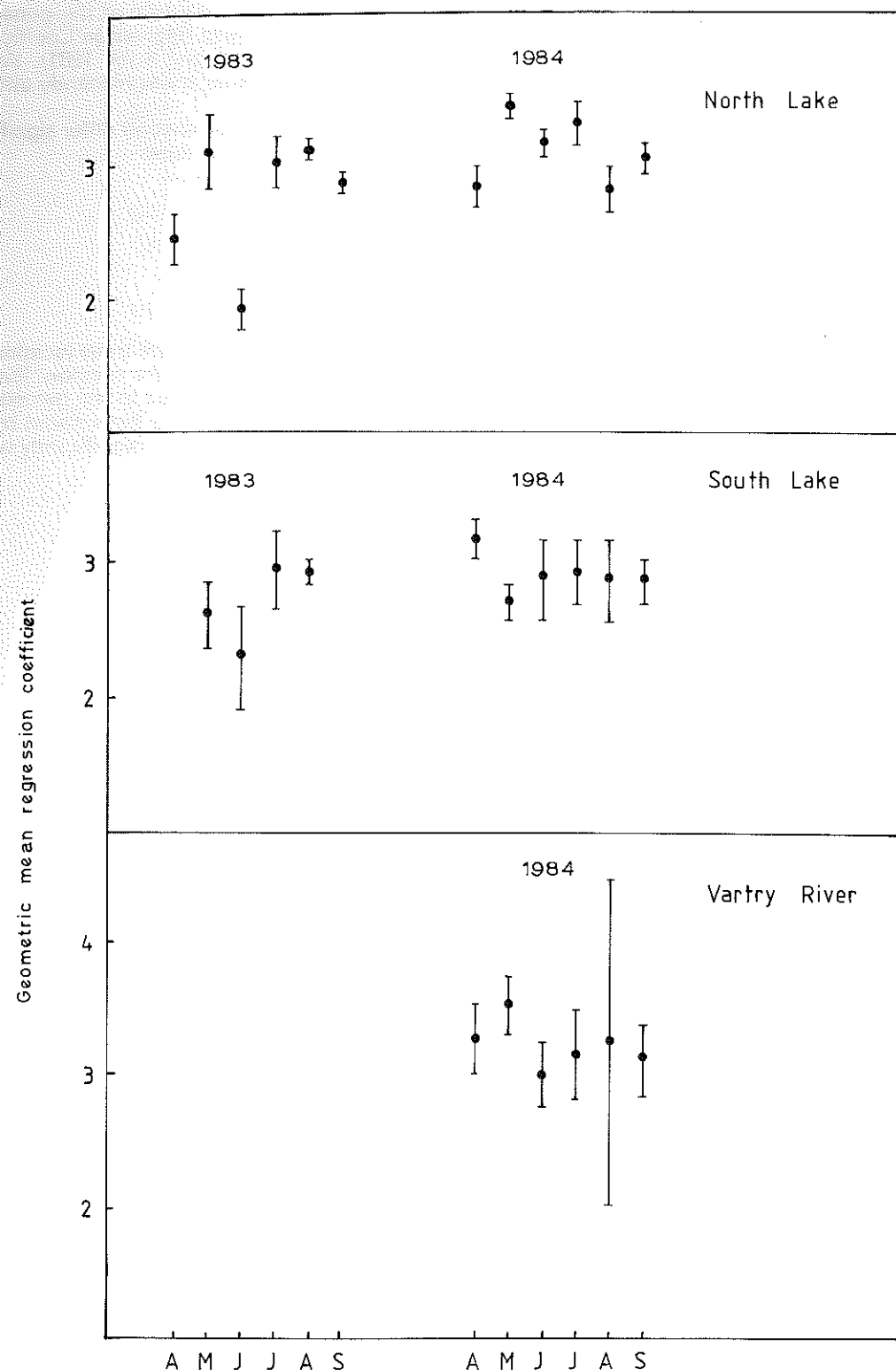


Figure 4. Geometric Mean Regression Coefficients of  $\log_{10}$  weight on  $\log_{10}$  length ( $\pm$  - 95% comparison intervals) for fish from the North and South Lakes and Varty River, on each sampling date.

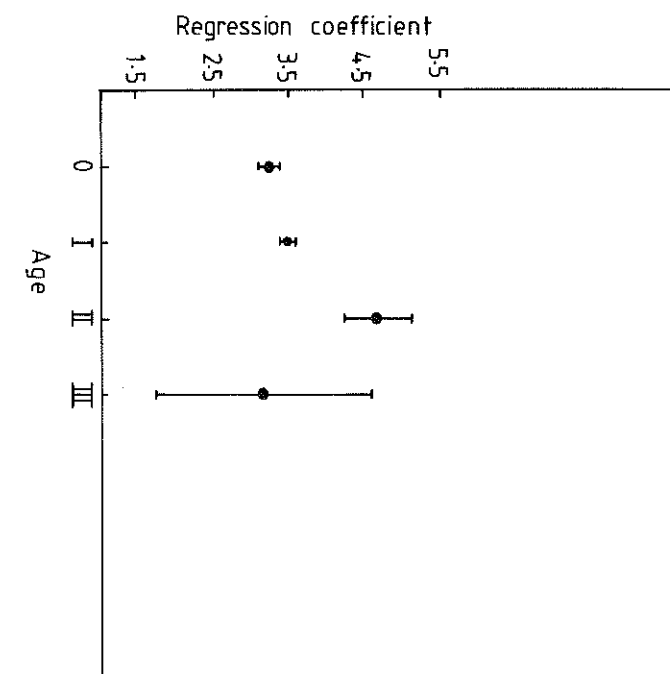


Figure 5. Geometric Mean Regression Coefficients of  $\log_{10}$  weight on  $\log_{10}$  length ( $\pm$  - 95% comparison intervals) for fish from the North and South Lakes and Varty River, according to age group.

