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Your reference

Our reference

Date 20 March 1981

Dear Bob

I am still amazed at the amount of information that you manage to pack into your letter to me of 8 December 1980. I am still working on the final draft of our salmonid watch paper, and hope that it may be possible for me to quote you occasionally in it.

You have asked me to let me give you any comments on our Scottish Charr, and it has not really been possible for me to do this until just now. We have just completed a first and very rough draft of the paper which I hope to present at Winnipeg, but I thought that you might want to see it at this early stage. It will certainly give you some idea of what is known and our ideas as they stand at present. Please let me know if there is anything else you would like to know, or alternatively if you have any comments on the paper we would be delighted to receive them.

I am looking forward very much to meeting you again at the Charr Symposium, where I hope that we may be able to carry out a reasonable scientific experiment on an appropriate range of malts.

With best wishes,

Yours sincerely

Dr P S Maitland



Appendix 1. Current list of lochs in Scotland from which charts have been recorded.

LOCH

NATIONAL GRID REFERENCE

710
SOURCE



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- McDiarmid, J. 1794. Parish of Waeon, Perth. Stat. Acc. Scot. 12, 131.
- Mackenzie, R. 1793. Parish of Contin - Ross. Stat. Acc. Scot. 7, 162-163.
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ACKNOWLEDGEMENTS

We are grateful to Dr P.F. Friend for putting all his father's research notes and material at our disposal. Dr D.M. Mills was kind enough to allow us to quote his data from Loch Luichart, and we have received many useful notes and pieces of information from other workers, notably Mr A.E. Joyce, Mr A.F. Walker,

Useful comments on the manuscript of this paper were given by

Mr Friend's later research was supported by a grant from the Leverhulme Trust.

The identification and recording, in recent years, of the many charr lochs in Scotland have produced new horizons for research workers, as the considerable number of isolated charr populations, which have been evolving without contact with other charr populations since the retreat of the Quaternary Ice Cap ca. 14,000 years BP, offer more ideal material for the evolutionary biologist.

Although very many brown trout populations exist in conditions of genetical isolation it is impossible in Scotland, to state with certainty that any population has not been adulterated by the introduction of brown trout from different geographical areas. From the middle of last century on, most trout lochs and river systems were stocked by the landowners. Also, before that, trout were introduced into many fish-less lochs by the local inhabitants as a source of food when they were attending their cattle and sheep on high ground during the summer.

Charr were never used to any extent for stocking purposes although some very limited experimental stockings were carried out at the turn of the century. A further attraction to research on charr is in connection with energy-flow studies on the large, deep, recently-glaciated oligotrophic lochs, where the standing crop of fish seems to be high in relation to the chemical poverty of the water, lack of allochthonous organic material and the poor climate.

Finally there is another attraction, a subjective one; charr seem to strike an emotional chord in some freshwater fishery biologists and naturalists producing individuals intensely involved with this attractive fish.

The future of research on Scottish charr populations is, of course, very much tied up with sources of funding. In the foreseeable future very little finance can be expected as what is available will be invested

in research into the management of commercial species of salmonids, both in the wild and in cultivation. Charr research will have to be carried on as before by enthusiasts and occasional field research workers.

As a sport fish also there is likely to be little advance on the present situation as both indigenous, and tourist anglers in the Highlands are interested only in angling for salmon and trout, although there is a possibility that the recent introduction of rod-caught record status for charr, and the fact that some commercial sponsors are now awarding prizes for specimen charr may increase angling pressure slightly. Also there is more publicity on new charr angling techniques but the general run of charr are of too small a size ever to be attractive.

As several important charr populations have now become extinct special consideration must be given to the conservation of this species. A number of points are relevant here. - Firstly, the majority of Scottish charr populations are probably safe (as far as one can predict anything these days). Secondly, possibly the greatest danger is from (a) introductions of alien fish species - or from escapes from aquaculture units; (b) "new" diseases or parasites originating from such units. In certain places - pollution and eutrophication and in others the impact of acid rain have affected charr lochs. Hydro-electric installations, which often favour the same large highland lochs as charr, do not seem to have harmed charr populations.

At the present time there are four major charr lochs which are wholly or partly within National Nature Reserves managed by the Nature Conservancy Council in Scotland while several more, as well as a number of smaller ones, are similarly situated within notified Sites of Special Scientific Interest. The wildlife on land carrying either of these official designations is protected to some extent from adverse developments and/or introductions.

DISCUSSION

The charr in Scotland has been a much neglected fish in the past by local inhabitants and by anglers and research workers. The reason for its infrequent use as a resource was probably the fact that this species owing to its cryptic habits was seldom encountered and difficult (by contemporary methods) to harvest. Only in the few locations in Scotland, where charr migrate up streams to spawn, would this be possible to any extent. It is interesting to note that it is very rare to find a Gaelic name for a loch that refers to the presence of charr, while those referring to salmon, trout and pike (also to various birds and mammals) are not uncommon.

Sport-angling did not get underway in the Highlands until the late 18th Century but in the fairly prolific writings on angling that were produced from then on, very little attention was paid to charr, which were usually regarded as an oddity and not a worthy target species for anglers. In more recent times little research has taken place on Scottish charr as the emphasis (and government funding) on fishery research in Scotland has been directed at the main commercial species, the Atlantic salmon (Salmo salar) and migratory (sea) trout (Salmo trutta) and, to a lesser extent, at the main anglers' species, brown trout. University research has been on similar lines.

Had large migratory charr been present the picture would have probably been quite different. Investigations on Scottish charr have mainly been undertaken by individual enthusiasts, often in their spare time. At present however interest in the biology and ecology of charr is increasing - one reason being that these subjects offer (in Scotland) almost virgin fields for research.

<u>LOCH</u>	<u>ANGLING METHOD</u>	<u>REFERENCE</u>
Seil	Bait	*
Shin	Fly and Spinner	*
Tay	Spinner	Clemson (1976)
Uaine	Spinner	Campbell (1968)
Veyatie	wet fly	Gampbell (1979)
Voil	-	Hoy *
m? Vuchernich (Laxford)	Fly	Bynd (1974)

* caught by anglers but names unknown

XXXXXX

A number of new sites for Charr here!

