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# The phenotypic diversity of Arctic charr, *Salvelinus alpinus,* (Salmonidae) in Scotland and Ireland

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**Abstract**
The high phenotypic variability of Arctic charr and the nature of polymorphism in the species are briefly summarised. Photographs of Arctic charr from populations in Scotland and Republic of Ireland are presented to illustrate some of the phenotypic diversity of the species in these two countries.

**Zusammenfassung**
Die hohe phenotypische Variabilität des Wandersaiblings *(Salvelinus alpinus)* und die Natur der Polymorphismus der Spezies werden kurz zusammengefaßt. Fotos aus Schottland und Irland werden gezeigt, um die phenotypische Diversität einiger Populationen der Spezies aus diesen zwei Ländern zu zeigen.

**Résumé**
La grande variabilité phénotypique de l'Omble Chevalier *(Salvinus alpinus)* et la nature du polymorphisme de l'espèce sont résumées. Des photographies de formes d'Ecosse et d'Irlande sont présentées comme exemples locaux de cette diversité.

**Sommario**
L'alta variabilità del fenotipo del *Salvelinus alpinus* e la natura del polimorfismo delle specie viene riassunto brevemente. Vengono presentate fotografie delle popolazioni scozzesi e irlandesi per illustrare la diversità di fenotipico delle specie in questi due paesi.

## Introduction

The Arctic charr *(Salvelinus alpinus)* is a relatively widespread salmonid fish species in Scotland and the Republic of Ireland (hereafter referred to simply as Ireland), with around 175 and 50 populations thought to exist in the two countries respectively (Maitland, 1992). Despite this, and in contrast to other native salmonids, it remains one of the least-known fish species of these two countries.

Arctic charr were amongst the first fish to inhabit freshwaters in northern Europe following the end of the last Ice Age. An anadromous species at that time, it has since ceased its migratory lifestyle at lower latitudes to become resident in lakes, while remaining anadromous at higher latitudes. The species is now distributed throughout the cold waters of the northern hemisphere.

A characteristic feature of the species throughout its range is its diversity in life history and feeding habits. The species is also highly plastic in its morphological and meristic characteristics and varies widely in skin colour and markings. In many places it occurs as polymorphic populations, with up to three or four distinct morphs coexisting in some sites (Frost, 1965; Behnke, 1984; Walker *et al,* 1988; Sandlund *et al,* 1992; Adams *et al,* 1998).

In some populations polymorphism appears to be purely ontogenetic, with individual fish passing through two or more "morph" phases as they mature and grow, but with no reproductive isolation or genetic differentiation between morphs (Nordeng, 1983). In other populations morphs appear to be reproductively isolated, with the morphotypes of individual charr determined to some extent genetically, and therefore with no switching of fish between morphotypes (Hartley *et al,* 1992b; Sandlund *et al,* 1992; Adams *et al,* 1998). This latter type of polymorphism appears to be the most widespread known to date amongst British and Irish charr populations (Partington & Mills, 1988; Adams *et al,* 1998).

Genetic polymorphism in Arctic charr may have arisen via one or more of a number of possible mechanisms (Behnke, 1972; Nyman, 1972; Balon, 1980; Savvaitova, 1980). A single monomorphic strain may have colonised our freshwaters and subsequently evolved into different morphs to fit the available trophic niches. Alternatively, a single colonising strain may have evolved allopatrically into distinct strains, which have subsequently come together along river systems, but maintained their differences through differential exploitation of niches. Finally, it is possible that, at least in some places, a number of different charr types invaded, giving rise to the different types we see today. More than one of these processes may have occurred (Klemetsen, 1984).

A result of this high level of intra- and inter-population variation has been the division of Arctic charr into many nominal species across its range, including 15 species across Britain and Ireland (Günther, 1880; Regan, 1908, 1911). Current opinion, based on more recent biochemical analysis of both British and Irish charr, holds that these forms are conspecific (Ferguson, 1981; Partington & Mills, 1988; Hartley *et al,* 1992a,b).

Irrespective of the mechanism giving rise to this diversity, however, what we are left with today in Scotland and Ireland are Arctic charr populations that are relatively pristine, representing the consequence of the colonisation processes which occurred after the Ice Age, followed by the forces of natural selection.

Concern has arisen in recent years over the conservation status of charr in Scotland and Ireland (Maitland, 1992, 1995). This is particularly so for Irish charr, where there has been no recent survey of the species (Went, 1971) and where nearly half of the known populations are now believed to be extinct (Maitland, 1995). Arctic charr are adapted to cold, oligotrophic waters and are sensitive to pollution, particularly where trophic enrichment occurs. Acidification and changes in water level and regime are also known adversely to affect populations (Harriman *et al,* 1986).

