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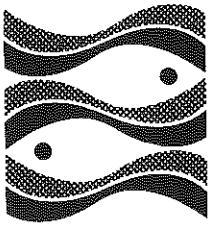

IRISH FISHERIES INVESTIGATIONS

H. A. Dauod, T. Bolger and J. J. Bracken

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

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H. A. Dauod, T. Bolger and J. J. Bracken

Zoology Department, University College, Dublin 4,

ABSTRACT

Monthly samples were taken using a small-meshed beach seine. A total of 1092 sticklebacks were captured, 725 fish were used to calculate the age distributions and 699 were examined for gut contents. The age data, determined from the otoliths, showed that there were four age classes present. The mean length of first year fish (0-Group fish) was 2.24cm, of second year fish (I-Group) 3.36 and 4.47cm and 5.72cm for II-Group and III-Group fish respectively. The breeding season was June-July. Sex ratios were similar in both lakes and did not differ significantly from 1 : 1. Sexual maturity was reached by all fish above 3cm. The smallest maturing virgin was 2.6cm in length. Egg diameters varied between 1.0 and 1.5mm. The diet was similar in the two lakes studied. In the North Lake Cladocera, chironomid larvae, copepods and molluscs dominated while in the South Lake Cladocera, copepods, chironomid larvae and surface insects were dominant.

Sticklebacks were extremely scarce in the Vartry River and feeder streams entering both lakes and would not pose a threat to egg production by trout and minnow in these streams. The influence of sticklebacks is discussed in relation to other fish species.

INTRODUCTION

The present investigation attempts to examine the role of the three-spined stickleback, *Gasterosteus aculeatus* L., as a potential competitor for food with the brown trout, *Salmo trutta* L., in the Roundwood Reservoir System. This is a predominantly freshwater species in Ireland but Bracken and Kennedy (1967) have recorded its occurrence in certain estuaries on the south coast, Dublin Bay and Rosslare Strand, Co. Wexford. Despite the fact that it is extremely widespread there is no published work on its ecology in Ireland. This is surprising in view of the paucity of freshwater species in this country, only 19 species occur, but is probably due to the fact that it is of no commercial value. According to Kennedy (pers. comm.) stickleback migrate during the springtime from deeper water into the shallow lake margins, while in rivers they tend to move away from the main channel into the tributaries and quieter backwaters. The general ecology of this species has been comprehensively described by Bertin (1925), Münzing (1959, 1963), Hagen (1967) and Wootten (1976). Aspects of feeding and food limitation have been reviewed by Hynes (1950), Wootton (1977) and Allen and Wootton (1982, 1984).

MATERIALS AND METHODS

The Site

The Roundwood Reservoir system is made up of two lakes lying approximately 200m a.s.l. on the eastern edge of the Wicklow Mountains. The Vartry River enters the smaller North Lake and its chemical parameters are similar to those of the two lakes. Both lakes are subjected to water level fluctuations (up to 9m) which affect the community structures of the contained macroinvertebrates. The geology, rainfall data and chemistry of the lakes are described in detail by Dauod *et al.* (1985).

Collecting Methods

A small-meshed (4mm) beach seine was used to collect monthly samples of three-spined stickleback from both lakes from April to September during 1983 and 1984. A total of 625 sticklebacks were caught in the North Lake and 467 in the South Lake. Very few specimens were captured from the Vartry River and these will be ignored.

Measurements

The specimens were measured using standard lengths viz., from the tip of the snout to the commencement of the caudal fin. The numbers measured, aged and examined for gut contents are listed in Table 1. Length — weight relationships were examined using geometric mean regression coefficients which were compared 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% comparison intervals do not overlap.

Age Determinations

Most workers have used the sagittal otoliths to age sticklebacks including Jones and Hynes (1950), Greenbank and Nelson (1959) and Coad and Power (1973). Craig and Fitzgerald (1982) also used length frequency distributions. Allen and Wootton (1982) found that only a small proportion examined survived beyond sixteen months and a few fish reached two years of age or older. The scheme described by Jones and Hynes (1950) was adopted to interpret the age of the Roundwood fish.

Stomach Examination

The stomach contents of 368 stickleback from the North Lake and 331 from the South Lake were examined. Three measures of the importance of food items were employed, frequency of occurrence, numerical percentage composition and percentage composition by 'bulk'.

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

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 stomach 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 2).

Determination of Maturity Stages

Maturity stages were recorded using the method of Nikolsky (1963). It was extremely difficult to separate stages IV and V in many specimens so these are treated as a single stage.

RESULTS

Habitat

In Roundwood the main aggregations of stickleback were found among the aquatic macrophytes in the littoral zone. Few specimens were taken outside the weed beds. They were slightly more numerous in the North Lake than in the South and only very small numbers were recovered from the Vartry River and other feeder streams.

