FRESHWATER BIOLOGICAL ASSOCIATION

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# THE STATUS OF THE WINDERMERE CHARR POPULATIONS

## INTERIM REPORT

BY

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Contents

## 1. Introduction

In 1986 North West Water commissioned a report "A general assessment of environmental and biological features of Windermere and their susceptibility to change" from the Freshwater Biological Association. In this report it was noted that the population of arctic charr, Salvelinus alpinus, in the lake had increased since the FBA started culling pike in 1947, but that detailed information was lacking. Concern was expressed that the charr might be sensitive to the reduced concentrations of hypolimnetic oxygen that are now occurring in the south basin of the lake. Consequently, North West Water agreed to part fund a two year study to investigate the status of the Windermere charr populations. This interim report presents results from the first year of the study and also draws on some earlier work.

## 2. Results

### a) The Windermere charr stocks.

Earlier work by Winifred Frost (1965) and the present investigation both demonstrate that Windermere contains both a spring-spawning and an autumn-spawning race of charr. The differences between these races are both genetic and morphological. The latter include differences in both the mean number and the mean length of the gill rakers. By using a combination of the number and the length of gill rakers, it is now possible, by means of a discriminant function, to predict with more than 95% accuracy whether an individual charr is a spring or autumn-spawner (Fig. 1). There are also differences, principally in growth rates, between fish in the two basins (Table 1). North basin autumn spawners grow relatively slowly, north basin spring spawners and south basin autumn spawners are intermediate and south basin spring spawners are by far the fastest-growing charr in any Cumbrian lake.

Adult charr are known to return to the same spawning site each year, there are consistent variations in growth rates between basins and both spring and autumn spawners have at least one spawning site in each basin. Consequently, each basin must be considered to hold separate stocks of the two principal races. It may even be that each of the separate spawning sites comprises a separate stock but this would depend on the extent to which juveniles imprint to a particular site within the lake.

b) Composition of catches.

Using plumb-line tackle anglers generally catch fish at depths ranging from about a metre to perhaps 20 metres. Both fish bought from anglers and fish caught in gill nets set along the bottom in deep water at over 30 metres contained an extremely high proportion (at least 95%) of the autumn-spawning race of charr. This was true for both basins of the lake.

c) Age-structure of the charr populations.

The mean ages of spawning charr from the four main stocks caught between 1986 and 1988 are surprisingly high. The mean age of females is always greater than that of males and that of spring-spawners is generally greater than that of autumn spawners. However, there is no obvious difference between basins (Fig. 2). The differences between the ages of male and female spawners arise because most male charr mature at five years-of-age (though a few mature precociously as young as 2 years old. Few females mature until they are six or more years old but they are clearly longer-lived than males. Seventy eight percent of charr between 9 and 14 years old were female. Male and female charr grow at the same rate (Fig. 2). The presence of quite a high proportion of old charr in both basins of the lake indicates that mortality through angling cannot be very great or few fish would survive to reach such ages (unless a proportion behave in such a way that they are not vulnerable to angling) (see Appendix 1).

It should be noted that earlier studies on Windermere charr which relied on scales rather than otoliths for aging almost certainly under-aged many fish, particularly the larger ones.

d) Long-term data.

The FBA has catch per unit effort (c.p.u.e.) data for autumn-spawning charr from the Low Wray Bay spawning site from 1939 to 1973. Due to interference with nets, the monitoring site was changed to another autumn site in the north basin at North Thompson Holme where data collection has continued from 1975 to the present (Fig. 3). These results show a steady increase in catches from around 1944 when the FBA started to cull the larger pike in the lake. This reduced the biomass of large pike by around 50% up to the mid-1960's. Since that time, the pike biomass has been kept at around 25% of the pre-cull level, and the spawning site c.p.u.e. data have shown considerable oscillations but around a much higher mean (Fig. 3). This pattern of increased catches, followed by relative stability, is very well echoed by changes in anglers c.p.u.e. (Appendix 2). Spawning charr form the main winter diet for the Windermere pike population and the decrease in pike stocks is almost certainly the principal factor behind the increase in charr stocks (Kipling 1984). The angling data also shows that from 1965-1975 and again in the early 1980's c.p.u.e. was equally high in the two basins. Only since 1984 has the fishing deteriorated in the south basin whilst, up to the end of 1987, catches remained good in the north (Appendix 2).

