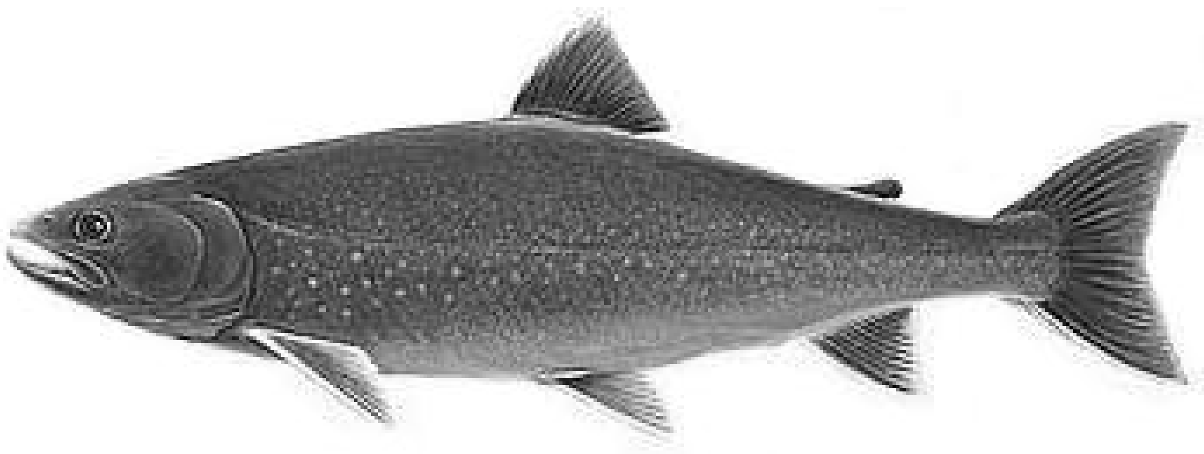
Production of Arctic char (*Salvelinus alpinus*) in a small mountain lake

Tina Hedlund



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Abstract

Production of Arctic char (*Salvelinus alpinus*) was estimated in a mountain lake in the north of Sweden. Char were individual marked with PIT tags shortly after the ice break and recaptured in the autumn. Weight and length were recorded at both occasions to calculate size dependent growth rates. The total number of char in the lake was calculated using the Petersen removal method. The lake had a population of 8241 char (710 char/ ha) larger than 100 mm and a total char biomass (>100 mm) of 353 kg (30,4 kg/ha). Specific growth rate of char decreased with size and was low. The yearly production of char (>100 mm) in the lake was estimated to 22,7 kg or 2 kg/ha.

Introduction

There are only a few studies of fish production made in Scandinavian mountain lakes (Hammar 1995, but see Langeland 1986). The fish populations in mountain lakes in Sweden have until recently been considered as an under exploited resource (Hammar 1995, Hammar 1996). However, the increasing use of mountain lakes for e.g. recreational and tourism based fishing may pose a considerable threat for overexploitation in many lakes (Hammar 1996, Post et al. 2002). Without knowledge of fish production it is not possible to determine the amount of biomass that can be removed from lakes each year by fishing without negatively affecting densities and size structures of fish populations.

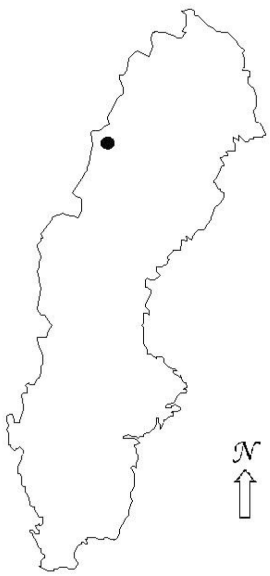
The climate in mountain lakes is harsh compared to lakes at lower altitudes. Mountain lakes are ice covered during eight to ten months a year and the average temperature in the lake rarely exceeds 10 °C (Karlsson et al. 2001). The water is often very oligotrophic, due to small catchment areas and the fact that the bedrock is often resistant to weathering, which all leads to low overall production rates. Arctic char (*Salvelinus alpinus* (L.)) is one of few fish species that can survive in these conditions, due to their ability to grow at low temperatures (Brännäs and Wiklund 1992). Even though char has the ability to grow at low temperatures, the growth rate in many mountain lakes may be very low due to strong resource limitation (Amundsen et al. 1993). In many lakes the char population is stunted, with high densities of char that is too small for attractive sport fishing (Langeland 1986, Amundsen et al. 1993). High accumulation of char biomass can also give the false impression of high fish production, in turn leading to a fishing pressure that may considerable exceed the actual annual production of char (Langeland 1986, Langeland 1995).

The aim of this project was to estimate yearly char production in a mountain lake in northern Sweden. Size dependent growth rate of char was determined by marking char individually with PIT tags (passive integrated transponders) soon after the ice break in the end of June. Recaptures of PIT tag marked char was then undertaken during the spawning period in the autumn. Mark–recapture methods was also used to estimate char population densities. Furthermore, size at different ages was determined as well as population size and age structure.

Material and methods

Study area

The study was conducted in Lake Nulpejauretje, which is situated 844 m above sea level at 65°46’N, 15°11’E in northern Sweden, near the village of Hemavan. (Figure 1 a). The lake has a surface area of 11,6 ha, a mean depth of 1,6 m and a maximum depth of 5,5 m (Figure 1 b). The volume is about 190 000 m^3. Ice is covering the lake for about 8,5 to 9 month a year, from the first half of October to the end of June. The lake is situated in a depression surrounded by steep slopes. Due to the steep slopes around the lake and the fact that the lake is situated high up on the mountain, the catchment area is only about 40 ha. The surroundings consist mostly of tundra heaths with patches of bare rocks and a few small bog areas.