SCOTTISH LOCHS WHERE CHARR ARE CAUGHT BY ANGLING

LOCHS	ANGLING METHOD	REFERENCE
An t Seilich	Spinner and worm	Cairney (1979)
Badenloch	-	Bulloch (1973)
Bhrodain	Spinner and worm	Cairney
Borgie		Bulloch (1973)
Borrallie	1. Natural sandeel trolling. 2. Fly 3. Deep Trolling spinner	Walker (1975) Campbell (1955)
Brora	wet fly	Bulloch (1973)
Brann	Spinner	Sutherland (1976)
* Bruiche Breivat?	wet fly	Burns (1979)
Calder	Spinner	* Burns (1979)
* Coirigerod?	Spinner	Burns (1979)
Guaich	Fly	Walker (1979)
Doon Duntelchaig Earn	wet fly at night	Campbell (1980)
Ericht	Bait and Fly	(1974)
Fada (N. Vist)	deep Spinner	Campbell (1979)
* Fhir Mhaoil?	Spinner	Burns (1979)
Garry (Perths)	Bait, Fly and Spinner	Greer (1974)
* Ehlas Beg More?		Bulloch (1973)
Insh	Spinner	Williams (1963)
Killin	wet fly	McBain (1978)
Langavat	Spinner	Sutherland (1976)
Lee Loch	Fly and Bait	Burns (1979)
Loyal	Fly	McLaren (1978)
Lubnaig	Fly and Bait	McLaren (1979)
Maree	{ Fly and Spinner } { wet fly at night }	McLaren (1979) Campbell (1963)
Meadie	Fly	McLaren (1979)
Mealit Na Sealga	Worm	Greer (1976)
* Nam Brathain	Spinner Fly	Sutherland (1975) MacDonnell (1978)
Naver	Fly	McLaren (1979)
Nell	Spinner	
Ness	{ Spinner }	Sutherland (1978)
River Ness	Spinner	Campbell (1971)
Orasay	Spinner	Burns (1979)
* Poll upper Polly Loch	Spinner	Joyce (1973) Campbell (1963)
Rimsdale	{ Fly }	Bulloch (1973) F.S. Stoddart (1966)
Stack	{ Fly }	Hynd (1976)
Stracsavat	Fly	(1980)
Seilg	Spinner	Campbell (1974)

where is loch - Borgie?

+ wet fly at night
+ Campbell (1955)

Oliver & Williams 1977
quite often
Catch them in 1/16.

Also see
Analys of Nat. Hist. ref.

Larger ones lost
Preserved at Cape Wrath Hotel. 2/16 1/2
using Windermere tackle.

(116 1403)
in autumn - congregating at head of loch at mouth of tributary.

1202.
won a Ballanthyne Trophy!
1980

frequently catch charr over 500 g in weight.

A more detailed survey of angling catches of charr in Scotland will be necessary before a full picture can be drawn up but it is evident from the existing information that charr are more frequently fished for and larger catches taken than previously supposed.

1958

♀

♂

1959

♀

♂

x immature
 o mature & ripe
 o spent

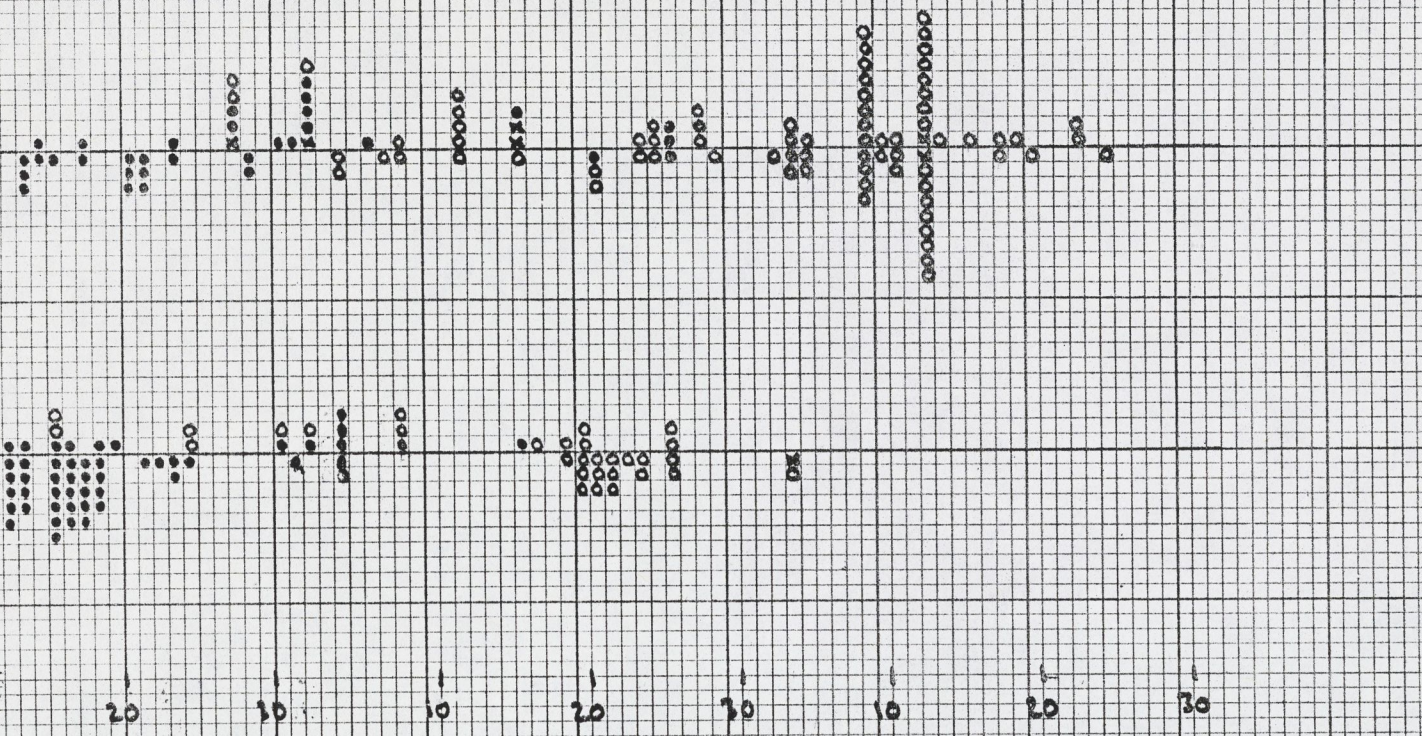
10 20 30 10 20 30 10 20 30

OCT

NOV

DEC

LOCH LUICHART CHARR



ANGLING FOR CHARR IN SCOTLAND

Charr in Scotland are considered by many anglers to be difficult to catch on rod and line and to be a rather rare and elusive fish.

The results of a rather limited survey however, indicated that charr are caught by angling in a large proportion of the lochs where they are known to occur (40 g ^{or} 104 listed in the present paper). Further, it is likely that this number is an underestimate as anglers may fail to record their catch of charr and in some cases fail to identify charr correctly. Greer, in 1978, found that anglers fishing in Loch Garry (Perthshire) had wrongly identified charr as being juvenile rainbow trout, (Salmo gairdneri, Richardson).