#### Reproduction

In the Roundwood system all minnow under 35mm were immature but most fish reached first maturity in the 35 - 45 mm length range.

The sex ratios of the Roundwood minnow are summarised in Table 6. All three ratios differ significantly from 1 : 1 and the proportion of females in the South Lake is significantly lower than in either of the other two locations ( $p < .01$ ).

The maturity stages of the fish during each month at each location are shown in Fig. 6. The fish spawned in August in 1983 and in the August-September period in 1984. The vast majority of the fish reached sexual maturity in their second year.

The diameters of ova from Roundwood were in the 1.0 to 1.4 mm range. Ova from a small number of ripe females from each site were counted. The results are summarised in Table 8.

#### Food and Feeding

Surface insects were all adults of both aquatic and non-aquatic species. The aquatic species included two species of Coleoptera (*Helophorus* sp. and *Hydroporus* sp.), two families of Diptera (Chironomidae and Simuliidae), two species of Hemiptera (*Corixa* sp. and *Notonecta* sp.). The non-aquatic species included a coleopteran (*Philonthus* sp.), two species of Diptera (*Dilophus* sp. and *Bibio* sp.) and one species of Hymenopteran (*Ichneumon* sp.).

Three species of mollusc were found *Potamopyrgus jenkinsi* (Smith), *Bithynia tentaculata* (L.) and *Sphaerium corneum* (L.). Trichopteran larvae and pupae included *Limnephilus vittatus* (Fbr.), *L. lunatus* (Curt.) and *Mystacides longicornis* (L.). Two cladocerans occurred *Daphnia hyalina* (Leydig) and *Chydorus* sp. Chironomid larvae and pupae included *Endochironomus* sp., *Tanytarsus* sp. and *Procladius* sp. Only the first two of these species were eaten as pupae. *Caenis* sp. was the only ephemeropteran nymph found in the guts. Other larvae included dipteran and coleopteran larvae not included in other categories. *Gammarus duebeni* Liljeborg was the only amphipod found and *Cyclops* sp. was the main copepod eaten.

The category 'chance food' included plant material, mainly *L. uniflora*, some unidentified green algae and an assortment of grass seeds.

A high proportion of the minnow examined had empty guts. The proportions varied significantly among the three locations ( $X^2 = 12.5$ ,  $p < .01$ ). Table 9 summarises the data for each location over the two year sampling period. The North Lake had the highest proportion of feeding minnow (77.4%) while the proportions in the South Lake and the Varty River were 73.3% and 70% respectively.

The proportion of feeding minnow also varied significantly within the three Roundwood sites with age and time of capture (Table 10, Fig. 7). In all cases the proportion of young fish feeding was lower than in the older age groups. No overall pattern of seasonal feeding was obvious in the data but the proportions feeding in the North Lake and the Varty River varied in synchrony.

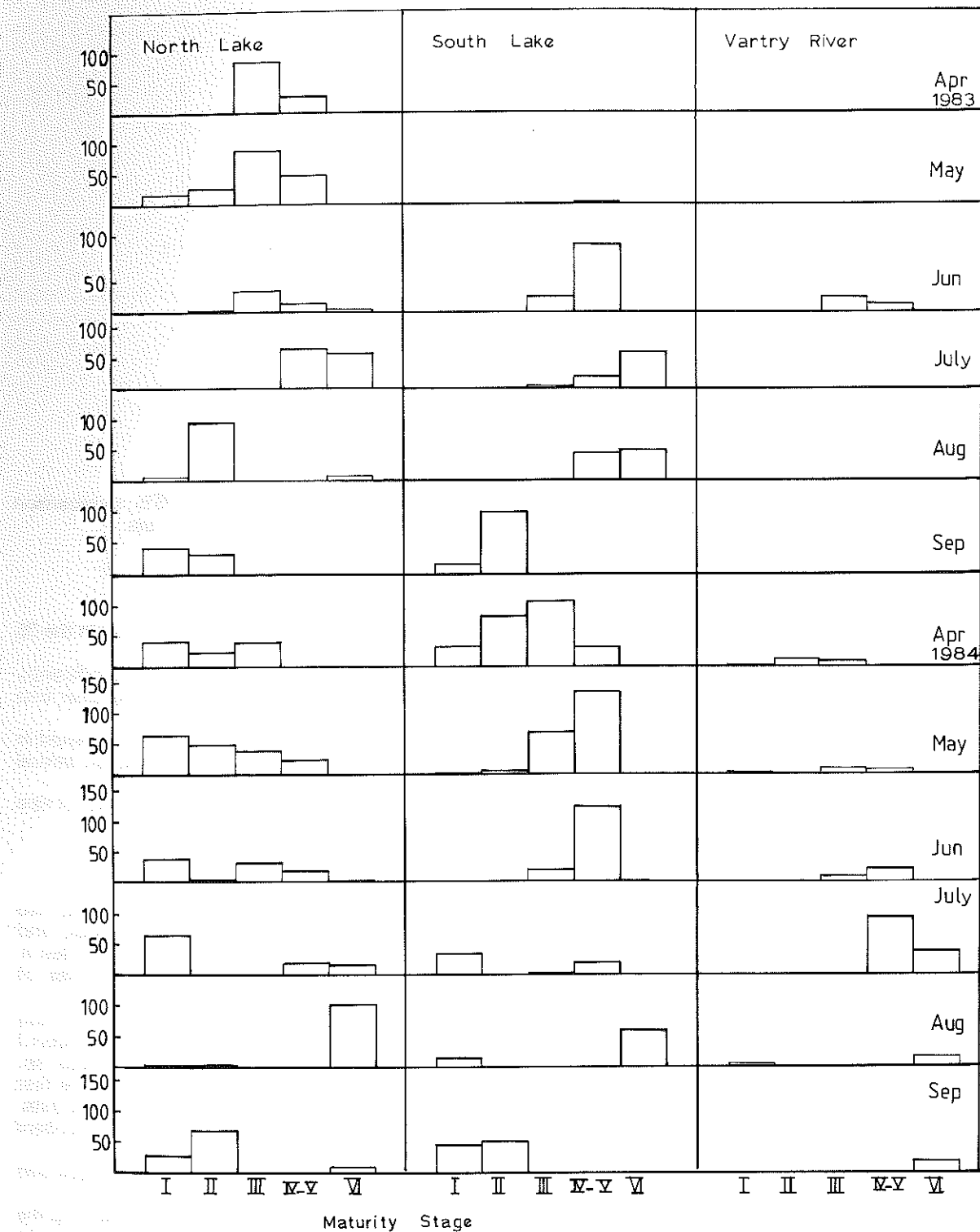


Figure 6. Numbers of fish in maturity stages in North and South Lakes and River Vartry on each sampling date.