Fluctuations in water levels occur frequently within the system. In 1983 water levels were down 7m during August and September and the following year were down 9m in June and July. The shape of both lake basins is such that a drop in water level of either of the above magnitudes totally exposes the littoral zones.

Age Distribution, Length and Growth

Four age classes were obtained as follows:—

0 — 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)

The age structure for the sticklebacks from both lakes is indicated by the sample sizes in Table 3. Young fish are inadequately represented because it was extremely difficult and time consuming to remove and read their otoliths. The oldest fish recovered was in its fourth year.

Mean lengths of fish in each age group in each lake are given in Table 3. There were no significant differences between the lengths of young fish in both lakes. However, the Group-II fish, captured in 1984, were significantly larger in the South Lake ($F = 26.87$, $p<.001$). The mean length of North Lake fish was 3.94 cm and 4.25cm for those from the South Lake (Fig. 1). The mean lengths given for Group-O fish are probably overestimates because, as explained above, smaller specimens were not aged.

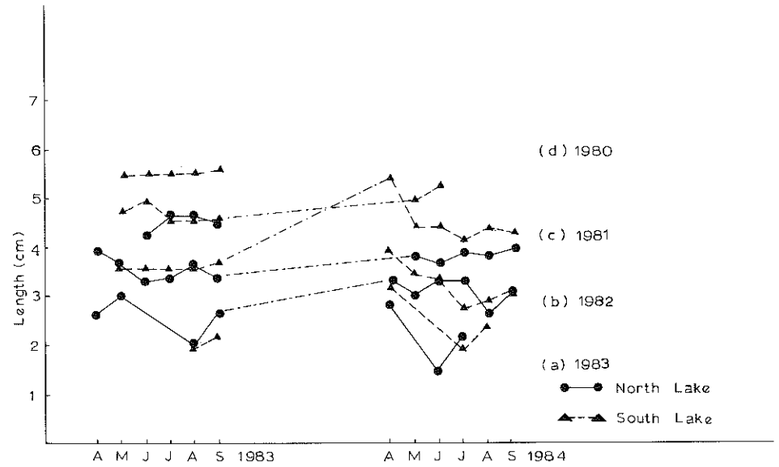

Figure 1. Mean lengths of fish of each age group.

Monthly length frequency distributions are illustrated in Fig. 2. The O-Group fish apear in the catches from June in the South Lake and make their appearance almost a month later in the North Lake. From August onwards their is a marked influx of young fish into the catches. There is also a decline in the number of old fish captured during August and September.

Length-Weight Relationship

In Roundwood there was a significant difference between the condition of the fish in the two lakes, those in the South Lake being heavier at a given length.

	Geometric Mean Regression Coefficients	95% Comparison Intervals
North Lake	3.329	± 0.085
South Lake	3.934	± 0.114

The presence of parasites also caused an increase in condition as illustrated by the geometric mean regression coefficients and 95% comparison intervals:

North Lake				South Lake			
No parasites	3.317	±	0.060	No parasites	3.992	±	0.170
With parasites	3.973	±	0.534	With Parasites	4.135	±	0.412

In the North Lake there was no difference between the condition of non-parasitized males and non-parasitized females, however, in the South Lake non-parasititized males had a higher regression coefficient.

Non-parasitized Males	4.528	±	0.608
Non-parasitized Females	2.878	±	0.655

Variations in length-weight relationships with gonadal maturity are summarized in Fig. 3. These appear to be similar for each sex in each lake.

In both lakes the condition of the fish improves in the late summer (Fig. 4).