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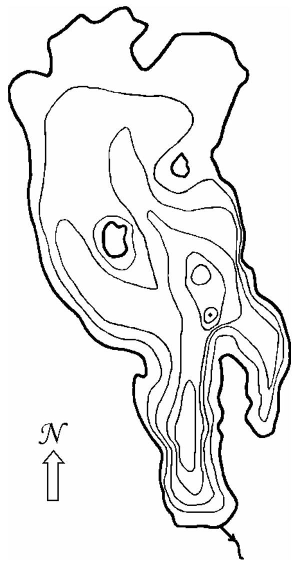

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Figure 1. a.) Geographical position of Lake Nulpejauretje. b. Lake Nulpejauretje with the depth contours, each line represents one meter. Maximum depth in the lake (5,5 m) is marked with a point in the map.

The lake can be characterizes as oligotrophic due to the low conductivity (Bergquist 1997). The secchi depth was measured during the study to more than 5,5 m. The alkalinity in the lake was very low in 1985 and onwards (Table 1) and the lake was therefore limed once in 1991.

Table 1. Chemical values in lake Nulpejauretje from August 1985, (before the liming took place) and onward. Data from the local government of Storuman, environmental office.

	pH	**Alkalinity (mek/l)**	**Conductivity (mS/m)**
1985	6,69	0,04	
1992	6,95	0,14	3,06
1993	6,7	0,13	2,51
1996	6,3	0,08	2,01

The temperature in lake Nulpejauretje was measured with a temperature log every fourth hour during the whole study period (29/6 to 6/9 2001), at a depth of 1 m at the deepest point in the lake (Figure 2).

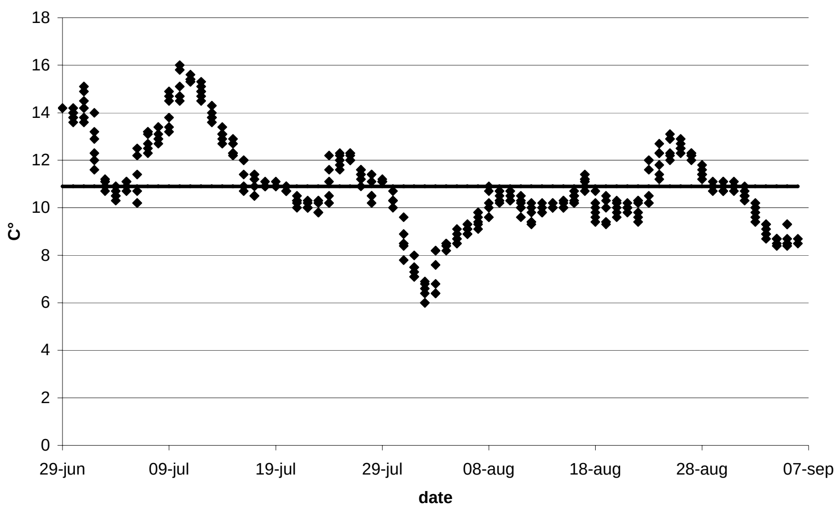

Figure 2. Temperature development in lake Nulpejauretje from 29/6 to 6/9 2001. The horizontal thick line indicate the mean temperature (10,9 C°).

The only fish species present in the lake is Arctic char (*Salvelinus alpinus*) which was introduced in 1938 into the lake. Migration of fish to the lake is not possible since the outlet of the lake consists of a waterfall of about 80 meters. The only fishing in the lake is carried out as sport fishing with hook and line, no gillnet fishing is allowed.

Marking and recapture of char

Char were marked on two occasions; 29/6 - 3/7 and 6/7 - 8/7 2001. Char were captured using benthic gillnets that were emptied every half-hour to minimize stress and injures on captured fish. The nets used were monofilament survey nets of the type Drottningholm with twelve sections of three meter each with different mesh sizes; 10, 12.5, 16.5, 22, 25, 30, 33, 38, 43, 50, 60 and 75 mm (bar mesh size) (Filipsson 1972). Electro fishing was also performed in shallow areas to capture small char. However only six char was caught during electro fishing. In addition ten Ella traps baited with frozen cod roe and a fine meshed beach seine was also used to catch char for marking, however only one char was caught with each tool.

Captured char were placed in two storage buckets (60-90 l), (with additional holes at the sides to allow the water to circulate), to check for negative effects of gillnetting and handling until they were marked. Char were individually marked with passive integrated transponders, hereafter only referred to as PIT tags (Prentice at al. 1990 a). All char were anaesthetized with MS 222 before the marking procedure. Total length was measured to the nearest mm with the lobes slightly compressed and weight was measured to the nearest g. A small incision (two to three mm long) was made between the pectoral fin and the pelvic fin on the ventral side of the body (Prentice at al. 1990 b) and the PIT tag was inserted into the body cavity. In addition to PIT tag marking, the adipose fin was also removed on all char. Char in the interval 89 to 248 mm was marked with PIT tags, char smaller than 89 mm were considered to be to small and was only marked by removal of the adipose fin. All marked char were held in a storage bucket for at least one hour after marking to check for negative effects of the marking procedure. When released, char were released in the same area as they were captured in. Char that showed signs of unnormal physical performance at the time of the release were disregarded. Six individuals were discarded in total. A total of 87 Arctic char with PIT tag markings and additionally two marked only with adipose fin cutting were released.

