River restoration and habitat improvements in the sub-arctic river Bognelva: effects on anadromous fish

Elve restaurering og habitat forbedring i den sub-arktiske Bognelva: effekter på anadrome fisk

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Master Thesis 30 credits 2010

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By Joachim Bråthen Schedel

Photo: NVE 2009

Preface

This document is the final thesis in my master's degree program in Natural Resource Management at the Norwegian University of Life Sciences (UMB), department of Nature Management. It is written as a script for an article and based on data collected in Bognelva, Langfjordbotn in Finnmark, northern Norway.

There are several people from different institutions that participated in the production of this paper and all deserve a big thank you. First and foremost I want to thank Professor Jonathan Edward Colman for much help with fieldwork and writing, not to mention patience. I would also like to thank Bjørn Otto Dønnum from Sweco Grøner AS and Knut Aune Hoseth at the Norwegian Water Resources and Energy Directorate (NVE) for constructive criticism and guidance. I thank Professor Reidar Borgstrøm for teaching me electro fishing and showing me how to quantify my catches. I also thank Trond Andreassen for help with the practical electro fishing and all the experience and knowledge he shared with me while working together in the river. Langfjordbotn hunting and fishing association (LJFF) also deserves a thank you for the useful background information about the river. Most of all, I must thank Ivar Mikalsen and his family for lending me their house, good company and help during fieldwork. Last but not least, I thank UMB for providing me with the opportunity to complete this paper.

Norwegian University of Life Sciences
Ås, December 2010

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Abstract

Alterations of watercourses in the form of channelization, dam building and digging of dikes has been ongoing for centuries. This has eliminated much of the vital natural variation found in rivers that is necessary for optimal fish habitat, and thus, a major cause of declines of the fish population in many watercourses. In recent times, these effects have been recognized and efforts to restore these altered rivers have been initiated. I examined the river Bognelva located in northern Norway to test whether restoration measures improved conditions for the salmonid species Trout (*Salmo trutta*), Atlantic salmon (*Salmo salar*) and Arctic char (*Salvelinus alpinus*). Restoration measures included removal of flood banks, improvements of erosion control, opening of old side channels and tributary streams, placement of boulder groups and creation of weirs. The river was divided in sections at restored and un-restored sites and electro fished to investigate whether changes occurred in the number of fish compared to previous counts. Furthermore, a number of environmental variables were registered to test how and why restoration measures may or may not have improved fish habitat as predicted. Trout showed the greatest gain from restoration. The most important cause for this was the re-opening of side channels that proved to be "full" of small (<60 mm) trout. Salmon gained most benefit from flood bank removal and other restoration measures in the main river. Arctic char represented a very low percentage of the catch and therefore were difficult to include in the study of specific restoration measures in this study. Because shallow habitats that represent known "trout habitats" were over represented in the sampling sites, there was likely a bias towards catching more trout. Overall, side channel and tributary re-openings and flood bank removal were the restoration measures that had the most positive effects. Comparing catches from previous years before restoration measures were begun confirmed a large increase in the trout population most likely resulting from restoration measures.

Sammendrag

Endringer av vassdrag i form av kanalisering, bygging av demninger og grøfting har pågått i århundrer. Dette har eliminert mye av den livsviktige naturlige variasjonen som finnes i elver som er nødvendig for et optimalt fiske habitat, og er dermed en viktig årsak til nedgangen i fiskebestanden i mange vassdrag. I nyere tid har vi blitt klar over disse effektene og arbeidet med å gjenopprette disse endrede elvene er igangsatt. Jeg undersøkte elven Bognelva, som ligger i Nord-Norge, for å teste om restaureringstiltakene hadde bedret forholdene for laksefisk artene ørret (*Salmo trutta*), atlantisk laks (*Salmo salar*) og røye (*Salvelinus alpinus*). Restaureringstiltakene inkluderte fjerning av flomvoller, forbedringer av erosjonssikringsanleggene, gjenåpning av gamle sidekanaler og bekker, utlegging av steingrupper og bygging av terskler. Elva ble delt inn i seksjoner på restaurerte og urestaurerte strekninger og elektro fisket å undersøke om det var endringer i antall fisk i forhold til tidligere tellinger. Videre ble en rekke miljøvariabler registrert for å teste hvordan og hvorfor de enkelte restaureringstiltakene bedret eller ikke bedret habitatet for fiskene som spådd. Ørret viste størst gevinst fra restaureringen. Den viktigste årsaken til dette var gjenåpningen av sidekanalene som viste seg å være "fulle" av små (<60 mm) ørret. Laks hadde fått størst utbytte av fjerningen flomvoller og de andre restaureringstiltakene i selve hovedelven. Røye ble representert av en svært lav prosentandel av fangsten, og var derfor vanskelig å inkludere i studiet av konkrete restaureringstiltak i denne studien. På grunn av en overrepresentasjon av grunne habitater, som representerer kjente "ørret habitater", var dette sannsynligvis et bias, noe som gav en tilbøyelighet mot større fangster av ørret i forhold til de andre artene. Generelt sett var det gjenåpningen av sidekanalene og bekken samt fjerningen av flomvollene som var de restaureringstiltakene med mest positiv effekt. Sammenligning med fangstene fra tidligere år før restaurerings tiltak ble påbegynt, bekreftet en stor økning i ørret bestanden, mest sannsynlig som følge av restaureringstiltakene.

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Introduction

Rivers can provide a vast amount of services to humans. Mankind began early to build structures and change the natural aquatic environment to increase fishing harvest and/or to control the flow of water to capture energy or promote irrigation. These structures and changes, many of which continue today, were often unsustainable and destructive to the natural ecological functioning of the environment. Various ecosystem services (for example, clean water, fishing and hunting, swimming, boating and other recreational uses) of many rivers and their connected areas were negatively influenced from our invasive actions.

Rivers are under the influence of numerous natural processes. They tend to have one or more annual floods and in low gradient sections tend to meander out into the surrounding landscape. Processes such as flooding can be unfavorable and unpredictable for human settlements, causing damage to anthropogenic structures or landscapes in flood areas. In an effort to control and protect ourselves from various natural processes, we build dams, dikes and channelize sections or entire rivers and streams.

River channelization is defined as *the alteration of a natural stream by excavation, realignment, lining or other means to accelerate the flow of water* (Landy 1979). *It frequently involves straightening and shortening natural fluvial contours, destruction of riffle-pool sequences and the removal of accumulated debris* (Kelly & Bracken 1998). Side channels and small tributaries also tend to be closed off from the main river channel. Channelization results in loss of structural complexity, simplified flow patterns, and decreased availability of microhabitats for a wide array of lotic organisms (Petersen et al. 1987). Another typical result is reduced species diversity and population densities (Carline & Klosiewski 1985). Globally, this is the type of encroachment in watercourses that is causing the majority of stream habitat loss and degradation, making it a serious threat to biodiversity in running water ecosystems (Allan & Flecker 1993; Petersen et al. 1987).