More recently, Arctic charr have attracted close attention from fish farmers as a potential "new" species (Jobling *et al,* 1993), though work with the species began as far back as 1882 in Howietoun, Scotland (Maitland, 1887). This may benefit the species by raising its profile and increasing public awareness of its existence and associated conservation issues. However, fish farming, particularly in freshwater cages, also increases the risks to the species through the high likelihood of escaped foreign or domesticated strains interbreeding with wild native strains (cf farmed Atlantic salmon, *Salmo salar).*

The purpose of this paper is to show some of the phenotypic diversity of Arctic charr in Scotland and Ireland.

## Methods

While collecting samples from Arctic charr populations (Alexander & Adams, 1999), typical specimens in good condition were photographed at each site. Sampling was carried out from June to November 1997 and from September to November 1998 in Scotland, and from November to December 1997 in Ireland. Standard multimesh gillnets were set overnight, close to the surface and on the bottom, covering the full depth range of each lake. Typical examples of fish from each population were photographed on site while alive or relatively fresh and still showing life colours (except for some populations where scarcity of fish meant photographs of faded fish have been used).

## Results

A selection of the clearest photographs of charr from each of the lakes sampled is shown (Figs. 1-32) and the physical description of the fish is given in summary. Descriptions were compiled from photos of between 12 and 40 fish per lake, unless otherwise stated below.

Most Arctic charr populations spawn in autumn, with a corresponding brightening in skin and fin coloration at this time of year. Populations were sampled at different times of year, therefore some of the colour variation shown here is the result of variation in breeding stage. In order to illustrate this effect, where appropriate, we present the fish in the order in which they were sampled, from June to December. In addition, three populations sampled in 1997 were re-sampled in 1998, but in different months. Photographs of these are presented to give an indication of the effect of season on coloration.

No attempt was made to sex the fishes illustrated, but sexual dimorphism was apparent in some populations, and larger, more coloured individuals shown are most likely males. Descriptions may be biased to larger and more coloured fish, such that the accounts are male-biased. However, this should be relatively equal across all populations and still allow fair comparison.

Where populations were known to be polymorphic, we have identified the morphotypes of the fish illustrated. Some of the sampled populations may have as yet undetected polymorphism, resulting in greater intra-population diversity than has been described here. Such polymorphism may be revealed in the future when genetic and morphometric characteristics of the fish caught during the present survey are analysed.

A typical feature of the charr caught for this survey was that, as in many other freshwater species, skin colour changed in hue and faded after death. Bright metallic purple, pinkish and red, as well as dark life colours, would fade to dull grey-purple, grey-pink, olive brown, or even creamy white, depending on location on the body (for example, Fig. 28). Dark fins became noticeably paler. Unspotted, near-black backs faded after death to reveal often dense pale spots. Previously invisible or faint parr-marks (dark, fingerprint-like marks, generally similar in shape to those seen in salmon parr) and spots along the flanks often appeared or became more obvious, the colour of spots often intensifying. These changes to spots and parr marks also occurred after the skin was abraded. Colour and pattern changes of these types should be taken into account when comparing or describing specimens of Arctic charr, and should also be borne in mind when comparing some of the specimen descriptions in older publications.

White edges on fins are described as being fine, moderate, or heavy, with increasing extent and opacity of the white area.

## Population Accounts

Information on charr from each lake is presented in the following order: name of lake; location; grid

reference; month of sampling; size range (fork length in millimetres) of maturing, mature, or spent fish; description of coloration and markings of body and fins; notable physical characteristics.

The scale bar shown in each photograph represents approximately 30 mm. Grid references are derived from the standard 1:50,000 Ordnance Survey maps of the UK and Republic of Ireland.

**Loch Awe, Argyll** (Figs. 1, 2, & 3) 2005 7175

Two forms, spawning in spring and autumn. Fish cages present, occasional pellet-feeders showing typical bloated appearance.

Spring spawners (Fig. 1). Early March. 100-274 mm. Uniformly dark over all except for lower jaw (off-white) and underparts (pale brownish-orange). Fairly indistinct orange spots on lower flanks. No parr marks. All fins dark, with some red on trailing edge of pectorals and anal. Moderate white edging to pelvic and anal fins. Slim-bodied, snout fairly blunt, maxilla extending just beyond posterior edge of eye.

Autumn spawners (Fig. 2). Mid August. 101-240 mm. Dark along back, fairly uniform grey-brown flanks, near-white along lower flank and belly. Parr marks generally not visible except in smaller fish (7-10). Frequent small pale spots visible on some individuals, but generally indistinct. Dorsal and caudal fins dark, lower fins medium to dark yellow or reddish brown. White edging absent to moderate on pectoral fins, moderate to heavy on pelvics and anal. Large eyes. Maxilla extending beyond posterior edge of eye in large fish. Generally fairly slim-bodied.