The recapture of the marked char was carried out between 31/8 - 6/9 2001 using benthic gillnets. Gillnets used were monofilament survey nets of the types of Norden (*n* =10) with bar mesh sizes: 5, 6.25, 8, 10, 12.5, 15.5, 19.5, 24, 29, 35, 43 and 55 mm (Appelberg 2000). Other types of nets used were Drottningholm survey nets (*n* =8), and a special edition of Drottningholm survey nets with 2 extra sections (*n* = 2); (6.25, 8, 10, 12.5, 16.5, 22, 25, 30, 33, 38, 43, 50, 60 and 75 mm bar mesh size) (Nyberg and Degerman 1988). Ordinary monofilament gillnets with mesh sizes of 21,5 mm (*n* = 5) and 25 mm (*n* = 5) were also used. During the first night, ten Nordic gillnets were used to perform a standardized gillnet fishing with survey nets and the nets were therefore randomly dispersed in the lake. The other gillnets (and the Nordic gillnets during the rest of the sampling period) were placed where they caught the highest number of char. At the end of the sampling period some gillnets were also set during the day to increase the catch. The number of gillnets used each day varied between eight and thirty and the total number of gillnet efforts made during the sampling period were 100.

All captured char was measured to the nearest mm with the lobes slightly compressed (total length) and weight was measured to the nearest g. The char captured in the standardized gillnet fishing with survey nets during the first night of fishing, the recaptured marked char and some char of unusual sizes (large and small ones and individuals in the interval 138-196 mm) were deep frozen for later analyses of age, sex and maturity in laboratory. Additionally a few small fish were conserved in 95% ethanol for the same analyses.

Analyses

Age was determined by surface reading of the sagittal otoliths. After removal the otoliths were dried for approximately one month. The otoliths were placed whole in propandiol and read against a black background under a binocular microscope. Each otolith was studied thoroughly on both sides and the hyaline zones were counted.

Sex and maturity was determined according to Filipsson (1972) where the size of the gonads was examined.

The total number of char in lake Nulpejauretje was calculated by using the Peterson removal method (Krebs 1989):

$$N = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1$$

where N is the total number of char, n_1 is the number of marked and released char, n_2 is the number of char in the total catch at the recapture and m_2 is the number of marked char at the recapture.

A 95% confidence interval for the population estimate was calculated according to Krebs (1989):

Lower 95% confidence limit: $N = \frac{(n_1 + 1)(n_2 + 1)}{(R_2 + 1)} - 1$

Upper 95% confidence limit: $N = \frac{(n_1 + 1)(n_2 + 1)}{(R_1 + 1)} - 1$

where R_1 and R_2 is the upper, and the lower values obtained from the Poisson distribution for m_2.

To increase the statistical precision in the population estimate, data was added from another study performed in the same lake at the same time (Mattsson 2002). Since these length data was recorded as fork length, they had to be transformed into total length. This was performed using the formula (Jensen 1995 b):

$$L_f = 0,927L_t - 0,228$$

where L_f is fork length (cm) and L_t is total length (cm).

The growth rate of the marked char was expressed as the specific growth rate and was calculated as:

$$G_w = 100 * \frac{\ln W_2 - \ln W_1}{t_2 - t_2}$$

where G_w is the specific growth rate and W_1 and W_2 are the weights at time t_1 and t_2 respectively. G_w is expressed as the percentage increase in weight per day.

The initial weight distribution of the char population used in the production estimates was calculated by numerical solving of W_1 in the following equation, based on the size distribution of char obtained from the standardized gillnet fishing in September:

$$\frac{\ln W_2 - \ln W_1}{t} * 100 = a * e^{-b*W1}$$

where W_1 is the initial weight and W_2 is the weight at the recapture, t is the time interval between the first day of marking and the last day of recapture (71 days). a and b were calculated from the weight dependent function for specific growth rate (Figure 8) and were 1,1818 and 0,0303 respectively.

Individual fish condition was estimated with Fulton's coefficient of condition (Bagenal and Tesch 1971):

$$K = 100 * \frac{W}{L^3}$$

K is the condition factor, W is the weight in g and L is the length in cm.

CPUE (catch per unit effort) was calculated from the initial standardized gillnet fishing in September and was expressed as number of char or biomass (g) of char per Nordic gillnet and night.

Results

Population size and age structure

The length distribution of char in lake Nulpejauretje was bimodal, with roughly equal number of individuals in each peak (Figure 3). The first peak was narrow and constituted of individuals around 100 to 140 mm in length; the other peak was wider and constituted of individuals between 160 to 240 mm in length. The largest char caught in the standardized gillnet fishing with multimesh survey nets was 248 mm in total length and the smallest one was 95 mm. A total of 104 char were caught during the standardized gillnet fishing. The CPUE in lake Nulpejauretje in the standardized gillnet fishing was 10,4 char/gillnet and night or 450,9 g/gillnet and night.