In Norway, channelizing is presently becoming much less common than it was in the 1900s. Channelization often leads to an overrepresentation of lotic habitats compared to lentic habitats (Welcomme 1979), severely reducing the quantity and quality of habitats for wild salmonids (Armantrout 1981; Heggenes 1988). This in turn results in reduced productivity and recruitment of salmonid species. Ecological problems resulting from these encroachments are not the only challenge, salmonids and especially salmon (*Salmo salar*) have great commercial and recreational value for anglers worldwide. Hence, the loss of salmon populations is a great loss of potential income and socioeconomic value. The devastations caused by these manmade changes to many of the natural watercourses became more recognized during the end of last century. Eventually, and as our knowledge about natural river systems has improved, we have begun making efforts to restore and rehabilitate altered watercourses (Cowx & Welcomme 1998; NRC 1992).

Rivers that have economic or cultural value are the ones that are restored or rehabilitated in most instances (Roni et al. 2008). Presently, many different types of restoration or rehabilitation are used to mitigate previous degradation (Swales 1994). The restoration is conducted at various scales from parts of single reaches to entire watersheds. The most commonly used type of measures is the reconnection of old flood plains or side channels, addition of in-stream structures like boulders, weirs (a low dam built across a stream to raise its level or divert its flow) and logs (Roni et al. 2008) and re-meandering (the recreation of curves and pools). Although many restoration projects have been conducted, our knowledge about which projects reach their goals and what type of measures are best remains limited. Monitoring of the restoration or performing studies to assess the results has been in many instances neglected when projects are planned and implemented (Frissell et al. 1992; Kondolf et al. 1996). Without monitoring, it is difficult to assess whether the restoration is successful or not (Kondolf et al. 1996), and without testing specific measures, knowing why and/or how restoration works will remain unclear.

In 2003, the Norwegian water and energy department (NVE) made a list of 90 potential environmental measures in waterways (Hamarsland et al. 2003). Over 62 safeguard and environmental measures were implemented or under implementation in 2007. Around 5 % of the cost/expenses of these were specifically used for environmental measures like river restoration and biotope adjustments (Øvre et al. 2008). In 2008, this number had increased to about 70 flood protection and environmental measures (Øvre et al. 2009). Pre- and post evaluation of many of these projects have been conducted. However, knowledge is still lacking about the effectiveness of specific restoration measures used in various projects. Therefore, it remains difficult for project managers to decide what type of measures function appropriately at different restoration sites. Hence, many environmental measures that are implemented could be useless in achieving a project’s goals.

Fish and macroinvertebrates are often the target organisms in restoration and are frequently used in monitoring programs (Karr & Chu 1999; Rosenberg & Resh 1993). This study focused on testing affects of various restoration measures on young (less than 25 cm long) salmonoid fish in the Bognelva river (from here after only Bognelva). Using electro-fishing, I collected samples of young Atlantic salmon (*Salmo salar*), trout (*Salmo trutta*) and Arctic char (*Salvelinus alpinus*) at predefined sections of Bognelva that represented either restored or un-restored sections, as well as newly opened side channels. Numerous habitat measurements were recorded (repetitively) at all sites. I investigated whether the present restoration practices were achieving their set goals of improving the habitats for fish production. Furthermore, I determined which of the common restoration measures used were most useful at reaching these goals and also use my knowledge to identify areas that need improvements. I tested two hypothesis; H1: areas that were restored will have higher densities of young fish than areas that were not restored and that there was an overall increase in fish density after restoration compared with samples taken during two separate years before restoration was begun. H2: young fish favor more heterogeneous habitats. Importantly, I also tested which of the restoration measures or habitat factors best explained young fish densities in Bognelva.

Method

Study area

The study was conducted in Bognelva (Bávnnjajohka) in the county of Finnmark in northern Norway. The start of the river lies in the mountains along the border between the counties Troms and Finnmark (Fig. 1). The catchment area is approximately 89 km^2, and the river drains to the innermost part of Langfjorden ("the long fjord") at Langfjordbotn (UTM: 549400 E, 7768800 N), a small community with around 140 inhabitants. The average discharge from the river is about 7 m^3/s in July and about 3 m^3/s in the months August, September and October (NVE 2005).

The last 4 km runs through an agricultural landscape where erosion- and flood protection measures, including extensive channelization, was conducted on several occasions between the 1930's and early 1990's (NVE 2005) (Fig. 2). Before these modifications, natural fluvial processes dominated the river and it supported a rich population of salmon, sea trout and sea char (NVE 2005). After the channelization (see Appendices), the lower 4 km of the river lost many of its natural fluvial processes together with many suitable habitats for salmonids.

In 1972, NVE was notified by LJFF (Langfjorden Jeger- og fiskeforening) that the salmon catches had been severely reduced. This led to some small attempts towards improvements in the form of a weir and the placement of some large stones in the river. In 2002, LJFF attempted another effort to implement restoration measures without successful approval from NVE. Finally in 2004, they were successful in convincing NVE to prioritize a plan for the restoration of Bognelva. Following detailed organization and planning, LJFF and NVE began restoration activities in the river in autumn 2005.