Pellet-feeders (Fig. 3). Mid August. 451 & 470 mm. Brownish and silvery upper parts, pale flanks and off-white underparts. No parr marks. Indistinct pale spots. Lower fins pale brown to brownish red with moderate to heavy white edging on these and lower caudal fins. Maxilla extending beyond posterior edge of eye. Very large-mouthed and heavy-bodied.

**Loch Lee, Angus** (Fig. 4) 3424 7797

Late June. 250-347 mm. Moderate to dark steel grey back and upper flanks, belly and lower flanks moderate to deep orange-red. Forebelly and underside of head near-white. Even cover of small pale spots, orange on lower flanks. 8-11 faint parr marks on smaller individuals, generally absent from larger mature fish. Pectoral fins dark, with red trailing edge and fine white leading edge. Pelvic and anal fins with less red coloration and moderate (pelvic) to heavy (anal) white edging. Pectoral fins long. Pale opercula with light purple sheen. Slim, streamlined, body with long head and jaws and pointed snout. Maxilla extending beyond posterior edge of eye.

**Loch Doine, Trossachs** (Fig. 5) 2470 7192

Mid July. 109-251 mm. Dark grey-brown back, lighter down the flanks to near-white belly. Pale opercula. Parr marks absent. Moderate numbers of medium-sized pale spots, mainly below lateral line, indistinct in many individuals. Lower fins yellowish- to reddish-brown with fine white edging along pelvic and anal fins. Maxilla not extending beyond posterior edge of eye.

**Loch Builg, Cairngorms** (Fig. 6) 3187 8035

Late July. Single specimen, approximately 240 mm. Upper and mid flanks predominantly blue-grey, light orange along lower flank and white along belly. Operculum olive brown. Parr marks absent or indistinct. Few small pale spots along the mid flank. Dorsal fin dark. Caudal fin dark proximally, becoming deep red through rear half. Lower fins bright cherry red, with fine to moderate white edging on pelvic and anal fins. Maxilla not extending beyond posterior edge of eye. Slim body.

**Loch Meallt, Isle of Skye** (Fig. 7) 1505 8651

Late August. 155-223 mm. Moderately dark back, with silvery steel-grey flanks. Belly either white or pale pink to bright orange. Numerous, small to medium-sized, near-white spots, mainly along back and upper flanks. Parr marks indistinct in mature fish, 8-10 where visible on smaller individuals. Lower fins orange-brown to orange-red, pelvics to cherry-red; dorsal, adipose and caudal fins dark. White edging most prominent on anal and pelvic fins, less so on pectorals and absent from caudal. Relatively small pectoral fins, but large robust head and mouth with blunt snout. Maxilla generally extending to posterior edge of eye, but variable on either side. Tapered body.

**Loch Earn, Perthshire** (Fig. 8) 2643 7232

Late August. 164-314 mm. Dark colour restricted to upper back, fairly uniform metallic purple-grey colour extending down flanks. Silvery scales, particularly obvious on back. Belly, throat, and under-jaw near-white, occasionally to dull orange-pink. Purple sheen across operculum. Small to medium-sized pale spots generally sparse and indistinct. Parr marks absent, although occasionally around 8 faintly visible. Dorsal and caudal fins dark. Lower fins dark grey-brown, some with reddish tinge. White edging fine to moderate on anal and pelvic fins, absent to fine on pelvics. Medium to deep body. Maxilla extending just beyond posterior edge of eye in larger fish, not as far in smaller fish.

Fish cages present, some larger individuals clearly pellet-feeders.

**Loch Shin, Sutherland** (Fig. 9) 2495 9160

Early September. 141-253 mm (pellet-feeders 382-410 mm). Variable. Mid grey to near black back, flanks paler with orange-pink cast; silvery. Dull orange-pink to near-white belly and throat. Pale pink spots, variable but often quite large, more prominent on darker fish. Parr marks (8-11) prominent on lighter coloured fish, absent or faint on darker ones. Lower fins mid to dark reddish brown, fine white edging only on pelvic

and anal fins. Body depth moderate to deep. Posterior edge of maxilla extending to, but generally not beyond, posterior edge of eye.

Fish cages present. Pellet-feeders larger and deeper-bodied, with longer maxilla and often denser white edging to lower fins. Potential high level of threat from non-native charr stock if charr are cultivated in cages.

