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GROWTH OF ARCTIC CHARR (*Salvelinus alpinus* L.) IN A PILOT COMMERCIAL REARING SYSTEM

by

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ABSTRACT

Papst, M.H., and G.E. Hopky. 1983. Growth of Arctic charr (Salvelinus alpinus L.) in a pilot commercial rearing system. Can. Tech. Rep. Fish. Aquat. Sci. 1182: iv + 16 p.

Preliminary experiments to determine the feasibility of the intensive culture of Arctic charr (Salvelinus alpinus L.) are described. After 209 days of growth in a pilot commercial fish production system, at 13C, the mean weight of individuals in the population increased from 2.2 to 158.1 g. On day 209 a wide variation in body weights, from 10 to 530 g was observed. Despite significantly larger mean weights, growth rates of the largest fish were comparable to those observed for other members of the population. Smallest fish in the population had minimal to nil weight gains. Rearing of the population as three separate weight classes ("small", "medium" and "large"), during the last 48 days of the growth trial did not result in improved growth of the smallest fish. There was no increase in the dispersion (coefficient of variation) of body weights in either the "medium" or "large" weight classes, compared to a marked increase in the dispersion of the "small" weight classes' distribution. This latter effect was in part attributable to precocious maturity among the smallest of the males. Mortality in the Arctic charr population was not significant, and was comparable to that previously observed in rainbow trout pilot production trials.

Between days 70 to 154 the mean growth rate of the Arctic charr population was 1.9% Day^{-1} compared to 1.4 and 1.9% Day^{-1} for two rainbow trout strains previously reared in the pilot system under similar conditions.

Key words: aquaculture, intensive; waste heat; trout, rainbow; growth; mortality; maturity, precocious.

RESUME

Papst, M.H., and G.E. Hopky. 1983. Growth of Arctic charr (Salvelinus alpinus L.) in a pilot commercial rearing system. Can. Tech. Rep. Fish. Aquat. Sci. 1182: iv + 16 p.

Ce rapport décrit les expériences préliminaires visant à déterminer la possibilité d'élever l'omble chevalier (Salvelinus alpinus L.) de façon intensive. Après avoir passé 209 jours, à titre d'essai, dans un établissement piscicole commercial où la température de l'eau était maintenue à 13°C, le poids moyen des alevins était passé de 2,2 à 158,1 g. Au 209^{e} jour, on nota d'importantes divergences (de 10 à 530 grammes) dans le poids des alevins. Malgré une augmentation considérable dans le poids moyen, les taux de croissance chez les plus grands poissons étaient comparables à ceux des autres membres de la population, tandis que les plus petits individus présentaient de légères, sinon aucune, augmentations de poids. La séparation des alevins selon leur poids (petits, moyens et gros) au cours des derniers 48 jours de l'expérience n'a pas amélioré le taux de croissance des plus petits poissons. Il n'y a pas eu d'augmentation dans l'écart (coefficient de variation) dans le poids des alevins des catégories "moyen" ou "gros", alors que cet écart chez les petits alevins connut une augmentation marquée. Ce dernier résultat est en partie attribuable à la maturité sexuelle précoce des plus petits mâles. La mortalité chez l'omble chevalier n'était pas un facteur considérable, se comparant à celle observée chez la truite arc-en-ciel lors d'expériences d'élevage semblables.

Entre les 70^{e} et 154^{e} jours, le taux de croissance moyen de l'omble chevalier se chiffrait à 1,9 % par jour^{-1}, comparativement à 1,4 et 1,9 % par jour^{-1} pour deux espèces de truites arc-en-ciel élevées dans des conditions semblables.

Mots-clés: aquiculture intensive; chaleur perdue; truite arc-en-ciel; croissance; mortalité; maturité sexuelle précoce.

INTRODUCTION

Arctic charr (Salvelinus alpinus) have become recognized as a food delicacy in North America, and appear to have a high consumer acceptability (Iredale 1983). The species has not however, been widely cultured (MacCrimmon and Gots 1980).

Attempts to rear Arctic charr in sea cages under Norwegian fish farming conditions have not proved promising (Gjedrem and Gunnes 1978). Wandsvik and Jobling (1982) reported that Arctic charr (size range 25-78 g) reared at 13C in freshwater had a specific growth rate of 1.4% Day^{-1}. They also reported a significant degree of variation in the size and growth rates of the Arctic charr and concluded that this variation was highly detrimental to their future commercial culture. Uraiwan (1982) observed that Arctic charr (size range 10-30 g) reared at 13C in freshwater had a specific growth rate of 2.0% Day^{-1}. Growth performance of Arctic charr from fry (2 g) to a minimal market size (200 g) under freshwater commercial fish culture conditions has not been tested.

Papst and Hopky (1982) described a pilot commercial fish production system utilizing a low grade heat source and water recirculation. In this system, the growth performance of rainbow trout stocks reared for commercial production is a function of the stock's conversion efficiency, mean growth rate and the degree of dispersion of individuals about the stock's mean weight. The latter factor was shown to be an important consideration, as it affects the timing of harvests and the production performance of the culture cycles.

This study had two objectives. The first was to assess the growth of an Arctic charr population in the pilot commercial system, and the second was to investigate the sources of variation amongst individual growth rates. This was an initial evaluation of their culture potential and results were compared to those for two rainbow trout strains previously reared in the culture system during separate trials.

METHODS

DESCRIPTION OF REARING SYSTEM

Growth trials were conducted at the Rockwood Experimental Fish Hatchery of the Freshwater Institute, Department of Fisheries and Oceans, in the pilot commercial fish production facility (Ayles et al. 1980; Papst and Hopky 1982). The Rockwood Hatchery is located approximately 65 km north of Winnipeg, Manitoba (50°N 97°W).

The production strategy employed for the Arctic charr growth trial was similar to that described by Papst and Hopky (1982) for rainbow trout growth trials, except that the trial began with 2 g fish and the final production level utilized four tanks (Fig. 1). The Arctic charr growth trial was divided into four periods: period one - days 0 to 69, period two - days 70 to 118, period three - days 119 to 154, and period four - days 161 to 209 (Fig. 1). The rainbow trout growth trials were conducted employing the production strategy previously described (Papst and Hopky 1982). Typically, this strategy utilized fish with an initial mean weight of 10-15 g and consisted of four levels arbitrarily designated as level "A" through to level "D", each of approximately 42 days duration. Periods one and four, as described above, are unique to this Arctic charr growth trial. Periods two and three are directly comparable to level "A" and level "B", respectively.

For the Arctic charr growth trial oxygen and temperature were monitored daily in the rearing tanks using a YSI Model 54 temperature - oxygen meter, and samples for water quality were taken periodically. Temperature values decreased between days 90 to 140, but were relatively constant otherwise (Fig. 2). Oxygen saturation levels remained stable throughout the trial (Fig. 2). Temperature and oxygen saturation means (±S.E.) were 13.3 (±0.06) C and 87.6 (±0.33)%, respectively. The photoperiod was set at 12 hours of light and 12 hours of darkness. A detailed report of water quality variables was not within the scope of the present study.

Throughout the experiment all fishes were fed at approximately 150% of the rations recommended in published tables for rainbow trout (Bardach et al. 1972), an amount well in excess of maintenance requirements (Baker 1983). Fish were hand fed three times daily on a commercial trout feed (Martins Feed, Elmira, Ontario, Canada). Amounts fed were adjusted for changes in fish size as determined by periodic weight censuses. During the Arctic charr growth trial rearing tanks were examined daily for the presence of fish carcasses. However, estimates of total mortality were based on numbers of fish counted at the begining and end of the periods. Similar procedures were also followed for the rainbow trout growth trials. These results are not reported here because they were comparable to those previously observed for rainbow trout (Papst and Hopky 1982).

SOURCES OF FISH STOCKS

Arctic charr

Arctic charr used in this study were part of a population collected in early October, 1980 as eggs from the Fraser River, Labrador (56°N 62°W). The collection, initial life history and rearing of this stock were described in detail by Baker (1983).

Rainbow trout

The Sunndalsora trout strain was originally obtained from a research hatchery in Sunndalsora, Norway. The exact origin of this stock, introduced to Norway many decades ago from a freshwater North American strain, is unknown. The parental stock was received at the Rockwood Experimental Fish Hatchery in April, 1975 and eggs for the present study were spawned in January, 1981.