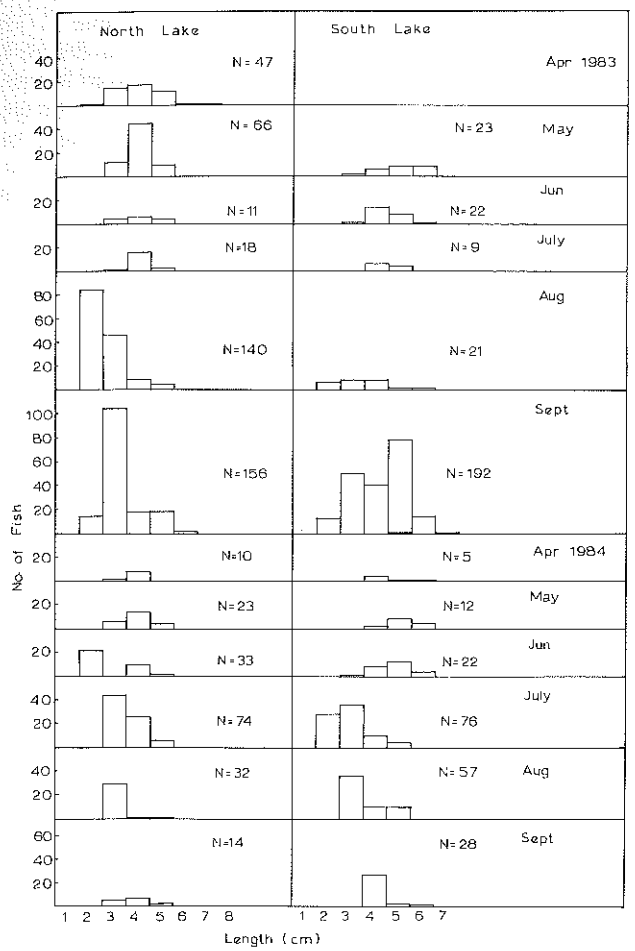

Figure 2. Numbers of fish in cm length groups (rounded downwards).

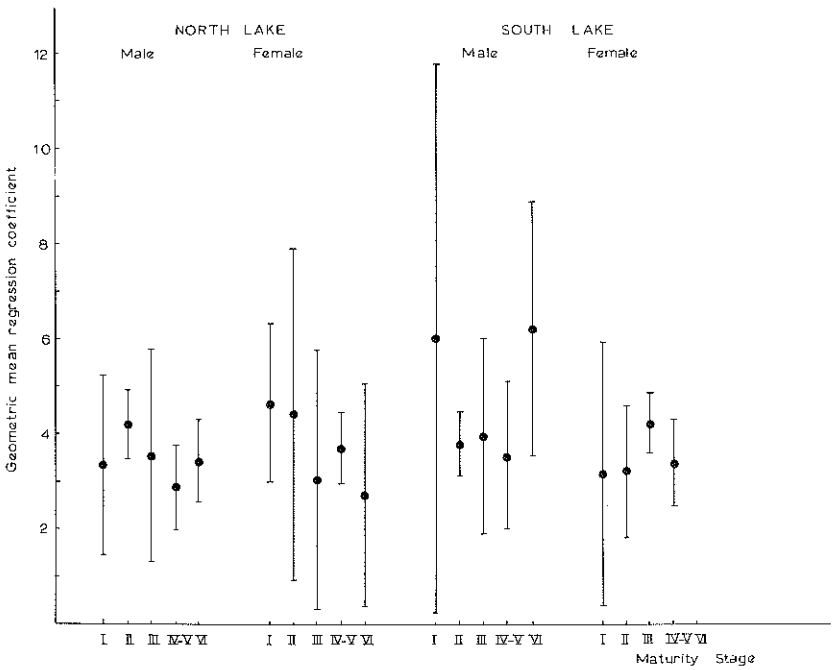

Figure 3. Geometric mean regression coefficients of $\log_{10}$ weight on $\log_{10}$ length (±95% comparison intervals) related to maturity stages.

Reproduction

In the present study the sex ratios were as follows:—

	Males	Females
North Lake	124	96
South Lake	107	111

The ratios were similar in both lakes and did not differ significantly from 1 : 1. Both males and females reached first maturity at 3.0cm and within the first year of life. The smallest maturing virgin fish was 2.6cm in total length. In Roundwood there was an increase in the size of the gonads of older fish in September and there was marked gonadal development in both sexes during April and May.

The maturity stages for the different months of the year are summarized in Fig. 5. In 1983 the fish spawned during June and July while in 1984 the spawning was slightly later in both lakes.

The mean number of eggs counted in fifty Roundwood sticklebacks was 130. The number of eggs was related to both length and weight of the fish ($p < 001$) and did not vary between the two lakes when fish size was taken into account.

The diameter of eggs varied between 1.0-1.5mm. The fish in the South Lake produced larger eggs, a factor which is though to be related to the richer food supply in this lake.

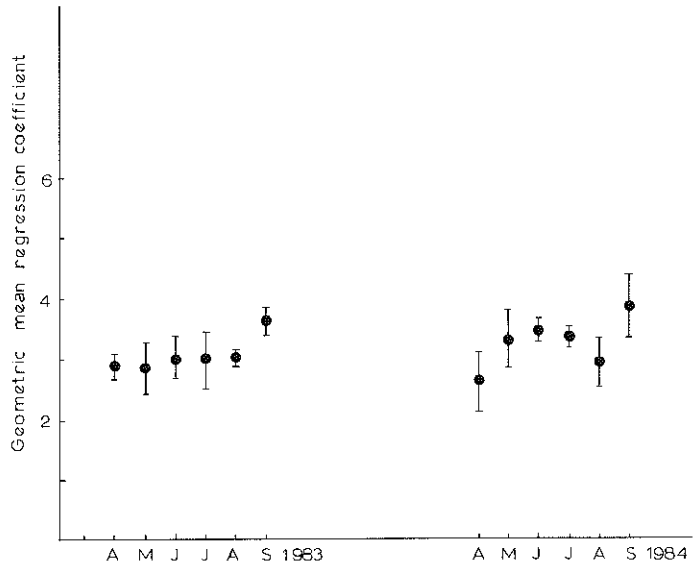

Figure 4. Geometric mean regression coefficients of $\log_{10}$ weight on $\log_{10}$ length (±95% comparison intervals) related to sampling date.

