The growth of a Welsh strain of Arctic charr (*Salvelinus alpinus* L.) and investigations into its aquaculture potential.

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Abstract

The growth in captivity of a wild Welsh strain (Llyn Cowlyd) of Arctic charr (*Salvelinus alpinus)* was compared to that of a commercial Scottish strain over the course of a 12 month experiment. At the conclusion of the study, the Welsh strain had a lower mass and condition factor than the commercial fish, but a similar length. Aspects of the growth and population structure of the Welsh strain imply that it could be a subject for aquaculture development, but such practises will be dependant on further work on selection and broodstock development.

Keywords: Arctic charr, growth, development, aquaculture.

Arctic charr (*Salvelinus alpinus* L.) is a holarctic species representing the most northerly of all freshwater and anadromous fish (Klemetsen, 2003). Consequently the species is adapted to cold water temperatures and shows good growth, development and survival rates in low temperature ranges (Wallace & Aasjord, 1984a; Jensen *et al*., 1989; Jobling *et al*., 1992; Jobling *et al*., 1998), being the salmonid able to survive the lowest water temperatures (Baroudy & Elliott, 1994). They have also been shown to grow and survive well when reared at densities higher than those favoured by other commercially-reared salmonids (Jobling *et al*., 1992; Siikavuopio & Jobling, 1995; Jobling *et al*., 1998; Brännäs & Linnér, 2000). Additionally, Arctic charr have long been prized for their taste and this, as well as currently limited levels of production [*e.g.* 3.5 tonnes of Arctic charr were reared in Scotland in 2006 (Anon., 2006)], has led to market prices significantly higher than, for example, Atlantic salmon, *Salmo salar* (L.), or rainbow trout, *Oncorhynchus mykiss* (Walbaum), (FAO statistics, http://www.fao.org). These characteristics all indicate that Arctic charr represent a species with potential for aquaculture, in particular in climates and conditions where the culture of other salmonids may not prove profitable.

There has been increasing interest surrounding the ecology and aquaculture potential of U.K. populations of Arctic charr in recent times (Heasman & Black, 1998; Maitland *et al*., 2007). However, in North Wales, where three native and four translocated resident populations exist (McCarthy, 2007) detailed information on the biology of charr populations, necessary for aquaculture development, is not available. Importantly, the threat that commercial Arctic charr farming practises present to the genetic integrity of native U.K. stocks has been highlighted (Heasman & Black, 1998; Maitland *et al*., 2007). Consequently, decisions regarding the commercial culture of

Arctic charr and the development of breeding programmes will be enhanced by the use of regional stocks, which reduce the chances of genetic contamination, as well as a detailed knowledge of the culture potential of native charr within localised regions. Consequently, the current study aimed to investigate the aquaculture potential of a Welsh strain of Arctic charr by comparing its growth with a commercial strain from Scotland.

Spawning adult Arctic charr were collected from Llyn Cowlyd, North Wales ($53^{o}08'$ N; $3^{o}54'$ W) using multipanel benthic gill nets (Lundgrens Fiskredskap; Sweden) on 8 December 2004. Eggs were hand stripped from females [mass (M) = 64.5 ± 8.0g, fork length (L_F) = 196.0 ± 8.4mm, (mean ± S.D., n=5)] and each batch fertilised using milt hand stripped from a single male [M = 69.7 ± 10.2g, L_F = 190.8 ± 5.1mm, (mean ± S.D., n=5)]. The eggs (approx. n=500) were water hardened and transferred to aquarium facilities at the University of Wales, Bangor. On 11 February 2005, 1000 eyed eggs of a commercial Scottish strain of Arctic charr were obtained from John Eccles Hatcheries, Orkney. A sub-sample of eggs (n=20) from each strain were weighed and measured, with those of the Llyn Cowlyd fish [M = 61.4 ± 5.5mg, 5.11 ± 0.25mm diameter, (mean ± S.D.)] found to be larger than those from the commercial strain [M = 50.3 ± 5.7mg, 4.59 ± 0.19mm diameter, (mean ± S.D.)] ($P<0.05$, students t-test).