The Idaho strain is a domestic stock originating from the Caribou Trout Ranch, Soda Spring Hatchery, Idaho. This stock is of uncertain origin, but was probably taken from a northern California stream many generations ago (Ayles 1975). The stock was received at the Rockwood Experimental Fish Hatchery as eggs in November, 1971. Eggs for the present study were spawned in December, 1980.

FISH SAMPLING

Arctic charr

During the first (days 0 to 69) and second (days 70 to 118) periods, fish growth was monitored on approximately a weekly basis. Mean fish weight in each tank was determined by hand counting and then weighing four lots of 50 fish from each of the tanks. Means were based on the four lot weights. During the third (days 119 to 154) and the fourth (days 161 to 209) periods a subsample of the fish in each tank was anesthetized, individuals were weighed and tank mean weight calculated. Sampling frequency for period three was weekly and for period four, biweekly.

On day 69, at the end of period one, all individuals in the tank were hand graded by weight. Fish weighing < 6.0 g (N = 193) were removed and replaced with 259 fish from the stock tank weighing between 6.0 - 25.0 g (Fig. 1). This reduced the wide variance in fish weights and resulted in an Arctic charr population, at the start of period two, with a weight distribution comparable to that for rainbow trout at the start of level "A" in a typical production trial. Arctic charr more than 25.0 g were marked using a wire branding method (Bernard and Van der Veen 1974).

On day 154, at the end of period three, all fish in both tanks (Fig. 1) were anesthetized and weighed. Between days 155 and 160 all individuals in the population were hand graded into three weight classes: "small" (< 65.0 g), "medium" (65.0 - 180.0 g), and "large" (> 180.0 g) (Fig. 1). Fish growth during this grading period was excluded from growth calculations. At the start of period four (day 161), the "small" and "large" groups were placed into individual tanks and the "medium" group was divided equally between two tanks (Fig. 1). At the termination of the growth trial (day 209), all fish were anesthetized and weighed. Additionally, for a subsample from each weight class the gonads were dissected out and weighed, and the sex of each fish determined.

Rainbow trout

Since the Arctic charr growth trial commenced with fry (2.2 g) smaller than those commonly used in the pilot system (10-20 g) (Papst and Hopky 1982), and because during period four (days 161 to 209) the population was grown in an atypical configuration (ie: modified by extensive grading), only growth between days 70 to 154 (periods two and three) was used for comparison to the previously conducted rainbow trout trials. As noted, this interval corresponded to the level "A" and level "B" periods of the pilot production system (Papst and Hopky 1982). For purposes of comparison these are referred to as the 85 day growth trials.

In each of the rainbow trout growth trials fish growth was monitored on approximately a weekly basis by hand counting four lots of 50 fish from each tank and determining the mean weight of fish in each tank based on the four lot weights. Similar to the Arctic charr growth trial, the rainbow trout populations were censused for individual weights at the start (day 0) and end (day 85) of their respective growth trials.

CALCULATIONS AND DEFINITIONS

Specific growth rates for each period in the Arctic charr growth trial were calculated by multiplying the slope of the regression of ln (mean fish weight) versus time by 100 (Brett 1979). Growth rates for fishes in the 85 day growth trials were similarly calculated. Additionally, for the Arctic charr growth trial specific growth rates between weekly censuses were calculated by:

$$G = \frac{(\ln W_2 - \ln W_1) \times 100}{(t_2 - t_1)}$$

where W_2 and W_1 are final and initial weights, respectively, t is the time in days and G is expressed as a percent of body weight per day (Ricker 1975). Period specific growth rates calculated by this method may be different than those calculated using the "regression" technique. For the purpose of expressing growth over a given time period the latter method is prefered as it is probably more indicative of "average" growth performance.

For the Arctic charr growth trial ration was expressed as a percentage of wet fish weight. In the calculation of gross conversion efficiency (G.C.E.), ration and growth rate were adjusted to a dry weight basis using a conversion factor (3.44) calculated by Uraiwan (1982) for rainbow trout. Baker (1983) examined the dry weight to wet weight conversion for Arctic charr reared under different conditions and, based on his results, Uraiwan's conversion factor appeared to be a reasonable estimate. Gross conversion efficiencies were calculated as:

$$G.C.E. = (G/\text{Ration} \times F) \times 100$$

where G is as defined above and F is the wet to dry conversion factor.

During the third and the fourth ("medium" weight class only) periods of the Arctic charr growth trial, differences between replicate tank (Fig. 1) mean fish weights were tested by analysis of variance. If no significant difference was observed at the 0.05 level of probability, data were pooled for subsequent comparisons. Data were reported as arithmetic means (± the standard error of the mean). When there were differences in the number of days between weekly censuses, calculations were weighted appropriately.

The gonad and body weight data were analyzed by calculation of the gonadal somatic index (G.S.I.) and by comparisons of plots of ln (gonad weight) versus ln (body weight). G.S.I.

(%) was calculated by:

$$G.S.I. = W_g/W_b \times 100$$

where W_g is the gonad weight and W_b is the whole body weight.

RESULTS

ARCTIC CHARR GROWTH TRIAL

Period one (days 0 to 69)

Mean fish weight increased from 2.2 to 14.0 g during the first 69 days of the growth trial (Fig. 3A,I). The period specific growth rate was 2.6% Day^{-1}, but there were large variations between census dates (Fig. 3A,I). Specific growth rates ranged from 0.3 to 7.9% Day^{-1} (Fig. 3B), with one period of essentially no growth (Fig. 3A,a). No explanation for this variation between censuses was evident. Similar variations in growth rates were observed for rainbow trout reared under comparable conditions (Papst and Hopky 1982). Gross conversion efficiency dropped markedly during those periods in which poor growth rates were also observed (Fig. 3C). The mean gross conversion efficiency for the 69 days was 14.1 (±10.8)%.

When the population was graded on day 69 (Fig. 4A), a large range in individual body weights was observed. The population mean weight was 14.0 g, with 15.8% of the individuals weighing less than 6.0 g and 11.6% of the individuals weighing more than 25.0 g. A small proportion of the former group had visible ailments, primarily deformed mouth parts or cataracts. The majority however, were visibly healthy and did not appear emaciated. Fish weighing less than 6.0 g (N = 193) were removed from the population and 259 fish weighing between 6.0 and 25.0 g were added from the stock tank (Fig. 1). The population was then regraded (Fig. 4B) with a new mean weight of 15.3 g.

The number of fish declined during period one by 29, from 1 249 to 1 220. However, only four dead fish were actually removed from the tank leaving the loss of 25 animals unexplained. Dead individuals may have been consumed by members of the population or the difference may have indicated some limited cannibalism.

Period two (days 70 to 118)

During the 49 days comprising period two the mean weight of the population increased from 15.3 to 46.9 g, with a period specific growth rate of 2.2% Day^{-1} (Fig. 3A,II). Growth rates, between period two censuses, varied from 1.5 to 3.3% Day^{-1}, and the variation was less than that observed during period one (Fig. 3B). As in period one, variation in the gross conversion efficiency between censuses parallelled the observed variation in specific growth rates (Fig. 3C).

During period two the mean weight of the branded fish (> 25.0 g on day 69) in the population increased from 27.7 to 93.1 g, while that of the non-branded fish (< 25.0 g on day 69) increased from 12.8 to 37.3 g. The respective specific growth rates for these two groups were 2.5 and 2.2% Day^{-1}. Two of the mortalities observed during this period were attributable to handling during censusing. Based on the difference in total numbers counted at the start and end of period two, there were an additional 16 mortalities, but no carcasses were recovered on the daily checks during the period.

Period three (days 119 to 154)

The mean fish weight of the population increased from 46.9 to 84.7 g during the 36 days in period three. There was no significant difference ($p > 0.50$) in mean fish weights on any of the census dates, between the two rearing tanks. The period specific growth rate was 1.8% Day^{-1} for the population (Fig. 3A,IV). Specific growth rates between censuses ranged from 0.6 to 3.5% Day^{-1} (Fig. 3B). At the end of period three individual fish weights in the population ranged from 13.0 to 304.0 g (Fig. 4C). The coefficient of variation [C.V. =100 x (s.d./mean) in percent] of the population weight distribution was 59%. The gross conversion efficiency values between censuses corresponded to changes in the specific growth rate (Fig. 3C).