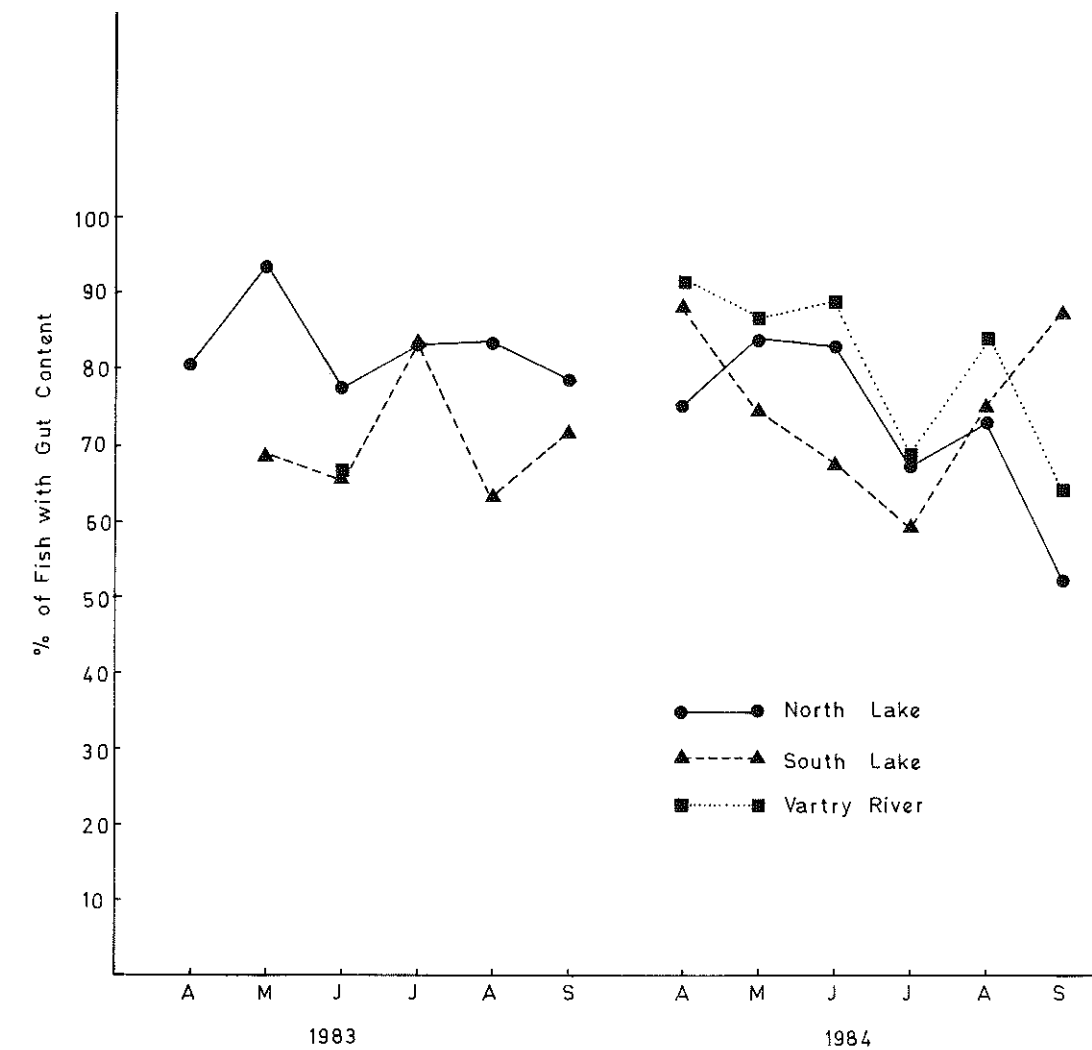


Figure 7. Percentage of guts containing food on each sampling date in the North and South Lakes and Vartry River, Roundwood, Co. Wicklow.

The frequencies of occurrence, expressed as percentages, with which items of the different food categories were found in the fish guts are given in Table 11. The results are similar for the two lakes but show marked differences between the two lakes and the Vartry River. The most frequent food items in the lakes were surface insects, molluscs, chance food, trichopteran larvae and cladocera. In the river fish, chance food and molluscs still occurred frequently but chironomid and other larvae and ephemeropteran nymphs became important in the diet.

The numerical and 'bulk' composition of the food was substantially the same at all sites but ephemeropteran nymphs and other insect larvae were more important in the diet of river fish ( $p < .01$ ).

The composition of the diet varied markedly between sampling dates (Figs. 8, 9, 10). In the North Lake during April 1983, chironomid larvae (*Endochironomus* sp.), molluscs (*S. corneum*) and trichopteran larvae (*L. vittatus*) were the most important food items. These were replaced by Cladocera (*Daphnia* sp.) and surface insects during May. By August and September the fish had again reverted to the original items eaten in April, however, the dominant trichopteran larva was now a *Mystacides* species. The early dominance of chironomid and trichopteran larvae and of molluscs was not as evident in the diet in 1984 but the pattern for the remainder of the year was similar to 1983.

