THE STATUS OF ARCTIC CHARR, *SALVELINUS ALPINUS* (L), IN SOUTHERN SCOTLAND: A CAUSE FOR CONCERN

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Introduction

In the British Isles, the arctic charr (Morton 1955), *Salvelinus alpinus* (L.) (see Fig. 1), in individual lakes have been isolated from each other for thousands of years and have developed a variety of phenotypic characteristics (Gunther 1865; Day 1887; Regan 1909, 1914) which are probably genetically based (Nyman 1972; Child 1977, 1984; Ferguson 1981). The differences between some populations are so great that many were originally described as distinct species.

FIG. 1. An arctic charr from Loch Doon, Ayrshire.

Altogether, about 200 populations of arctic charr have been recorded from different parts of the British Isles: approximately 12 in England, 50 in Ireland, 175 in Scotland and 4 in Wales. However, several populations have disappeared in Ireland (Avondhu 1951), in England

and Wales (Maitland et al. 1984) and in Scotland. All the known Scottish losses have been in the south and the objective of this article is to review the populations concerned and the reasons for their demise. The article is dedicated to the late Charlotte Kipling who has done so much to advance our knowledge of charr biology in Britain.

Loch Leven

Arctic charr were once abundant in Loch Leven and the stock seems to have been particularly interesting because of the large size of the adults. It was commonly known among fishermen as the "gelly-troch trout" - a local name derived from the fact that the main food item was a black leech, commonly called a "gelly" which abounded in the loch. The leech involved was probably *Erpobdella octoculata* (L.), which is still common there and important in the diet of both brown trout, *Salmo trutta* L., and perch, *Perca fluviatilis* L. (Maitland & Hudspith 1974).

One of the earliest accounts is that of Sibbald (1684): "The gelle-troch or red-womb trout . . . is usually 18 inches (46 cm) long . . . taken in October with nets - some are reddish within some whitish". Charr seem to have been caught in some numbers, mainly from October to January, and they were split, salted and dried for winter provision. At least some of the stock seem to have migrated into running water to spawn and Burns-Beggs (1934) recalls an old record of "two sacks filled with charr caught by poachers during the spawning season in the North Queich" (one of the main feeder burns).

Smith (1973) noted that "The gelly-trough or charr abounds in the loch. What is remarkable of them is the size to which they grow, some of them weighing near 2 lbs, and they are never known to rise to a fly or be caught with a hook baited in any way whatsoever". The unit of weight referred to here is the old Scottish pound - equal to three modern pounds or 48 ounces (1.36 kg). This means that the fish commonly weighed up to 6 lbs (2.72 kg) - by far the largest ever recorded anywhere in the British Isles until recently. For example, a previous British rod-caught record for arctic charr was 1.502 kg for a fish caught in 1985 in Loch Earn. This was subsequently beaten by a fish caught in Loch Garry (Inverness) in 1987 which weighed 2.182 kg. Even this fish was subsequently demoted by several other large arctic charr, the most recent of which was a very large fish of 3.373 kg caught in 1990 in Loch Arkaig (National Anglers' Council 1991). All these recent records are of fish caught in the vicinity of fish-farm cages, discussed further below. The exceptional size of the original Loch Leven charr is confirmed by both Sibbald (1684) and Pennant (1769) who noted "the length of the Loch Leven charr at two and a half feet" (76 cm).

The last arctic charr caught in Loch Leven was in 1837, the loch level

having been lowered in 1830 to leave only three-quarters of its original area. Burns-Begg (1934) noted that "the charr has entirely disappeared from Loch Leven and none have been caught for 100 years". The very "last of the race" is believed to have been caught with a net in the latter part of the season in 1837, near Kinross House pier. Charr had evidently been caught several times earlier that year, but "always restored to its native element from a desire to preserve the species from utter extirpation". Subsequent attempts to secure specimens all failed. The "Perthshire Advertiser" of 20 April 1843 noted that recent attempts by Sir William Jardine and Mr Wilson to find "the missing and delicate char or gelly-trough proved utterly unsuccessful".