At day 154, as on day 69, branded fish comprised the majority of the large individuals in the population (Fig. 4C). Mean weight of the branded fish increased from 93.1 to 172.9 g during period three, while that of the non-branded fish increased from 37.3 to 66.5 g. Specific growth rates of the branded (Fig. 3A,V) and non-branded (Fig. 3A,III) groups were 1.8 and 1.5% Day^{-1}, respectively. Of the 11 mortalities recorded during period three, eight were non-branded and three were branded fish.

Period four (days 161 to 209)

After hand grading was completed (days 155 to 160) and the population had been divided into the three weight classes, a census on day 161 indicated a limited amount of overlap between them. Fish weights in the "small" weight class (Fig. 5, Day 161) ranged from 10.0 - 70.0 g, with 5.2% of the class heavier than the intended 65.0 g upper limit. Fish weights in the "medium" weight class (Fig. 5, Day 161) varied from 40.0 - 180.0 g with 8.7% of the fish weighing less than 65.0 g. Fish weights in the "large" weight class (Fig. 5, Day 161) ranged from 170.0 - 310.0 g with 6.0% of the class weighing less than 180.0 g.

Fish in the "medium" weight class were divided equally between two rearing tanks with 365 fish in each. No significant differences were observed in the mean fish weights between the two units on any given census date ($p > 0.50$). At the start of period four, the fish density in the "small" weight class tank was 11.9 kg m^{-3}, while fish densities in the "medium" and "large" weight class tanks were 22.2 and 14.6 kg m^{-3}, respectively.

During period four the mean weight of the population (ie: all individuals, pooled over weight classes) increased from 84.7 to 158.1 g. Mean fish weight of the "small" weight class increased from 41.6 to 68.5 g, while that of the "medium" and "large" weight classes increased from 91.1 to 175.3 g and 223.6 to 397.2 g, respectively. The period specific growth rates of the "small" and "large" weight classes were 0.9 and 1.1% Day^{-1}, respectively (Table 1). Analysis of the ln (weight) versus time linear regression relationships for the two "medium" weight class tanks (Table 1) showed that slopes, and consequently specific growth rates, were not significantly different (df. 1, 1 126; $p > 0.50$). Census data for the two "medium" weight class tanks was therefore pooled. The period specific growth rate of the "medium" weight class, derived from the linear regression analysis on the pooled data, was 1.4% Day^{-1}.

The coefficient of determination (r^2) for the ln (weight) versus time linear regression of the "small" weight class was markedly lower than that observed for the "medium" and "large" weight classes (Table 1). This suggested a particularly high degree of variation in growth amongst individuals of the "small" weight class. Consistent with this was the observed increase in the coefficient of variation for the weight distribution of the "small" weight class, from 26 to 39% during period four. Note that there was no significant change in the coefficient of variation in either the "medium" or "large" weight classes (Table 1). At the end of period four (day 209), 2% of the "small" weight class weighed between 10 - 20 g, the same proportion as on day 161 at the start of the period (Fig. 5). Clearly, a segment of the "small" weight class did not increase measurably in weight during the period. In contrast, weight distributions of the "large" and, to a lesser extent, "medium" weight classes differed greatly between day 161 and day 209 (Fig. 5). For both weight classes, little or no overlap was apparent suggesting that most, if not all, fish grew.

The mean gross conversion efficiencies were 12 (±5.5)% for the "small", 22.4 (±2.4)% for the "medium", and 23.9 (±6.6)% for the "large" weight classes during period four. Of the 26 mortalities, all occurred in the "small" weight class with no carcasses recovered during the daily tank checks.

Within the subsample of 56 fish examined for gonad weights in the "small" weight class, 29 were identified as females and 27 as males. Mean gonad weight for these females was 0.17 (±0.01) g, with gonad weights ranging from 0.04 to 3.98 g (Fig. 6B). The ln (gonad weight) of females increased linearly with ln (body weight) irrespective of weight class (Fig. 6B). Gonad weights amongst males sampled from the "small" weight class ranged from 0.01 to 10.00 g (Fig. 6A). However, unlike females sampled from the "small" weight class, two different groups of males were clearly evident (Fig. 6A). One group (Fig. 6A) was comprised of twelve males with gonad weights of 1.00 g or more and had a mean gonad weight of 2.91 (± 0.71) g. Note that the only males observed in this group were sampled from the "small" weight class. The remaining 15 males sampled from the "small" weight class had gonad weights of considerably less than 1.00 g, with a mean gonad weight of 0.04 (±0.01) g. These latter males formed part of a larger second group, comprised of males sampled from all three weight classes (Fig. 6A). A linear trend between ln (gonad weight) and ln (body weight) was apparent for each of these groups of males (Fig. 6A).

The sex-specific, body weight frequency distributions for the "small" weight class subsample were compared, relative to the total sample for the "small" weight class (Fig. 7). Although males exhibited a wider range of body weights than females they were predominantly the smallest members of the "small" weight class (Fig. 7B). Also, most of the smaller males had a gonadal somatic index (G.S.I.) of 3.0% or more; whereas proportionately more of the larger males had a G.S.I. of 0.3% or less. McCart (1980) found that male Arctic charr from the western Arctic had a mean G.S.I. of 4.4% when mature, and 0.3% when immature. Therefore, males in this study with G.S.I. of 3.0% or more were defined as precociously mature. Mean body weights of precocious and non-precocious males in the "small" weight class, 49.3 (±8.65) and 74.4 (± 6.77) g respectively, were different ($p = 0.02$). Females were generally larger than either group of males with a mean weight of 79.9 (±3.65) g.

COMPARISON OF ARCTIC CHARR AND RAINBOW TROUT - 85 DAY GROWTH TRIALS

The specific growth rate of the Arctic charr population for the 85 day growth trial (days 70 to 154) was 1.9% Day^{-1}. Comparable values for the Idaho and Sunndalsora rainbow trout strain populations were 1.2 and 1.9% Day^{-1}, respectively (Fig. 8). At the end of their respective trials, 31% of the Arctic charr population weighed more than 100 g, compared with 4% for the Idaho and zero for the Sunndalsora rainbow trout (Fig. 9) populations. The coefficient of variation for the final weight distribution of the Arctic charr population was 59%, compared with 32% for the Idaho and 25% for the Sunndalsora rainbow trout strain populations. These latter values are typical for trout reared in the pilot system (Papst and Hopky 1982).

The larger mean weight observed for the Arctic charr population at the end of its trial resulted primarily from the greater proportion of Arctic charr > 100 g (Fig. 9, branded group). For example, compared to the Arctic charr population the Idaho rainbow trout population had a larger mean starting weight and a similar percentage of the its initial population weighed between 25 - 35 g (Fig. 9), but none of the Idaho trout weighed more than 100 g at the end of their trial. Otherwise, the weight distributions of all the test populations at the end of the trials were very comparable, as indicated by the similarity in modal values (Fig. 9).

DISCUSSION

The mean specific growth rates observed for the Arctic charr population of 2.6% Day^{-1} (2.2 - 14.0 g), 2.2% Day^{-1} (15.3 - 46.9 g) and 1.8% Day^{-1} (46.9 - 84.7 g) during periods one, two and three, respectively, were similar to the 2.1% Day^{-1} (7.9 - 14.4 g) and 2.2% Day^{-1} (7.9 - 25.1 g) reported by Uraiwan (1982) for Arctic charr reared at 13C in freshwater. They were considerably higher than the 1.0% Day^{-1} (24.6 - 77.7 g) reported by Wandsvik and Jobling (1982) for Arctic charr reared at 13C in freshwater. Because the culture methods and environments varied between experiments, all of the differences in observed growth rates cannot be attributed to inherent differences in the stocks. The growth rates observed in this experiment for the anadromous Labrador stock supports the hypothesis that Arctic charr can be reared successfully in an intensive freshwater culture system.