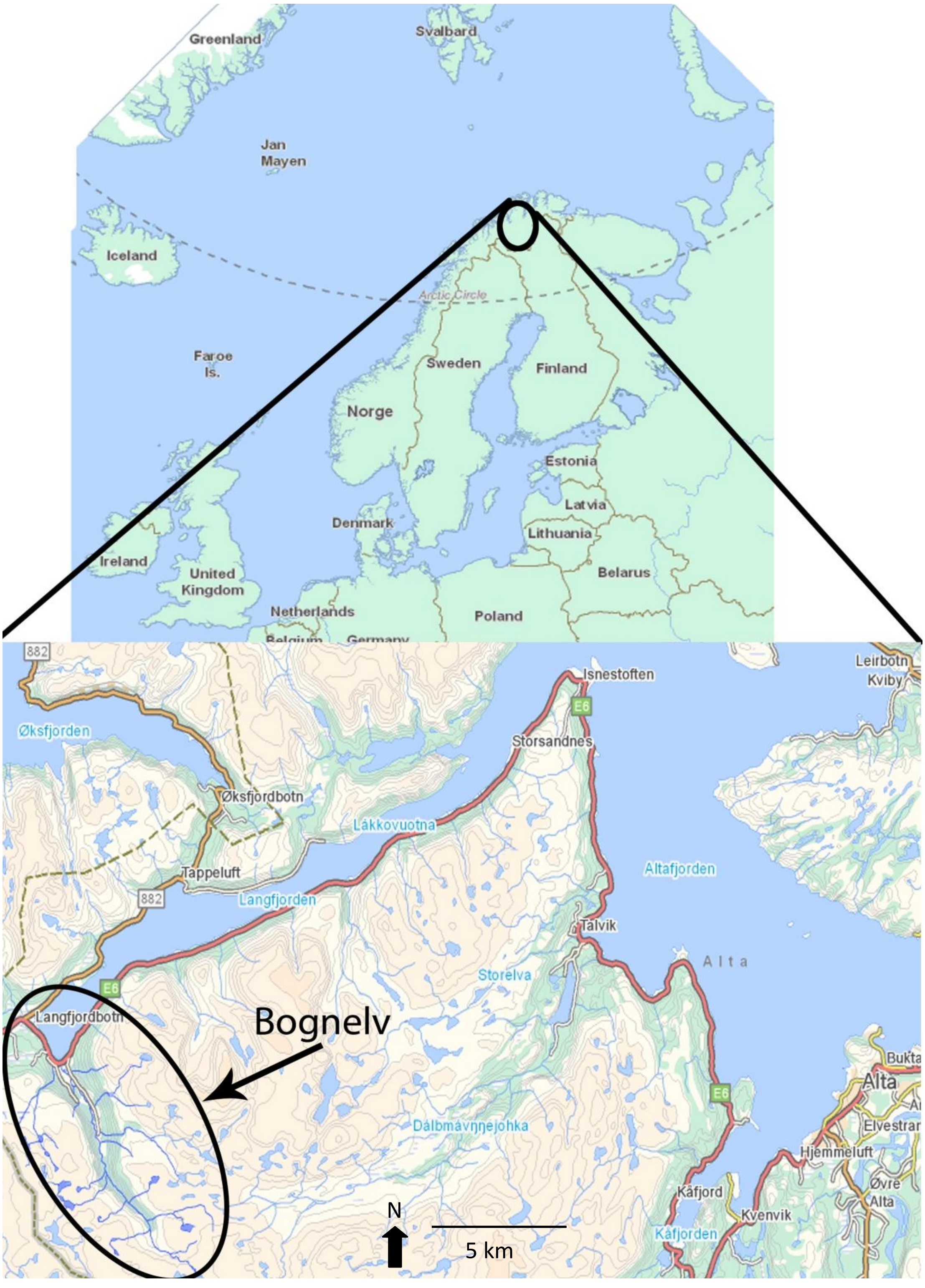

Figure 1. The Bognelva River (black circle), located near the border of the Troms and Finnmark counties (the grey dotted line south-west of the river valley in the lower left corner of the picture), Northern Norway.

Figure 2. Orthophoto over the same lower section of the Bognelva river taken in 1946 before channelization (top) compared to after channelization over many years taken in 1972 (bottom) (Norges Flyfoto arkiv).

Restoration measures

A total of nine restoration measures were suggested in the plan of 2005 (NVE 2005) (see Appendices). These focused on erosion control, flood bank and channel restoration, floodway/side channel systems, tributary streams, improving access to the river for fishing and outdoor activities, and biotope measures in the channelized stretches. In 2008, four of these nine measures had been conducted. The first measures were number three and five and were finished autumn of 2006 (NVE 2006a; NVE 2006b). Measures three included removal of a short stretch of the flood banks and opening two side channels, some minor digging work and placement of stone groups that acted as weirs to aid the flow of water through the side channel. Number five consisted of removal of flood banks and re-opening a side channel so that old wetlands could get rejuvenated. Much of this resulted in more current variation, natural pool creation and increasing the water covered area bordering to riverine vegetation. Erosion control for neighboring agricultural land was kept intact, but arranged so that natural erosion could occur. Measures number four and six in the plan of 2005 (NVE 2005) were finished autumn 2007. Number four consists of opening the small tributary stream, Mikkelveita, which was thought to be a potentially important spawning and nursery area for trout and Arctic char (Dønnum 2005). Number six included moving and improving old flood banks to create a more natural flow pattern in the river. During this last work, boulder groups along the river stretch were designed to create flow and habitat heterogeneity. These boulder groups would also function as resting and shelter areas for fish and invertebrates. The final and concluding restoration measure were planned to be conducted during summer of 2010.

Sampling methods

Sampling occurred in summer of 2008 and was conducted during two visits. The first visit was between July 8 -15. During this brief visit, sampling sites along the river and surrounding floodplain/river valley were prepared. Fifteen meter sections at chosen sample sites were measured with a measuring tape and marked with red spray paint on the ground well above the water line.

Sample sites were chosen from the outlet of Bognelva to about 3 km upstream. Sections were set up on both riverbanks, in the main river channel, in side channels that were newly opened and in the tributary (Mikkelveita) (Fig. 3). A distance of at least 20 meters was allowed between sections. A total of 52 sections were prepared; 33 in the main river channel, 6 of which were in river stretches where restoration measures were conducted. The remaining 19 sections were situated in side channels and the tributary. Two more sections situated further upstream than the first 52 were chosen during the second visit. Additionally, both water and air temperatures were measured for the first 52 sections during the first visit. Air temperature was measured at approximately 1 m above ground and water temperature was measured 1 meter from the riverbank and approximately 10 cm over the bottom of the streambed.

The second and last visit was between August 20th and September 8th. Each section was divided into four transects where the riverbed profile and substrate, water velocity, depth, temperature and number, size and species of fish were registered (Fig. 4).

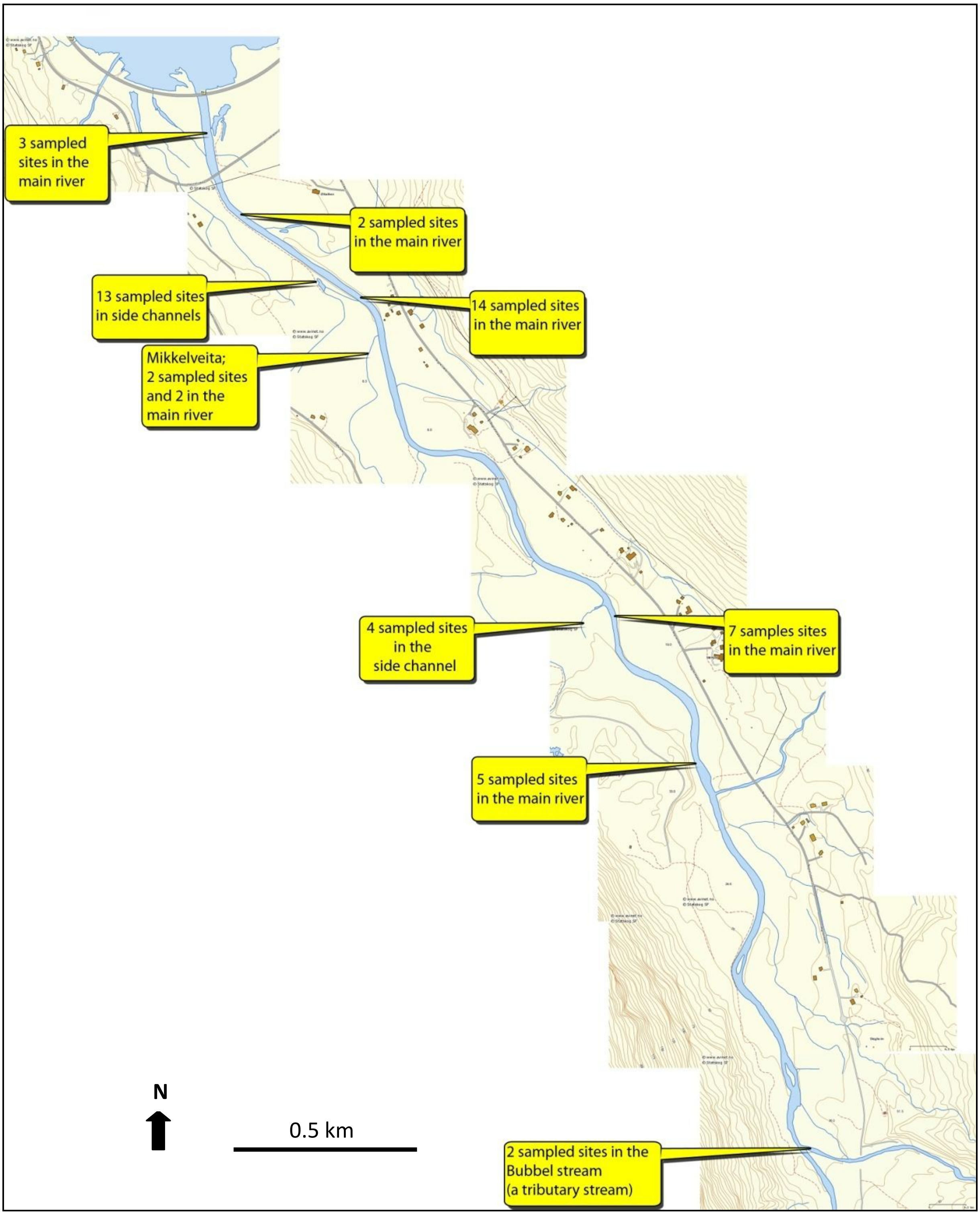

Figure 3. The Bognelva river with location of the sampled sites in 2008.