**Loch a'Ghriama, Sutherland** (Fig. 10) 2391 9265

Early September. 158-256 mm. Dark purple-grey flanks, rose pink belly. Numerous small to medium-large pale pink spots, distinct on some individuals while virtually absent on others. Parr marks (8-10) narrow, generally indistinct on larger fish. Opercula mid to dark purple. Lower fins dark brown, trailing edges of paired fins reddish. White edging absent from pectoral and absent to moderate on pelvic and anal fins. Maxilla generally reaching posterior edge of eye, but extending beyond edge in larger fish. Body depth moderate.

**Loch More, Sutherland** (Fig. 13) 2330 9372

Early September. 108-128 mm. Small, slim, drab-coloured charr. Dark back, through shades of grey, some with slight purple sheen, to white belly. Small to medium whitish spots across flanks, but many fish without spots. 8-11 parr marks clearly visible. Lower fins dark, honey-brown, with no white edging. Occasional purple sheen on opercula. Large eyes. Maxilla not extending beyond posterior edge of eye.

**Loch Merkland, Sutherland** (Figs. 11, 12) 2390 9315

Early September (Fig. 11). 173-236 mm. Mid to dark grey back and flanks, some with slight purple hue. Belly sometimes near-white, but more usually light orange-pink. Medium-sized pale spots frequent on flanks. Parr marks indistinct (8-9) or absent. Dark brown paired fins. No white edging on pectoral fins, little or none on pelvics and anal. Fairly deep-bodied. Maxilla either just short of or reaching posterior edge of eye.

Early November (Fig. 12). 229-283 mm (pellet-feeder 428 mm). Moderate to very dark, with the exception of belly and, in some cases, posterior flanks. Lower jaw cream, underparts cream to dark orange. Moderate numbers of small to medium-sized pale spots on mid to lower flanks. Parr marks (up to 8) generally indistinct but visible when fish has faded. All fins dark. Moderate white edging on pelvic and anal, but none on pectoral fins. Maxilla extending beyond posterior edge of eye.

Feeding influenced by presence of fish farm cages; potential high level of threat from non-native charr stock if charr are cultivated in cages.

**Loch Doon, Ayrshire** (Fig. 14) 2496 5973

Mid September. 181-208 mm. Dark back, dark grey flanks with purple hue. Near white belly. Little or no spotting or parr marks. Medium brown/reddish-brown lower fins (more red on pelvics). Little or no white edging to pectoral fins, moderate to heavy on pelvic and anal fins. Slim to medium body. Maxilla extending to, or just beyond, posterior edge of eye.

This population is under threat from acidification (Maitland *et al.,* 1991).

**Talla Reservoir, Peebleshire** (Fig. 15) 3115 6215

Mid September. 185-284 mm. Very uniformly coloured fish. Dark along the back, grey flanks, some with purple sheen. Belly white to pale creamy-pink. Spots and parr marks absent. Lower fins dark grey-brown, some with reddish-brown inner edges. White edging absent to fine on pectoral fins, moderate to heavy on pelvic and anal fins. Medium to deep body. Maxilla extending just beyond posterior edge of eye in larger fish, but not extending as far in smaller fish.

This population is derived from fish translocated from Loch Doon in the 1980s (Maitland *et al,* 1991).

**Loch Clair, Wester Ross** (Fig. 16) 2001 8571

Late September. 189-234 mm. Strikingly dark charr, near black on back, dorsal and caudal fins, and nearly all of the head in some individuals, with the exception of the under-jaw. Flanks dark brown. Parr marks (8-9) absent or faint. Belly bright red. Moderate numbers of pink to belly-red spots along flanks, mainly below lateral line. Dorsal and caudal fins dark. Lower fins dark with red trailing edges and fine (pectoral) to heavy white edging. Body depth moderate. Maxilla extending beyond posterior edge of eye in larger fish.

**Lochan Uaine, Wester Ross** (Fig. 17) 1968 8524

Mid October. 99-173 mm. Small-maturing charr. Dark, but silvery back, with copper-brown flanks and white belly. Darker, greyish, parr marks (8-10) on flanks. No spots. All fins dark, greyish brown, with fine to moderate, occasionally heavy, white edges on pelvic and anal fins. Copper sheen on operculum. Maxilla reaching or extending just beyond posterior edge of eye.

**Loch Coulin, Wester Ross** (Figs. 18,19) 2015 8552

Late September - late October (Fig. 18). 177-198 mm. Dark back, purple-grey flanks. Near-white belly, some with pink tinge spreading up lower flanks. Indistinct parr marks (8-10). White to pale pink, medium-sized spots, mainly below the lateral line, sparse or absent. Purple operculum. Lower fins dark reddish-brown. White edging absent from pectoral and fine to moderate on pelvic and anal fins. Medium body, blunt snout. Maxilla level with or extending just beyond posterior edge of eye.