Comparison of the Arctic charr growth rates to those observed for the two rainbow trout strains must be considered as tentative primarily because the Arctic charr were reared on a commercial feed formulated specifically for rainbow trout. It may not represent the best diet for optimal Arctic charr growth. Yet for the 85 day Arctic charr growth trial, which was comparable to the "A" and "B" levels of a production cycle (Papst and Hopky 1982), the growth rate of the Arctic charr population was as great if not slightly greater than those for the rainbow trout strains tested. It is not known whether Arctic charr would maintain comparable growth rates during the latter stages of a production cycle. Our use of a tank configuration atypical to that employed in the standard production cycle for rainbow trout was in response to the unexpectedly greater variation in both individual body weights and mean growth rates observed in the Arctic charr population at the end of period three (i.e. end of level "B").

Compared to rainbow trout, these two factors suggest that a single harvest of commercially sized Arctic charr at the end of a production cycle would be precluded, and that some individuals would never grow to harvest size. Therefore, with respect to successful culture in the pilot system, the Arctic charr's overall growth performance was poorer than that achieved by the two rainbow trout strains. This was hardly surprising given that the Arctic charr was a wild stock which has yet to be domesticated, while both rainbow trout strains are the result of intensive domestic breeding programs, the objective of which is the production of a culture stock.

The extent of variation in body weights of the Arctic charr was consistent with that reported by Wandsvik and Jobling (1982). It may represent the natural growth variation of the species, or reflect the effects of size hierarchies formed within the population, as concluded by Wandsvik and Jobling (1982).

The occurrence of early maturation (precocious development) amongst the smallest of the male Arctic charr was a factor contributing to the large variation in observed body weights. This was shown by the increase in the coefficient of variation for the "small" weight class weight distribution during period four. Precocious males were amongst the smallest individuals in the "small" weight class and comprised the proportion which did not grow significantly during the period; while larger non-precocious members of the "small" weight class did. Thus it was not possible to determine whether the growth rate of the "small" weight class increased after separation from the rest of the population at the start of period four. This effect would have been anticipated if a rigid size hierarchy had existed prior to the separation. However, the coefficients of variation for the weight distributions of the "medium" and "large" weight classes did not increase during period four suggesting that size hierarchies did not become established in fish of this weight range, either prior to or after grading and separation into weight classes.

Brett (1979) summarized the general observation that growth rates decline with increased fish size, and the rate of decline is similar between various salmonids. During the 85 days between day 70 and day 154 the larger (branded) Arctic charr, which weighed more than 25 g on day 69, maintained growth rates similar to the rest of the Arctic charr population despite their larger body weights. Consequently, although the modal weight for the Arctic charr population was similar to those for the rainbow trout populations, at the end of their respective trials, the overall mean weight for the Arctic charr population was larger. It could be hypothesized that the greater growth rate of these larger fish, relative to the rest of the population, resulted from a smaller rate of decline in growth rate with size than would be expected. If so, such a trait might be positively exploited by a selection process, leading to the development of a domestic Arctic charr stock.

Mortality of Arctic charr in the pilot production system was comparable to that observed in rainbow trout production trials (Papst and Hopky 1982). The discrepancies between Arctic charr carcasses recovered and mortalities as estimated by the census counts may be significant if they reflect the consequences of cannibalism, as opposed to handling stress. The latter factor is the principal source of mortality in rainbow trout production trials (Papst and Hopky 1982). However, because there was an indication that smaller Arctic charr suffered a proportionately higher mortality, an examination of the possibility of cannibalism should be made. The overall mortality observed for the Arctic charr production trial would suggest however that it is not a significant factor limiting this specie's performance in freshwater culture.

The eventual feasibility of intensively culturing Arctic charr will, to some extent, depend on factors not examined in this preliminary study. The presence of a group of fish with low to nonexistent growth - i.e. precociously mature males - warrants further study, because they contribute to lower population mean weights and increased dispersion about the mean. Also, it will be necessary to successfully develop brood stocks, as the collection of spawn from the wild is far too costly for commercial enterprise. Results of the present study suggest that the freshwater intensive culture of Arctic charr is biologically feasible.

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Table 1. Linear regression parameters, by weight class, of ln (weight) - y - versus time - x - for period four (days 161 to 209); and coefficients of variation for the weight class mean weights on days 161 and 209.

Weight Class	Intercept a_i	Slope b_i±S.E.	$H_0:b_i=o$ pr > F	r^2	$H_0:x_i=o$ pr > F	Coefficient of Variation Day 161	Coefficient of Variation Day 209
Small	2.88	0.0089±0.00093	0.001	0.13	0.001	26	39
Medium	3.22	0.0138±0.00067	0.001	0.43	0.001	26	26
Medium	3.17	0.0140±0.00068	0.001	0.43	0.001	25	27
Large	4.38	0.0114±0.00056	0.001	0.67	0.001	15	17

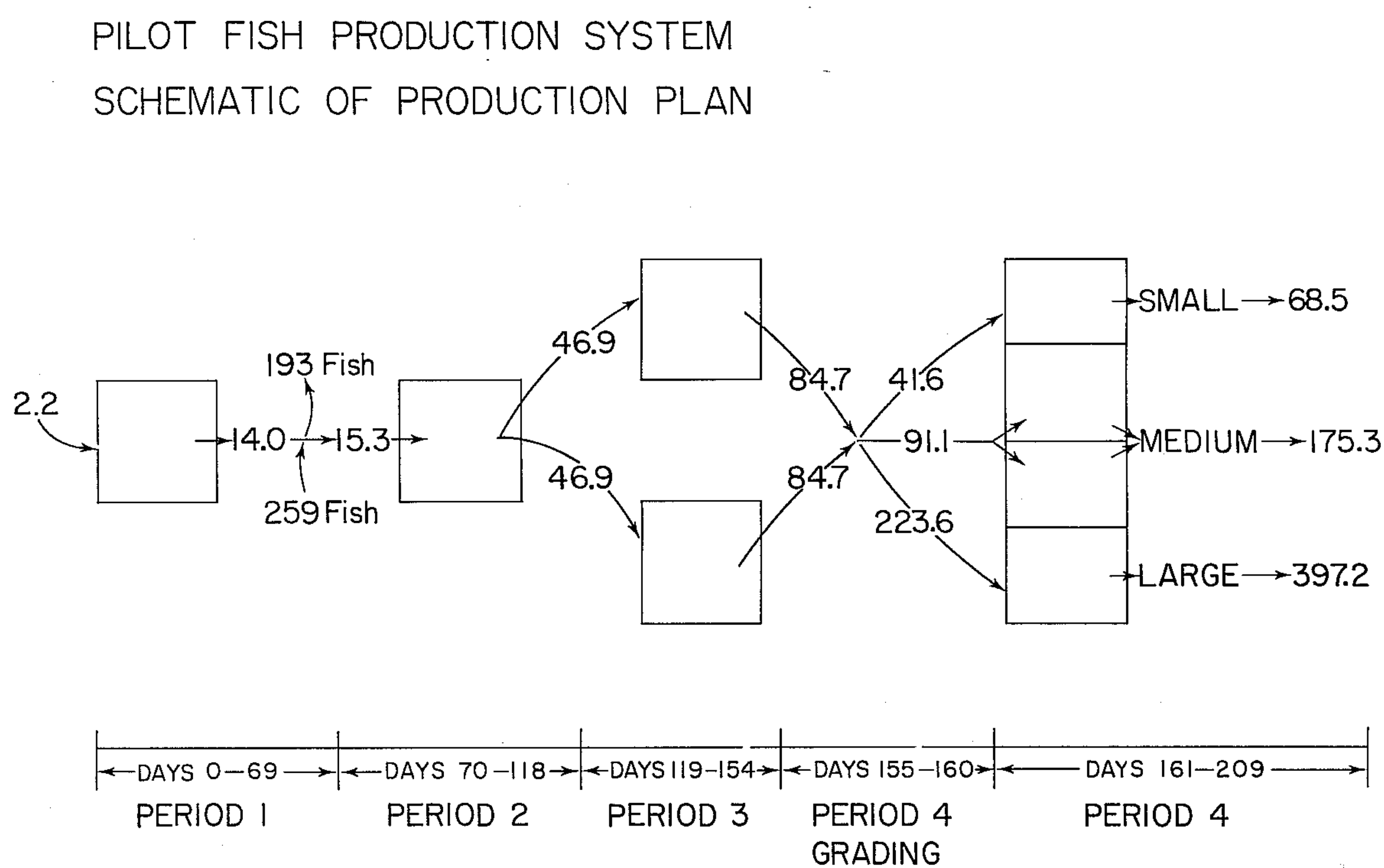

Figure 1. Schematic layout of tanks used for the Arctic charr growth trial in the pilot fish production system. Numbers between periods represent mean fish weight (g) at transfer. Numbers of fish exchanged on day 69 grading are indicated.