Minnow from the South Lake showed similar trends in their diet to those from the North Lake with one notable exception, the proportion of Cladocera eaten declined markedly during the summer months 1984.

The dominant food items eaten by the river fish were chironomid larvae (*Endochironomus* sp. and *Tanytarsus* sp.), molluscs (*A. fluviatilis* and *P. jenkinsi*) and ephemeropteran nymphs. The chironomid larvae predominated in April and May, ephemeropteran nymphs and other insect larvae were the most important in June and July and molluscs and chance food dominated in August and September.

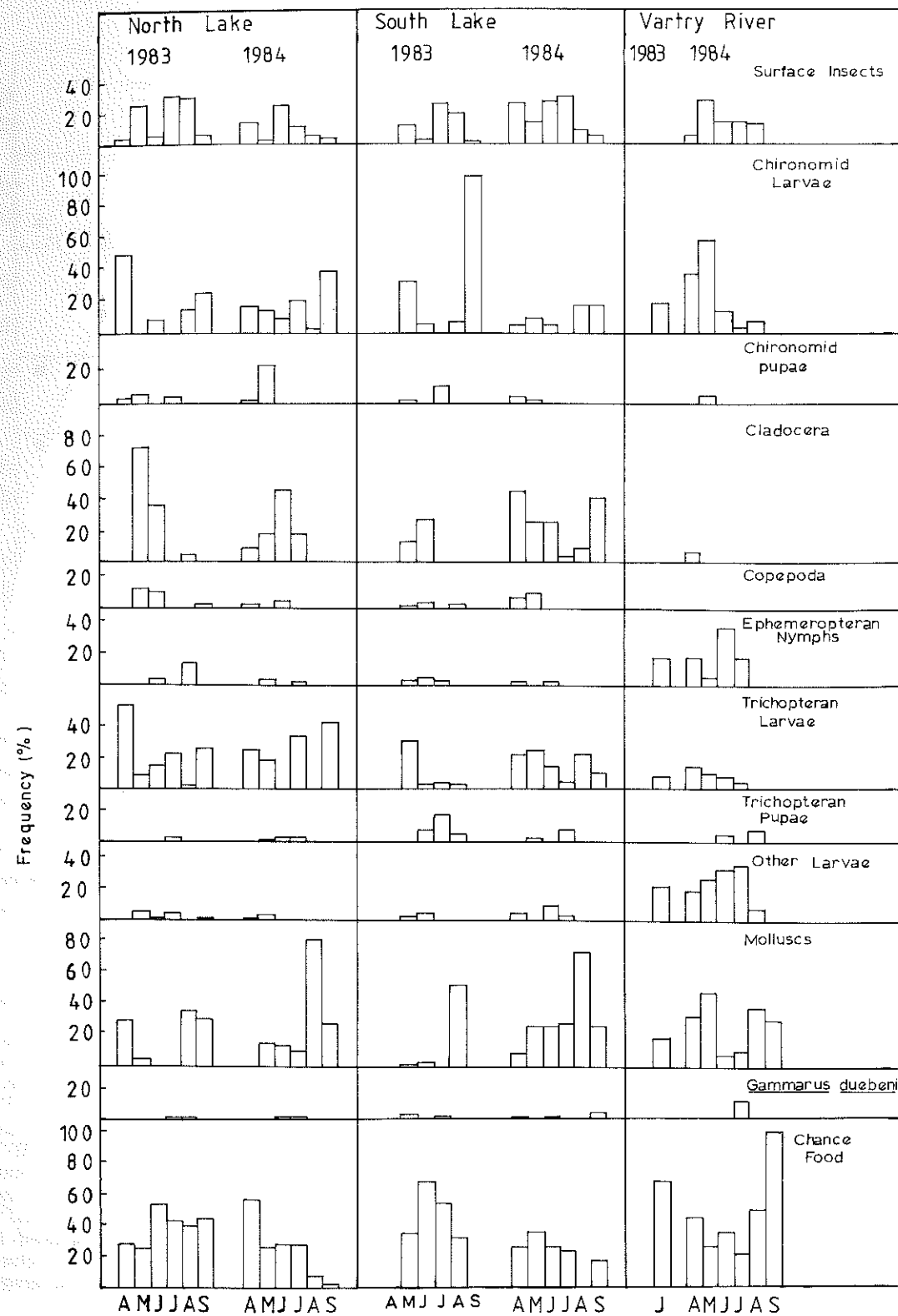


Figure 8. Frequency of occurrence of each food category in fish which were feeding in the North and South Lakes and Vartry River.

One further point of interest about the above data is the similarity of the results obtained using the three measures of dietary importance. This seems to suggest that where sample sizes are large and fish are small, as in the present study, frequency of occurrence may provide an adequate measure of the dietary importance of food categories.