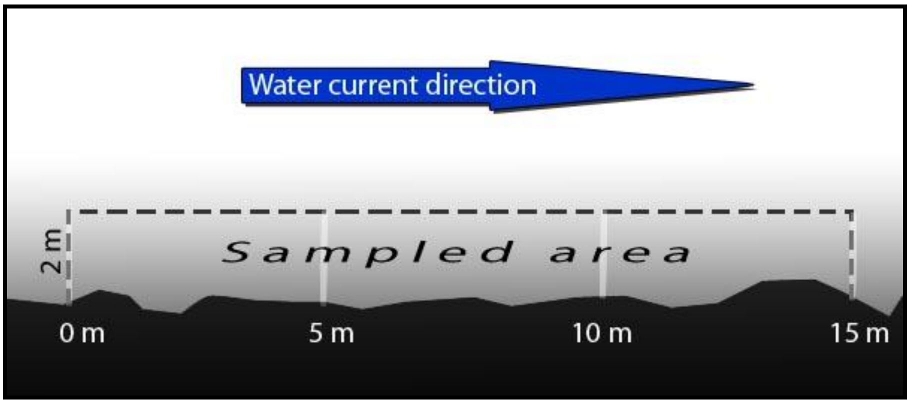

Figure 4. A sampling site with the sampled area inside of the dotted line.

The profile of the riverbed was recorded with a specially made “contour/profile capturer” with eighteen aluminum rods suspended through a sliding frame (Lepori et al. 2005a; Muotka & Laasonen 2002; Young 1993) (Fig. 5). Each rod was a 2 m ruler with cm marks that glided freely up and down within the frame. The contours of the riverbed, or riverbed’s profile, was recorded by setting the frame with the rods on the bottom and reading of the length of each rod sticking up from the sliding frame. The frame was automatically kept level because of potential tension caused by the 18 rods working in accord. The eighteen lengths from each rod/ruler were subtracted by the smallest length to get a relative measurement of the riverbed profile. The variation between these 18 numbers was used in the analysis. This was done four times along each transect; one measure at 0 meters (at the start) and every 5 meters after that. Profile measurements were done 1 meter from the riverbank where the width allowed it. Otherwise, they were taken in the center and deepest part of the stream. The frame was always placed such that the frame and the 18 rods were parallel to the riverbank.

Figure 5. The contour/profile measurement device in use in the Bognelva river. Photo: Jonathan E Colman 2008.

Water velocity was measured with an OTT C31 Universal Current Meter and a CMC-200 counter (Fig. 6). Measurements were done 0.1 m over the river bed and additionally at 60 % of the total depth when the depth was 0.4 m or more. Along each transect, the velocity was measured for every 0.4 m out to 2 m. The velocity was categorized into calm (0.0-2.9 cm/s), slow (3.0-25.9 cm/s), medium (26.0-51.9 cm/s) and strong (52.0 cm/s and more) current. At some points where the water depth was too low or where algae made it impossible to make a satisfactory measurement, visual estimates based on previous measurements were done. Water depth and temperature was measured at every point were velocity was measured.

Figure 6. Author holding the C31 Universal Current Meter and a CMC-200 counter in the Bognelva river. Photo: Jonathan E Colman 2008.

The riverbed substrate in each transect was classified according to a predefined scheme. The categories were: mud, just small gravel/sand, some small stones with medium stones, mostly medium stones with some small stones, mostly medium stones with some large stones, mostly large stones with some small/medium stones and just large stones. Small stones were <0.1 m in diameter, medium 0.1-0.5 m and large >0.5 m. This is a self created classification scheme based on a grain size scale after Wentworth (1922). If large woody debris (LWD) was present at a section this was also registered. LWD is woody debris with a diameter of at least 0.1 m and a length of at least 1.0 m (Gregory et al. 2003). Large concentrations of small woody debris were also noted.

Each section was electro fished using the removal method (Bohlin et al. 1989; Seber & LeCren 1967; Zippin 1958). When the density of fish was large, three removals were conducted. When the density was very little or no fish were caught on the first removal, only two removals were conducted at the section. Fish caught at the sections were stored in buckets of water between removals. When the fishing of a section was completed, total length and species was recorded. Most of the fish were sedated with clove oil to make measuring easier and to reduce stress for the fish. Following resuscitation in a bucket with freshwater, fish were released back into the river. No mortalities were recorded.

Statistics

Data analyses were done with Minitab version 15. Some calculations were also done using Microsoft Excel 2007. The variables water current velocity and substrate were given numerical categories. Water current was categorized 1 to 4 and the substrate 0 to 6. Since, in most cases, there were five measurements per transect and four transects per section of the water current velocity, the median of these was used as the overall water current for the section. The substrate measurements were done four times per section and the section median was used. For LWD, the total per section was used. To get one number for the vegetation cover per section, the total of all transects at each section was used. For both water depth and temperature, the mean was used.

To estimate the density of the fish at each section, the methods and equations in Bohlin et al.(1989) was used. The densities at sections used to do analyses between years and between sections per year were standardized to number of fish per 100 m^2.

The main statistical tests used were, ANOVA, GLM, Regressional analysis and Pearson correlations.

Results

Electro fishing in 2008 found 91.04 % trout (N=691), 8.43 % Atlantic salmon (N=64) and 0.53 % Arctic char (N=4). Arctic char were larger than both trout and Atlantic salmon (206 ± 26 mm, 73 ± 41 mm and 88 ± 32 mm, respectively) (Fig. 7).