Eggs were incubated under darkness in gently aerated static water baths (10 l.) held at 4.0 ± 1.5^{o}C, with 75% of the water changed with fresh, aerated lake water at 7d intervals. The eggs were incubated in one 10 l. water bath for each strain (Llyn Cowlyd and the commercial strain). Whilst this did not allow replication at the incubation stage, the rearing conditions accurately matched those commonly used in commercial production. The experiment focused primarily on juvenile growth in the first year of development and the egg rearing conditions were not considered detrimental to the overall aims of the study. 50% hatching occurred on 14 February and 16 March for the commercial and Llyn Cowlyd fish respectively and at hatch the water temperature was gradually increased and maintained at 7.4 ± 0.4^{o}C until first feeding on 4 April (340 degree days post hatch) and 23 April 2005 (270 degree days post hatch) for the commercial and Llyn Cowlyd fish respectively. At first feeding, the water temperature was further increased to 10^{o}C and three groups of fish from each strain (n=100 per group and n=75 per group for the commercial and Llyn Cowlyd fish respectively) were transferred to each of six 1m x 1m x 0.75m fibreglass rearing tanks, which were part of a recirculation system where water was filtered and re-used, with approximately 10% of the recirculated water replaced per day. The fish from each strain were reared for 12 months from their respective date of first feeding. Water temperature was 12.6 ± 5.0^{o}C over the course of the experiment and water flow rates were initially 0.1 l.s^{-1} but were increased to 0.25 l.s^{-1} as the fish became larger. Fish were exposed to a natural photoperiod regime and fed commercial salmon feed (EWOS Micro; EWOS Ltd., U.K.) throughout the light phase of the photoperiod, according to feed rates described by Johnston (2002). At monthly intervals from first feeding all fish were weighed (M, ±0.1g) with fork length (L_F, ±1mm) recorded from three months after first feeding.

Condition factor (K) was calculated as: $100ML_F^{-3}$. Data were analysed using Minitab *v*14. Changes in M, L_F and K between strains were compared using a General Linear Model, with natural log transformations used to improve the normality and homogeneity of variance of the M and L_F data. A significance level of 5% was applied to the statistical tests (Zar, 1999).

The M of both strains of fish increased throughout the experiment ($P<0.001$) (Fig. 1a). The average M of the Llyn Cowlyd fish was greater than the commercial strain charr for the first three months post first feeding ($P<0.001$) and then from month seven onwards the commercial strain fish were significantly heavier than the Llyn Cowlyd fish ($P<0.01$). The L_F of both strains increased over the course of the experiment ($P<0.001$) (Fig. 1b). In month three, the Llyn Cowlyd fish were significantly longer than the commercial fish ($P<0.05$), but from month four onwards the average lengths of the two strains were similar. The K of both strains increased over the experimental period ($P<0.001$) (Fig. 1c) and from month five onwards, the K of the commercial strain fish was significantly higher than that of the Llyn Cowlyd fish ($P<0.01$).

At the conclusion of the experiment there were differences in the coefficient of variation in M, L_F and K between the two strains of fish (Table I). The commercial fish were significantly heavier with a higher K than the Llyn Cowlyd fish (both $P<0.05$) but the coefficient of variation in the M and K of the Llyn Cowlyd fish was larger (by an order of magnitude) than that of the commercial fish. The L_F of the commercial and Llyn Cowlyd fish were similar at the conclusion of the experiment, and although the coefficient of variation in L_F of the Llyn Cowlyd fish was larger than for the commercial fish, the difference in variation was not of a similar magnitude to that recorded for M and K.