Charr may be caught by accident in the course of fishing for trout, but in a number of lochs are fished for deliberately, (Ericht, Garry, Maree, Voil, Lubnaig, an Seilich, Ebrodain). Most of the angling methods used to catch charr are those practiced in normal trout fishing using bait, fly or spinning lures. Anglers specialising in angling for charr may further adapt these trout angling methods specifically for catching charr.

Walker (pers comm. 1979) mentioned that while fishing in Loch Garry (Perthshire) he successfully caught charr by allowing his fly line to sink much deeper than in the course of normal fishing. A line fished normally was not successful in catching charr. McLaren (pers comm. 1979) found that fly fishing was frequently successful in catching charr in Loch Maree and in a number of other lochs in the Northern Highlands. Spinning and trolling with small spinners is also a successful method of catching charr; Burns, Cairney (pers comm. 1979). Campbell (pers comm 1979) caught charr by using tackle similar to that described by Frost () for catching charr in Windermere.

Bait fishing using mainly worms and maggots is commonly used for catching charr. The current rod caught record in Scotland (a charr of ^{approx} 1 kg from Loch Insh) was taken using a bottom fished earthworm.

A paternoster tackle rigged with multiple hook droppers and baited with maggots is frequently used by anglers fishing for charr in the Trossachs area. Greer has found this to be a successful method in Loch Garry (Perthshire) particularly if the tackle is retrieved very slowly along the bottom. Williams (1979, 1980) gave a full description of methods for charr fishing in several articles in the popular angling press.

Large individual catches are reported. Greer (in prep.) mentioned a catch of over 200 charr, taken by three anglers in Loch Garry (Perthshire) during an afternoon and evening. McLaren (pers comm. 1979) stated that catches of over 20 charr in a single outing were taken in Loch Maree. He recorded one catch of over 100 charr taken in an evenings fly fishing. Cairney (pers comm 1979) has taken up to 40 charr in Loch Ebrodain and up to 80 charr in Loch an Seilich in single outings.

The size of charr taken by angling varies considerably according to locality. In Loch Ericht Craib (pers comm. 1973) few charr in excess of 23 cm (c.100 g) length are taken by angling. Malloch, (1910) however, caught a charr of approximately 1 kg in weight in this loch. Walker (1975) caught a charr of 30.5 cm in Loch Garry but normally few fish greater than 25 cm in length are caught here. In most lochs a charr of 30 cm is considered to be a large fish. Much larger charr are however commonly taken in Loch Insh. McBain (pers comm. 1978) reported that anglers fishing for salmon ^{here}

SPAWNING

Little previous information is available on the spawning of charr in Scotland. A summary of information at present available is given in Table . All the populations studied so far appear to spawn in the autumn and there is no evidence of spring spawning as occurs in Windermere (Frost 19) in England. The only detailed information available to date is from Loch Luichart, where Mills (personal communication) caught numbers of charr while gill netting for pike during the autumns of 1958 and 1959 (Mills, 1964). The data on gonad condition (Figure) indicate that in 1958 spawning probably took place from late October to late November and in 1959 from mid October to mid November.

Although it is probable that the majority of Scottish charr spawn in the lochs themselves - usually along wave-washed shores or over off-shore reefs - it is clear that there are a number of populations which migrate into running water during the spawning season (Table). The stream chosen may be the inflow (as at Loch Insh and Loch na Sealga) or the outflow (as at Loch Tarff) of the loch concerned. There appear to be no detailed observations of the spawning act or the actual site of spawning in Scottish waters.

Information on the fecundity of charr in Loch Luichart is available from the samples taken by Mills (personal communication) and shown in Figure . In 1958, females with a mean length of 210 mm (range: 197-220) had a mean fecundity of 319 eggs (range: 257-406). In 1959, females with a mean length of 233 mm (range: 192-293) had a mean fecundity of 308 eggs (range: 200-437). The relationship between fecundity and length (Figure) or weight was poor, but the average number of eggs per gram body weight of fish was 2.42.



Table . Mean length in cm of charr of various age groups from different Scottish lochs.

LOCH	A G E G R O U P									
	1+	2+	3+	4+	5+	6+	7+	8+	9+	10+
Garry	12.3	15.8	18.5	20.3	19.9		22.5			
Rannoch (b)		15.8	16.8	19.7	19.9	22.1	22.9	22.4	25.0	
Rannoch (p)		15.9	17.4	18.4	19.6	19.5	19.3			
Awe		14.4	16.2	17.8	19.1	18.0				
Hess		15.1	16.3	21.5	24.1					
Insh				33.6	36.5	32.8	35.0	38.5	37.0	
Shin	12.5	16.3	20.5							
Lurgain		15.2	17.5	17.0						
Meallt			15.8	16.8						
Bornalie	8.4	16.3	22.9	26.5	34.0					
Uaine	5.6	11.2	14.8	16.2						



Table

Mean density (on infested fish) and percentage occurrence of S. alpina* and occurrence of Hexeguya on charr where ectoparasites were recorded.

LOCH	<u>SALMINKOLA ALPINA</u> *		<u>HEGEGUYA</u>
	DENSITY	OCCURRENCE	
an Dubh	-	-	+
Assynt	-	-	+
Doine	-	-	+
Doon	1.8	42	+
hee	1.3	60	+
Moy	2.2	50	+
Stack	1.0	33	-
Tay	1.5	33	-
Voil	-	-	+

* Now edwardsii see new paper by Fryer.

SIZE, AGE AND GROWTH

Adult charr in Scotland vary greatly in size from one loch to another (Figure). For instance those of Lochs Doon and Eck are small, with mean lengths of and cm, and weights of and gm respectively, whereas those of Lochs Borrallie and Tay are much larger with mean lengths of and cm, and weights of and gm. The reasons for these differences are uncertain. The largest known Scottish charr was gm in weight and come from Loch .

The age of a large number of Scottish charr from many locations has been determined using loch scales and otoliths (see Swan 19). The adult populations of many lochs were usually dominated by fish of 3, 4 or 5 years of age (eg Lochs Garry, Rannoch and Awe) but in some waters (eg Loch Insh) much older charr occur and fish of 8 and 9 years are not uncommon (Table).

The growth of charr is variable (Table). In some lochs (eg Lochs Garry and Awe) growth in length is slow, and fish taking some 4 or 5 years to reach about 20 cm. In other waters (eg Loch Insh) growth is much more rapid and fish are usually well over 30 cm after 4 or 5 years. The growth of the two races of charr in Loch Rannoch is of special interest. It appears that although the benthic form may grow more slowly than the pelagic one at first, after 4 years growth in the benthic race is better and most of the larger (and older) fish belong to this group.