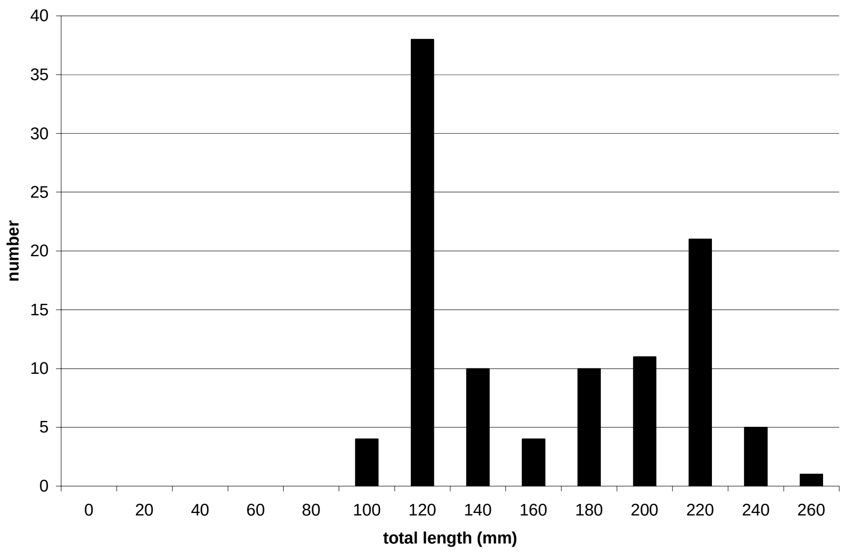

Figure 3. Length frequency distribution of Arctic char in lake Nulpejauretje caught during the standardized gillnet fishing with multimesh survey nets, (*n* =104).

Similarly, the age structure was bimodal with a peak at the year classes two to five and one smaller peak at the year classes seven to ten (Figure 4). The oldest char caught was twelve years old and the youngest was one year old.

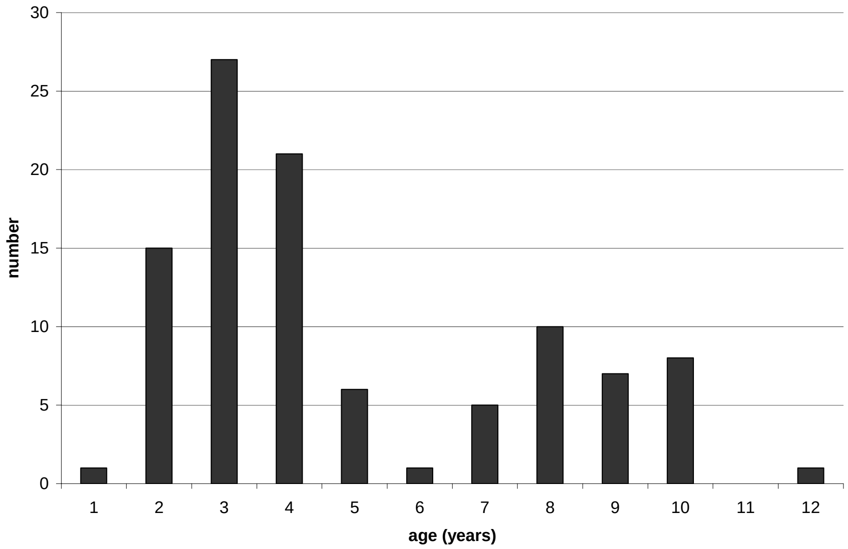

Figure 4. Age structure of Arctic char in the standardized gillnet fishing with Nordic multimesh survey nets in lake Nulpejauretje, *n* =102.

Maturity

Most females seven years or older were mature and ready to spawn this year (Figure 5 a). Only one female above this age was not going to spawn this autumn. Most males were also mature and ready to spawn at the age of seven, only three males older than seven were not going to spawn this year (Figure 5 b). On a large proportion of the chars, younger than six years, sex was not possible to determine and these char were classified as juveniles (Figure 5 c).