Analysis of the size and age of the spawning stock of charr from North Thompson Holme confirms anglers reports that fish size has increased in the north basin over the past few years. Fig. 4 shows the change from 1982 to 1987. Preliminary results suggest that this change has resulted from a change in the age-structure of the spawning stock, not from a change in growth rate.

It is likely that there were very successful spawnings 8 and possibly 9 years ago followed by much less successful ones 5, 6 and 7 years ago. Thus large, older fish formed a greater than usual proportion of the spawners in 1987. There is evidence that this type of change in the spawning stock has occurred several times over the 50 years that the FBA has monitored a north basin autumn spawning site.

e) Echo-sounding.

A series of echo-soundings have been made in both basins over the past year, together with less frequent surveys for the previous two years. The results show that large numbers of charr move into mid-water in the spring (but not until June in 1988) and disappear again in October or November. In the intervening period they are too close to either the lake bottom or edge to be detectable, but can be readily caught in bottom-set nets. Stomachs of bottom-caught fish usually contain benthic invertebrates such as chironomids and Asellus whilst charr caught in mid-water usually contain zooplankton. A consistent pattern has emerged from the summer months with estimates of between 30,000 and 55,000 pelagic echoes for the whole of the north basin and between 5,000 and 20,000 echoes for the south basin. The maximum echo density usually occurs between 10 and 25 metres and the echoes are more often quite evenly scattered through the lake than in the form of dense shoals.

Even if almost all the estimated 50-70,000 echoes from the whole lake represented charr, they must still only represent a proportion of the total charr population because it is still possible to catch charr in bottom-set nets in the summer and a stock of this size and age-structure would clearly not support anglers catches estimated at between 10,000 and 20,000 fish per annum (Appendix 1). The lower densities of echoes from the south basin provide further corroboration for the frequent claims by anglers of poor fishing in

this basin in the past few years; a situation that did not occur between 1967 and 1972 (Appendix 2). As in the north basin, there appear to be relatively few fish of intermediate age. However, anglers are catching some 2 and 3 year-olds from the south basin and we have caught 1 and 2 year-olds in bottom-set nets. Thus successful spawning is taking place, certainly amongst the dominant autumn-spawning race.

f) Juvenile charr.

This year fine-meshed gill nets have successfully caught 1 and 2 year-old charr from the deepest points in each basin. The great majority of these juveniles was again from the autumn-spawning race. These small charr had eaten benthic invertebrates, especially larval chironomids. This is the first time that one-year-olds have been located in Windermere and we will continue to sample these locations when the oxygen concentrations fall to determine the levels at which they leave this habitat.

g) Spawning sites.

Frost (1965) illustrates 9 sites where the autumn race spawns and 4 sites for the spring-spawners. We have obtained spawning fish from several of these autumn sites and will try others later in the year. Our main difficulty has been the very low catches obtained in the past two years from the best known spring site in the south basin which is south of Rawlinson's Nab. Nor have we been able to locate spawning fish from this race elsewhere in the basin despite setting nets at several sites and night-time searches with an echo-sounder. The physical structure of the Rawlinsons's Nab site has not been investigated in detail but earlier diver observations at a spring spawning site in the north basin at Holbeck point found the site to be gravel and large stones arranged in a 'tongue' about 14 to 18 m wide which extended from a depth of 9.5 to 28 m. This is much smaller than the autumn sites that have been well characterised (Frost 1965).

h) Parasites.

Almost all charr over three years of age contain cysts of the intermediate stage of the tapeworms Diphyllobothrium dendriticum and D. ditremum. The parasites enter the charr in infected copepods and burrow through the stomach or intestine wall. They usually encyst on the stomach or other internal organs or, less often, on the abdominal wall. Of the two species D. dentriticum is the more invasive and the encysted worm can reach 100 mm in length compared with 30 mm for D. ditremum. The normal final hosts are gulls for D. ditremum and probably ducks and cormorants for D. dendriticum though the latter species can infect a variety of mammals including man (Curtis 1984).

In Windermere the parasite burden increases with size and age with some large, old charr containing 50 D. dendriticum and several hundred D. ditremum. Most charr caught by anglers probably contain between 1 and 10 cysts of D. dendriticum but cleaning the fish will remove almost all the cysts and cooking will kill the remainder so they are unlikely to cause a threat to health.