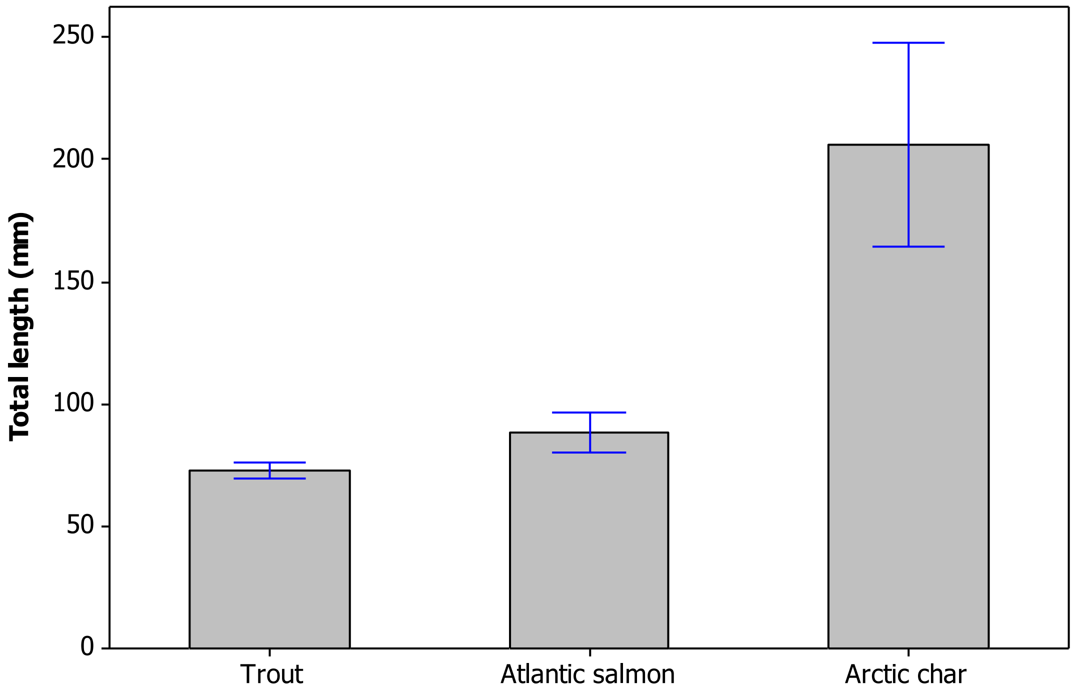

Figure 7. Mean sizes of species with 95 % confidence intervals.

Analysis of the total lengths of the fish caught resulted in dividing trout and Atlantic salmon into three age classes (Table 1). A similar analysis of the Arctic char catches was not possible due to low numbers.

Table 1. Total length intervals and their respective age classes.

Total length (mm)	Age class
25-60	0+
60-90	1+
≥90	2+ and older

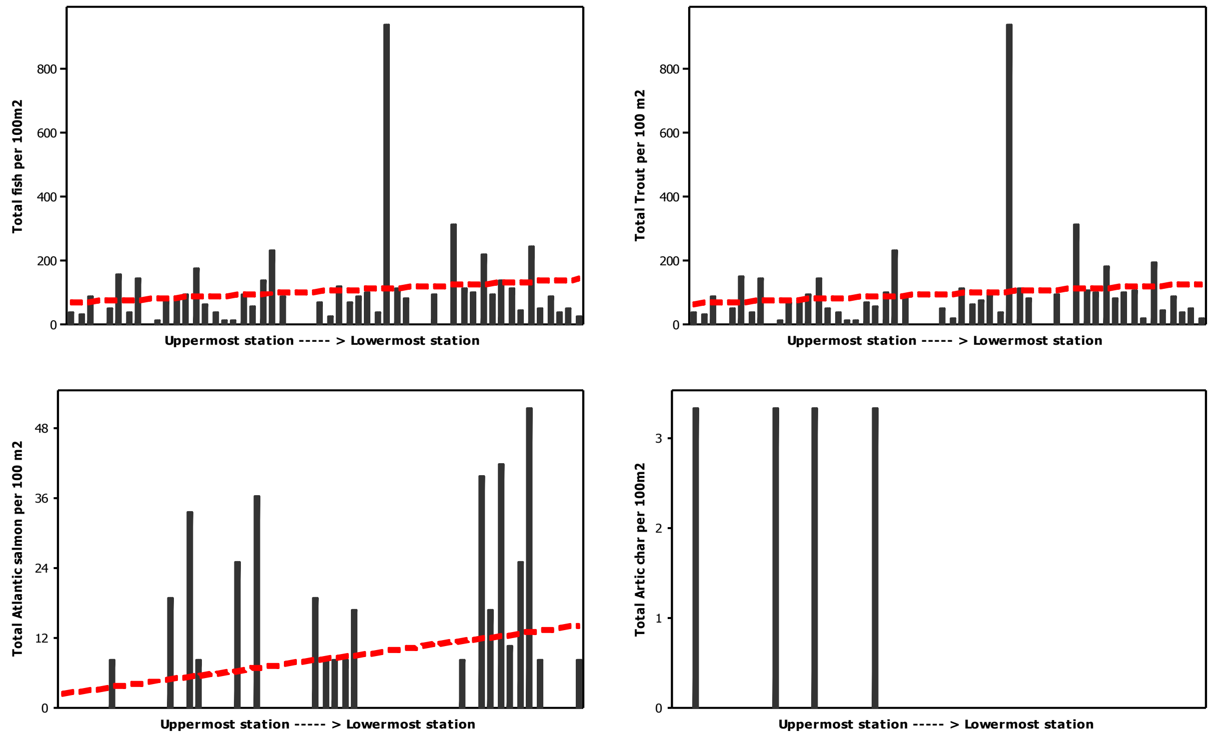

Figure 8. Plot of overall and species density versus catch location in the Bognelv river. Stipulated line indicates trend.

The densities of fish were plotted against the catch location in the river (Fig. 8). Overall and for both trout and Atlantic salmon, there was a trend for more fish caught as you move closer to the outlet of the river. Most Arctic char caught were caught in the upper half, above the outlet of Mikkelveita (one was caught 100 m down from the outlet), of the study sites.

Analyses of age classes, location and fish per 100 m^2 with habitat factors as covariates using data from 2008 (Fig. 9) showed that overall, there were more trout than both Arctic char and Atlantic salmon ($p= 0.0132$ and $p < 0.000$). Atlantic salmon were also more numerous than Arctic char ($p < 0{,}000$). Estimation of the percentages of the total density at the three different locations, main river channel, main river channel with measures and the side channels and the tributary gave 28.37, 24.95 and 46.67 % respectively. Trout dominated at all locations with the largest catch in the side channels and the tributary (Fig. 9). All Atlantic salmon were caught in the main river channel with and without measures. There was a significant difference between all three species in the main river. Trout is more numerous than Atlantic salmon, which is more numerous than Arctic char (all comparisons $p < 0.000$). All three age classes of trout are more numerous than all age classes of the two other species ($p < 0.000$). When considering the position of capture in the analyses, the following is apparent; trout age class 0+ were more numerous than Atlantic salmon of the same age class in the main river and in the side channels and tributary ($p > 0.000$). Trout age class 1+ at all positions were more numerous than Atlantic salmon of the same year class and the same positions ($p < 0.000$ and $p = 0.0153$ for the side channels and tributary). Trout age class 2+ and older were more numerous than Atlantic salmon of the same age class in the main river ($p = 0.0382$). Atlantic salmon age class 2+ and older were more numerous than Arctic char in the main river ($p = 0.0025$). Trout age class 2+ and older was more numerous than Atlantic salmon of the same age class in the main river with measures ($p < 0.000$). Comparisons of all age classes and positions of trout and Arctic char with the corresponding age class and position showed that trout were more numerous in all cases ($p < 0.000$) except for age class 2+ and older in the side channels and tributary. Trout age class 0+ were more numerous than both age class 1+ and 2+ and older in the side channels and tributary ($p = 0.0075$ and 0.0001 respectively). The age class 2+ and older of trout was less numerous in the side channels and tributary than in the main river with measures ($p = 0.0049$). 25.5 % of the total trout caught were in the side channels and tributary. The tributary, Mikkelveita, was only estimated to house 11 trout per 100 m^2. No Arctic char or Atlantic salmon were caught in the side channels or the tributary. All Atlantic salmon 2+ and older were caught in the main river channel without measures.