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.) and one family of Diptera (Chironomidae). The non-aquatic species included one dipteran family (Anisopodidae).

Three species of mullusc were found *Potamopyrgus jenkinsi* (Smith), *Physa fontinalis* (L.) and *Sphaerium corneum* (L.). The most abundant species of trichopteran larvae was *Limnephilus vittatus* (Fbr.). Two cladocerans occurred *Daphnia* sp. (Leydig) and *Chydorus* sp. *Diaptomus gracilis* (Lillj) and *Cyclops* sp. were the main copepods eaten. Both larval and pupal chironomids occurred in the diet mainly *Endochironomus* sp., *Tanytarsus* sp., *Procladius* sp. and *Microtendipes* sp. *Caenis* sp. was the dominant ephemeropteran nymph found in the stomachs.

Chance food included gammarid eggs, small nematodes and plant debris.

The frequencies of occurrence of the various food categories in the stomachs of all the fish examined are listed in Table 4. Chironomid larvae, trichopteran larvae and molluscs occurred more frequently in the stomachs of fish from the North Lake while surface insects and Cladocera were more commonly found in fish from the South Lake.

Temporal variations in the frequencies of occurrence are illustrated in Fig. 6. During April and May, 1983, in the North Lake, chironomid larvae *(Endochironomous* sp., *Tanytarsus* sp., *Procladius* sp. and *Microtendipes* sp.) Copepoda *(Cyclops* sp. and *Diaptomus gracilis* Sars.); Cladocera *(Daphnia* sp.) and trichopteran larvae *(L. vittatus)* were the most frequent food items. By June Cladocera, Copepoda and chance food were the most commonly occurring items. In July the fish concentrated on chironomid larvae *(Microtendipes* sp.); ephemeropteran nymphs *(Caenis* sp. and *Baetis* sp.) and molluscs *(P. fontinalis).* During August and September they reverted to the same diet taken in April and May. In 1984 the same trends occurred but surface insects became more important in the diet.

Similar patterns emerged in the South Lake but some differences were noted. Surface insects and chironomid pupae were more important in the diet over the two years.

The numerical and 'bulk' composition of the food was similar in both lakes. The seasonal patterns closely reflect those illustrated by the frequency of occurrence data (Figs. 7, 8).

During July and again in September a high percentage of the fish were found without food in their stomachs (Fig. 9). There is a direct correlation between the large numbers of empty stomachs in July and the emergence of aquatic insects. The low percentage feeding in September is related to the appearance of large numbers of small fish in the population, a high proportion of which have empty guts (Table 5).

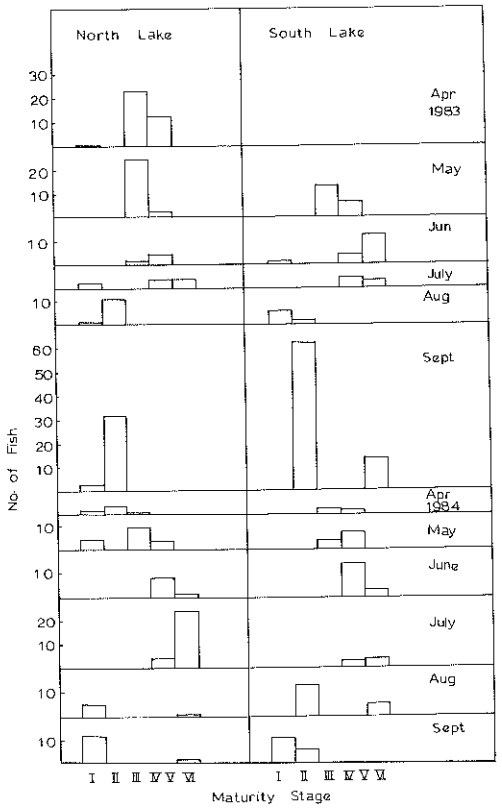

Figure 5. Numbers of fish in maturity stages.

Parasites

Many of the sticklebacks from Roundwood contained a cestode, *Schistocephalus solidus* (Muller), in their body cavities. An unidentifiable digenean also occurred in the stomach and intestine of a small number of fish.

In the present study the proportion of fish parasitized varied between the two lakes ($X^2 = 8.31$, $p < .01$), 32% were parasitized in the South Lake and 21% in the North. Equal proportions of males and females were infected and as would be expected older fish were more heavily parasitized than young (Table 6).