St Mary's Loch

Arctic charr were at one time common in this loch (Robson 1986). Early records note that "In this Loch are Trouts, Eels, Pearches, Pikes and a kind of Fishes called by the Countrey people Red Waimbs from the bloud red colour of their Belly. The fish itself is about the bigness of a herring with a forked tail. The Herds about Michaelmass use to take great numbers of them catching them in their Blankets at a little Rivulet that comes from the Loch of the Lowes into this, the two Lochs being almost one and divided by a very small nick of ground". Another account records " . . . Red waimbs. It is about the bigness of a Herring, and the belly of it wholly red. It is only to be found about Michaelmass and that only in the little stream that runneth betwixt the two Lochs, but not seen at any other time or in any other part of the Lochs. Yet at that Season the Countrey people with Plaids sewed together like a Net have taken such Store of them, that they carried them home and salted them up in Vessels for the food of their families".

Therefore the species was evidently very heavily exploited by the local shepherds at spawning time. This may well have been the cause of extinction in this system and it seems to have disappeared before the middle of the 18th century for it is not mentioned by Handyside (1794) in his account of the area. Recently, St. Mary's Loch has been echo-sounded and gill-netted by the author but no charr were recorded (Hook 1990).

Loch Grannoch

At Loch Grannoch, the earliest arctic charr to be recorded seem to have been those mentioned by Pennant (1769) and they too were known locally as "red-wames" (Maxwell 1919). There is one early specimen *(Salvelinus willughbii)* in the British Museum (presented by G. R. Murray). Several others were caught by Thompson (1841): two

specimens on 25 October 1836, then on 17 October 1838 - "they appear 13 October (for 10 days only) 12 red fish (males) and 12 gray fish (females)". These specimens were 7-8 inches (17-20 cm) long. A recent owner, Mrs Murray-Usher, reported (ca. 1955) that no charr had been taken for several years although she had tried with a net.

Loch Grannoch has been gill-netted several times in recent years during acidification research programmes (Harriman et al. 1987; Maitland et al. 1987). No arctic charr were found, and the stocks of brown trout were very low, with the chemistry of the loch and its outflow showing clear signs of acidification. Not only is the loch and its catchment lying on base-poor granitic rock in an area of high atmospheric acid deposition, but also a high proportion of its catchment has been afforested by coniferous plantations over the last 40 years.

Loch Dungeon

Arctic charr definitely occurred here though most reports this century are rather vague (Maitland 1970). Last century, Moss (1899) records "Shortly since I had the pleasure of receiving a fine specimen of Char from a friend, who had caught it in Loch Dungeon with a fly when angling for trout. A few are caught each year in this way in the loch named, as well as in Loch Doon." The last specimen reported was in 1952 (R. Watson, pers. comm.) and the species seems to be extinct here now, for recent netting proved negative (Maitland et. al. 1987).

Loch Doon

Arctic charr in Loch Doon appear first to have been mentioned by Crawford (1792) as "cuddings or char". Later, Knox (1845) mentions the charr of Loch Doon "which rise not to a fly". The British Museum collection contains five specimens of Loch Doon charr taken in May 1893 by Robert Service. Hardie (1940) notes that they can be "captured with fly in the month of May".

Loch Doon is a large oligotrophic lake which has been designated as an SSSI by the Nature Conservancy Council mainly because of its population of arctic charr (Figs 1, 2). The nearest surviving populations are found in Cumbria in England and in the southwest highlands of Scotland (notably in Lock Eck and Loch Lubnaig). Recently, Partington & Mills (1988) have shown that the Loch Doon charr are clearly distinct from English and Welsh charr on meristic grounds, for in the Loch Doon fish, both the mean numbers of gill rakers on the first gill arch and the number of branchiostegal rays are substantially lower than in all British populations further south.

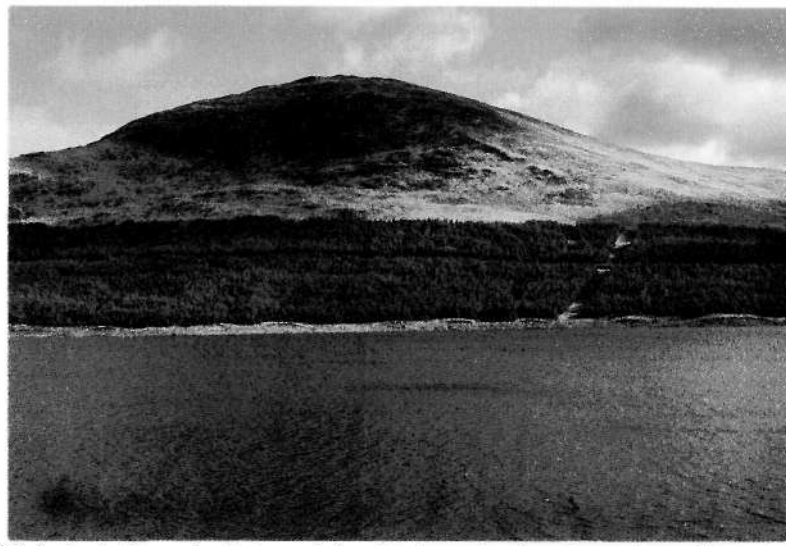

FIG. 2. Loch Doon, the last remaining site for arctic charr in southwest Scotland. The population here is threatened by acidification and the effect of blanket afforestation, as seen above on the far shore of the loch.