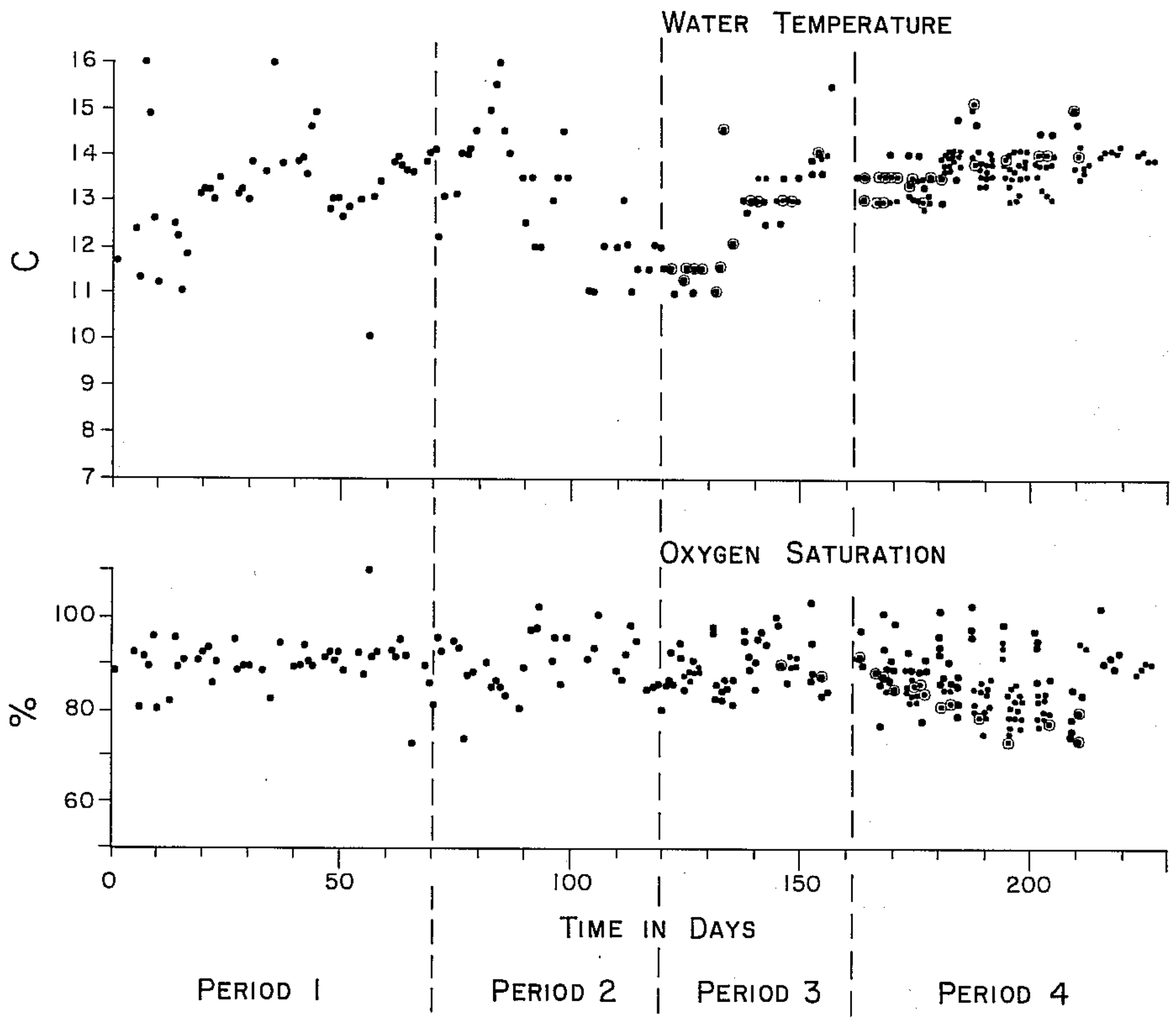

Figure 2. Rearing tank water temperature (C) and oxygen saturation (%) throughout the Arctic charr growth trial. Large circles represent days when tanks had equal values.

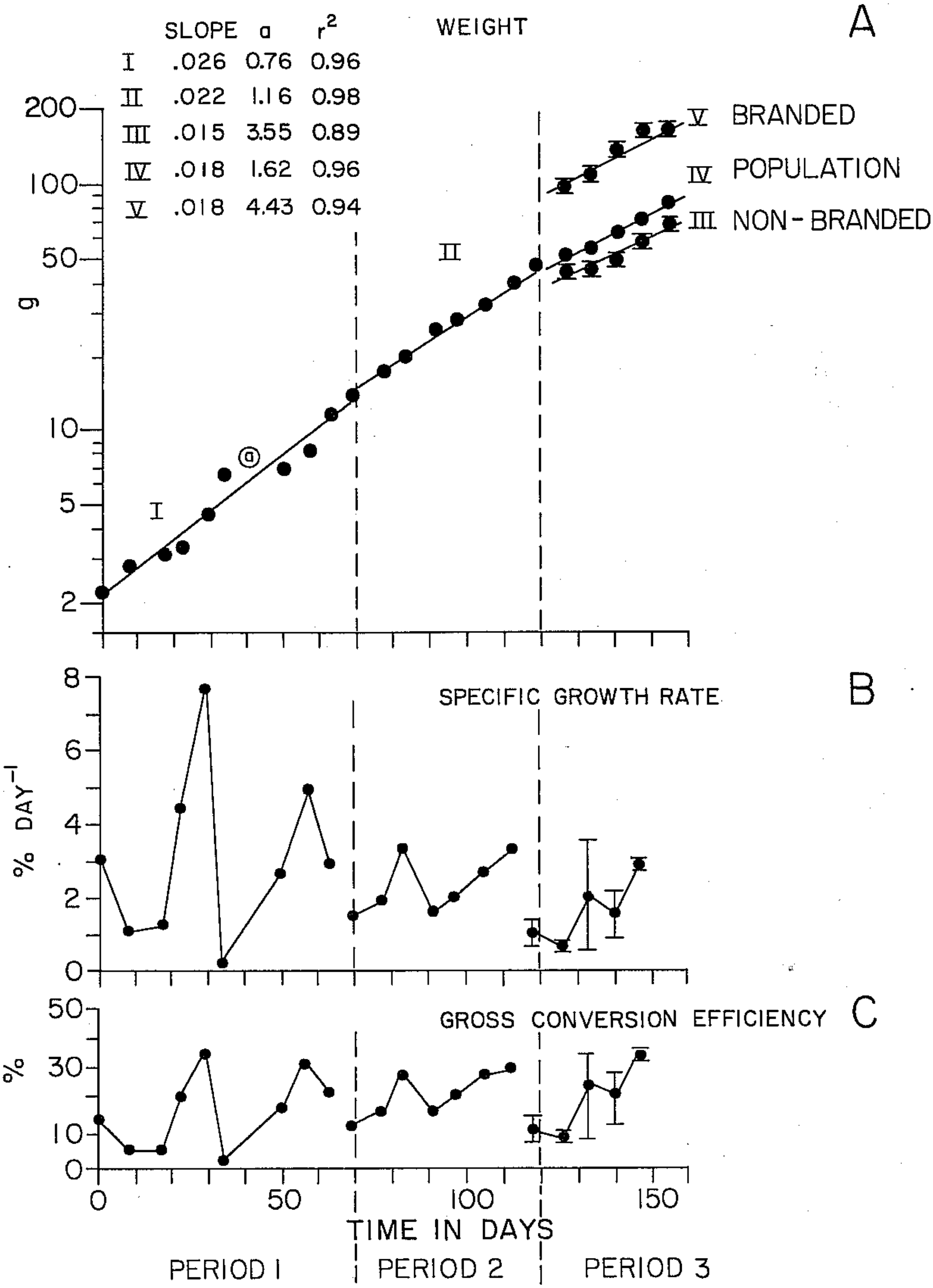

Figure 3. Changes in mean fish weight - A, specific growth rate - B, and gross conversion efficiency - C, between days 0 to 154 for the Arctic charr population. Linear regression parameters for ln (weight) versus time are shown in A, by period and group. Vertical bars represent ± 2 S.E.