The negative binomial distribution has been found suitable by several authors for the description of host-parasite relationships (Crofton 1971, Pennycuick 1971b). The frequency distribution of parasites among hosts at Roundwood also takes this form (Table 7).

Lateral Plate Counts

The lateral plates were counted on 239 fish from the North Lake and 267 fish from the South Lake. The results are summarised in Table 8. More than 97% of the fish have 3-5 lateral plates and the number of plates appears to be related to the size of the fish.

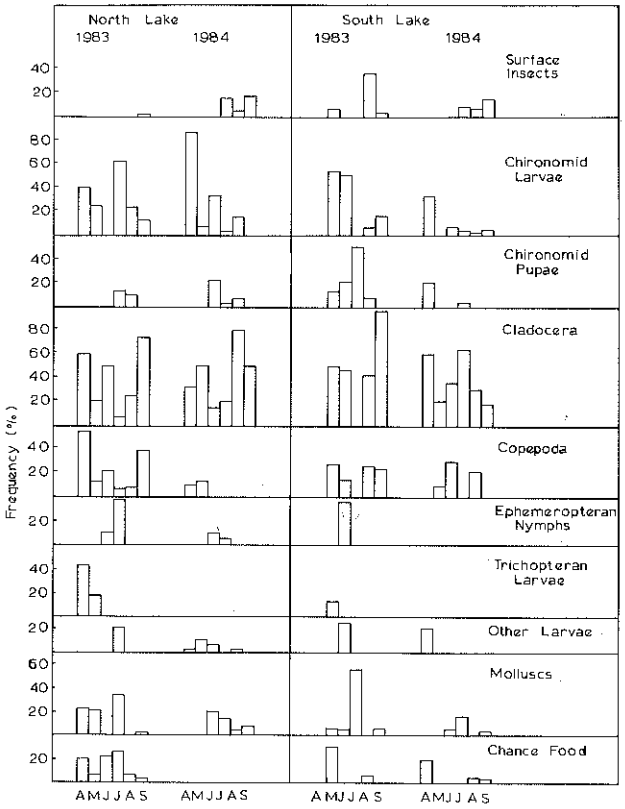

Figure 6. Frequency of occurrence of each food category in stickleback from the North and South Lakes.

DISCUSSION

The results obtained for the age, length and growth of the leiurus form of the three-spined stickleback at Roundwood are similar to those obtained by other European workers. In particular they agree closely with Jones and Hynes (1950) who found the oldest fish to be 3+ and stated that most of the growth occurred during the summer months. Growth during the first year was rapid but in subsequent years tended to slow down. They also suggested that the faster growing fish have a shorter life span.

The condition of sticklebacks is affected by a number of factors such as diet, gonadal weight and the presence or absence of parasites in the body cavity. Wootton (1978) found that there was a decline in condition during autumn and a sharp increase during May which represents the spawning period. Pennycuick (1971a) has shown that the presence of plerocercoid larvae of *Schistocephalus solidus* (Müller) affects the weight of individual fish. Similar results were found in the present study.

There is little agreement in the literature on the exact spawning time of three-spined stickleback or on the number of times individual fish spawn during their life-history. Regan (1911) states that the spawning season occurs in spring or summer but varies from year to year in different locatities. Rühmer (1952) gives April to June as the spawning time. Roule (1945), Swarup (1958), Greenbank and Nelson (1959) all agree on the April-May period. Carl (1953), however, found that the spawning season was prolonged and extended from April to September. Nests containing fertilized eggs have been collected in Irish waters from late April to June (Kennedy pers. comm.) which agrees with the results obtained by Rümher. In Roundwood the sticklebacks spawn during June and July (Fig. 5) and most fish appear to spawn more than once in their life cycle.