Early work on arctic charr in Loch Doon by Friend (1958) has been extended recently by Maitland et al. (1991). The population there has suffered substantial mortalities during hot dry summers and there is considerable evidence that the loch is acidifying. Both the arctic charr and brown trout populations are showing signs of population decrease, with increasing size of the surviving individuals. Lochs in the upper parts of the Doon catchment have recently become acid and completely fishless (Maitland et al. 1987) or are showing signs of increasing acidification (Hay 1984). As with Loch Grannoch, the catchment of Loch Doon is mostly on base-poor rock and has been heavily afforested in recent decades (Maitland et al. 1991).

Other Lochs

An early record of the transfer of arctic charr in southern Scotland is that of Moss (1889) who noted "A few years ago char were introduced into Lochenbreck, but whether they have succeed in establishing themselves therein I am ignorant." There have been no records since then and recent netting there (Maitland et al. 1987) proved negative.

Reports of arctic charr in the Ken system of rivers and lochs (Hunter-Blair 1987), to the east of Loch Doon, have been verified by several

anglers. These charr are assumed to have come from Loch Doon via the connecting hydro-electric scheme. Specimens angled in Carsphairn Lane (into which water from Loch Doon is passed) showed damage attributable to passage down pipes from Loch Doon (R. Ade, pers. comm.). Further downstream, several charr have been caught in Kendoon Loch. However, recent netting by the author in this water (where the population of brown trout has been depressed by escapees from a cage-farm for rainbow trout, *Oncorhynchus mykiss* (Walbaum)) indicated large numbers of rainbow trout, with fewer brown trout and perch. No charr were caught and the situation is felt to be unsuitable for them ever to become established here.

At least one specimen has been caught even further down the system, in Loch Ken, during the last decade (E. Hunter-Blair, pers. comm.). Again, this is assumed to have come from Loch Doon via the hydro-electric scheme.

Threats to arctic charr from acidification

One of the most characteristic effects of acidification on fish populations is the failure of recruitment of new age-classes into the population (Harvey 1982; Rosseland et al. 1980). This is manifest in an altered age structure and reduction in population size, with decreased intra-specific competition for food and increased growth or condition of survivors. The fish stock then starts to "improve" and there are lower numbers of large fish. However, with no recruitment the population contains fewer and fewer fish until eventually there are none.

Acid precipitation has caused major damage to fish stocks in various parts of the world including North America, Scandinavia and the British Isles. Salmonid fish are particularly vulnerable, but all fish species have been affected. A survey of fish populations in 50 lakes in southwest Sweden showed that, in acidified lakes, brown trout, arctic charr, roach *(Rutilus rutilus* (L.)) and minnow *(Phoxinus phoxinus* (L.)) were all affected (Aimer et al. 1974). Atlantic salmon *(Salmo salar* L.) have been completely eliminated from several Swedish rivers over recent decades (Wright et al. 1977). Acid precipitation has also devastated fish populations in southern Norway where the principal fish species affected are Atlantic salmon, brown trout, arctic charr and brook charr *(Salvelinus fontinalis* (Mitchell)), (Aimer et al. 1974).

Several workers have tried to define and classify various levels of acidification and the resultant fish communities. Kelso & Minns (1981) have produced such a scheme which, if applied to recent conditions in charr lochs in southern Scotland, fits the disappearance of charr in some lochs and indicates that there should be concern for Loch Doon if acidification continues there. Arctic charr and brown trout are among

the least tolerant of freshwater species (Aimer et al. 1974) and this emphasises the fragile situation at Loch Doon.

Both population size and size-distribution of fish have been known to change dramatically in acid lakes following neutralisation. During the late 1960s and early 1970s, the pH of the Swedish lake Stora Skalsjon was 4.5-5.5 (Harvey 1982). It was limed in 1976 and 1977, gradually raising the pH to 6.0 The catch of perch per net increased in 1978 and 1979, concurrent with the reintroduction and expansion of arctic charr. Quite recently, liming experiments at Loch Dee and Loch Fleet, two other acidified lakes in Galloway, have verified the usefulness of the liming techniques developed in Sweden (Burns et al. 1984; Central Electricity Generating Board 1988). However, there is considerable controversy surrounding the adverse effects and long-term value of such liming techniques (Woodin & Skiba 1990).