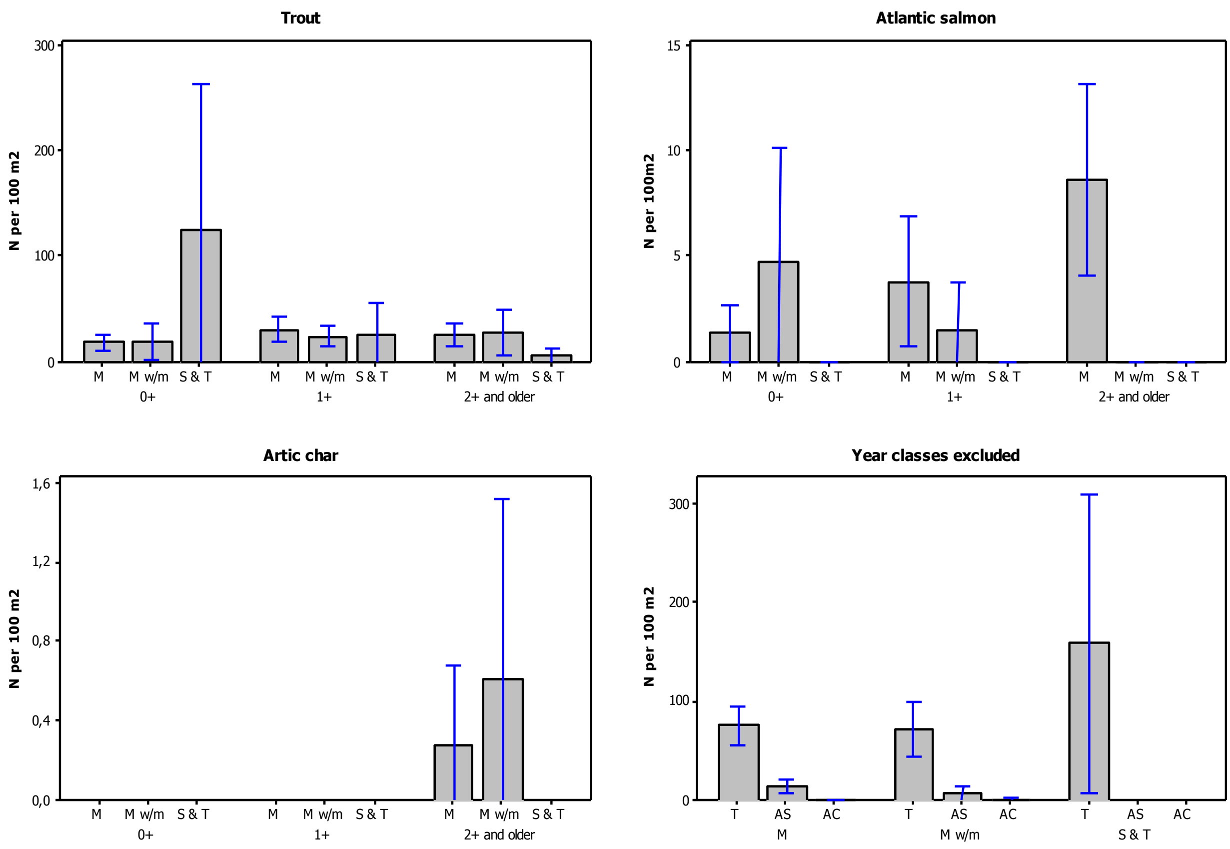

Figure 9. Distribution of age classes and species at the three locations against the mean fish number per 100 m^2. Lower right diagram shows overall species densities at the different locations. 95 % confidence intervals shown with vertical lines. (M = main river, M w/m = main river with measures, S & T = side channels and tributary)

Regressional analysis with species, year class, position and all habitat factors gave a significant equation (R^2 = 46.6 %, $p < 0.000$), but with only species as the significant predictor ($p < 0.000$). The best subset of predictors were species, year class, position, current speed, large woody debris, vegetation coverage, substrate/stones, water temperature and bottom profile. This equation (R^2 = 45.9 %, $p < 0.000$) showed species ($p < 0.000$), current speed ($p < 0.046$) and substrate/stones ($p < 0.028$) to be significant predictors.

Analysis of correlations between total fish numbers, species, the different age classes and the habitat factors are summarized bellow (Table 2). Only significant correlations are shown. All correlations that were between fish numbers, species and age classes were positive. Current speed correlations, which was found to be significant in the regressional analysis, were all negative and in the main river with and without measures. Substrate/stones correlations are all positive.

Table 2. All significant correlations, their location and their polarity. M = main river channel, M w/m = main river with measures, S & T = side channels and tributary.

	Location	Total fish	Total trout	T 0+	T 1+	T 2+ and older	Total atlantic salmon	AS 0+	AS 1+	AS 2+ and older	Total arctic char	AC 0+	AC 1+	AC 2+ and older
Total fish	ALL		+	+	+									
	M		+		+	+	+		+	+				
	M w/m		+				+	+						
	S & T			+										
Total trout	ALL			+	+									
	M				+	+	+		+	+				
	M w/m					+	+	+						
	S & T			+										
T 0+	M w/m						+	+						
T 1+	ALL						+		+					
	M						+		+					
	M w/m						+		+					
	S & T					+								
T 2+ and older	ALL						+			+				
	M						+			+				
Total atlantic salmon	ALL							+	+	+				
	M								+	+				
	M w/m							+	+					
AS 0+	M w/m								+					
AS 1+	ALL									+				
Current speed	ALL		−	−										
	M	−	−											
	M w/m	−	−				−	−						
Depth	ALL			−		+								
	M			−		+								
LWD	ALL				+									
	M w/m										+			+
	S & T				+	+								
Vegetation	ALL					+	+			+				
	M w/m					+								
	S & T				+	+								
Stones	ALL					+	+				+			+
	S & T	+	+	+										
Water temperature	ALL								−					
Bottom profile	ALL					+								
	M					+								
	M w/m					+	+							

ALL
M
M w/m
S & T

Analysis of the three different years 1998, 2004 and 2008 and the total number of fish, not considering the species, showed a significant effect of both year and species ($p < 0.000$). There were more fish overall in 2008 than in 2004 ($p < 0.000$). Including species (Fig. 10) showed that there were more trout in 2008 than in 2004 ($p < 0.000$). Trout in 2008 were more numerous than all species in 2004 ($p < 0.000$). For 1998, the only difference found were between Arctic char of that year and trout of 2008, which were more numerous than Arctic char ($p < 0.000$).