PARASITES

Ectoparasites

A total of some adult charr from different lochs have been examined for ectoparasites. The majority of fish have none, and only two species have been recorded from others. The details of positive records are given in Table .

In charr from several lochs, the base of the tail shows small whitish cysts which contain large numbers of the protozoan parasite Heneguya.

The most obvious ectoparasite of Scottish charr is Salmincola ^{edwardsii} ~~alpina~~ a parasitic copepod usually found attached to the walls of the gill cavity (never the gill filaments), but occasionally on the fins. This parasite is known to occur in only 5 of the Scottish lochs (Doon, Lee, Moy, Stack and Tay), but up to 60% of the charr in these populations may be infested. In some lochs (eg Loch Lee) about 15% of the brown trout, Salmo trutta fario carry quite another parasitic copepod, Salmincola gordonii, which is also found in about 1% of the sea trout Salmo trutta trutta in the River North Esk.

PREDATORS

The principal predators of charr in Scottish lochs appear to be other fish. Mills (1964) showed that pike (Esox lucius) in Loch Luichart fed mainly on other fish and that charr featured in their diet from April to August. Pike in Loch Rannoch have also been found to contain charr on various occasions. In an extensive study of the food of large trout (Salmo trutta) in Scottish lochs, Campbell (1979) lists 9 lochs where charr have been found in trout stomachs. He notes that small trout may take small charr, but stresses that the large ferox trout may be heavily dependent on charr as a main source of food and indeed that this form of trout rarely occurs where charr are absent.

As with whitefish (Coregonus albula and C. lavaretus), charr are very prone to attack by eels (Anguilla anguilla) when caught in gill nets, and in fact are clearly preferred to trout. How relevant this is to the natural situation is uncertain, but it seems likely that injured, dead or dying charr must be vulnerable to eels. Cannibalism also occurs among charr, and a 37.5 cm charr caught in Loch Rannoch was found to contain a ca 18 cm charr.

Table . Details of the food of charr in various Scottish lochs

SITE	DATE	NO FISH	FOOD (% COMP)			DOMINANT FOOD	SOURCE OF DATA
			PLANKTON	BENTHOS	FISH		
loch Meallt			3	90	7	Mollusca, Hemiptera	Campbell 1976
loch Fada			18	22	0	Cladocera	Campbell 1976
loch a Bharpa			100	0	0	Cladocera	
loch Uachdair	8.8.80	2	50	50	0	Cladocera, Diptera	Campbell & Maitland
loch Borrailie	July 1975	4	0	100	0	Ephemeroptera	Greig
loch Garry		309	50 ?	50 ?	0	Cladocera, Mollusca, Diptera	Greig
loch Rannoch			90	10	0	Cladocera	Greig & Welke
			5	94	0	Mollusca, Trichoptera	Greig & Welke
loch nam Brathain			50 ?	50 ?	0	Diptera, Cladocera, Ephemeroptera	Greig
loch Shin	June 1977	10	100	0	0	Cladocera	Greig
loch Lurgain	June 1977	10	100	0	0	Cladocera	Greig
loch Hess	July 1977	30	100	0	0	Cladocera	Greig
loch Morar							
loch Luichart	1958-59	18	48	52	0	Diptera, Cladocera	Mills p.c.
loch May			100	0	0	Cladocera	Friant

FOOD

Very little information has been published on the food of charr in Scotland waters and virtually nothing is known of the diet of young fish. Table summarises much of the available information. The food of adult fish consists almost entirely of aquatic invertebrates: sometimes it is dominated by crustacean zooplankton and sometimes by zoobenthos, often both these items form an important part of the diet. Seasonal data from several waters, eg Loch Garry (Greer 19), indicate that, as with whitefish (Slack 1957), plankton may dominate at one time of the year (summer) and benthos at another (winter). Uncommonly, fish (usually sticklebacks) form part of the diet - as at Loch Meallt (Campbell, 1976).

The situation at Loch Rannoch is of particular interest (Walker & Greer 19). Here, the two sub-populations of charr have quite distinct feeding habits. The diet of the pelagic form is dominated by crustacean zooplankton (usually about 95% of the contents), whereas that of the benthic form is made up almost entirely of zoobenthos. Thus the differences in morphology are reflected also in the ecology of these two forms.

Although the stomachs of many charr from Lochs Garry and Rannoch have been examined at spawning time, no eggs have ever been found. This contrasts with the situation with charr at Windermere () and whitefish at Loch Lomond (Slack, 1957) where adult fish eat their own eggs in large numbers during the spawning season.



Table : A classification of the pattern and colour among some Scottish charr populations.

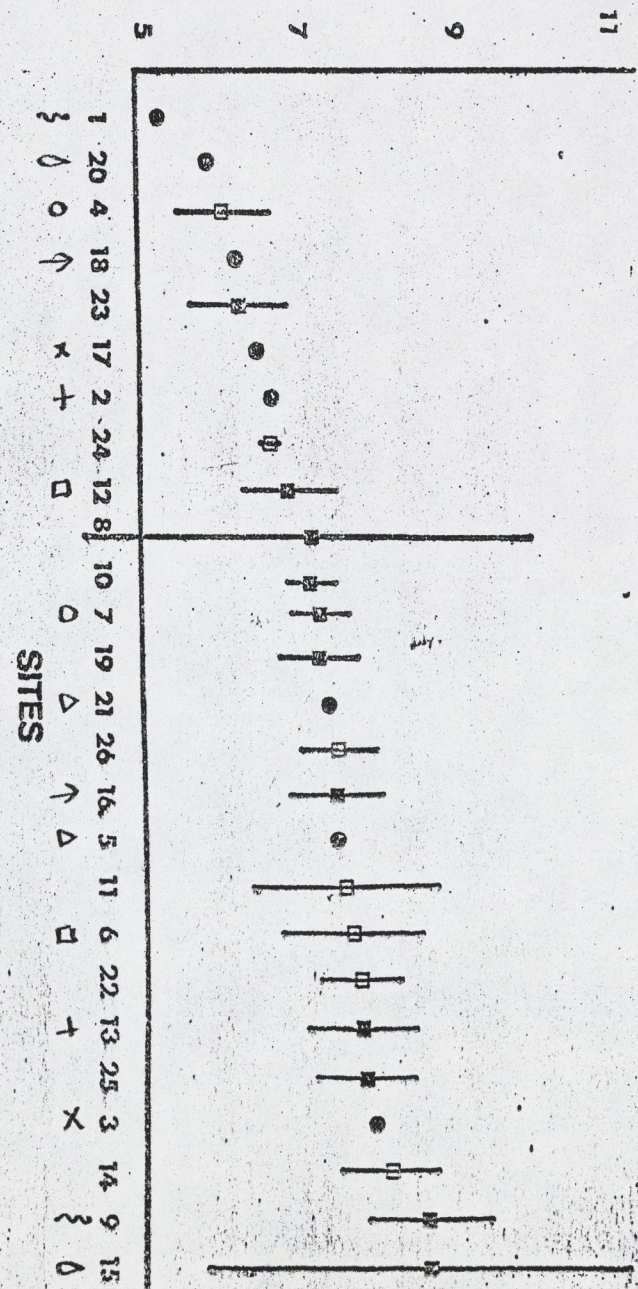
PARR MARKS	PRESENT			ABSENT		
	REDUCED	LATERAL	LATERO-DORSAL	REDUCED	LATERAL	LATERO-DORSAL
SPOTTING						
COLOUR:	Doine	Eck	Shin			
DULL		Moran Mess Rannoch (B)				
	Fada	Doon	Moy			
MEDIUM						
	Stack		Girista	Rannoch (P)	Insh	Borralie hee
BRIGHT						