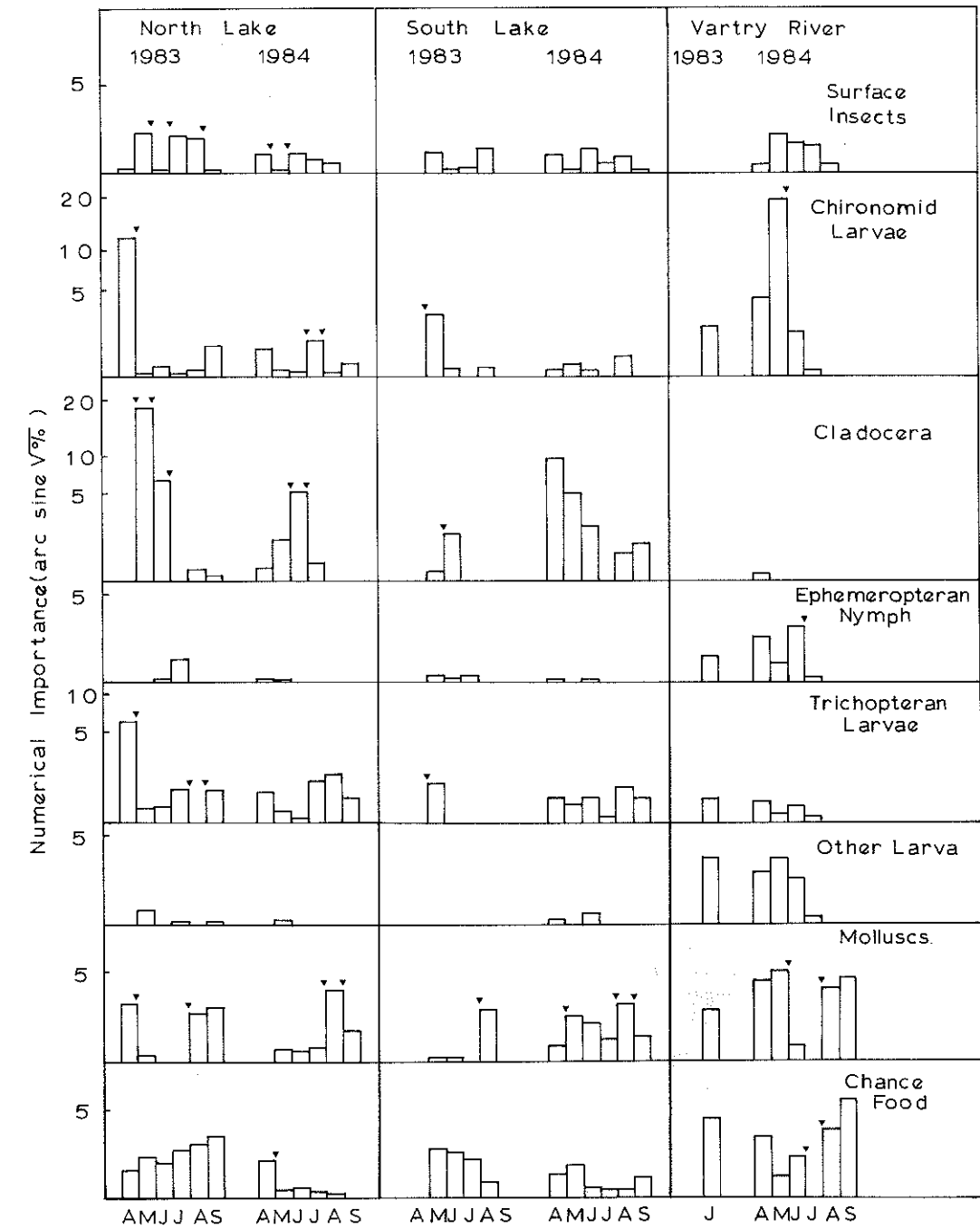


Figure 9. Numerical importance (arc sine  $\sqrt{\%}$ ) of each food category in the diet of minnow from North and South Lakes and Vartry River, ▼ = Significant difference between consecutive dates ( $p < .05$ ), tested using Bonferroni t-statistics.

**Abnormalities of the pelvic fin complex**

During this study a total of 39 minnow were found to lack pelvic fins or have abnormalities of the pelvic fin complex (Table 12). Further examination of these fish showed that 25 lacked both pelvic fins, 14 had retained a single reduced pelvic fin (4-5 rays) while three of the original 25 fish also lacked the pelvic girdle itself. Despite the abnormalities all the fish were found to be in good condition. Both length and weight measurements appeared to be normal. There was no sign of physical injury and in all cases where the fin or fins were missing a row of scales had developed where the fins should have emerged.