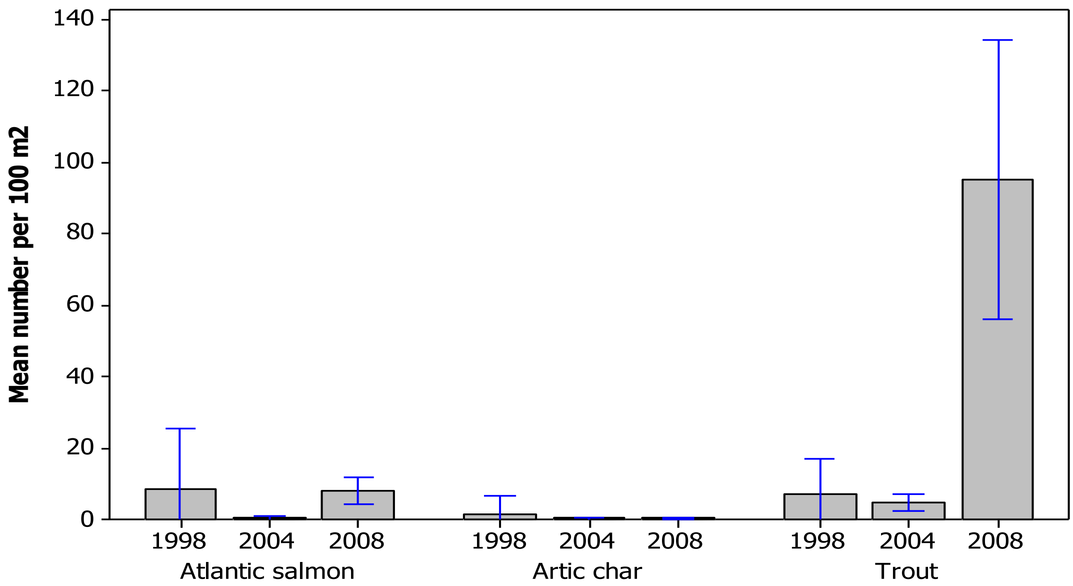

Figure 10. Mean number of fish per 100 m^2 in the different years. 95 % confidence intervals shown with vertical lines.

Discussion

The most common types of river alterations in Norway were meant to ease timber floating, allow the production of hydro power and increase agricultural production (Hamarsland et al. 2003). The latter was conducted in Bognelva and included channelization. River or stream restoration and rehabilitation have now become a common practice in Norway. There are examples of good projects, but there still remains a large potential for increasing and improving this type of work. Importantly, many of these projects lack good and thorough monitoring of post-restoration results. Lack of funding and to some extent knowledge could explain this. Hence, little is known about the effects of numerous restoration projects throughout the country. For success in future restoration projects, knowledge towards what measures work for the different species and habitats must be gathered and made available for others. I investigated specific restoration measures and their effects on the populations of young anadromous fish in Bognelva. There was varying results at this point in time.

There was clearly life in the river and many of the restored sites were utilized by fish. Looking at the species from 2008, the smallest trout, age class 0+, were most numerous. This was a result of the large catches of small trout in the side channels. These sites posses various characteristics of the preferred habitat for young trout (Heggenes 1988). They have shallow riffles and cobble substrate. They also provide shelter from high currents in high water level situations like annual floods. Inter- and intraspecific predation from larger individuals is also reduced at side channel sites. The age class 0+ of trout was significantly more numerous compared to the two larger age classes in the side channel sites, indicating that this habitat was a prime habitat for young newly hatched trout and not preferred by the larger trout. Comparing the difference between the habitats for trout age class 1+ showed no significant differences. There was significantly less trout age class 2+ and older in the side channel sites compared to the main river with restoration measures, and no difference between main river sites without measures and those with measures. Catches of larger individuals than 90mm were very small in the side channels and the tributary. This could indicate that trout change habitat as they reach lengths between 60 and 90 mm, moving out into the main river. This coincides with previous studies of this specie in rivers (Roussel & Bardonnet 1999). They found that trout during the first year reside in shallow areas (< 30 cm deep), often located along the river bank with moderately fast flowing water (0.2-0.5 m/s). When their age and size increases, they move to deeper, more slowly flowing areas of the stream (Heggenes et al. 2002). It has also been found that trout prefer slow flowing water when the water temperature is lower than 8°C (Heggenes & Dokk 2001). The mean temperature of the river was low (mean ± S.D. Main river = 7.6 ± 1.3°C, Main river with measures = 8.9 ± 1.5°C and Side channels and the tributary = 8.4 ± 1.3°C) and coincides with what was found in this previous study.

No Atlantic salmon were caught in the side channel sites or in the tributary. When living sympatric with trout and or Arctic char, trout and Atlantic salmon have been shown to have extensive niche overlap, although Atlantic salmon have a tendency to segregate to sites with faster currents (Armstrong et al. 2003; Heggenes et al. 1999; Heggenes & Saltveit 2007). The slow flowing current (median current category calm (0.0-2.9 cm/s)) in the side channels was therefore not preferred by salmon. It has been shown that trout are more aggressive than salmon of similar size (Harwood et al. 2002; Kalleberg 1958). This dominance relationship affects the spatial (Kennedy & Strange 1986) and temporal (Harwood et al. 2001) resource use for the Atlantic salmon and forces them into other habitats in the main river. Atlantic salmon age class 0+ had a tendency to be more numerous at the sites with restoration measures. From age class 1+ and older, young salmon tended to be more numerous in the main river at sites without measures. No Atlantic salmon in age class 2+ or older were caught in the main river sites with restoration measures. This could indicate that larger Atlantic salmon individuals move further from the river's littoral zone to areas with stronger currents as they grow. These stronger currents can result in underestimations because spotting and catching fish is made more difficult (Bohlin et al. 1989). Therefore, the few good Atlantic salmon sampling sites that were fished probably gave an underestimation of the density. Furthermore, since they stay in habitats with stronger currents, smaller individuals would be harder to spot and catch than the larger individuals. The new habitats created by the restoration measures in form of medium sized stones and more varied substrate and a slower current is a better habitat for small, 0+ and 1+, Atlantic salmon. Larger individuals could have a competitive advantage further out from the littoral zone since they are better adapted to the faster flowing currents (Klemetsen et al. 2003). Furthermore, hiding spots between stones in the littoral zone might be too small. The stone size increases towards the middle of the river and likely offers better hiding spots for larger individuals.

Arctic char almost exclusively occupy lakes (Halvorsen et al. 1997; Klemetsen et al. 2003). In some cases, they are also found in rivers, both as stationary and as anadromous Arctic char (Heggberget 1984; Heggenes & Saltveit 2007; Power 1973). The tendency for this species to become anadromous increases with latitude (Klemetsen et al. 2003). In these latitudes, Arctic char often coexist with trout and Atlantic salmon (Halvorsen et al. 1997; Klemetsen et al. 2003; Power 1973). When the three species live sympatric in rivers or streams, Arctic char tend to segregate from the two other species. Arctic char is then mostly found in more slow current, deep pool habitats (Heggenes & Saltveit 2007), and in the colder, uppermost parts of rivers or groundwater fed streams (Brabrand et al. 2005; Power 1973). This segregation is likely to be the result of both innate selective differences and interference competition (Heggenes & Saltveit 2007). Electrofishing in these slow flowing deep areas is inefficient (Bohlin et al. 1989) and was therefore not sampled. Hence, the typical Arctic char habitats were unfortunately very much underrepresented in this study. This partly explains the very small catch of Arctic char in the present study. All individuals caught were relatively large (206.3 ± 26.1 mm) and from the main river sites with and without restoration measures. There was a slightly larger catch on the sites with restoration measures, though not significant. The Arctic char individuals caught in this study might have been randomly swimming through the sample sites looking for food or on the move to a new location. The small catch indicates either a sampling flaw for Arctic char, or that their preferred habitat was elsewhere and that the restoration measures conducted have not yet improved the Arctic char population in this river.