Colour

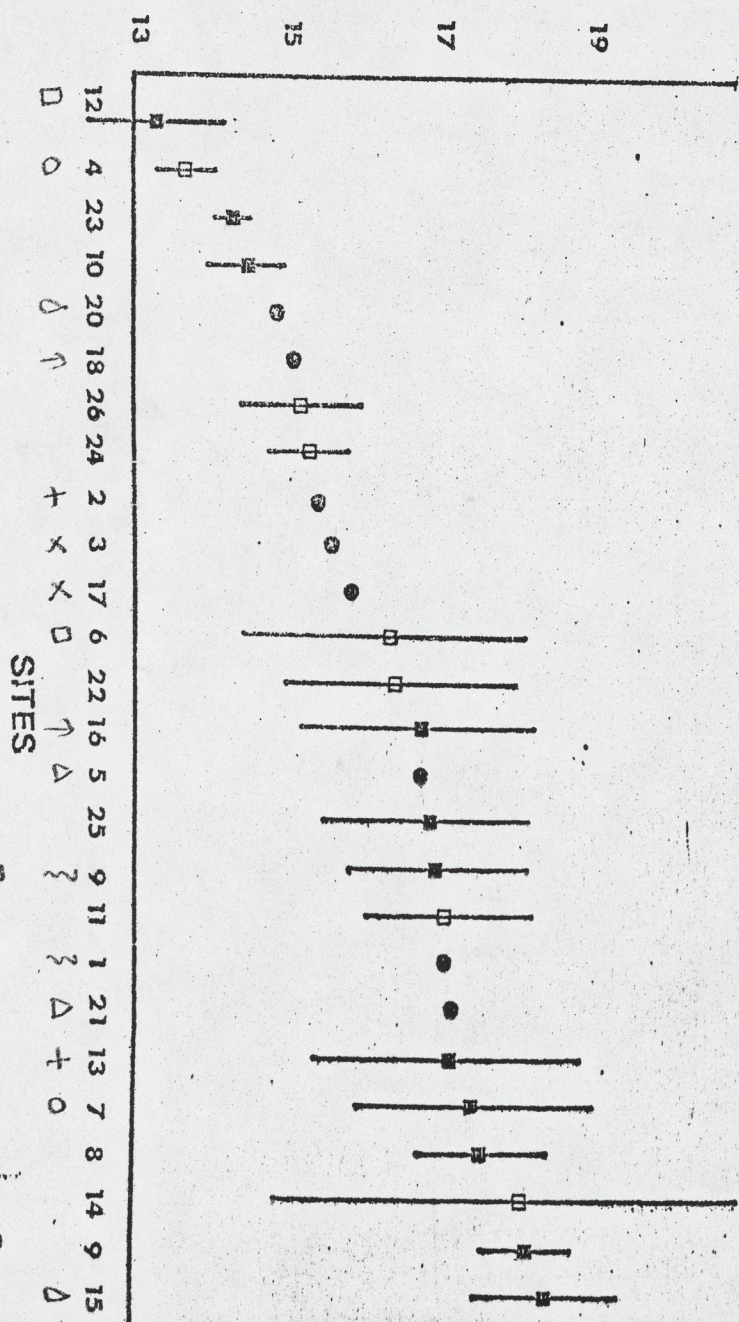
One of the attractions of charr is the variability and sometimes surprising brightness of their colour. Although there are undoubtedly major differences among many Scottish populations, it must be remembered that within any populations there may be variations related to size, sex, season and sexual maturity. An analysis of the adult colour and colour patterns in populations of Scottish charr has been carried out using objective criteria and three reasonably consistent characters were found to be of value in characterising colour forms. These were the persistence of parr marks (which may be clearly marked as quite absent in adults of different populations), the pattern of spotting (spots may be absent, present on the sides only, or present on the sides and on the back, where they may elongate to form vermiculate matter) and the degree of brightness of red pigment, especially on the belly. The latter was categorised using standard colour charts and ranged from pale cadmium yellow through mandarin and blood reds to deep magenta.

Table shows the colour typing of the few populations which have been examined in detail; so far. Considerable variation exists but there is a tendency for the dull, poorly spotted forms to have persistent parr marks (eg at Loch Ness) whereas the brighter, better spotted forms do not have parr marks as adults (eg Loch Lee). There is no detailed information on the colour changes in any population related to age, season or sex. The colour of the two forms existing in Loch Rannoch is quite obviously different, the benthic form having persistent parr marks, no spots and a dull colour whereas the pelagic form has no parr marks, faint pink spots on the sides and a general dark claret colour on the body.

CAUDAL FIN



DORSAL FIN



19
?
3

Walker and Greer (in prep) discovered, in 1975, two morphometrically distinct sympatric forms of charr in Loch Rannoch. These two forms also show differences in their ecology. Analysis of heavy metal concentrations in viscera and muscle tissue also revealed substantial differences between the two forms. This is the first recorded instance of two sympatric forms of charr occurring in a Scottish loch and apart from the two sympatric forms in Windermere described by Frost () is the only record of this phenomenon in Britain.

MORPHOLOGY

Meristic characters

A detailed study of meristic characters in samples of adults from Scottish lochs has been carried out. The logistics and methodology of this work has been described in a preliminary paper (Friend 19) and the results from the basis of a more detailed paper to be presented elsewhere (Maitland & Friend 1982). It is clear from this that there are considerable and consistent differences in the morphology of various populations. How much of this is due to ecotypic and how much to phenotypic variation is uncertain and considerable further research is warranted in this field, especially using modern techniques such as eletrophoresis, etc.