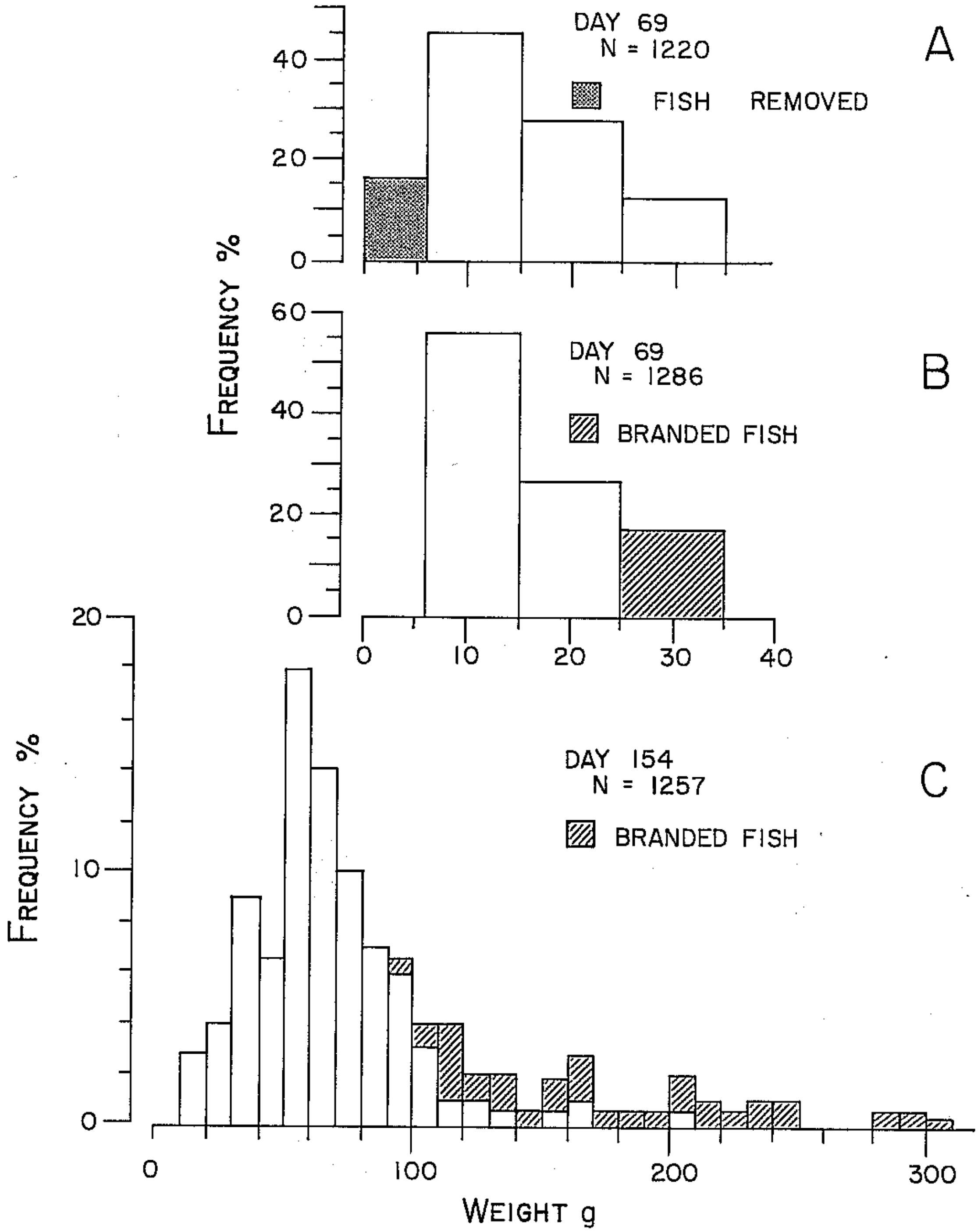

Figure 4. Weight frequency distributions for the Arctic charr population on day 69, prior to - A - and after - B - grading; and on day 154 - C.

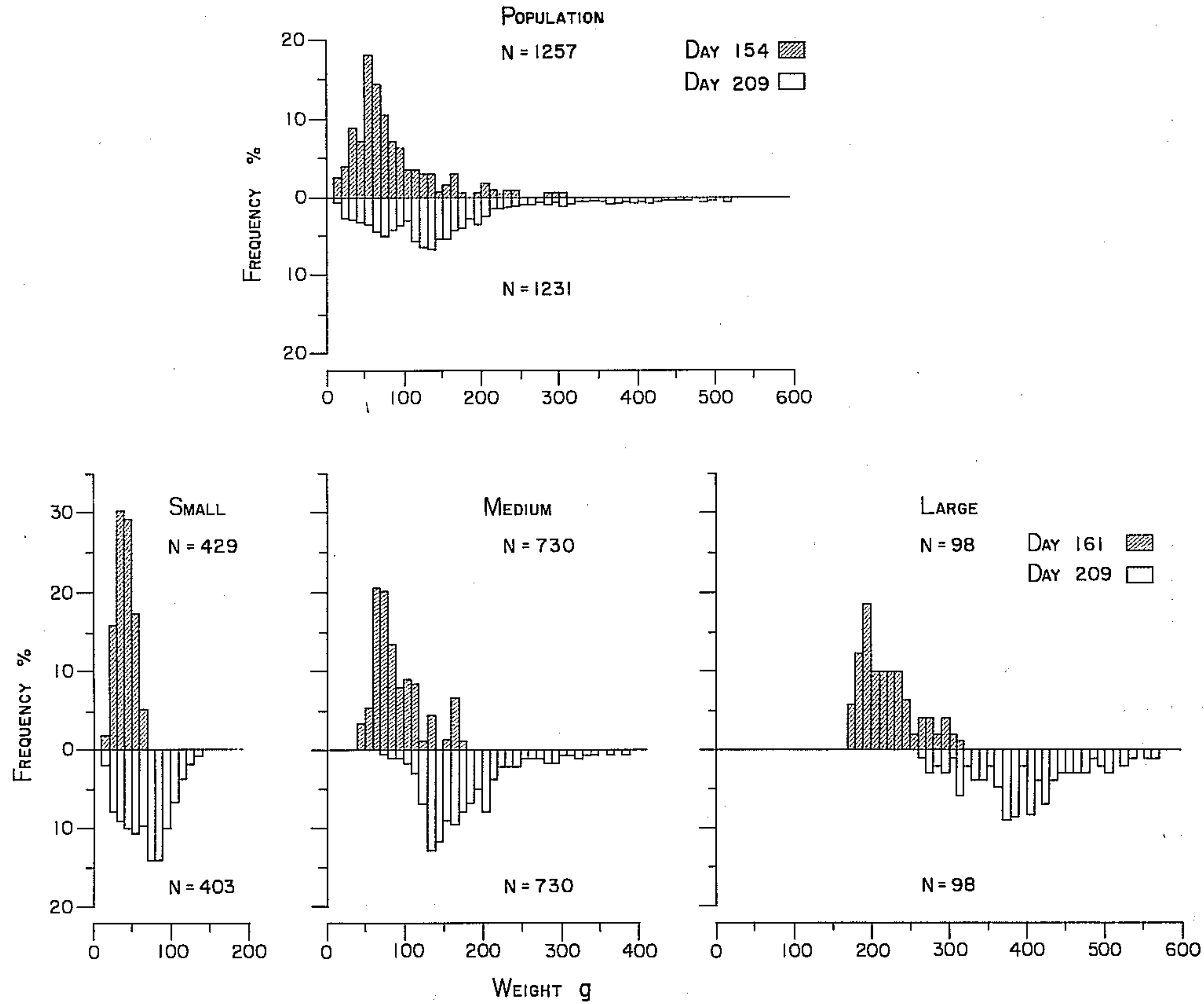

Figure 5. Weight frequency distributions for the Arctic charr population on days 154 and 209; and the "small", "medium" and "large" weight classes on days 161 and 209.