Threats from afforestation

The impact of coniferous afforestation and forestry practice on freshwater habitats in the British Isles has caused much concern in recent years. The effects of each stage of the forestry cycle - ground preparation, tree planting to canopy closure, the maturing crop and felling - may have an impact on local fresh waters (Maitland et al. 1990). The physical aspects of afforestation affect: (i) the hydrology of streams, as shown by (a) increased loss of water through interception and evaporation from the coniferous forest canopy, and (b) a tendency to higher flood peaks and lower water levels during droughts; (ii) the release of sediments to streams because of erosion following ploughing and weathering of exposed soils; (iii) reduced summer water temperatures in afforested streams where the channel is shaded.

The principal chemical changes in fresh waters in afforested catchments include: (i) increased nutrient levels from the leaching of exposed soils and applied fertilisers, and (ii) the acidifying effect of air pollutants (especially sulphates) which are intercepted by conifers (as airborne particles) and then transferred to the ground (by rain - itself often very acid) and eventually to adjacent water courses. The base-richness of local soils and rocks is of major importance here, for it is only in areas lacking basic ions that acidification occurs. Much of the biological damage is due to the high amounts of aluminium (leached from the acid soils).

These physical and chemical effects combine in various ways to affect the plants and animals of fresh waters in afforested areas. Changes in hydrology and ambient water temperatures tend to make conditions in streams more extreme for most biota. Turbidity decreases plant growth through reduced light penetration and physical siltation. Increased

amounts of nutrients alter plant communities and cause problem crops of algae in streams and lakes. Acidification of water-courses affects the composition of their plant and invertebrate communities and completely eliminates fish in some cases. Other vertebrates, such as amphibians and birds, may also disappear.

It seems highly likely that recent extensive afforestation in the catchments of Loch Grannoch, Dungeon and Doon has exacerbated acidification already taking place in their headwaters. Several lochs in the area, well above the forest and once populated with brown trout, are now highly acid and fishless (Maitland et al. 1987). It appears that the same is happening at Loch Doon, but at a slower rate. The new forest surrounding the loch is certain to increase the acidic input as further planting proceeds and the forest canopy closes.

Threats from engineering schemes

It is well known that hydro-electric schemes can have deleterious effects on local fisheries and this is certainly the case with Atlantic salmon in some waters. However, arctic charr seem to be less affected than other salmonids, and there is evidence that some stocks (which are mainly plankton feeders) may be favoured by the fluctuating waters levels, which adversely affect brown trout. It is believed that, because the fluctuating levels often devastate the littoral flora and fauna (Smith et al. 1987), the trout population, which mainly feeds in the littoral area, is also adversely affected. The plankton, on the other hand, is not affected and so charr still have their main food source. Certainly many hydro-electric reservoirs have large populations of arctic charr and indeed new populations have developed in some reservoirs (e.g. Cruachan Reservoir above Loch Awe) where water (and charr) have been pumped up from an established charr loch.

Water-supply schemes may also have significant effects on fish populations, especially where large volumes of water are transferred from one catchment to another. In England, for instance, large numbers of arctic charr and schelly *(Coregonus lavaretus* (L.)) are pumped out of Haweswater each year as part of the water-supply systems supplying Manchester (Maitland 1985a). The impact can be particularly serious where no account is taken of local fish ecology when the engineering works are being designed. This can lead to serious damage of fish stocks as, for example, at Loch Lee where substantial numbers of adult fish are washed out of the loch each year at spawning time, due to construction of a spillway near charr spawning grounds.

Threats from angling

In general, the management of fresh waters for angling poses various

problems for fish, notably because of litter, disturbance, habitat damage, the use of piscicides, the control of predators and the introduction of new species (Maitland & Turner 1987). Perch are supposed to have been introduced relatively recently into Loch Doon by anglers from England; perch and pike *(Esox lucius* L.) are also abundant in Loch Leven and St Mary's Loch.