3. Preliminary Conclusions.

a) Anglers catches and echo-soundings indicate that over the past few years the south basin of the lake has a smaller charr stock than the north basin. Anglers catches indicate that this was not the case in the period 1967-1972 or in the early 1980's (Appendix 2).

b) The spring-spawning race is much rarer than the autumn-spawning one. Whilst this is true of both basins, it has even proved difficult to catch the south basin spring spawners on their main spawning site.

c) At present there is a high proportion of older charr (8-12 years) in both basins and from both spring and autumn spawning stocks (Fig. 2). However, it

is clear that variations in spawning success from year to year have occurred in the past and changes such as the one documented here from a north basin spawning site (Fig. 4) probably result from natural phenomena.

d) Catches of juveniles in both basins show that successful reproduction is occurring but that at least some of the juveniles occupy and feed in the deepest areas of the two basins. In the south basin they will be progressively excluded from these areas during the summer by the decreasing oxygen concentration.

4. Proposals for second year's research.

a) Complete analysis of angler records and angler caught fish.

b) Continue survey on juvenile charr.

c) Use divers to compare the state of the spawning gravels between the shallow (1-5 in deep) autumn sites and the deep (20 m) spring sites and if possible, to locate redds and check on egg survival.

d) Continue survey of spawning stocks, especially the south basin spring spawners.

5. Preliminary recommendations.

a) It is important for the health of the charr populations that the removal of large pike from Windermere continues at least at its present level (around 300 pike aged 4 years and over per annum - around one tonne in weight). This, of course, has to be balanced against pike-fishing interests.

b) The population monitoring exercise at North Thompson Holme should be maintained and, if possible, regular monitoring should be extended to a south basin site to allow a comparison between the two basins.

c) A new mark-recapture exercise should commence to obtain a more accurate estimate of population size and angling mortality.

Acknowledgments

I wish to thank the anglers for their excellent cooperation and the members of FBA staff who have assisted in this study.

6. References.,

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Frost, W.E. (1965) Breeding habits of Windermere charr, Salvelinus willughbü (Günther), and their bearing on the speciation of these fish. Proc. Roy. Soc., B, 163, 232-284.

Kipling, C. (1984) Some observations on autumn-spawning charr, Salvelinus alpinus L., in Windermere, 1939-1982. J. Fish Biol., 24, 229-234.

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Table 1 Mean lengths and numbers (n) of aged charr from eleven Lake District and one Welsh populations.

| Age | 2 | n | 3 | n | 4 | n | 5 | n | 6 | n | 7 | n | 8 | n | 9 | n | 10 | n | 11 | n | 12 | n | 13 | n | 14 | n |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Buttermere | 139 | 1 | 221 | 2 | 242 | 5 | 271 | 5 | 300 | 9 | 301 | 6 | 304 | 3 | | | 326 | 2 | | | | | | | | |
| Coniston | | | 151 | 1 | 207 | 4 | 254 | 12 | 272 | 19 | 288 | 17 | 296 | 18 | 299 | 3 | 299 | 2 | 329 | 1 | | | | | | |
| Crummock | | | 116 | 4 | 160 | 8 | 187 | 19 | 227 | 4 | 251 | 8 | 261 | 1 | 260 | 1 | | | | | | | | | | |
| Cwellyn | 113 | 1 | 164 | 3 | 182 | 7 | 200 | 7 | 218 | 1 | 219 | 3 | | | | | 241 | 1 | | | | | | | | |
| Ennerdale | | | | | | | 270 | 2 | 288 | 20 | 304 | 41 | 317 | 19 | 339 | 3 | 392 | 1 | | | | | | | | |
| Haweswater | 138 | 1 | 155 | 1 | 217 | 7 | 236 | 19 | 251 | 4 | 270 | 4 | 252 | 1 | | | | | | | | | | | | |
| Thirlmere | 122 | 4 | 162 | 14 | 182 | 6 | 209 | 7 | 225 | 6 | 235 | 3 | 234 | 4 | 239 | 2 | 238 | 2 | | | 248 | 1 | | | | |
| Wastwater | 117 | 16 | 140 | 15 | 171 | 4 | 185 | 7 | 187 | 1 | | | | | | | | | | | | | | | | |
| Windermere North Basin Autumn sp | | | 204 | 4 | 236 | 8 | 248 | 30 | 212 | 34 | 283 | 33 | 289 | 21 | 301 | 26 | 307 | 2 | 321 | 10 | 311 | 1 | | | | |
| Windermere North Basin Spring sp | | | | | 254 | 1 | 254 | 14 | 289 | 10 | 300 | 14 | 318 | 35 | 329 | 31 | 342 | 23 | 353 | 11 | 348 | 3 | 338 | 1 | | |
| Windermere South Basin Autumn sp | 168 | 3 | 219 | 1 | 247 | 3 | 282 | 17 | 300 | 46 | 320 | 35 | 331 | 35 | 341 | 22 | 346 | 17 | 343 | 8 | 359 | 8 | 355 | 3 | | |
| Windermere South Basin Spring sp | 167 | 1 | | | | | 303 | 5 | 318 | 5 | 325 | 8 | 343 | 24 | 351 | 22 | 360 | 6 | 361 | 7 | 380 | 8 | 378 | 3 | 367 | 1 |