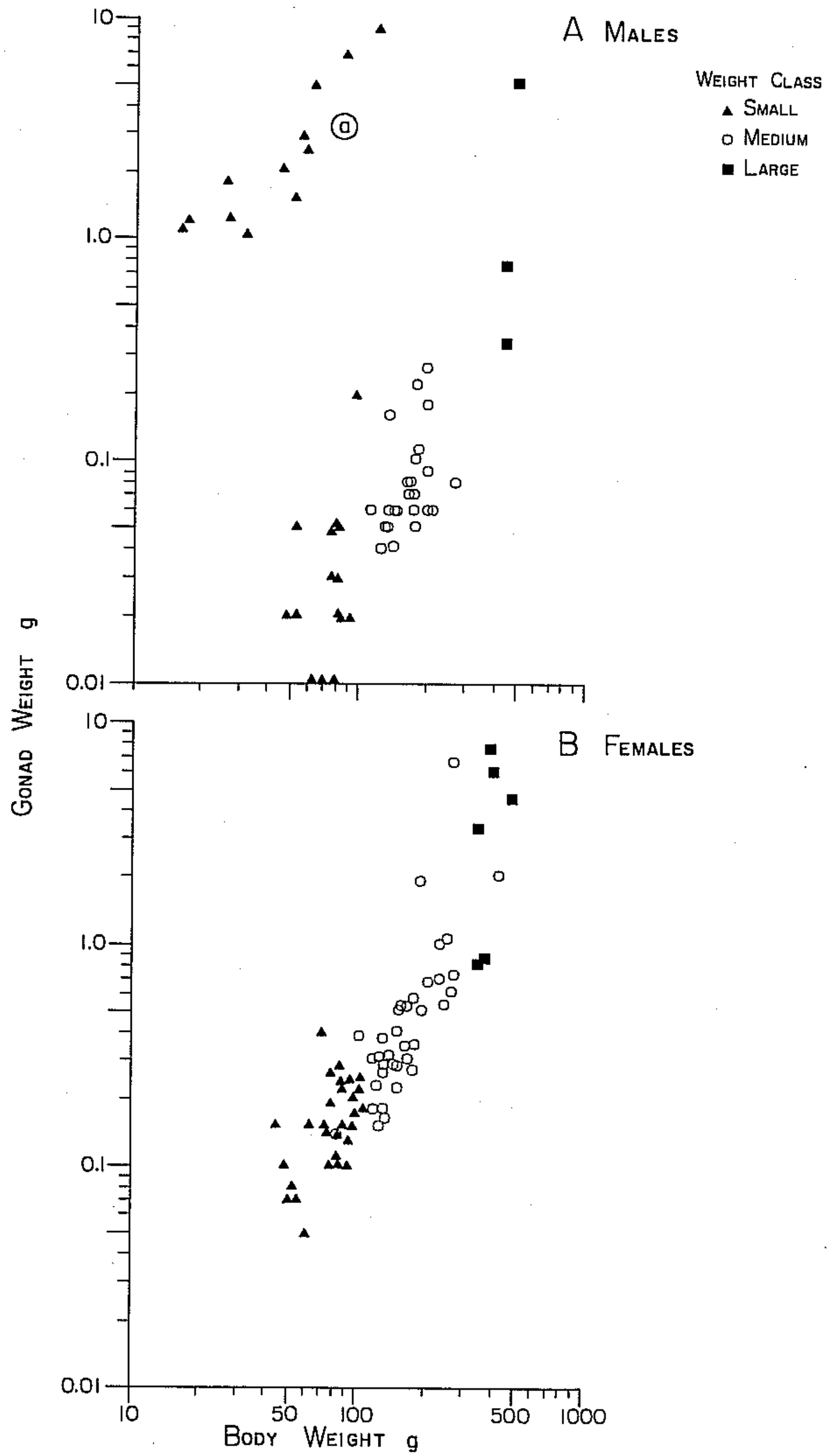

Figure 6. Gonad weight versus body weight for Arctic charr males - A - and females - B - by weight class. The (a) denotes precocious males.

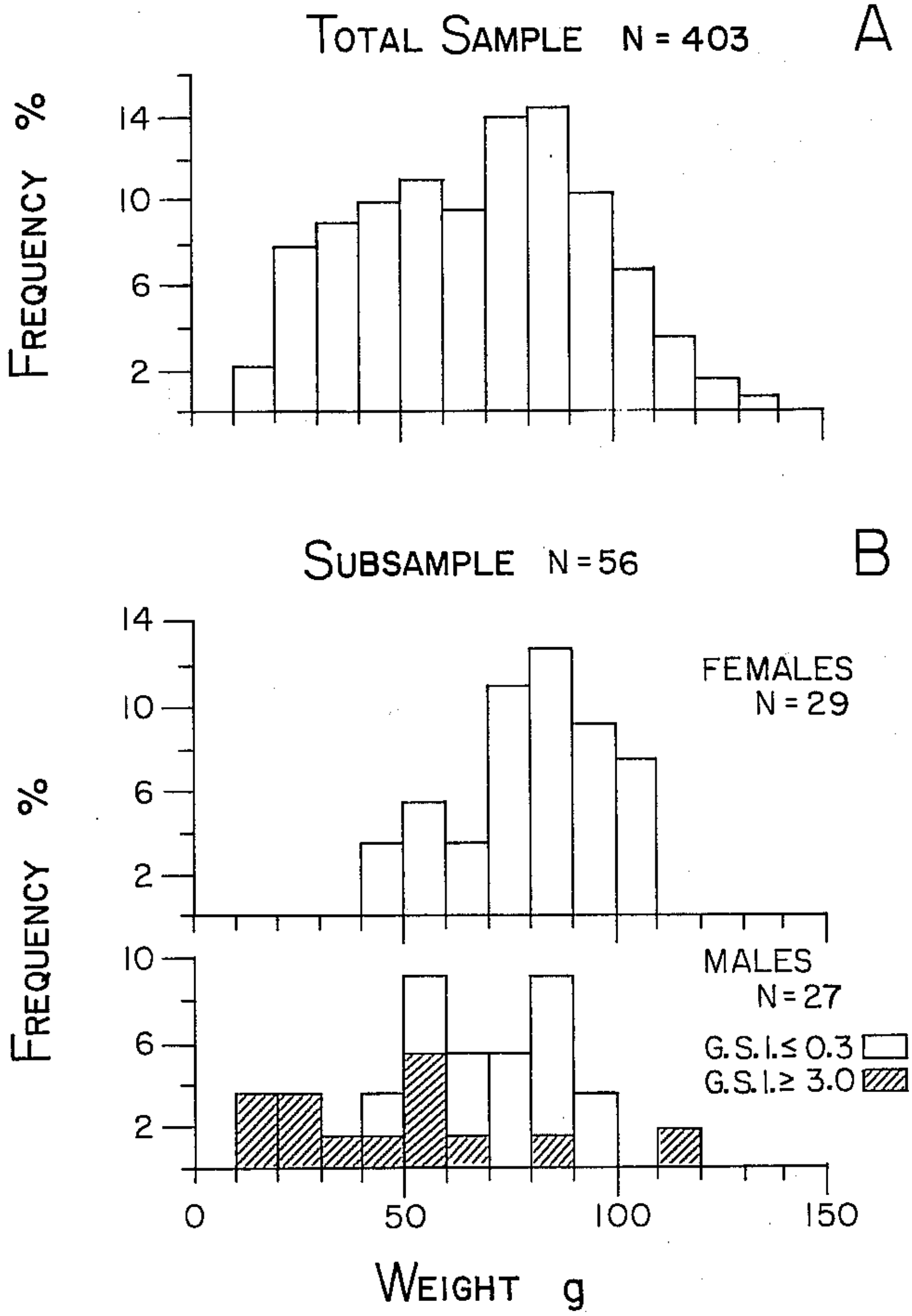

Figure 7. Weight frequency distributions on day 209 for the Arctic charr "small" weight class total sample - A - and subsample - B - with distribution by sex and gonadal somatic index (G.S.I.) for males.