Early November (Fig. 19). 183-232 mm. Dark head and back, brown operculum and flanks. Belly bright orange. Parr marks absent. Few medium-sized orange spots along mid to lower flanks. Dorsal and caudal fins dark with fine to moderate white edging. Lower fins red, pectorals darker in the middle, with heavy to very heavy white edging. Fairly deep body, pointed snout.

**Fig.1.** Loch Awe, Argyll, late March. Spring spawners.

**Fig. 2.** Loch Awe, Argyll. mid August.

**Fig. 3.** Loch Awe, Argyll, mid August. Pellet-feeders.

**Fig. 4.** Loch Lee, Angus, late June.

**Fig. 5.** Loch Doine, Trossachs, mid July.

**Fig. 6.** Loch Builg, Cairngorms, late July.

**Loch Maree, Wester Ross** (Figs. 20, 21, 22) 1963 8693
Late September - late October. 101-240 mm. Apparently more than one form; probably a polymorphic population.

Small fish (probably of two morphs, one maturing at small size): variable. Body colour in some (Fig. 20) silvery-grey with strong purple hue, light grey to white belly, few to moderate numbers of large pale spots along flanks, 6-8 faint parr marks and light to mid brown lower fins. Typical of juvenile charr from many other lakes, fish of this coloration tend to be slimmer and more streamlined in shape. Others (Fig. 22) are more pinky-brown in colour, with white to yellowish-white belly, around 8 parr marks, with yellow to bright red paired fins, no spots, stockier bodies, blunt snouts and large eyes.

Large fish (Fig. 21) (apparently a single morph): back and flanks almost uniformly dark brown. Bright red belly. Pale spots small to medium and numerous, but indistinct. Parr marks absent or indistinct. Dorsal and caudal fins dark, lower fins grey-brown, with trailing edges reddish brown to bright red. White edging absent to fine on pectoral, moderate to heavy on pelvic and anal fins. Anterior part of body fairly deep. Maxilla extending to, or just beyond, posterior edge of eye.

**Loch Eck, Argyll** (Fig. 23) 2138 6924
Mid October. 141-258 mm. Colour moderately dark and brownish on the back, paler purplish-brown on mid flanks, and creamy pink on lower flanks and belly. Belly light orange on larger individuals. Spots absent. Parr marks absent or indistinct (8-10). Fins generally dark, lower fins reddish, particularly around edges. White edging fine on pectoral fins, moderate to heavy on pelvic and anal fins. Pinkish hue on operculum. Eyes very large. Pectoral fins long, frequently extending beyond the front of dorsal, and, in larger fish, as far as pelvic fins. Long jaws and snout, particularly in larger fish. Maxilla level with or extending beyond posterior edge of eye.

**Loch Rannoch, Perthshire** (Figs. 24, 25, 26) 2585 7574
October. 178-285 mm. This is the best-documented example of a polymorphic population in Scotland, three morphs having been described and studied to date (Walker *et al.*, 1988; Adams *et al.*, 1998; D. Fraser pers. comm.): planktivorous, piscivorous and benthivorous.

Planktivorous (Fig. 24): Very dark to near-black upper parts, flanks, and fins. Red lower belly. Dull cream under-jaw mottled with black. Moderate numbers of pink to red spots on flanks. No parr marks. Moderate to heavy white edges on paired and anal fins. Pectoral fins black to dark red trailing edge. Head relatively small, with narrow maxilla extending beyond posterior edge of eye. Slim-bodied. Eye relatively small.

Piscivorous (Fig. 25): Steel grey flanks, dark head and operculum. Pale under-jaw, extending to creamy orange belly and lower flanks. Undersides becoming redder with increasing body size. 9-10 parr marks on fish under 20cm, obscured by darker coloration on larger fish. Few white spots along mid flanks. Fins dark, with the exception of bright red trailing edge to pectoral fins. Fine white edging to paired and anal fins only. Anterior part of body deep, with very large head and mouth. Maxilla broad, extending beyond posterior edge of eye. Eye larger than in the other two morphs.

Benthivorous (Fig. 26): Similar to piscivorous where sizes overlap. Steel to dark grey upper flanks and upper part of head. Lower parts, including head, pale to strong creamy white. Lower halves of 9-11 parr marks clearly visible along mid flanks, these becoming progressively obscured as larger fish grow darker. Generally no spots. Paired fins dull yellow to brown, other fins dark. Fine white edge on pelvic and anal fins. Head and snout blunt, maxilla broad and usually not reaching posterior edge of eye. Jaw wider than in planktivorous, but gape smaller. Eye relatively small.