Two examples of the variation in meristic characters are given in Figure . The number of gill rakers ranges from 13 to 17 and, as in whitefish Coregonus () may have evolved differentially in relation to feeding habits. Thus a low mean gill rakes number is found in populations such as those at Loch Eck (Site 9) where the fish are small and inconspicuous in colour (Table), apparently having been forced into a benthic habit by competition from whitefish and trout (cf Nilsson 19). The charr of Loch Stack, on the other hand have a much higher mean gill rakes number as is appropriate to their pelagic and plankton-feeding niche in this large loch. Considerable differences occur too in other characters, such as the length of the dorsal fin (Figure) where long fins appear to be commonly associated with dull benthic races and short fins with the more brightly coloured pelagic forms.

EXTINCTIONS

It is quite certain that charr are now extinct in some lochs where they were previously abundant. The best documented case is that of Loch Leven () where charr were at one time very common and

However, in 18 the loch level was lowered by some m and its surface area by as part of a local land drainage and reclamation project. Charr appeared to disappear shortly after this and have never since been recorded in this well fished and studied water. The population formerly present in St Mary's loch also appears to have disappeared though the reasons are less clear.

In recent years it appears that acid precipitation may have changed the water chemistry of many lochs in granite unbuffered areas. It is well known that this effect in Scandinavia has caused the extinction of many populations of charr () and some other fish. Certainly, recent fishing (gill netting and angling) in several lochs likely to be affected in this way have failed to produce any charr. The waters concerned so far are Lochs Grannoch, Dungeon, Achray and Venfacher.

Charr have never been recorded in several Scottish ^{lochs} where their presence on historical grounds seems likely. Examples of such waters are Lochs Lomond, Shiel and Tummel. Loch Lomond is one of only two Scottish lochs to contain whitefish (Coregonus lavaretus) and it is known from Scandinavia () that where this species is introduced to waters containing charr the latter often disappear, apparently through competition. However, in Loch Eck, both whitefish and charr co-exist - though the latter are unusual morphologically (see below). In shallow waters such as Loch Tummel, it has been suggested that the presence of pike may eliminate charr.



Table . Unpublished records of charr from running waters in Scotland.

RUNNING WATER	DATE		NEAREST LOCH	DETAILS OF CHARR	OBSERVER
	MONTH	YEAR			
River Borgie		19			A.E. Joyce
River Tunnel		19	Dunalistain		W.R. Munro
Inflow burn		1979	Fhir Maol		Burns
River Spay		19	Inish		
River North Esk		19	Lee		W. Shearer
Outflow Burn		1975	Meallt	Three fish	R. Green
Inflow Burn		1975	Meallt	Several young	R. Green
Inflow burn	Oct/Nov	197	na Sealga	ca 24, both sexes	(A. Sutherland) confidential
River Hess	Oct	1979	Hess	One ripe female	R.N. Campbell
River Kingie		1954	Quoich		R.N. Campbell
	May	1960		One fish (laing)	R.N. Campbell
River Shin		19			A.E. Joyce

Running waters

Although, as previously discussed, there are no anadromous charr left in Scotland and all existing populations occur predominantly in lochs, fish are not infrequently found in running waters. Some of the more recent records are listed in Table . These appear to fall into several categories:

1. Fish accidentally entrained into power station systems and forced downstream (eg fish in the Rivers Kingie and North Esk below the hydroelectric stations on Lochs Quoich and Lee).
2. Ripe fish which may have accidentally moved downstream into outflows during the spawning season (eg fish caught in the River Ness below Loch Ness).
3. Ripe fish which have actively migrated upstream during the autumn into suitable inflow burns to spawn. Formerly the Loch Insh population was thought to be the only one with this habit, but it appears that the same situation exists at Loch na Seilga, possibly Loch Meallt, and probably other lochs.
4. Young fish (probably 0+ and 1+) which, like trout, use suitable inflow burns as nursery areas. The Loch Meallt population is the only one known to have this habit.



Table . Physico-chemical characteristics of Scottish chern lochs from which data are available.

CHARACTER	MINIMUM	MEAN	MAXIMUM	NO LOCHS
Area (km ²)				
Length (km)				
Altitude (m)				
Catchment (km ²)				
Distance sea (km)				
Depth: mean (m)				
Depth: max (m)				
pH				
Ca (mg/l)				
Alkalinity (mg/l)				
Na (mg/l)				
Conductivity				



Table . A comparison of the size of all Scottish lochs (from Smith & Lyle (1974)) and Scottish chann lochs from which data are available.

AREA CLASSES (KM ²)	ALL SCOTTISH LOCHS		SCOTTISH CHANN LOCHS		
	No	%	No	%	% OF EACH CLASS
0-0.25	2973	78.5	7	7.1	0.2
0.25-0.5	417	11.0	15	15.3	3.6
0.5-1	209	5.5	20	20.4	9.6
1-2	83	2.2	11	11.2	12.3
2-4	54	1.4	19	19.4	35.2
4-8	27	0.7	12	12.2	44.4
8-16	12	0.3	5	5.1	41.7
16-32	9	0.2	1	7.1	77.8
32+	4	0.1	2	2.0	50.0
TOTALS	3788	99.9	98	99.8	—

Charr are inexplicably absent from a number of large and apparently suitable lochs ^{in Scotland} (eg Loch Shiel) and their presence cannot be assumed as it can with brown trout. Toivonen (1972) considers that shallowness and staining of the water by humic colloids, together with the presence of some other fish species (eg whitefish) are contributing factors responsible for the absence of charr from many otherwise suitable Fennoscandian lakes. These factors do not however apply to all Scottish lochs without charr.

HABITAT

Standing waters

The general conditions in known charr lochs from which data are available are given in Table . The great majority of Scottish lochs, especially upland ones are glacial in origin. Many lie in basins, some of great depth, gouged from acid, weather-resistant rocks. Others are ponded back by glacial moraine^s. All such lochs are oligotrophic in character, many being dystrophic because of extensive areas of peat in their catchments. In a large number (eg Loch Sionascaig) little sedimentation has taken place (Pennington *et al* 1972). The physical and chemical conditions in Scottish charr lochs indicate that, in general, they are large deep lochs in areas of moderate altitude at varying distances from the sea with an acid to neutral water which is low in nutrients. Data on conductivity, sodium and chloride show that the areas concerned are oceanic with significant amounts of cyclic salts in many waters.