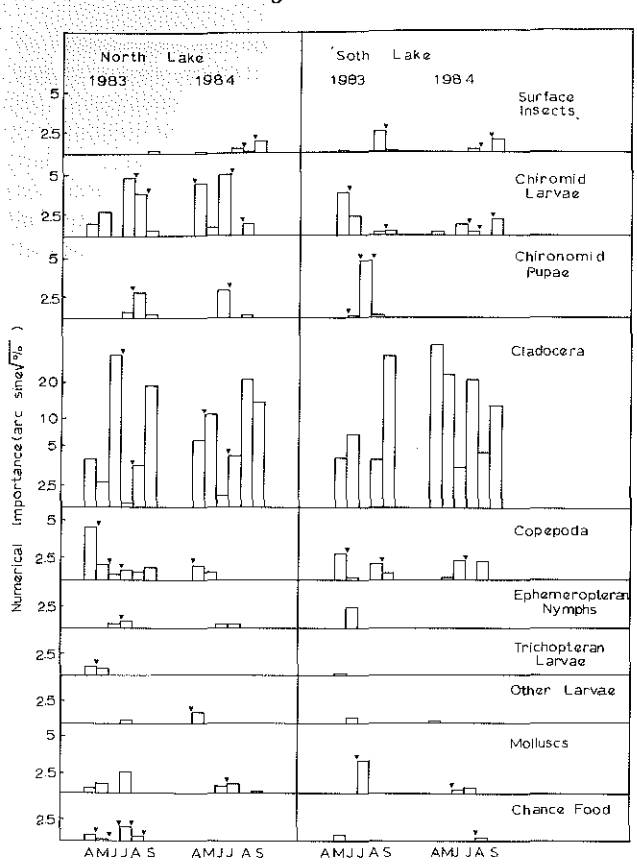

Figure 7. Numerical importance (arc sine $\sqrt{\%}$) of each food category in the diet of sticklebacks from both lakes. ▼= significant difference between consecutive dates ($p<.05$), tested using Bonferroni t-statistics.

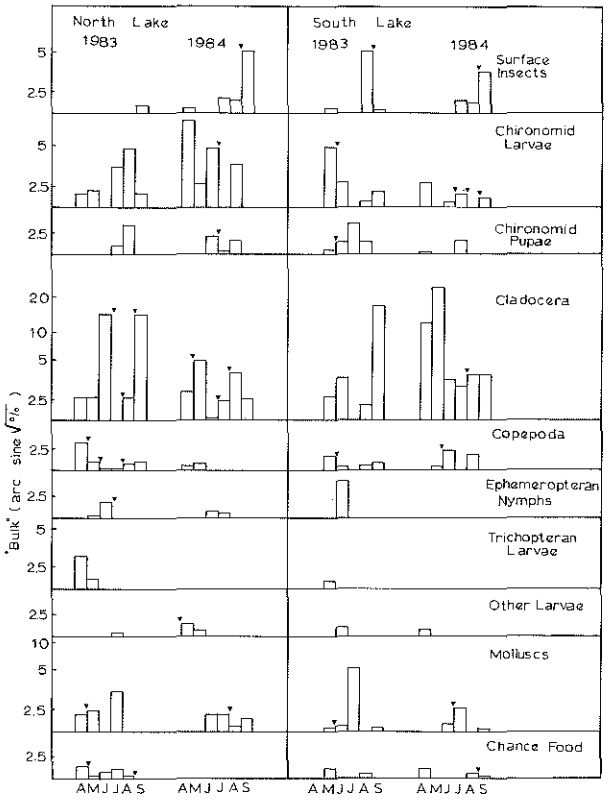

Figure 8. Contribution of each food category to the 'bulk' (arc sine $\sqrt{\%}$) of the diet of sticklebacks from both lakes, ▼= significant difference between consecutive dates ($p<.05$), tested using Bonferroni t-statistics.

No evidence was found to show that the lake sticklebacks migrate into the feeded streams or Vartry River to spawn as the brown trout and minnow do. Since the sticklebacks tend to inhabit and spawn in the weed beds of the littoral zone the drop in the water level is extremely critical and probably indirectly controls recruitment of O-Group fish. If young fish have no weed cover they become more exposed to predation by trout and cormorants. Nest building and egg laying must also be adversely affected.

Great variations in sex ratios have been reported by various workers. Jones and Hynes (1950) working on sticklebacks from the Birket River found more females to males with a ratio of 1 : 0.83. Swarup (1958) found that the sex ratio in April was 1 : 1 but during May and June a dramatic change occurred whereby more males than females were found giving ratios of 4 : 1 and 6 : 1 in May and June respectively. Fitzgerald (1983) states that significant differences in sex ratios occurred at different times of the year in Canadian sticklebacks. In May there were significantly more males present but there was not a significant difference from a 1 : 1 ratio when the total catch was pooled over the entire sampling period. The Roundwood ratios did not differ significantly from 1 : 1.

There is little agreement as to when sticklebacks reach first maturity. Bertin (1925) states that European sticklebacks reach maturity within their first year of life. Wunder (1930) reports that yearling fish do not spawn in German waters and Craig-Bennett (1931) has shown that all male sticklebacks under 4.5cm were immature. Leiner (1930, 1931, 1934) records that the fish do spawn in their first year. Greenbank and Nelson (1959) found sticklebacks spawning at the age of one and two years after which they died off. Fewer than fifty percent, however, spawned as one year olds. Swarup (1958) showed that male sticklebacks reached first maturity at 2.5cm and that all males above 3.0cm had ripe testes at Radley pond. The results obtained for Roundwood agree closely with Swarup.