Fig 1

The separation of spring- and autumn-spawning Windermere charr by a discriminant function based on gill raker number and length.

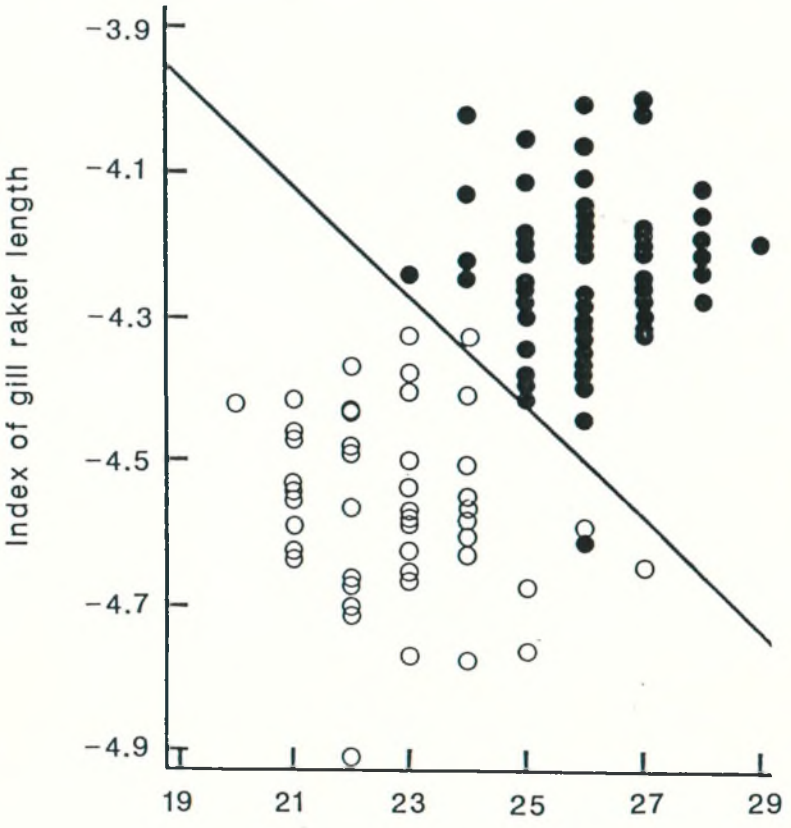
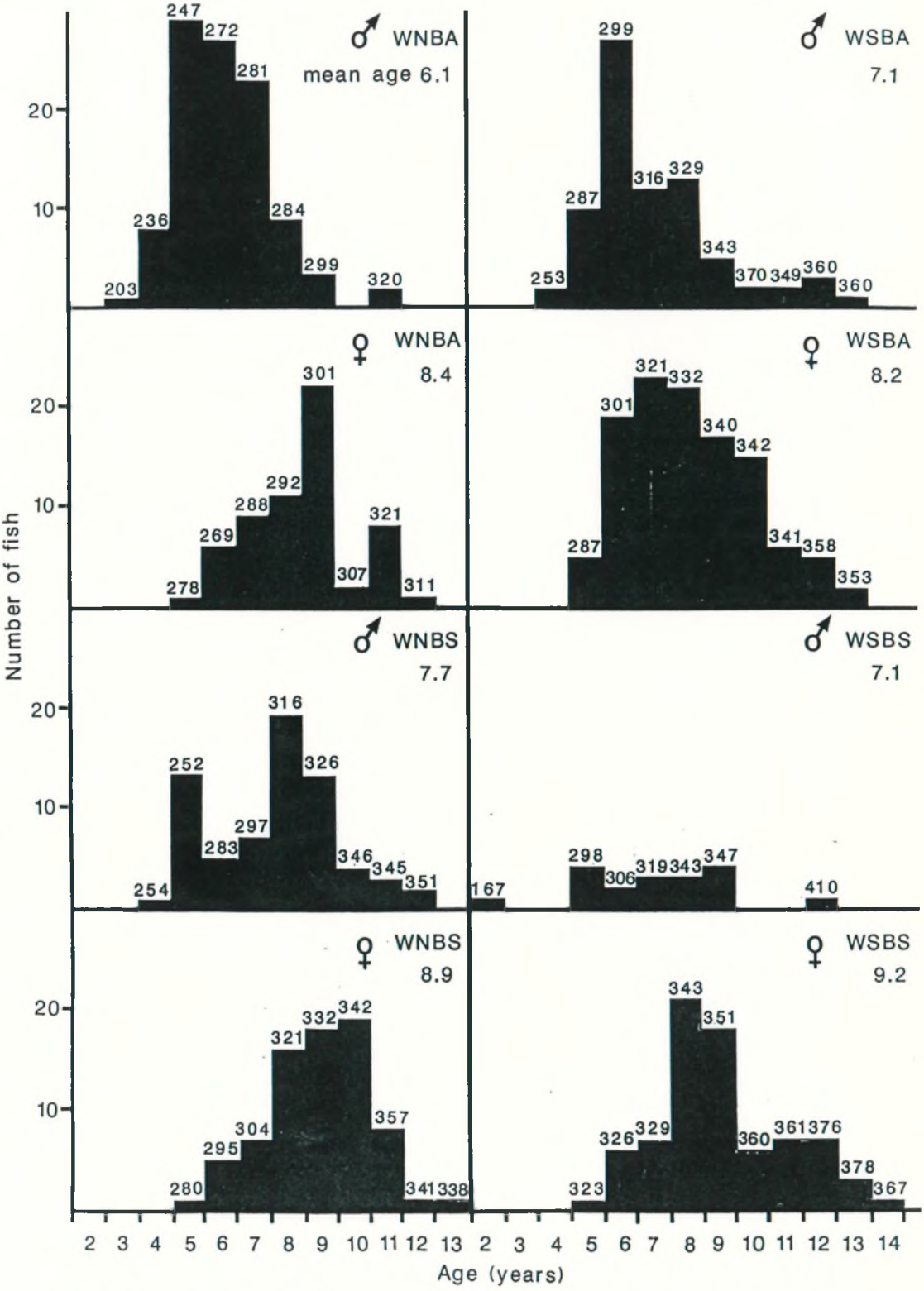