Of considerable interest is the question, not only of the nature of charr lochs themselves but how these relate to the fresh waters of Scotland as a whole. In terms of number, only a small fraction (%) of the

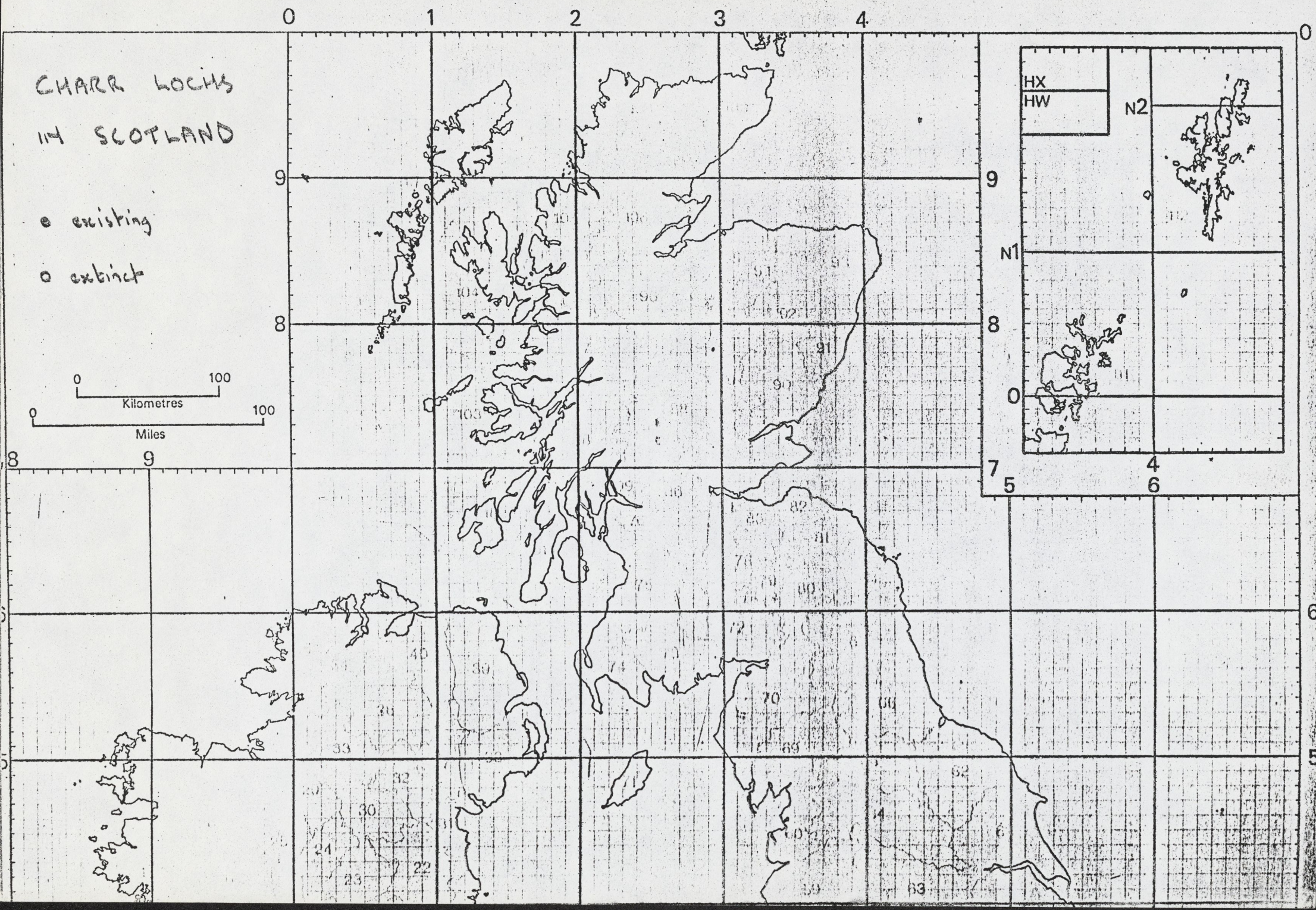
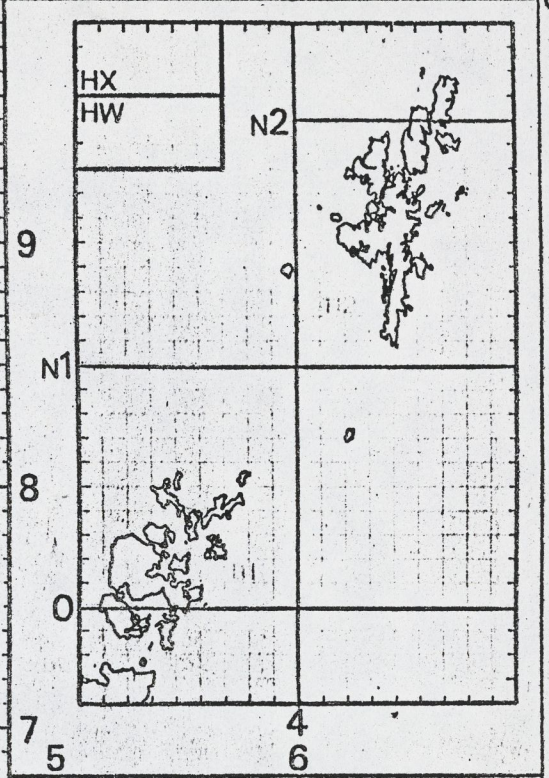
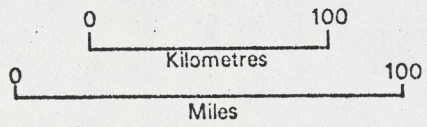
lochs in Scotland greater than 4 ha (Smith & Lyle 1979) are known to contain charr. The charr lochs, on the whole, represent the larger waters (Table) which are also the deepest. One of the best known areas of Scotland limnologically is the Tayside area (Maitland, 1981) and here comparisons of the known charr lochs with those of the area as a whole are of considerable interest (Table). The data show quite clearly that the charr habitat in Tayside tends to be the large lochs (six out of the seven largest lochs contain charr) in areas of moderate (but never high) altitude and base poor geology. It is perhaps significant that the only base rich charr loch in the catchment (Loch Leven) is one in which the species has become extinct.

two species were hybridised successfully ()
and it has been suggested (A F Walker, personal communication) that if
such hybrids were introduced to waters (such as the Uaine Lochs) the
stock could have separated back into the present types: this would
explain the present odd communities in these waters. *More recently similar hybrids
have been introduced to several Scottish lochs (A. Walker, personal communication).*
Charr arrived in the newly-made Loch Errochty in the late 1950's by
way of the ^{no}~~tunnel~~ which picks up water from the upper River Garry -
the fish originating from Loch Garry. Similarly, in the new Cruachan
Reservoir - part of the Cruachan pumped-storage hydro-electric scheme
constructed ^{at}~~in~~ Loch Awe - charr are now quite common, having presumably
been pumped up through the 1 km tunnel and m altitude of the pumped-
storage system by its giant turbines.