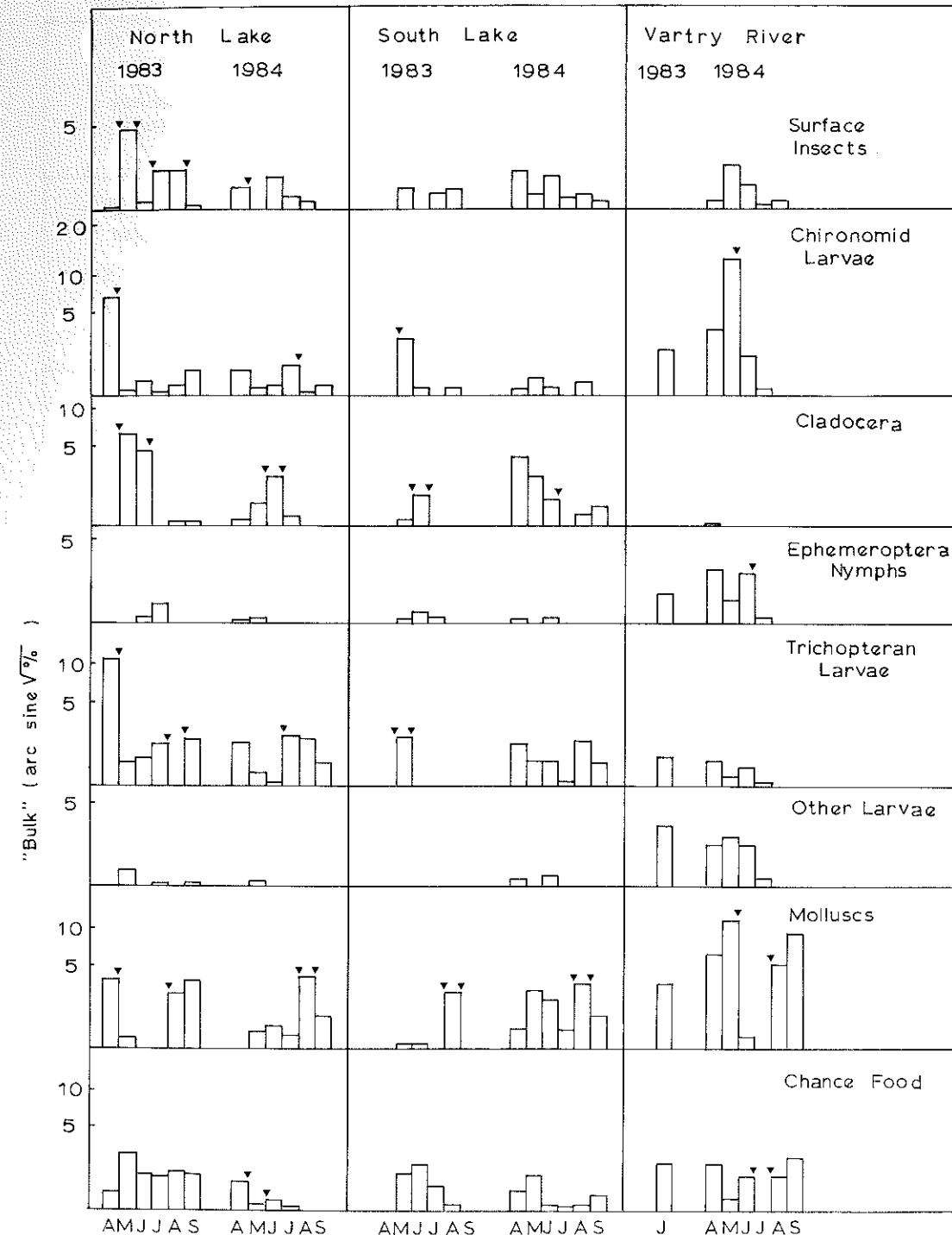


Figure 10. Contribution of each of the food categories to the 'bulk' (arc sine  $\sqrt{\%}$ ) of the diet of minnow from North and South Lakes and Vartry River.  $\nabla$  = Significant difference between consecutive dates ( $p < .05$ ), tested using Bonferroni t-statistics.

**DISCUSSION**

The most comprehensive works on the general ecology of minnow are those of Tack (1940), Frost (1943) and Lien (1981) and aspects of the reproductive biology are described by Bullough (1939, 1940, 1941), Papadopol and Weinberger (1975) and Wootton and Mills (1979). Comparisons of the present data with other studies suggest that there are important similarities and differences between the Roundwood and other populations.

The age distribution, size and growth of the minnow in Roundwood are similar to those recorded by Tack (1940) and Frost (1943) but differ markedly from other studies (Starmach 1961, Pitcher 1971, Papadopol and Weinberger 1975) all of which record lower average lengths (Table 5).

The fact that condition did not vary with maturity stage is surprising as condition would be expected to disimprove in spent fish. However, Wootton and Mills (1979) noted a sharp increase in both carcass weight and total body weight in minnow immediately following the spawning season and three-spined stickleback have been observed to gain weight within 90 hours of spawning (Wootton 1974).

The standard length of mature minnow ranges between 42-72mm for most of the river and lake drainages of Europe (Tack 1940, Frost 1943, Dottrens 1943, Starmach 1963, Zukov 1965 and Balon 1966). In the Roundwood system most fish reached first maturity in the 35-45mm length range.

Frost (1943) has shown that most minnow from Windermere, over 40mm in length, were sexually mature and that there was a preponderance of females among these fish viz., 63% female and 37% male. Frost states that the high percentage of females may be explained on the basis that the females live longer than the males. However, Bullough (1940) has shown that in their old age functional females were being transformed into functional males. If minnow of 40mm or less are removed from the Roundwood data 55% of the remainder are males but the proportion of females increases with age.

The spawning season is later than normal and is thought to be related to low water temperatures at these altitudes (approx. 200m a.s.l.).

The diameters of eggs from the Brathay River lie within the 1.3-1.4mm range (Frost 1943). These eggs are smaller than minnow eggs from midland waters in Ireland (1.5-1.8mm) but ova from the Roundwood system were even smaller than those from Windermere fish (1.0-1.4mm).

Littoral and benthic surveys of macroinvertebrates were carried out in both lakes during 1983 and 1984. The results of these surveys are presented elsewhere (Dauod *et al* In Prep.). It suffices to say that the littoral and benthic fauna were similar in each lake but more food organisms per square metre were found in each zone of the South Lake. However, the oligotrophic nature of the watershed is such that faunal numbers are poor by Irish standards.

The percentages of feeding minnow in this study are much lower than those recorded by Frost for Windermere (91.7%) and the River Brathay (88.5%). The difference may be due to the oligotrophic status of the Roundwood system and to water level fluctuations.

Early in the year the most important food items were chironomid larvae (*Endochironomus* sp.), molluscs (*S. corneum*) and trichopteran larvae (*L. vittatus*). These were replaced by Cladocera (*Daphnia* sp.) and surface insects during May. By late August and September the fish had reverted to the original April diet. However, the dominant trichopteran larva was now a *Mystacides* species. Cladocera were not as important in the diet as they were in Windermere but surface insects played a more important role in the Roundwood fish.

Trout of all sizes are known to feed on minnow and at Roundwood, following the emergence of *L. vittatus* in July, a large proportion of trout guts are either empty or contain minnow or stickleback. However, as both minnow and trout feed extensively on *L. vittatus* and as the presence of minnow in large numbers may lead to a reduction in fly hatches (Kennedy pers. comm.), the presence of minnow essentially means less rather than more food for the trout. Thus, in an oligotrophic system, such as Roundwood, the presence of minnow may be considered a wasteful addition to a meagre food chain.

Brindley (1891), Thompson and Adams (1936), Welander (1946), Donaldson (1955), Eisler (1961), Kaushik (1960) and Nelson (1971) have recorded abnormalities of the pelvic fin complex of a variety of fish species from other countries. In general terms they have all suggested that the abnormalities are genetic in nature and are caused by a mutant gene. In Roundwood less than 1% of the number examined (4342 fish) exhibited some form of abnormality. The fact that all 39 fish were in good condition and did not appear to suffer as a result of the abnormality would seem to suggest that it is relatively unimportant in the population as a whole.