The current study has been the first to examine the growth of a Welsh strain of Arctic charr in captivity and compare it to a commercial strain. After 12 months, the Welsh charr had a lower M and K than the commercial fish. Previous studies have shown differences in performance between wild and commercial strains of Arctic charr (Ringø *et al*., 1988) as well as other salmonids (Fleming & Einum, 1997; Handeland *et al*., 2003) with these results likely to be due to the selection for rapid growth in commercial strains (Handeland *et al*., 2003; Brännäs *et al*., 2005). Conversely though, Brännäs *et al*. (2005) found no difference between the growth of fourth generation selected charr and their wild strain of origin. However, in their study culture conditions were adapted to promote dominance hierarchies, with the result that fish having undergone selection for fast growth had reduced subordinate behaviour, leading to less size variation, and indeed a similar mechanism may have been influential in the size differences recorded in the current experiment. Importantly, although there was a difference in M between the strains in the current experiment, the Llyn Cowlyd fish achieved a M of approximately 75% of the commercial strain. A 10% per generation increase in growth rate has been reported for Arctic charr in a captive rearing programme in Sweden (Brännäs *et al*., 2005) and it may be that continued breeding of the Llyn Cowlyd strain could rapidly improve its performance. Furthermore, the Llyn Cowlyd fish maintained a similar L_F to the commercial fish and grew much larger than their wild parents. Although differences between the nutritional content of the commercial diets and those gained in the wild would have been a major factor in the size differential between the reared Llyn Cowlyd fish and their wild parents, it seems that the Llyn Cowlyd fish can perform well on commercial diets when reared in captivity. Consequently, it seems sensible to suggest that with continued research there may be scope for developing commercial Welsh charr lineages.

The two strains of charr exhibited different patterns of growth during the experiment. Initially the Welsh fish had a greater M and L_F than the commercially farmed strain. A positive correlation between egg size and hatch size is well documented in salmonids (Wallace & Aasjord; 1984b; Springate & Bromage, 1985) and the larger eggs clearly resulted in the Welsh fish being larger during the early stages of the experiment. However, this size differential only persisted until month three, indicating that the early growth of the commercial strain was greater than that of the Welsh fish. This also indicates that large size at hatch or first feeding does not necessarily equate to a growth advantage in later life (Fowler, 1972; Thorpe *et al*., 1984). In the current study, the commercial strain became heavier than the Llyn Cowlyd fish seven months after first feeding, with the differential in M increasing to the conclusion of the experiment. This indicates that the growth in M of the commercial fish was not only higher during early development but may have persisted in being higher throughout the experiment. Both strains maintained a similar L_F and because the differences in M and L_F were not coupled, the commercial fish had a higher K than the Llyn Cowlyd fish. The reasons for this differential in M and L_F between the strains are not clear, but it may be that M and/or K have been traits preferentially selected for over L_F in the commercial strain.

Interestingly, the Welsh strain exhibited more variation in M, L_F and K at the conclusion of the experiment, with this variation more prominent in the M and K data. Previously, Brännäs *et al*. (2005) found similar differences in weight variation between wild and captive strains of Arctic charr and ascribed this difference to the selection for fast growth favouring selection against subordinates, which then resulted in a decrease in individual differences in growth. In the current study social status was not determined but it is likely that similar differences in population social structure between the two strains caused the notable differences in size variation.

In summary, the current study has identified differences between the development of a Welsh strain of Arctic charr and a commercial U.K. stock, although this is to be expected when comparing the first generation of a wild strain with a commercial strain (Handeland *et al*., 2003). The results of this study show that there is potential for the development of Welsh Arctic charr strains for aquaculture.