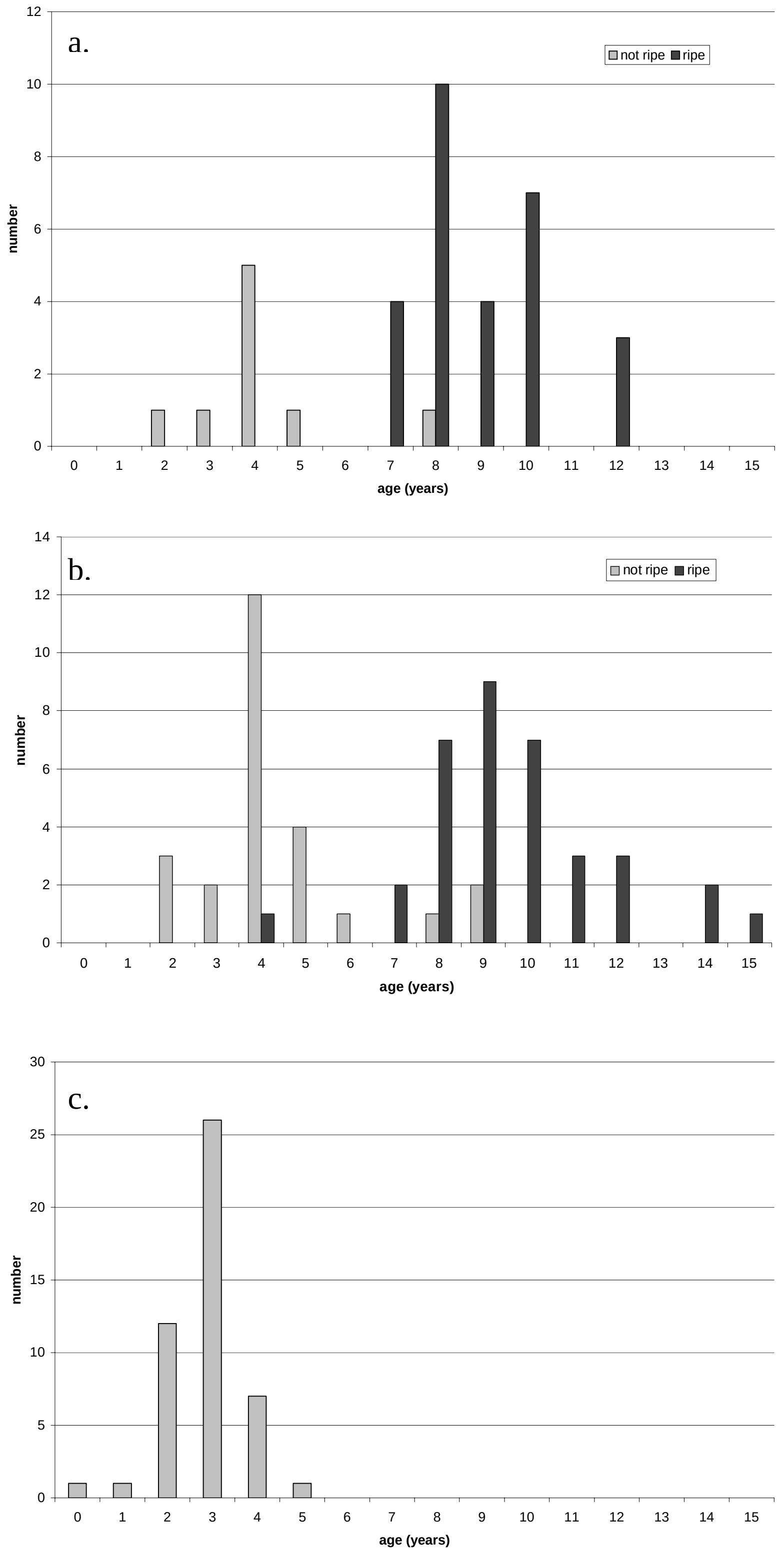

Figure 5. Maturity structure in Arctic char in lake Nulpejauretje. a) females (*n* =37), b) males (*n* =62) and c) juveniles (*n* =49). Stages three and four was defined as ripe in males and stages 3/4 and 1/1 with a roe size of more than three mm was defined as ripe in females. Char with to small goads to be sex determined were classified as juveniles.

Condition and growth

The coefficient of condition of small char (62 to 175 mm) varied between 0,56 and 1,08 with a mean of 0,80. The coefficient of condition of larger char (182 to 276 mm) varied between

0,64 and 1,17 with one extreme at 1,33 and a mean of 0,89. The mean value of the coefficient of condition of all char was 0,88. The growth of Arctic char in lake Nulpejauretje was slow. Very few char reached a size larger than 250 mm (Figure 6).

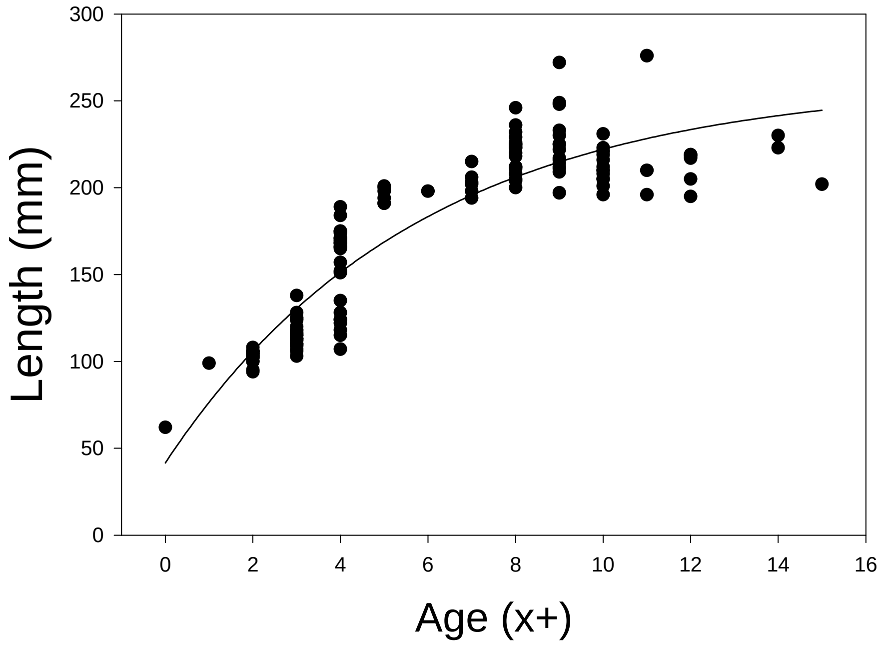

Figure 6. Total body length at different ages in Arctic char in lake Nulpejauretje (*n* =145). The function length = a*(1-exp(-b*(age+1))) was fitted to the data, a =260.83, b = 0.17, R^2 =0,86.

The age-weight relationship formed a sigmoid curve (Figure 7). The growth in weight slowed down at an age of about eight to nine years for most char. A small number of individuals continued to increase in weight but very few char reached a weight above 150 g.