Craig-Bennett (1931) and Stanworth (1953) state that in early autumn the oocytes undergo primary growth which involves an increase in size of the gonads. DeVlaming (1972) reports that further gonadal development is stimulated by long photoperiod and high temperatures or short photoperiod and low temperatures. Since the Roundwood lakes lie 200m a.s.l. gonadal development is likely to be stimulated by a short photoperiod and low temperatures.

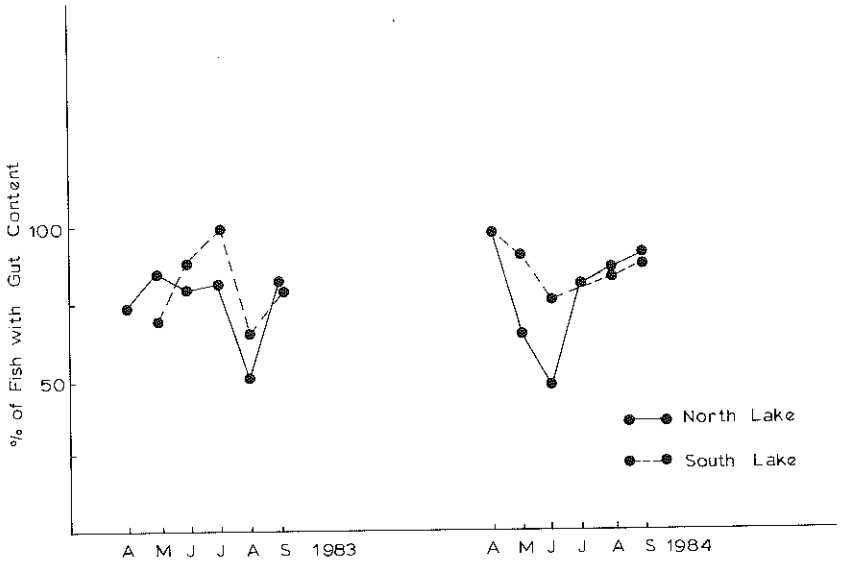

Figure 9. Percentage of stomachs containing food.

Moodie (1972), working on Mayer lake on the Queen Charlotte Islands, found that large sticklebacks were capable of producing an average of 257 eggs. Wootton (1973) stated that the number of eggs produced per spawning was dependent on female size. Larger fish tended to produce more eggs per spawning and to spawn for longer periods during the breeding season, provided there was an adequate food supply. Small fish, around 0.4g, which is the minimum weight at which females become mature, produced 20-30 eggs per spawning. Larger fish, weighing 3g or more produced 300-400 eggs (Wootton 1976). Females in the 4.0 to 7.4cm range produced egg numbers from 40-295 (Wootton 1973). Fitzgerald (1983) working on Canadian sticklebacks found the range to be 116-838 eggs per female. The mean number of eggs for Roundwood fish was 130 and was related both to length and weight of fish examined. The diameters of the ova varied between 1.0 to 1.5mm which is smaller than the range recorded by Bracken and Kennedy (1967) for midland Irish waters.

Numerous investigations have been carried out on the food of stickleback (Markley 1940, Hartley 1948, Hynes 1950, Carl 1953, Greenbank and Nelson 1959, Assem 1967, Wootton 1971, Kynard 1978 and Allen and Wootton 1984). Three faunal groups, viz., Copepoda, Cladocera and chironomid larvae appear to be the commonest organisms eaten. In both the North and South Lakes these three items were also found to be dominant but with the addition of molluscs in the North Lake and surface insects in the South Lake. The available evidence suggests that sticklebacks are not serious competitors for food with the trout and minnow. Jordan (1905) and Norman (1936) state that sticklebacks predate the ova and young of other species of fish while egg cannibalism has been noted by Hynes (1950) and Allen and Wootton (1984).

Such predation is highly unlikely to occur at Roundwood as both the minnow and trout spawn in the Vartry River and other feeder streams where sticklebacks are virtually absent.

Cooper (1918) found plerocercoid larvae of *S. solidus* in at least eight species of fish although more recently Hopkins and Smyth (1951) report finding this species in only the three-spined stickleback in the British Isles. Other authors have found sticklebacks infected with the same parasite but the percentage infection and the numbers of parasites present in individual fish are very variable. Arme and Owen (1967) report that parasitic infection rarely affects more than 50% of a given population and the number present per individual never exceeds ten. Chappel (1969) gives a similar percentage result with usually only one parasite per fish. On the other hand, Pennycuick (1971a) found high levels of infection (88.3%) and a mean number of 4.4 parasites per fish. She found that infected fish weighed less than uninfected ones in the same length group and that the presence of parasites also retarded growth and delayed sexual maturation. The level of parasitization in the Roundwood fish was much lower.