It is likely that stocks of brown trout benefit from the presence of arctic charr. Trout collected when charr were actively spawning along the shores of Loch Doon were found to be so full of charr eggs that these were regurgitated in considerable numbers as the trout were handled. The reverse would not happen when trout are spawning because at that time trout will have migrated into the burns where there are no charr. Additionally, larger trout are known to eat charr (Hardie 1940) and it is believed that the latter are the main prey of the large ferox trout found in many Scottish lochs (Campbell 1979), including Loch Doon.

Threats from fish farming

The recent advent of fish farming in several lochs containing arctic charr has led to a number of changes. There is clear evidence that charr learn to aggregate around the fish cages and feed on waste food falling through the meshes. These charr also grow much larger than normal and all the recent rod-caught records, mentioned above, have been of fish taken in the vicinity of cages in Scottish lochs. However, many of the rainbow trout being reared in these cages escape and grow to a large size, becoming predators of arctic charr and Atlantic salmon (e.g in Loch Awe and in Loch Tay).

Perhaps even more worrying than the escape of farmed rainbow trout, or the effects of waste food and faeces or transfer of disease to arctic charr, is the potential threat posed by the development of charr farms. Fish farmers in Great Britain are taking an increasing interest in arctic charr as a farmed fish and there could well be a distinct threat to the genetic integrity of individual stocks if charr are moved around the country for commercial purposes. The recent suggestion that farmed arctic charr could be moved from England to be farmed in the north of Scotland must be deplored. Even worse is the importation, in 1991, of stocks of arctic charr from two sources in Canada to two different fish farms in Scotland. There is no scientific or economic justification for such practice.

Extinct and threatened populations in Scotland

It is always difficult to prove the extinction of a fish species, but the recent nettings and echosoundings in the former charr lochs discussed

above do seem to indicate that arctic charr have become extinct there. This is a matter of considerable regret, not only for the loss of an attractive and colourful species which was a useful local resource, but also because their individual genetic make-up was likely to be unique and therefore cannot be replaced. Because of this it is important to review the remaining stocks of arctic charr in Scotland and implement conservation management plans for the future.

Relatively little was previously known about arctic charr distribution and biology in Scotland, and even today new populations are occasionally being discovered. Very few of the populations have ever been studied, available information being reviewed by Maitland et al. (1984). More recent studies by Gardner et al. (1988) and Walker et al. (1988) have demonstrated the presence of sympatric populations in Loch Rannoch and these are being further studied. Other populations which are little known but appear to be of particular interest are those in Loch Eck (Friend 1956), Loch Insh, Loch Meallt (Campbell 1984), Loch Croispol, Loch Ness and Loch Morar (Maitland 1981). Many other stocks of arctic charr may be of significance but nothing is known of them.

Lochs where arctic charr may be under particular threat include, as well as Loch Doon (discussed above), Loch Lee, Loch Girlsta (Swan 1964), Loch Heldal and many of those now supporting floating fish-farm cages (e.g. Loch Awe). At Loch Lee, for example, the dam intended to enlarge the loch for water-supply purposes was constructed close to a charr spawning area. In many years, during the spawning period (October), large numbers of adult fish are washed out of the loch during periods of strong wind. Most of them survive and are found in the river below but cannot make their way back into the loch.

Active management: establishing new populations

One of the most positive areas of management for endangered stocks of fish lies in the establishment of new populations - either to replace those which have become extinct or to provide an additional safeguard for valuable stocks in threatened waters (Maitland 1985b). Any species which is found in only a few waters could be in potential danger, and the creation of additional independent stocks is an urgent and worthwhile conservation activity.

This can be done without any threat to the existing stocks. It is possible to obtain substantial numbers of fertilised eggs by catching and stripping adult fish during their spawning period. They can then be returned safely to the water to spawn in future. Most fish produce a considerable excess of eggs and so substantial numbers can be taken at this time without threat to the parent population. Having identified an appropriate water in