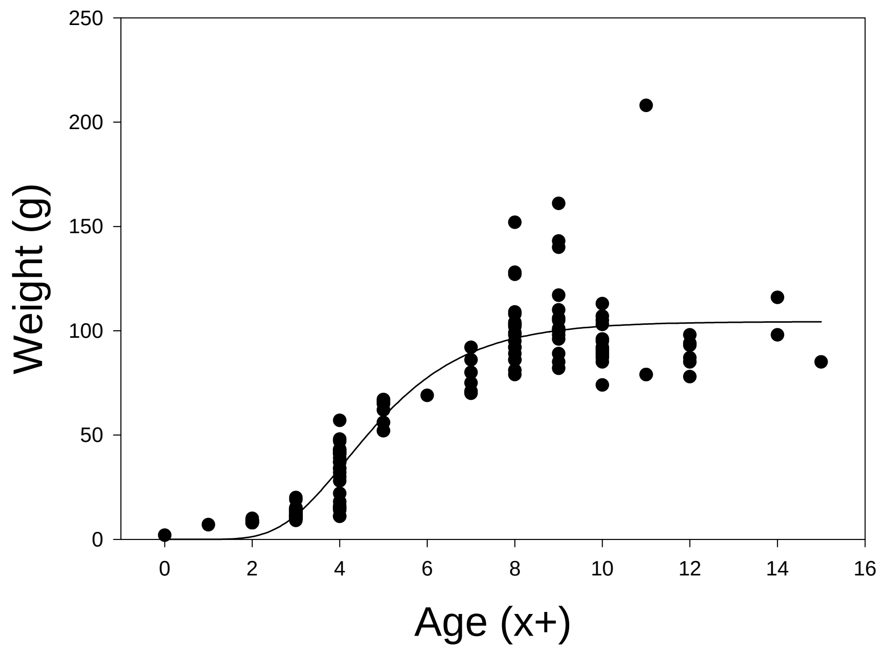

Figure 7. Weight at different ages in Arctic char in lake Nulpejauretje (*n* =145). The function weight=a*(1-exp(-b*(age+1)))^c was fitted to the data, a = 104.34, b = 0.66, c = 29.28, R^2 =0,86.

Specific growth rate

30 char marked with PIT tags were recaptured in September; 29 of those weighted between 70 and 125 g and were between 196 and 246 mm in length. Only one small char was recaptured; weight 10 g and length 107 mm.

There was no correlation between initial weight and growth rate in char in the size interval 70 to 125 g R^2= 0,018, P = 0,49 (Figure 8). The highest growth rate recorded was 0,25 % per day in a char of 88 g in weight and the lowest recorded was –0,23 % per day in a char 108 g in weight. The mean growth rate in the size interval 70 – 125 g was 0,08 % per day.

When the only small char was added to the dataset a negative correlation between weight and growth rate was present (Figure 8). When data was added from another similar study (Byström unpublished) with growth of Arctic char from a lake with similar conditions, i.e. the same temperature regime and char density, these data supported the general shape of this relationship (Figure 8).

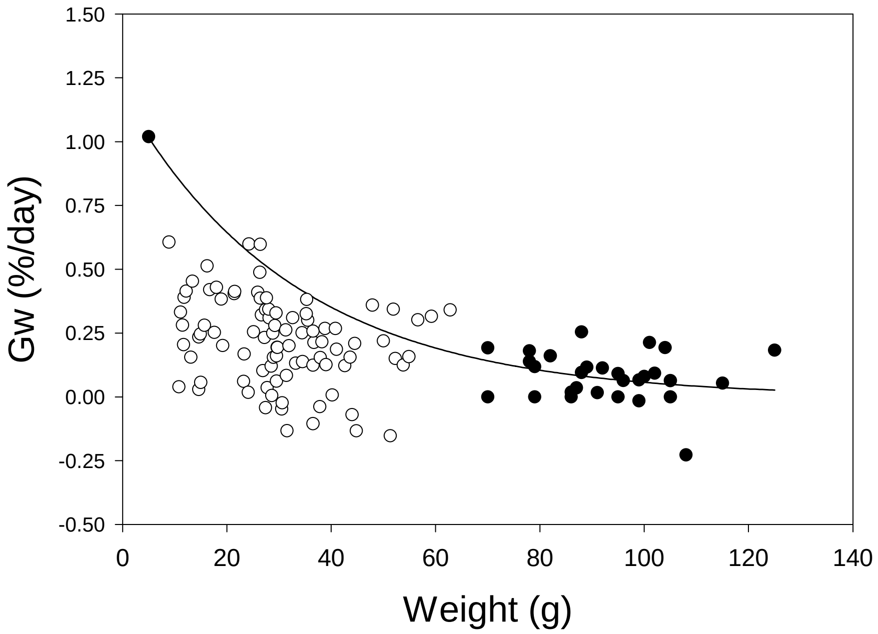

Figure 8. Specific growth rate as a function of initial weight of char in lake Nulpejauretje (filled circles) (n =30). The function G_w =a*exp(-b*weight) was fitted to the data, a=1,18, b=0,03, R^2= 0,77. Open circles are data from another lake, lake Vuorejaure, (n = 91) (Byström unpublished data).

Population estimate and production

A total of 32 char was recaptured in September that had had the adipose fin removed of which 30 had retained their PIT tags. The remaining two char had lost their PIT tags but were nevertheless included in the population estimation since it was certain that they once had been marked, (the scars were still visible and they had their adipose fin removed). Of these 32 recaptured char, 30 was 200 mm in length or more which led to the fact that only the number of char in lake Nulpejauretje in this size interval could be estimated with any certainty. Furthermore, since additionally one marked char > 200 mm was recaptured by Mattsson (2002) in September; data from his survey in September was added to improve the population estimate. The total number of char in the size interval ≥ 200 mm was 3008 in lake Nulpejauretje (Table 2). According to the standardized fishing with Nordic multimesh gillnets, these char made up 36,5% of the population. Assuming that the standardized gillnet catches reflected the actual size distribution of char this would mean that the total population of char in Lake Nulpejauretje consists of 8241 char (Table 2).