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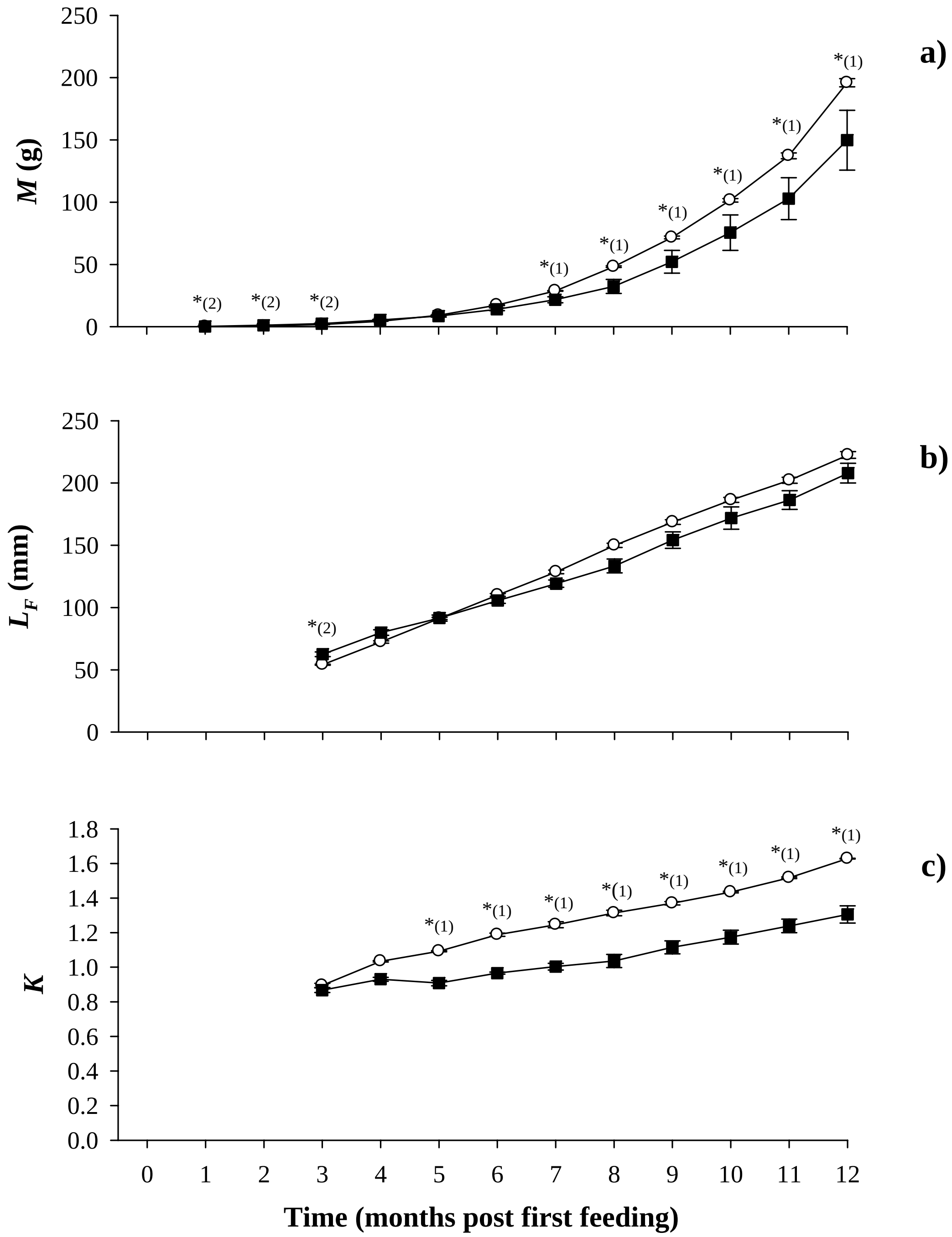
Table I.

The mean and coefficient of variation (CV) in mass (M), fork length (L_F) and condition factor (K) (n=3) of a commercially reared and Welsh strain of Arctic charr at the conclusion of a 12 month growth experiment. * denotes a statistical difference (P<0.05) between the mean values of the two strains.

Strain	M (g)		L_F (mm)		K	
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
Commercial	195.9*	2.9	222.5	2.1	1.63*	0.2
Llyn Cowlyd	149.7*	27.8	207.9	6.6	1.31*	6.6

Fig. 1 Changes in mass (*M*) (a), fork length (L_F) (b) and condition factor (*K*) (c) (mean ± S.E.M., n=3) of two strains of Arctic charr; a commercially reared Scottish strain (–○–) and those reared from eggs collected from spawning adults caught in Llyn Cowlyd, North Wales (–■–), following a 12 month growth experiment starting from first feeding. Significant differences are indicated by asterisks (P<0.05) with the numbers (1) and (2) indicating a larger mean value for the commercial or Llyn Cowlyd strain respectively.

Fig. 1



a)
b)
c)
M (g)
L_F (mm)
K
*(1)
*(2)
0
50
100
150
200
250
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
0 1 2 3 4 5 6 7 8 9 10 11 12
Time (months post first feeding)