Fig 2

Age-structure of spawners from the principal Windermere charr stocks




North Basin Autumn Spawners WNBA; South Basin Autumn Spawners WSBA;
North Basin Spring Spawners WNBS ; South Basin Spring Spawners WSBS

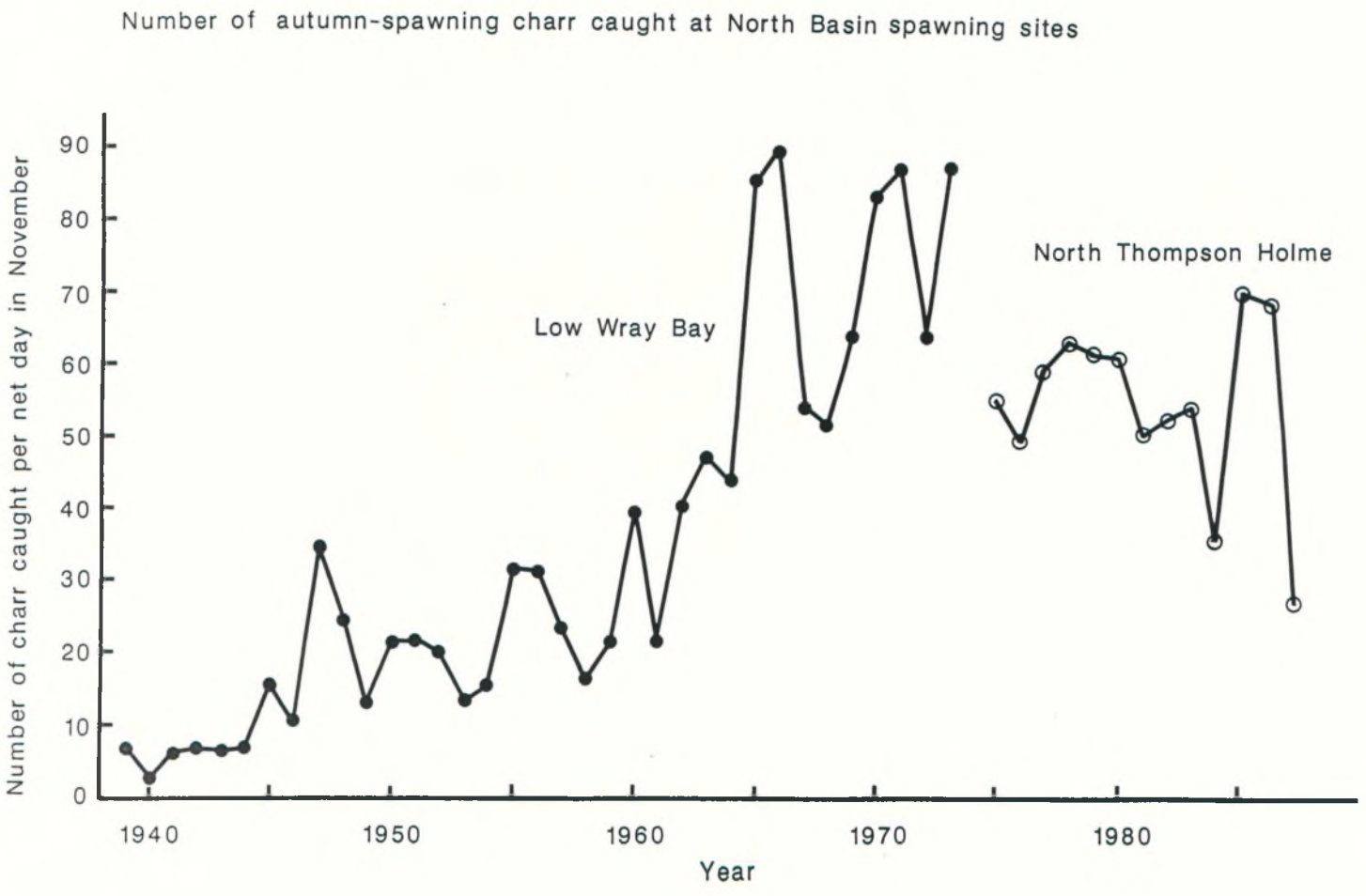

Number of autumn-spawning charr caught at North Basin spawning sites
Number of charr caught per net day in November
0
10
20
30
40
50
60
70
80
90
1940
1950
1960
1970
1980
Year
Low Wray Bay
North Thompson Holme

Fig 3

Size-frequency distribution of autumn-spawning charr caught at North Thompson Holme using a 32mm (bar) gill net