**Loch Langavat, Isle of Lewis** (Fig. 27) 1175 9185
Late October. 189-239 mm. Medium to dark brown upper flanks, some specimens with an olive hue. Orange-brown lower flanks and deep orange belly. Low to moderate numbers of medium-sized orange spots along flanks, smaller and paler above lateral line. Parr marks (5-9) indistinct or absent, more apparent on rear half of flanks. Operculum dark olive, with characteristic pale olive to orange patch. Distal half of caudal fin red. Lower fins predominantly red, with variable-sized darker centre. White edging heavy on all lower fins, particularly pelvic and anal, and moderate on anterior lower edge of caudal fin. Slim to medium body. Maxilla extending variably, from in front of to behind posterior edge (in larger fish) of eye.

**Loch na Craobhaig, Isle of Lewis** (Fig. 28) 1065 9205
Early November. One specimen only, 190 mm. Dark brown to near-black head, back, and upper flanks. Lower belly pale peach-orange. Sparse medium-sized pink spots below lateral line. Parr marks absent. Pectoral fins dark brown with orange-red trailing edge and fine to moderate white edging. Other fins dark, with white edging heavy on pelvic and anal, and fine on lower edge of caudal fin. Medium body. Maxilla not reaching posterior edge of eye. Specimen illustrates characteristic post-mortem coloration changes.

**Lough Melvin, Co. Donegal, Ireland** (Fig. 29) 1890 3540
Mid November. Not brightly coloured fish. Flanks purple-grey to olive-green. Belly near-white to dull orange. Operculum purple-grey or olive-green, depending on body colour. Small to medium-sized pale spots on upper flanks, extending, in more coloured fish, as far down as pectoral fin and over caudal peduncle. Many small spots also visible on dorsal and caudal fins. All fins dark, with very fine white edging on pelvic, anal and