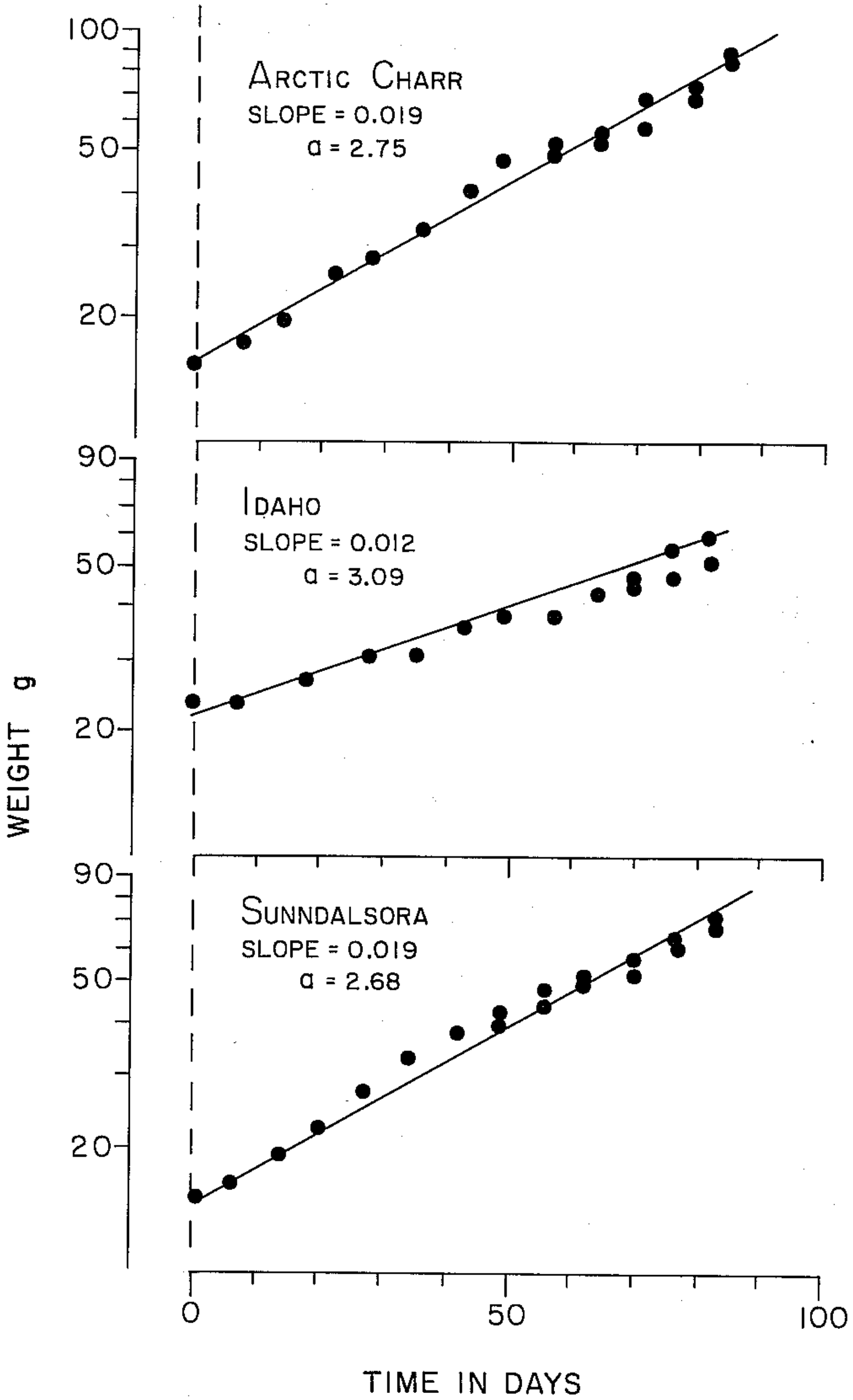

Figure 8. Linear regressions of ln (weight) versus time for the 85 day growth trials for Arctic charr, and Idaho and Sunndalsora rainbow trout strains.

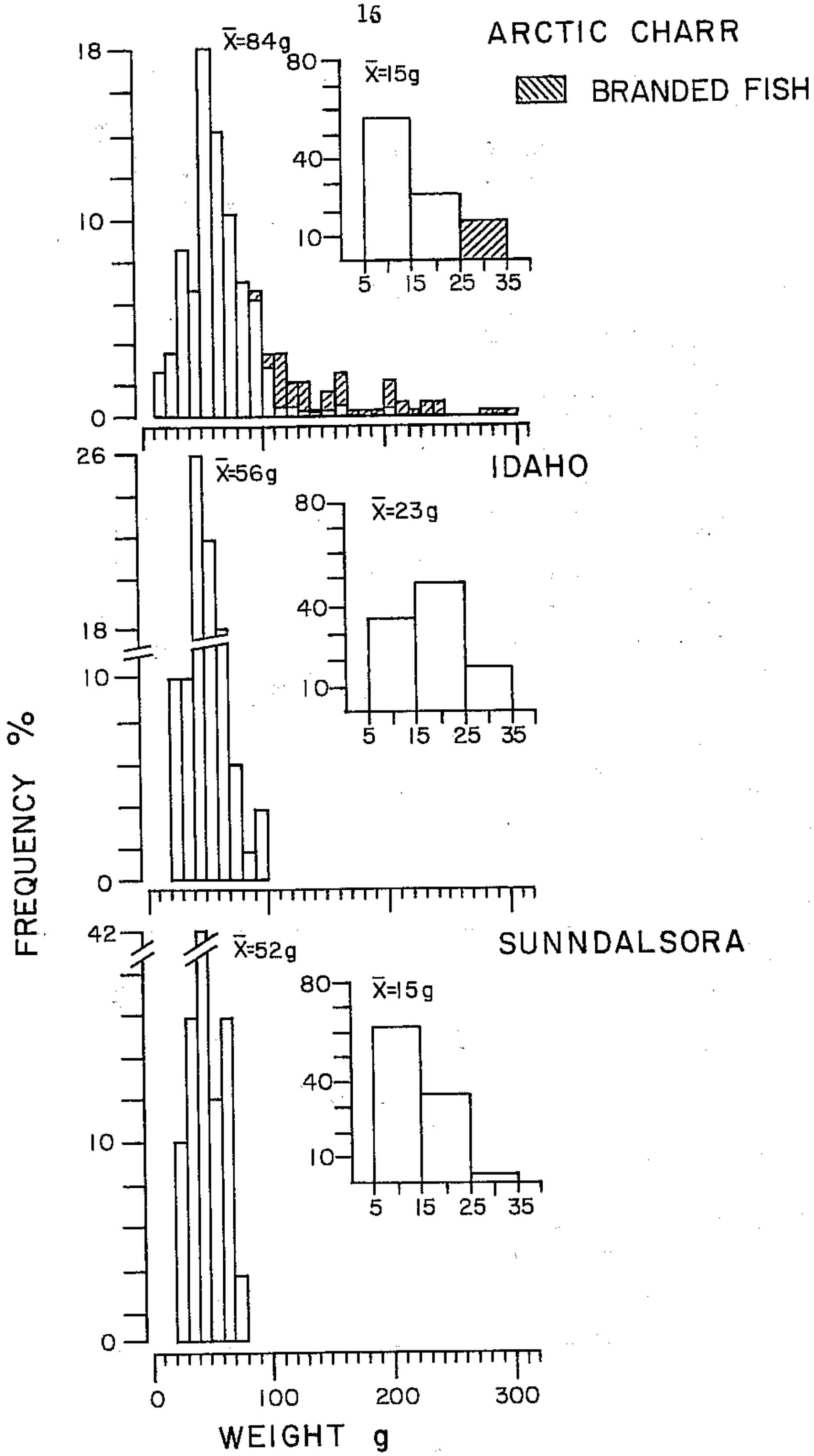

Figure 9. Weight frequency distributions at the beginning - inserts - and end of the 85 day growth trials for Arctic charr, and Idaho and Sunndalsora rainbow trout strains.

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