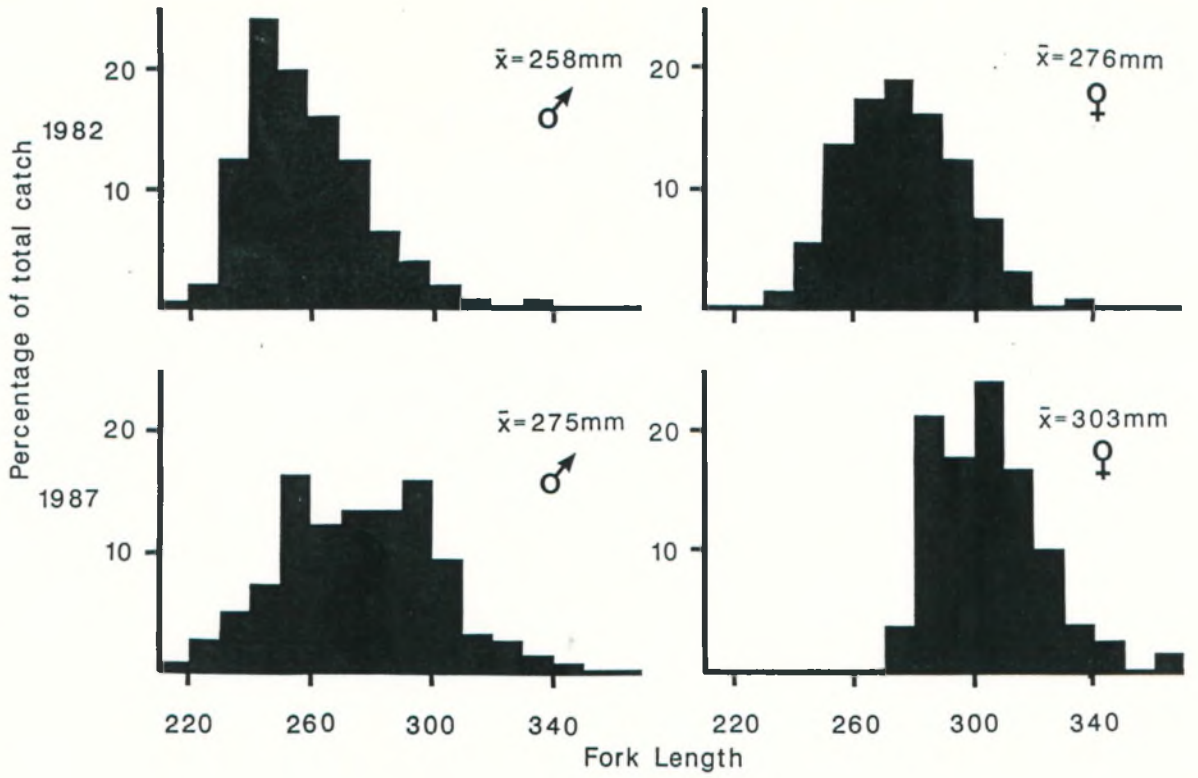



Fig 4

Appendix 1. Population estimate.

LeCren & Kipling (1963) used mark-recapture techniques to estimate that in the early 1950's 3 autumn spawning populations (= sites) comprised 11 000 mature fish and that 1 spring site comprised 1950 fish. Since this time c.p.u.e. at the FBA's long-term monitoring site has risen approximately 4-fold. Thus we can estimate that the 3 autumn populations may now contain 44 000 mature fish and that all 9 autumn spawning populations might consist of 132 000 mature fish. It seems unlikely that there are more than a few thousand mature spring spawners. Thus the total mature population could be around 140 000 mature fish weighing some 30-35 tonnes. An intermediate figure of 15 000 angler-caught charr per annum will over-represent angler impact on the mature stock as our preliminary data suggest that only 50-60% of these will be mature fish. Thus anglers may catch around 8000 adults per annum which would comprise 5.7% of the total stock. Clearly this estimate involves a number of assumptions but it would be difficult to reconcile an angler mortality rate of much over 10% with the present age-structure of the stocks.

Appendix 2. Anglers catches.

The FBA holds a set of angling diaries for most years from 1927 to 1942 and thanks to the cooperation of two anglers we also have sets of catch data for the periods 1965-1972, 1982-1987 and most years from 1975-1987. It is possible to use this information to examine variations in catch per unit of effort both within and between years and in the case of the more recent data sets, also between the north and south basins of the lake. Little information on the size of the fish caught and none on their age is available from these records however.

Between 1927 and 1942 the average catch per session using charr plumb line tackle was 2.84 charr (range 0.88 in 1931 to 3.82 in 1941) and 0.33 trout. There was no obvious general upward or downward trend in catches during this period. What information there is on the times fished indicates that the average session almost certainly lasted at least 4 hours (which would give averages of 0.71 charr and 0.08 trout per hour) and could easily have lasted 6 hours (giving an average of 0.47 charr and 0.06 trout per hour). Most of this fishing was in the north basin but it may be possible to extract some comparison of catch rates between the two basins of the lake.

From 1965-1972 catches of charr were much higher, averaging 2.58 fish per hour (range 1.65-3.50) but more similar for trout at 0.088 per hour (range 0.043-0.158). There were no overall significant differences in catch rates between the two basins of the lake or for any particular month between April and September though there were considerable variations from year to year.

The most recent information has not yet been fully assessed but it appears that whilst fishing was particularly successful in both basins in the early 1980's there have been relatively poor catches in the south basin since 1983. The yearly average catch of one of the first anglers from 1984-1987 was 1.57 charr per hour in the south basin but 3.25 fish in the north basin. In 1987 and again in the present season there has been an unprecedented upsurge in catches of trout on charr tackle in the south basin.

In addition anglers report a considerable increase in the average size of the charr they are catching over the past few years. This applies to both basins but the tendency of south basin fish to be larger than those from the north has been consistently noted since the 1920's