**Fig. 7.** Loch Meallt, Isle of Skye, late August.

**Fig. 8.** Loch Earn, Perthshire, late August.

**Fig. 9.** Loch Shin, Sutherland, early September.

**Fig. 10.** Loch a'Ghriama, Sutherland, early September.

**Fig. 11.** Loch Merkland, Sutherland, early September.

**Fig. 12.** Loch Merkland, Sutherland, early November.

**Fig. 13.** Loch More, Sutherland, early September.

**Fig. 14.** Loch Doon, Ayrshire, mid September.

**Fig. 15.** Talla Reservoir, Peebleshire, mid September.

**Fig. 16.** Loch Clair, Wester Ross, late September.

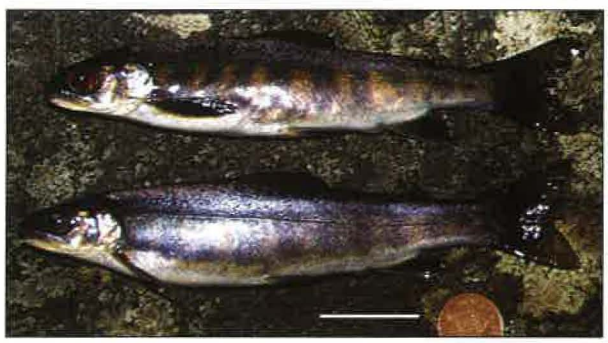

**Fig. 17.** Lochan Uaine, Wester Ross, mid October.

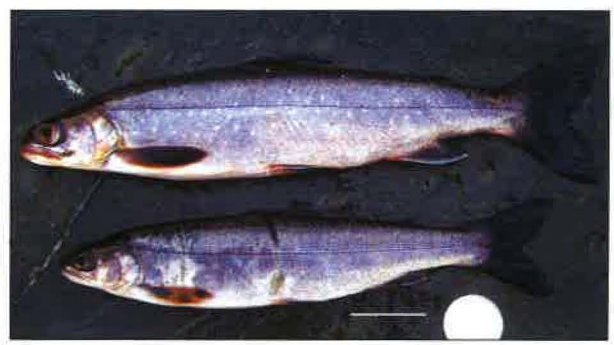

**Fig. 18.** Loch Coulin, Wester Ross, late September.

**Fig. 19.** Loch Coulin, Wester Ross, November.

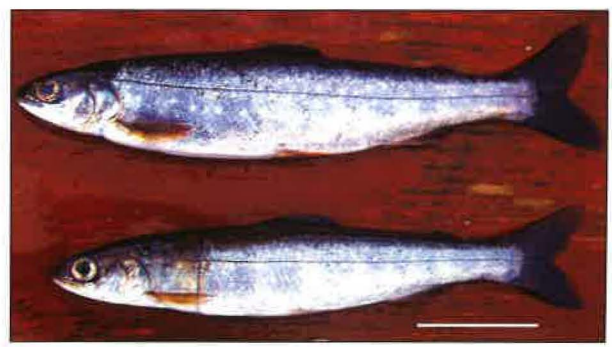

**Fig. 20.** Loch Maree, Wester Ross, late September.

**Fig. 21.** Loch Maree, Wester Ross, late October.

**Fig. 22.** Loch Maree, Wester Ross, late October.

**Fig. 23.** Loch Eck, Argyll, mid October.

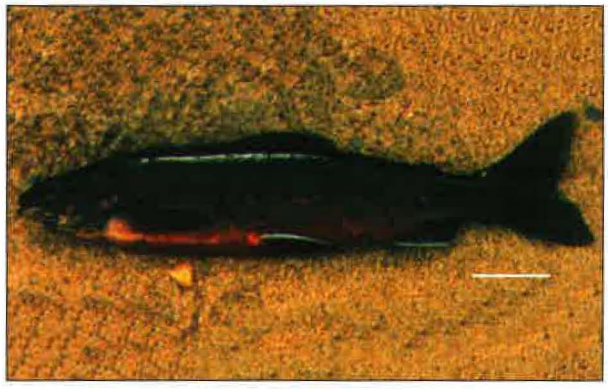

**Fig. 24.** Loch Rannoch, Perthshire, October. Planktivorous morph.

**Fig. 25.** Loch Rannoch, Perthshire, October. Piscivorous morph.

**Fig. 26.** Loch Rannoch, Perthshire, October. Benthivorous morph.

**Fig. 27.** Loch Langavat, Isle of Lewis, late October.

**Fig. 28.** Loch na Craobhaig, Isle of Lewis, early November.

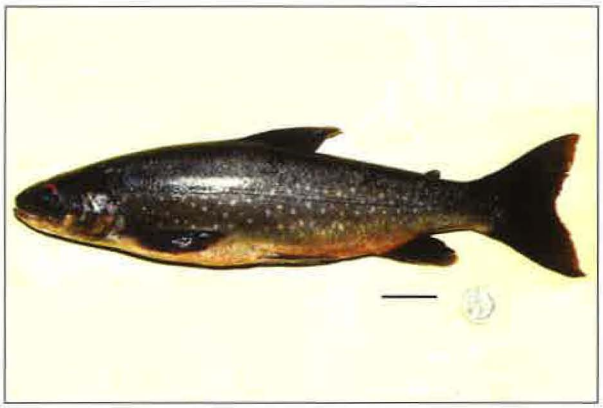

**Fig. 29.** Lough Melvin, Co. Donegal, Ireland, mid November.

**Fig. 30.** Lough Nalughraman (Glen River), Co. Donegal, Ireland, mid November.

**Fig. 31.** Lough Inagh, Co. Galway, Ireland, early December.

**Fig. 32.** Doo Lough (Bundorragha River), Co. Mayo, Ireland, early December.

caudal fins. Parr marks absent. Body depth moderate. Maxilla extending beyond posterior edge of eye.

**Lough Nalughraman (Glen River), Co. Donegal, Ireland** (Fig. 30) 1658 3886

Mid November. 139-167 mm. Small, characteristically dark. Dark brownish flanks, colour extending far down, with metallic purplish hue on lower parts. Belly coloration restricted and narrow, off-white or light to medium orange. Few medium to large pale or orange spots on flanks - sometimes six or less - with more frequent and faint or indistinct small spots on upper flanks and back. 8-11 large dark parr marks, often merging with each other and obscured dorsally where they blend into dark colour of back. Operculum similar to flank in colour. Lower fins dark, with dull to bright orange on pelvics, trailing part of pectorals, and, less often, distal half of anal fin. White edging fine to heavy on pelvic, absent to moderate on anal, and occasionally fine on caudal fin. Caudal often with reddish trailing edge. Slim body. Maxilla not extending beyond posterior edge of eye.

This population is potentially under threat from silt from the quarry alongside the lough. In addition, a water abstraction scheme is proposed for this lough.

**Lough Inagh, Co. Galway, Ireland** (Fig. 31) 0843 2500

Early December. 140-223 mm. Dark muddy-brown flanks, more olive lower down. Bright red belly. Frequent, but often indistinct, small to medium, pink to red, spots along lower flanks. Parr marks small, generally absent from all but some lighter individuals (9-11). Lower fins mainly dark, slightly or moderately red on trailing edges. White edging generally absent to fine on pectoral, fine to moderate on pelvic, and fine to heavy on anal fin. Slim body. Maxilla extending beyond posterior edge of eye only in larger fish.