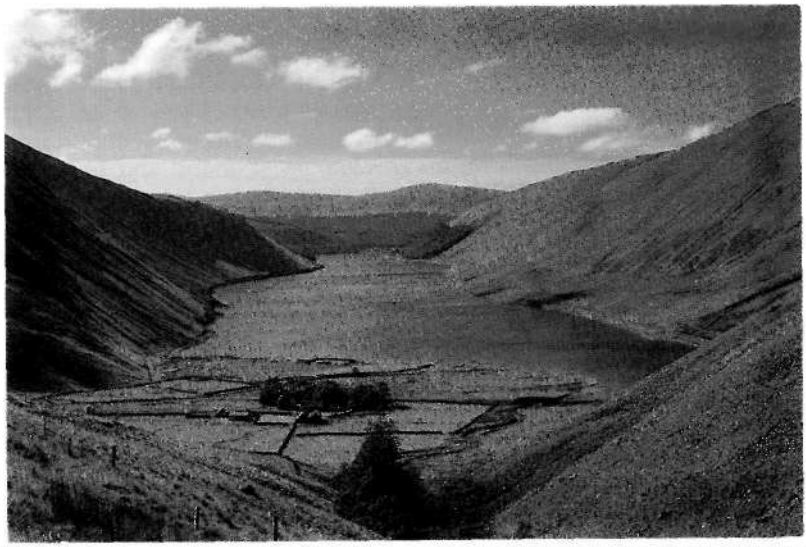

FIG. 3. Talla Reservoir in the Scottish Borders, where arctic charr from Loch Doon have been introduced and are known to have bred successfully.

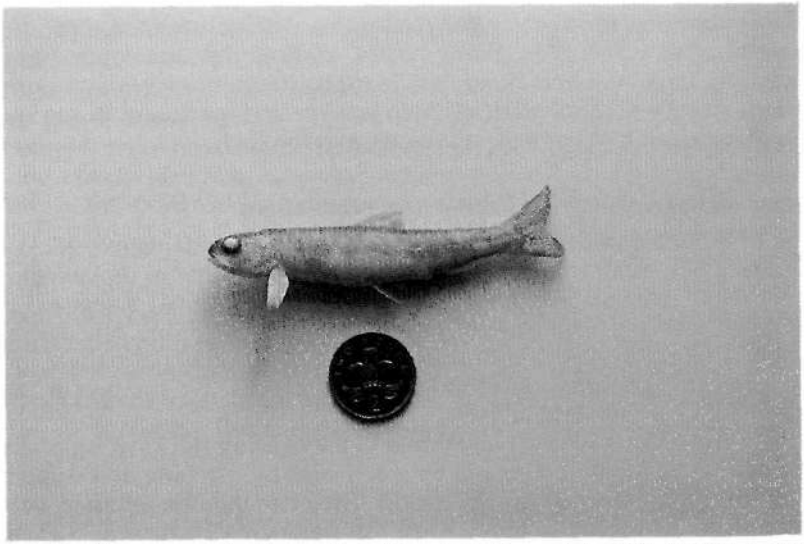

FIG. 4. The first young arctic charr collected from Talla Reservoir in 1991, bred from adults introduced in 1988.

which to create a new population, this can be initiated by placing the eggs there, or by hatching the eggs in a hatchery and introducing the young at various stages of development. Depending on the state of the parent stock, adults may also be moved in some cases.

The stock of arctic charr in Loch Doon seems clearly to be a case where the creation of new stocks is valid (and indeed urgent) in view of the disappearance of the populations in other lochs in southwest Scotland and the threat to the stock in Loch Doon itself (Maitland & Lyle 1990). In the autumns of 1986, 1987, 1988, 1989 and 1990 fertilised eggs were obtained in early October. These eggs were hatched under controlled conditions and numbers of young fish (and some adults) have been introduced to two large waters in the Scottish Borders - Megget and Talla Reservoirs (Figs 3, 4). It is believed that these will provide ideal conditions for new populations (Table 1). Megget Reservoir is linked to St Mary's Loch where arctic charr, as discussed above, are now extinct. Already, there is evidence that the adult charr in Talla Reservoir have bred successfully over two spawning seasons and in 1991 an adult charr was caught by an angler in Megget Reservoir.

Practical conservation measures of this kind, coupled with further studies of charr distribution and ecology in Scotland, are essential if the future of this attractive and potentially valuable fish is to be secured for the future.

Table 1. Comparative chemical data for some Scottish charr lochs. Concentrations of calcium, aluminium and sulphate are in milligrams per litre, conductivity is in µSiemens per centimetre, and water colour is in Hazen units (HU).

Loch	*Date*	*pH*	*Ca*	*HU*	*Al*	*Conductivity*	*SO_4*
Grannoch	5 Dec. 1984	4.3	1.3	50	0.19	82	5.8
Dungeon	12 Oct. 1984	5.4	0.9	5	0.06	46	2.5
Doon	24 Oct. 1986	6.0	1.8	20	0.06	56	7.8
Einich	13 Aug. 1984	6.6	1.4	5	0.02	25	0.6
Megget	1 Oct. 1987	7.0	11.0	30	<0.05	49	4.0
Talla	22 Sep. 1987	7.1	16.0	20	<0.05	59	5.0

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