Three-spined sticklebacks in Irish waters all belong to the leiurus form which is characterised by the presence of one to nine lateral plates or scutes and the absence of a caudal keel. Bertin (1925) has demonstrated that the number of plates found in these fish is directly correlated with the salinity of the water. He maintains that there is a continuous gradation in plate numbers from salt water to freshwater. In general terms the number of plates tends to be lower in freshwater fish and some individuals occur in certain populations without lateral plates. The results from Roundwood support this hypothesis.

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Table 1. Numbers of stickleback caught, aged and examined for gut contents on each sampling date.

Date	North Lake Sample Size	North Lake Number Aged	North Lake Number of Guts Examined	South Lake Sample Size	South Lake Number Aged	South Lake Number of Guts Examined
1983						
28 April	48	48	48	—	—	—
17 May	66	57	53	23	23	23
14 June	11	11	11	22	22	21
12 July	18	18	18	9	9	9
16 August	140	35	27	21	21	21
14 September	156	54	54	192	98	98
1984						
10 April	10	10	10	5	5	5
22 May	23	23	23	12	12	12
14 June	33	27	21	22	22	22
11 July	74	63	57	76	36	35
15 August	32	32	32	57	57	57
7 September	14	14	14	28	28	28

Table 2. Weighted averages for weights of each food category and conversion factors used in the estimation of 'bulk'.

Food Category	Weighted Average Weight per Item (g).	Conversion Factor
Cladocera	2.95×10^{-4}	1
Copepoda	3.35×10^{-4}	1
Surface Insects	7.25×10^{-3}	25
Chironomid Larvae	2.30×10^{-3}	8
Chironomid Pupae	3.92×10^{-3}	13
Ephemeropteran Nymphs	6.16×10^{-3}	21
Trichopteran Larvae	9.67×10^{-3}	33
Other Larvae	4.10×10^{-3}	14
Mollusca	1.26×10^{-2}	43
Chance Food	1.93×10^{-3}	7

Table 3. Length (cm) for age relationships of stickleback.

Location	Age Group O	I	II	III
North Lake				
Number Examined	108	245	37	2
Mean	2.27	3.39	4.20	6.9
Range	1.1-3.8	1.7-5.0	2.9-5.0	6.8-7.0
S.D.	0.51	0.55	0.44	0.14
South Lake				
Number Examined	35	202	78	18
Mean	2.06	3.34	4.60	5.59
Range	1.0-3.2	2.0-4.5	4.0-5.5	5.1-6.2
S.D.	0.52	0.59	0.36	0.23

Table 4. Frequency of occurrence, expressed as percentage, of the food categories in all the stickleback examined for food.

Category	North Lake	South Lake
Surface Insects	5.4	9.6
Chironomid larvae	24.2	15.4
Chironomid pupae	3.8	4.5
Cladocera	43.5	58.7
Copepoda	14.4	17.5
Ephemeropteran nymphs	4.3	2.4
Trichopteran larvae	7.6	0.6
Other larvae	2.4	1.2
Mollusca	12.0	6.0
Chance food	5.7	3.3

Table 5. Relationship between length and proportion of stickleback feeding.

Length Group (cm)	Percentage Feeding	Number of Fish Examined
$1 < 2$	30.0	30
$2 \leqslant 1 < 3$	71.4	196
$3 \leqslant 1 < 4$	86.9	267
$4 \leqslant 1 < 5$	86.5	170
$5 \leqslant 1 < 6$	82.4	34
$6 \leqslant 1 < 7$	100.0	2

Table 6. Relationship between age of stickleback and percentage parasitized.

Age Group	Percentage Parasitized
O	5.3
I	26.3
II	46.2
III	53.8
	$X^2 = 47.34$, $p < .001$

Table 7. Distribution of *Schistocephalus solidus* among host individuals.

Number of Parasites	Number of Hosts
0	400
1	92
2	38
3	9
4	5
5	3
6	1
13	1

Table 8. Relationship between length of stickleback and number of lateral plates.

Length group	Number of lateral plates						Total Examined
	2	3	4	5	6	7	
North Lake							
$\leqslant 1 < 3$	1	0	0	0	0	0	1
$3 \leqslant 1 < 4$	21	16	2	0	0	0	39
$4 \leqslant 1 < 5$	1	62	85	14	0	0	162
$5 \leqslant 1 < 6$	0	2	9	19	1	0	31
$6 \leqslant 1 < 7$	0	1	0	4	0	0	5
$7 \leqslant 1 < 8$	0	0	1	0	0	0	1
South Lake							
$\leqslant 1 < 3$	3	1	0	0	0	0	4
$3 \leqslant 1 < 4$	6	49	63	17	2	0	137
$4 \leqslant 1 < 5$	1	5	25	47	9	0	87
$5 \leqslant 1 < 6$	0	0	2	23	13	1	39
$6 \leqslant 1 < 7$	0	0	0	0	0	0	0
$7 \leqslant 1 < 8$	0	0	0	0	0	0	0

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