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## APPENDIX

The minnow, *Phoxinus phoxinus* (L.), is found all over Europe and the British Isles with the exception of the Iberian Peninsula, Russian Turkistan, Siberia and the northern highlands of Scotland (Regan 1911). Berg (1932) recorded it from the Crimea.

The minnow is essentially a river and stream fish but it has been found in canals, ponds, shallow lakes and in the littoral zones of deep lakes and reservoirs. It prefers moderate to slow flows and a gravelly substratum. Altitude does not appear to affect its distributions and it has been successfully introduced into the mountain lakes of southern Norway (Borgström 1973). Lien (1981) found minnow in Øvre Heimdalsvatn, 1,090m. a.s.l., in southern Norway. It can tolerate a range of water temperatures from 0 - 31°C. In Ireland it is common in both acid and alkaline waters thus contradicting Day (1880) who states that it does not occur in waters where calcareous rocks predominate.

According to Day (1880) the minnow was introduced into Ireland in 1822, in the Dublin/Wicklow region. McCarthy and Kennedy (1965) reviewed the distribution of minnow in Irish waters and concluded that it occurred more commonly in the eastern half of the country. Specimen collections, housed in the National Museum, were examined by O'Riordan (1965) and confirmed these findings. Went and Kennedy (1969) commented that it was common locally but that its distribution was expanding. Undoubtedly these remarks referred to the wide usage of minnow as live bait by visiting coarse anglers during the sixties and seventies. This practice is now prohibited by law.

Recent information on the distribution of minnow in Irish lakes and rivers, collected from a wide variety of sources, may be summarised as follows:

### Leinster

Widely distributed throughout the province. Not recorded from the small coastal rivers and streams. Absent from Lough Sheelin and the upper reaches of the River Inny.

**Ulster**

Widespread throughout the Erne and Macnean systems. Common in the Lough Neagh catchment, present in most rivers and especially abundant in the Upper and Lower Bann and Blackwater. Not recorded from a large number of coastal rivers including the Bush, Margey, Glenshesk and Carey rivers, Co. Antrim. Distribution sporadic in the Foyle catchment but found in the River Faughan. No records available from Co. Donegal but minnow appear to be absent from the lakes and rivers within the Glenveagh National Park.

**Connaught**

Common in the Corrib and Mask catchments. No records available from the coastal rivers. Widespread in the Shannon system and abundant in the Rivers Suck, Brosna and Little Brosna. Absent from the Clare River, Co. Galway.

**Munster**

Present in all the larger river systems in the Killarney Valley catchment. Absent from the Lee system, Co. Cork. No information on its occurrence in small coastal rivers and streams.

**Table 1. Location and physical parameters of the North and South Lakes, Roundwood, Co. Wicklow.**

	South Lake	North Lake
Grid Reference	0 202 037	0 204 045
Maximum Volume (m)	11,283,172	5,632,494
Maximum Depth (m)	18.59	13.41
Maximum Length (km)	2.42	2.82
Maximum Width (km)	0.80	0.40
Area (h)	165.52	122.62
Trophic Status	Oligotrophic	Oligotrophic
pH	6.4 - 7.6	6.4 - 7.6
Conductivity (µmhos)	69-114	69-114
Height a.s.l. (m)	213.36	226.77

**Table 2. Numbers of minnow caught, aged and examined for gut contents on each sampling date at each site.**

Date	North Lake			South Lake			Vartry River		
	Sample size	Number aged	Number of guts examined	Sample size	Number aged	Number of guts examined	Sample size	Number aged	Number of guts examined
1982									
9 October	—	—	—	—	—	—	131	73	100
1983									
28 April	124	70	124	—	—	—	—	—	—
17 May	198	88	92	154	64	106	—	—	—
14 June	84	83	83	81	81	81	42	42	42
12 July	136	132	109	92	91	91	—	—	—
16 August	160	102	123	135	123	135	—	—	—
16 September	196	107	107	7	7	7	—	—	—
14 October	—	—	—	—	—	—	70	57	70
1984									
10 April	212	130	140	269	95	143	24	24	24
22 May	423	163	165	215	112	116	22	22	22
14 June	267	131	131	168	121	127	35	35	35
11 July	238	125	125	110	101	95	146	134	134
15 August	194	110	115	80	79	79	19	19	19
7 September	148	125	123	110	98	98	22	22	22
10 October	—	—	—	—	—	—	30	30	30
Total	2380	1366	1437	1421	972	1078	541	458	498

**Table 3. Weighted averages for weights of each food category and the conversion factors used in the estimation of 'bulk'.**

Food category	Weighted average weight per item (g)	Conversion factor
Cladocera	2.95 x 10 <sup>-4</sup>	1
Copepoda	3.35 x 10 <sup>-4</sup>	1
Surface Insects	9.96 x 10 <sup>-3</sup>	34
Chironomid Larvae	4.51 x 10 <sup>-3</sup>	15
Chironomid Pupae	3.55 x 10 <sup>-3</sup>	12
Ephemeropteran Nymphs	6.16 x 10 <sup>-3</sup>	21
Trichopteran Larvae	1.59 x 10 <sup>-2</sup>	54
Trichopteran Pupae	3.75 x 10 <sup>-2</sup>	127
Other Larvae	3.65 x 10 <sup>-3</sup>	12
Mollusca	1.46 x 10 <sup>-2</sup>	50
<i>Gammarus duebeni</i>	9.58 x 10 <sup>-2</sup>	325
Chance Food	3.38 x 10 <sup>-3</sup>	11