**Doo Lough (Bundorragha River), Co. Mayo, Ireland** (Fig. 32) 0834 2683

Early December. 115-217 mm. Flanks dark olive-brown above, lower parts very pale. Belly cream to light orange. Medium-sized spots along lower flanks, generally sparse and often indistinct; occasionally along upper flanks. Parr marks (9-11) absent or indistinct. Some fish with red tinge to lower leading edge of caudal fin. Lower

fins medium-brown centred, with red outer edges. Pelvic fins highly coloured. White edges moderate to heavy on pelvic and anal fins, occasionally fine on caudal. Moderate body. Maxilla generally not extending beyond posterior edge of eye.

## Conclusions

Within the geographical area in which they were sampled, the Arctic charr described and illustrated vary to a high degree in coloration, pattern, and the more obvious morphological characteristics.

At one end of the colour scale were fish showing dull grey and brown base colours, often with a purplish tint, with the usual darker dorsal region, whitish or yellowish underparts, and dull-coloured fins. Examples of these include those shown in Figs. 3, 13, 18, & 23. Other fish, for example those in Figs. 1, 11, 15, & 29, showed similar, but deeper colours. The most colourful charr showed very dark, often nearly black, dorsal and lateral areas, bright orange or red bellies and lower flanks, and brightly-coloured lower fins, often with bold white edges. Examples of such brightly-coloured fish include those in Figs. 4, 19, 21, & 27. Some fish, for example those shown in Figs. 6 & 22, fell in between these general categories, with pale bodies and brightly-coloured fins.

Similar variation existed in patterning, the primary differences being in the presence or absence of parr marks and/or spots, and the number, size, and colour of the latter. The presence of parr marks does not correlate with the depth of body colour, as is clearly shown in Figs. 1, 2, 8, 18, & 23. Many dark varieties did show parr marks (eg Figs. 25, 27, & 30), but some only after post-mortem fading of coloration (eg Figs. 9, 10, & 28). Within populations parr marks are more frequent amongst immature fish and females. However, as shown from these photographs, which are primarily of mature fish, these markings vary substantially between populations.

Spots vary from completely absent (Figs. 1, 15, 17, 23, & 26) to infrequent (Figs. 5, 18, 30, & 32) and dense (Figs. 7, 9, 24, & 29), with some size variation visible also. The colour of spots on the flanks generally reflected the colour of the belly, varying from near-white to bright red or orange.

Morphological variation is obvious in some features of the charr. The relative size and shape of the head, while generally similar between populations, differs in some. For example, the charr from Loch Meallt (Fig. 7) and those of the piscivorous morph from Loch Rannoch (Fig. 25) both have very large heads with short heavily-built jaws. Both of these forms are known to be piscivorous (Campbell 1984, Adams *et al,* 1998), and head and mouth morphology is known to be a function of dietary habit from many charr populations which have been studied (Sandlund *et al,* 1982; Barbour, 1984; Adams *et al,* 1998).

Eye size was greater in some populations, most notably those of Loch Eck (Fig. 23) and a small form from Loch Maree (Fig. 22). Charr in Loch Eck are the only example of a population in Scotland or Ireland which is sympatric with Powan *(Coregonus lavaretus).* Powan are known to be successful competitors with Arctic charr, and therefore the charr in Loch Eck may be be forced to inhabit deeper waters on a more regular basis, possibly explaining the development of larger eyes. The reason for large eyes in the Loch Maree fish might also be expected to be a function of deeper living.

Body size and shape differed between populations, ranging from small (Figs. 13 & 17) to large (Figs. 8, 21, & 29), and slim (Figs. 1, 7, 13, & 31) to deep (Figs. 9, 11, & 21). The most notable exceptions in size were the pellet-feeding charr from various lochs (including Merkland, Shin, and Awe), examples of which are shown in Fig. 3. With the exception of the pellet-feeders, body shape and size is probably a combination of food-limitation (either in terms of quantity or catchability) and adaptation to foraging and predator avoidance requirements.

More detailed analyses of the morphological characteristics of these populations will be described elsewhere.

The features of colour and pattern described here vary throughout the year within charr populations as a result of the reproductive cycle, and therefore some of the apparent inter- and intra-population variation is a consequence of seasonal differences in sampling. Most Arctic charr in the geographical zone studied here are thought to spawn in autumn. Evidence from the gonadal development of specimens sampled from each of the populations shown here supports this, with the exception of spring-spawning charr from Loch Awe (Fig. 1).

Differences in colour and pattern between populations may be functional (Barbour, 1984), as different forms occupy different environmental niches. Alternatively they may be the result of differences in diet, ie the result of either different food species in different environments, or of differential specialisation by sympatric morphs. They may also be the result of the long period of isolation and consequent genetic drift which these populations have experienced since they ceased to be anadromous some time after the last Ice Age. On-going analyis of the trophic niches, life history, and genetics of these populations may help to answer this question.

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