The information on charr in Scottish lochs has been carefully documented
by the authors, based on published data (eg Hardie 1940, Campbell 1979,
etc), unpublished communications from various people and personal fishing
records. The master list, ~~which~~ is regularly up-dated and ~~too large to~~ ^{the current version}
~~publish here~~ (Appendix 1), at present includes different lochs, the distribution
of which is shown on Figure . Only a few populations occur in the
southern part of Scotland, the great majority being confined to the
north-west. No existing populations are found in the south-east, and
though there are many charr lochs throughout the Western Isles, there
is only one population on Orkney and one on Shetland.

CHARR LOCHS IN SCOTLAND

- existing
- extinct



DISTRIBUTION

The indigenous freshwater fish communities of Scotland date from the retreat of the Pleistocene ice-cap about 10,000 years ago (Varley 1967). Initial recolonisation could only be carried out by species able to live in both salt and fresh water, and therefore the number of native species now common over Scotland, and virtually the only species in the north and west, is small: sea lamprey (Petromyzon marinus), river lamprey (Lampetra fluviatilis), Atlantic salmon (Salmo salar), trout (S. trutta), charr (Salvelinus alpinus), European eel (Anguilla anguilla) three-spined stickleback (Gasterosteus aculeatus), and ten-spined stickleback (Pungitius pungitius). These species probably recolonised Scotland by moving round the coast as it became progressively free from ice, penetrating river and loch systems. Other, purely freshwater, species gradually dispersed from the south of Britain northward but some have apparently not yet reached Scotland, while most of those which have (eg roach, Rutilus rutilus) are restricted to the south of the country.

From the original anadromous stocks of sea trout and sea charr the present sedentary populations of brown trout and freshwater charr have developed. There are no longer, however, any populations of anadromous charr in Scotland.

Most of the existing populations of charr are natural ones, but some have undoubtedly been created, intentionally and unintentionally by man. (1) refers to MacLaine of Lochbuie stocking his lochs on Mull with alpine charr, while Maxwell (1926) has given an account of his introduction of charr to Loch Ossian. The charr (and brook charr, Salvelinus fontinalis) of the Uaine Lochs were introduced during the 1890's (). At Howietoun in 1892 these

Apart from the interesting series of studies on the population of charr in Windermere, information on the status and biology of charr in the British Isles is fragmentary and generally ~~quite~~ inadequate. Apart from the fact that there ~~are still many~~ ^{must be a number of} charr populations still to be discovered, the current existence of several of those which have is in doubt and for most sites there is virtually no information on even simple aspects of local biology, such as spawning time and site, ages and growth rates, feeding habits, etc. Apart from the studies at Windermere, some work in Ireland and the recent account from Scotland (Campbell, 1978), little work is being carried out at present.

The present paper is a synthesis of the data ~~at present~~ ^{currently} available on the charr of Scotland. Most of it has been so far unpublished. The work of the ~~three~~ ^{four} authors has been carried out independently on different aspects of the biology of this fish though there has been collaboration and exchange of material from time to time. Much of the research was carried out by Mr G.F. Friend over a period of about 25 years. During this period he published two short papers on charr (Friend, 1956; 1959) but unfortunately his death in 1979 took place before he was able to prepare the bulk of his material for publication. It is included in this paper along with the results of recent studies by the other ~~two~~ ^{three} authors.



1st Draft.

THE STATUS AND BIOLOGY OF CHARR, SALVELINUS ALPINUS (L.) IN SCOTLAND

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ABSTRACT

This paper reviews available information on the charr in Scotland and presents new data on its biology. This fish is much commoner than formerly supposed and occurs in a large number of lochs, particularly in the north and west of the country. All known sites are listed and analyses of habitat characteristics presented. Extinct populations are reviewed. Meristic data on samples of charr from a number of habitats are tabulated and compared. There is considerable morphological variation among populations. Ecological data on food, growth, parasites and reproduction are presented and reviewed in relation to previous studies. The conservation of charr and aspects of future research, sport fishing and other topics are discussed. A comprehensive bibliography of all ^{known} references to Scottish charr is appended.

INTRODUCTION

The arctic charr, Salvelinus alpinus (Linnaeus, 1758) is a stenothermic holarctic species occurring widely in lakes and some rivers in northern and ^{alpine} Europe, Asia and North America. Like many other Salmonidae, the northern populations are anadromous and may grow to a large individual size, while the southern populations are purely freshwater and often of small individual size. In some areas the species is important commercially in net fisheries, ^{In Scotland, however, the species has been largely ignored as far as fisheries are concerned, in other areas it is angled.} Charr appear to be sensitive to pollution and other stresses and a number of populations - particularly in lakes on the southern edge of the geographic distribution of the species - have become extinct in the last 200 years.

In the British Isles there are well over ^{two} hundred lakes containing charr populations. The majority of these are in Scotland, but there are a considerable number in Ireland, about twelve in the Lake District of England and ^{three} ~~a few~~ in Wales. Systematically, the British charrs (like those in other parts of the world) are interesting because their local races are often quite recognisably different from one another. However, though it has been known for a long time that the morphological range of variation of charr is a wide one, the evidence for it has been imprecise and based often on a few specimens only and no knowledge of habitat.

Inevitably this has led to confusion in their taxonomy for though Day (1837) regarded all British charr as belonging to the single species Salvelinus alpinus, Gunther (1830) and Regan (1911) between them distinguished at least 14 species of charr in the British Isles alone. It is accepted now that all native charr in the British Isles do, in fact, belong to the plastic Salvelinus alpinus - though it must be remembered that there are several thriving populations of introduced American brook charr, Salvelinus fontinalis (Mitchell, 1815) in various lakes. Recently, stock from migratory charr from Norway have been introduced to ^{(D. Brown, personal communication).}

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*Fishery & Wildlife
Biology*

Uaine Lochs - odd types
perhaps fontinalis x alpinus introgr.
recently fontinalis x alpinus hybrids introduced
int Scottish lochs -

L. Eck morphol. unusual - ..

benthic ^{naes} chan - dull color, long fins, lower ranks

pelagic ^{naes} chan - bright color, shorter fins; higher ranks.

* Loch Rannoch, 2 reprod. isol.
pop.

Pop. differ in persistence of pair marks:

- type spotting, absent, on sides, on sides & back
- coloration

"generalist" - zooplankton summer
benthos winter

Loch Rannoch 2 pop
1. 95% zooplankton
2. 95% benthos

some lochs occasional fish in diet

max size age - 1-21g 8-9 yrs