The char production in lake Nulpejauretje during the sampling period in the length interval ≥ 200 mm (≥70 g) was 3,1 kg or 0,26 kg/ha calculated from the values of specific growth rate in Figure 8. When all size classes of char were included in the calculation the total production (≥100 mm) became 22,7 kg or 2,0 kg/ha (Table 2). Since the total biomass of char in lake Nulpejauretje was 353 kg (Table 2), the production to biomass ratio (P/B ratio) of the whole lake was 0,06.

Table 2. Char density and production in lake Nulpejauretje.

		95 % confidence interval	**Number or kg/ha**
Number of char ≥200 mm	3008	2181-4373	259
Total number of char (≥100 mm)	8241		710
Biomass of char ≥200 mm (kg)	247		21,3
Total biomass (kg) (≥100 mm)	353		30,4
Production of char ≥200 mm (kg)	3,1		0,26
Total production (≥100 mm) (kg)	22,7		2,0

Removal of char biomass

A total of 1564 char were caught at the time of the recapture. The total biomass of these char was 133,2 kg. In addition 200 char with a total biomass of 15,7 kg was removed from the lake by Mattsson (2002) and 14 char with a total biomass of 1,1 kg was removed from the lake at the time of marking. This gives a total of 1778 char with a biomass of 150 kg or 153 char/ha and 12,9 kg/ha that was removed from the lake during the project period.

Discussion

Population density, size structure and size at age

The density of char in the lake was high (710 char/ha) compared to other lakes with resident, allopatric populations of Arctic char (Table 3). Lake Grønsjøen, Norway, for example had a density of 150 char/ha (Langeland 1986) and Keyhole Lake, Canada, had a density of 163 char/ha (Hunter 1970). Only lake Øvre Stavåtjønn had a higher char density (Table 3). A similar pattern was found for biomass of char. Lake Nulpejauretje had a slightly higher density than lake Grønsjøen but lower than Keyhole Lake (Table 3). Lake Øvre Stavåtjønn however, had the highest biomass with 71 kg/ha (Langeland 1986).

Table 3. Char density in different lakes.

Lake, Country	**Number of char/ha**	**Biomass /ha**	**Age/size**	**Reference**
Lake Nulpejauretje, Sweden	710	30,4	>105 mm	Present study
Little Nauyuk Lake, Canada	107	12,3 – 15,4	>150 mm	Johnson 1994
Lake Grønsjøen, Norway	150	26	3 years and older	Langeland 1986
Keyhole Lake, Canada	163	43,8	Up to 18 years	Hunter 1970
Lake Vuorejaure, Sweden	380		2 years and older	Byström et al. 2002
Lake Ruozutjaure, Sweden	457		2 years and older	Byström et al. 2002
Lake Sourujaure	573		2 years and older	Byström et al. 2002
Lake Øvre Stavåtjønn	1100	71	2 years and older	Langeland 1986

Rubin (1993) have compiled data of growth in length at different ages from 31 different populations of landlocked Arctic char around the Northern hemisphere. Compared to these data the growth of Arctic char (length at different ages) in lake Nulpejauretje was low. Growth of char in lake Nulpejauretje was similar to the growth of char in Takvatn, Norway, before an intensive fishing programme was performed to rehabilitate the stunted char population (Amundsen et al.1993). In Takvatn the growth curve had the same shape as in lake Nulpejauretje and it slowed down at a similar size (Amundsen et al.1993). The growth slowed down at an age of around seven when char matured in lake Nulpejauretje (Figure 6 and 7). Thus the char in lake Nulpejauretje can be characterised as a slow growing and a high-density population.

In contrast to other slow growing char populations, which normally have a unimodal size distribution (Langeland 1986, Amundsen 1993, Johnson 1994), lake Nulpejauretje had a bimodal size distribution. One probable cause for the bimodal length frequency distribution was the presence of strong and week age classes (Hammar 1996). These variations in age class size could be seen in the age frequency distribution (Figure 4). One other thing that points towards this hypothesis is the high growth rate in the small age classes five and six and the poorer growth in the following two age classes (Figure 6) (Hammar 1996). Strong and week age classes are discussed as one reason for bimodality in size frequency distributions by Griffiths (1994). The high number of large char (≥ 200 mm) in lake Nulpejauretje was represented by a number of older age classes (Figure 6). Since growth slowed down at about 200 mm at an age of about seven, almost all char older than seven years were accumulated in this peak in the length frequency distribution. According to Griffiths (1994) accumulation of older, slow growing cohorts may be another reason behind the second peak in a bimodal size distribution. In lake Nulpejauretje a combination of both causes is probably the reason for the length frequency distribution. According to Hammar (2000) cannibalism and parasites may cause a bimodal size distribution. This is not however the case in lake Nulpejauretje since none of the individuals was found to be cannibalistic (Mattsson 2002).

Individual growth and production

The specific growth rate of the PIT tag marked char was very low in lake Nulpejauretje compared to the maximum growth rate of char. Maximum specific growth rate of a 120 g Arctic char at 10 C°, in laboratory was in average 0,97% per day (Brännäs and Wiklund 1992), while it only was 0,08% per day in the weight interval of 70 to 125 g in lake Nulpejauretje at a mean temperature of 10,9 C° during the growth rate measure period in the lake. Compared to the estimated maximum specific growth rate in lake Nulpejauretje during the project period (calculated from Larsson and Berglund 1998), the growth rate was only 2,1 - 9,6 % of the maximum specific growth rate in char between 70g and 125 g respectively, with the highest growth rate in the smallest fish.