**Table 4. Age distributions of minnow from the three locations as percentages of total in each.**

	Age group					Total aged
	0	I	II	III	IV	
<b>1983</b>						
North Lake	16.7	78.1	5.0	0.0	0.2	582
South Lake	7.1	79.3	12.5	1.1	0.0	368
Vartry River	0.0	92.9	7.1	0.0	0.0	99
<b>1984</b>						
North Lake	32.8	59.5	7.7	0.0	0.0	784
South Lake	9.8	67.0	22.0	1.2	0.0	604
Vartry River	1.0	87.2	11.5	0.3	0.0	286

**Table 5. Length (cm) for age relationships of minnow from a number of European waters compared with the Roundwood data. (Number of fish examined in parentheses after mean lengths.)**

Source	Location	Age group					V	
		0	I	II	III	IV		
Present Study	North Lake	Mean	3.46 (355)	5.21 (921)	6.68 (89)	—	8.5 (1)	—
		Range	1.9-5.0	3.0-6.7	6.0-7.6	—	—	—
		S.D.	0.55	0.64	0.31	—	—	—
	South Lake	Mean	3.19 (85)	5.27 (697)	6.66 (179)	8.05 (11)	—	—
		Range	1.5-4.4	3.6-6.8	5.7-8.0	7.4-8.8	—	—
		S.D.	0.74	0.64	0.38	0.53	—	—
	Vartry River	Mean	4.00 (3)	5.66 (413)	6.77 (41)	8.20 (1)	—	—
		Range	3.8-4.2	3.0-6.6	6.3-7.6	—	—	—
		S.D.	0.20	0.49	0.31	—	—	—
Frost (1943)	Windermere	Mean	3.37 (91)	5.62 (130)	6.88 (65)	—	—	—
		Range	2.4-4.2	4.2-6.8	5.6-7.7	—	—	—
		S.D.	0.47	0.56	0.43	—	—	—
	Brathay River	Mean	3.66 (66)	5.44 (106)	6.53 (33)	—	—	—
		Range	2.7-4.3	4.1-6.8	5.7-7.4	—	—	—
		S.D.	0.45	0.66	0.46	—	—	—
Tack (1940)	Germany	Mean	3.43 (162)	5.31 (221)	6.94 (106)	8.53 (62)	9.56 (18)	11.38 (3)
Starmach (1961)	Poland	Mean	—	4.50 (2)	6.10 (73)	6.80 (87)	8.20 (1)	—
		Mean	—	5.01 (75)	6.04 (201)	7.22 (22)	—	—
Pitcher (1971)	England	Mean	—	2.62 (2)	5.21 (17)	6.11 (9)	—	—
		Mean	—	5.01 (75)	6.04 (201)	7.22 (22)	—	—
Papadopol & Weinberger (1975)	Romania	Mean	—	2.62 (2)	5.21 (17)	6.11 (9)	—	—
		Mean	—	5.01 (75)	6.04 (201)	7.22 (22)	—	—

**Table 6. Sex ratios of Roundwood minnow.**

	Males	Females	Ratio	X <sup>2</sup>
North Lake	735	643	1 : 0.87	6.14*
South Lake	767	513	1 : 0.66	50.4 ***
Vartry River	269	222	1 : 0.83	4.5 *

X<sup>2</sup> tests significance of departure from 1 : 1 ratio.

**Table 7. Percentages of females in each age group.**

Age Group	I	II	III	IV	Total aged
North Lake	33.7	45.6	87.6	—	1140 X <sup>2</sup> = 71.8 **
South Lake	21.7	39.7	51.7	63.6	885 X <sup>2</sup> = 14.35 **
Vartry River	50.0	43.0	50.1	100	469 X <sup>2</sup> not calculated *

\*X<sup>2</sup> not calculated because of large proportion of expected values less than 5.

**Table 8. Range of egg counts for minnow in different length categories at each location.**

Length (cm)	North Lake		South Lake		Vartry River	
	Number of fish	egg count range	number of fish	egg count range	Number of fish	egg count range
4.1 - 5.0	5	206 - 278	11	206 - 287	—	—
5.1 - 6.0	31	215 - 303	51	215 - 421	17	242 - 281
6.1 - 7.0	32	207 - 478	39	256 - 535	16	276 - 518
7.1 - 8.0	—	—	15	312 - 702	—	—

**Table 9. Numbers of minnow feeding at each sampling site for 1983 and 1984.\***

	Gut Contents Present	Gut Contents Absent
North Lake	1114	323
South Lake	791	287
Vartry River	248	150

\*1982 has been omitted for Vartry River (100 fish).

**Table 10. Proportions of Fish Feeding at each Site Related to Age Group.**

Site	Age group	Number of fish examined	Proportion with gut contents
North Lake	O	352	68.8
	I	894	79.6
	II	89	82.0
			$X^2 = 18.28^{**}$
South Lake	O	80	56.3
	I	685	74.5
	II	175	78.3
	III	11	63.6
			$X^2 = 15.15^{**}$
Vartry River	O	3	0.0
	I	413	69.5
	II	41	80.5
	III	1	100.0
			$X^2 = 9.64^*$

**Table 11. Frequency of occurrence (%) of food items in the guts of minnow from the three sites.**

	North Lake	South Lake	Vartry River
Surface Insects	47.2	44.0	8.0
Ephemeropteran Nymphs	1.7	1.3	9.8
Trichopteran Larvae	16.9	10.3	4.4
Trichopteran Pupae	0.6	2.3	0.4
Chironomid Larvae	12.8	7.0	18.7
Chironomid Pupae	3.2	1.3	0.6
Other Insect Larvae	1.1	1.5	19.5
Cladocera	13.0	14.7	0.2
Copepoda	1.7	1.8	0.0
<i>Gammarus duebeni</i>	0.2	0.8	1.2
Mollusca	15.4	17.5	15.5
Chance Food	25.1	22.8	27.7

**Table 12. Number of pelvic fin abnormalities at each location related to length of fish.**

Length (cm)	North Lake	South Lake	Vartry River
4.1 - 5.0	11	1	—
5.1 - 6.0	16	2	3
6.1 - 7.0	2	1	3

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