The estimated weight dependent function for specific growth rate was based on 29 char in the size interval of 70 to 125 g and with only one single small char weighing 5 g. Thus, the function may not accurately describe growth rate of intermediate sized char. However, comparison with data from another study from the same year suggests that the function does not at least underestimate growth rates in that interval (Byström unpublished data).

The estimated total annual production of Arctic char (≥ 100 mm) in lake Nulpejauretje was 2 kg/ha. This production was higher than estimated annual production in Char Lake, Canada, which was 0,547 kg/ha for char larger than 130 mm (Johnson 1980). One major difference between these two lakes is geographical positions. Char lake is situated at 74 °N compared to lake Nulpejauretje which is located at 65 °N. The production of char in lake Øvre Stavåtjønn (62 °N) on the other hand, was much higher than in lake Nulpejauretje. The annual production in 1979 was 26 kg/ha (i.e. before the reduction of biomass) (Langeland 1986). Thus, these data suggests a negative relationship between latitude and char biomass production in mountain lakes.

Compared to other lakes the *P*/*B* ratio was low in lake Nulpejauretje (0,06). In Keyhole Lake the *P/B* ratio was 0,15 (Johnson 1980) and in lake Øvre Stavåtjønn, Norway this ratio was as high as 0,37 (Langeland 1986), however it was similar to Char Lake (0,06) (Johnson 1980). There is little information about the production and sustainable yield of Arctic char under exploitation (Johnson 1980). This is due to the fact that most experiments and fishing records have been performed on a short temporal scale (Langeland 1995). One common rule discussed in the context of maximum sustainable yield (MSY) is that 10 to 20 percent of the annual production can be removed each year without affecting the population dynamics (Degerman et al. 1998). According to Hammar (1996) is the maximum sustainable yield in mountain lakes often only 10% of the annual production. Langeland (1995) argues that sustainable harvest in small oligotrophic lakes range between two and three kilo per hectare and year. If maximum sustainable yield in lake Nulpejauretje is calculated to be 10 to 20 percent of the production, harvesting may not exceed 0,2 to 0,4 kg/ha and year, which is about ten times less than suggested by Langeland (1995). Degerman et al. (1998) claims that MSY of char in mountain lakes in Sweden is between 0,2 and 3 kg/ha. Thus, the MSY based on the rules of Degerman et al. 1998 in lake Nulpejauretje suggests that production of allopatric char in high mountain lakes may be in the lower part of this interval.

Factors affecting the production estimate

Three factors may have caused an underestimation of the production estimates; reduced growth rates due to marking, increased mortality due to marking and gillnet selectivity. According to Baras et al. (2000) PIT tag marking may depress growth rates during the first two weeks after the marking in fish with a PIT tag/ fish weight ratio of 1,25 % or less. In this study, only the one char of 5 g came close to this ratio, in all other char the ratio was very far from this limit. Thus, even though all char may have been slightly affected by the PIT tag marking only the growth rate in the smallest char might have been underestimated. Removal of adipose fin might also lead to lower growth rates and higher mortality among marked char compared to the rest of the population (O'Grady 1984). However a lower growth rate in marked char doesn't seem to be the case in lake Nulpejauretje. For example: between age eight (weight 96 g) and nine the unmarked char had a specific growth rate of 0,05 % per day. A PIT tag marked char on the other hand with an initial weight of 96 g had a specific growth rate of 0,06 % per day. This indicates that the PIT tag markings has not affected the growth rate negatively, neither has the removal of the adipose fin. Since it was not possible to investigate whether mortality rates were higher among marked char compared to the rest of the population I cannot evaluate the possibility that this has underestimated the population and production estimate.

In the length interval where almost all the recaptured PIT tag-marked char belonged (200-250 mm) no bias due to gillnet selectivity would be expected (Jensen 1995b). However in the total sample, the size structure and thus the population, production and biomass estimates were probably biased towards an overestimation of large individuals and an underestimation of both the smallest char and the total number of char. This is partly due to a higher mobility of larger individuals (Jensen 1995 a, Finstad et al. 2000) and to a lower net selectivity for smaller individuals as small fish may easier detect gillnets in time due to a more finely tuned manoeuvring (Finstad et al. 2000). PIT tag marking, adipose fin removal as well as net selectivity may thus all be factors that could contribute to an underestimation of the production in the lake.

The removal of char will probably have a large influence on the size structure and growth rate in the lake the coming years, since as much as 43% of the char biomass was removed from the lake during the project period. The growth rate will probably increase significantly in the remaining char, leading to a population of larger individuals (Langeland 1986, Amundsen et al. 1993 and Langeland 1995). The older individuals were according to Amundsen et al. (1993) most affected by the reduction in competition and thus had the highest increase in growth rate. The reduction in competition between the remaining char might also give rise to a number of strong year classes during the next years (Amundsen et al. 1993). The char population will probably however go back to the original state after a few years (Johnson 1994, Langeland 1995), in this case a state with many small individuals. But there may be a chance that the reduction of biomass was large enough to push the lake into a new steady state with fewer but larger individuals, cannibalising on smaller char (Amundsen et al. 1991, Amundsen et al. 1993).

Conclusions

Since the estimated production in lake Nulpejauretje was quite low (2 kg/ha) and the production to biomass ratio was low (0,06) the population might be considered as sensitive to a high fishing pressure. When the MSY was calculated as 10% of the annual production it became apparent that only 0,2 kg char/ha could be removed from the lake each year without affecting the char population. Thus, the results from this project suggests that fishing restrictions is necessary in probably many mountain lakes, and care must be taken when setting these restrictions to prevent over fishing.

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