Trout at all sites are more numerous than the two other species. The catches in the side channel sites and the tributary were very likely a true reflection of the species composition in these locations. The entire width of the sample site was fished, and fish were easy to spot in these areas. The large number of trout in the side channel and tributary sites indicates that the re-opening of these areas as a restoration measure has had a very positive influence on this species. The catches in the main river both at sites with measures and without is likely biased for trout. This was caused by the specific section of the river sampled at each site, that were mainly located in the littoral zone were low currents and shallow water dominate (Armstrong et al. 2003; Heggenes et al. 1999; Heggenes & Saltveit 2007). Hence, the catches of trout could have become very large compared to the other species. As mentioned earlier, there are overlapping habitats between trout and Atlantic salmon, although the main habitat of the latter is in faster currents towards the middle of the river. This has likely resulted in an underestimation of the Atlantic salmon numbers for the entire river and the specific sites.

There was a certain amount of overlap between the habitats used by Atlantic salmon and trout as found in previous studies (Armstrong et al. 2003; Heggenes et al. 1999; Heggenes & Saltveit 2007). Trout from age class 1+ and older tended to stay at the same areas in the side channel sites. The overlap was found for Atlantic salmon age class 0+ and 1+ in the main river sites with restoration measures. There was also an overall overlap between Atlantic salmon from age class 1+ and older. The age class 0+ for both of these species showed an overlap in the main river with restoration measures. The same was found for the age class 1+ between these two species in all site categories (not side channels and the tributary) and overall. Lastly, an overlap between the two species age class 2+ and older in the main river sites without measures was found. Arctic char did not show any overlapping tendencies.

The most influential habitat factors on fish catches were current speed and substrate type. Less fish got caught with increasing current speed, especially the smallest individuals of trout and Atlantic salmon. This was not found for Arctic char, likely because of the small catch of these as mentioned above. A reason for the low catches at higher current speeds could be a result of increased difficulty of catching and spotting the fish in these instances (Bohlin et al. 1989). Substrate type was categorized from very fine, in the form of mud, to coarse, in the form of large boulder-like stones. There is a tendency towards larger catches in sites with larger stones. Sites with large stones offer greater possibilities to hide and find shelter from various threats. They also create an area with reduced current where fish can rest. Other habitat factors that had a significant effect were the river bed profile, the presence of large woody debris (LWD), vegetation cover and depth. Temperature also showed a minor negative effect on Atlantic salmon, however the temperature variation during the study was very small. A more varied or heterogeneous river bed had a tendency to provide larger catches. This was mostly found for larger (ca. ≥60 mm) individuals. A reason for this could be that the method used to measure this was not able to pick up variation on small scales, which is very important for the smallest (ca. <60 mm) individuals. The presence and larger number of LWD gave larger catches of trout and Arctic char. Sites with more vegetation cover resulted in higher catches. This was more pronounced for the larger (ca. ≥60 mm) individuals. Smaller (ca. <60 mm) individuals could also be numerous in these habitats, but because of their size and the dense vegetation cover, spotting and catching these was more difficult. Increasing depth had a tendency to result in lower catches of small individuals of trout and higher numbers for larger individuals. Smaller individuals prefer shallower sites than larger individuals (Klemetsen et al. 2003). Furthermore, smaller (ca. <60 mm) fish are more difficult to spot in deep water together with the fact that electrofishing in deeper (greater than 70 cm) areas is overall inefficient (Bohlin et al. 1989; Heggberget 1976).

Comparing catches from the three different years, there is an obvious larger amount of fish in 2008, but the only significant difference is between 2008 and 2004. The side channels were not yet opened in 1998 or 2004, but even if one compares without the data from the side channel sites from 2008, there was more fish in 2008 (Fig. 10). Neither Atlantic salmon nor Arctic char were caught in the side channel or tributary sites, so a fair comparison can be made between the years when omitting the these sample sites from 2008.

Overall, opening side channels and tributaries have been very successful restoration measures for the trout population of the river, with 46.67% of the catches in 2008 from these sites. Compared to the two other species, trout clearly gained most from the restoration measures at the time of this study. There were significantly more trout in 2008 than in 2004. No other significant differences were found when comparing species between years. The fishing methods were the same in 1998 and 2008, although the sample sites fished were not exactly the same (Saltveit & Brabrand 1999). The numbers used to compare data from each year were means, and since more sites were fished in 2008, the data from this year is likely more accurate than for 1998. The fishing that was conducted in

2004 was not meant to give an accurate number of the fish density (Dønnum 2005) and a different method was used. Therefore, the comparison of the three years is not accurate, but nevertheless provides a good indication of the direction of the trend.

Conclusion and recommendations

The most positive restoration measure was the re-opening of the side channels and the tributary. There are indications that Atlantic salmon also has had a positive reaction to the restoration measures, although they did not utilize the side channels. It is also probable that fish caught at sites without measures also gained indirect positive effects from the restoration measures elsewhere in the river. For instance, the production of food in the form of insect larva and other invertebrates was likely increased by opening the side channels, making the tributary more accessible, as well as the placement of boulders in the main river. Restoration creates a riverbed that is more retentive of CPOM (coarse particulate organic matter), which in turn has a bottom up effect on the nutrient availability for invertebrates that act as food for fish (Lepori et al. 2005b). The side channels act as sinks and sources for CPOM and other nutrients (Preiner et al. 2008). During annual floods CPOM flow into the side channels and get trapped. Breakdown of CPOM is initiated in the side channel, and during floods and high water level conditions these nutrients get flushed into the main river making them available for fish there (Preiner et al. 2008). The restored sites were clearly used differently by fish in various stages of growth. While the smallest fish (<60mm) used the side channels and tributary, migration and spawning conditions were likely improved for larger individuals in the main channel. Although my sampling techniques and study focused on smaller individuals, larger fish were observed regularly in the main channel. According to the local landowners, larger fish have been more prevalent since the restoration measures began in 2006 (Ivar Mikalsen, pers. com.). Even though no effects were apparent for Arctic char, one cannot conclude that the restoration has not been positive for the species. More studies were the whole width of the river and other sites gets examined should be conducted.

Improvements of the side channels to create more habitat variation should also be conducted. The side channels as they remain at present seem only to be utilized by trout. Parts or certain stretches could be dug deeper and placement of LWD should be done to improve habitats more suitable for small Atlantic salmon and Arctic char. One of the side channels more or less dried out before the end of the summer in 2008. The inlet to this side channels could be reconstructed to have a smaller angle to the main river and thereby increase the current into the side channel and increasing the overall amount of water in the entire side channel. In addition, some larger stones could be placed in the side channels, as larger stones in the river were shown to be positive for all three species. Finally, data collection and registrations of the fish population should be conducted on a regular basis, or at least once every two years. Monitoring studies similar to this one are vital to insuring which measures of river restoration actually function and those that do not, and importantly, why and how they do or do not function.

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Appendices

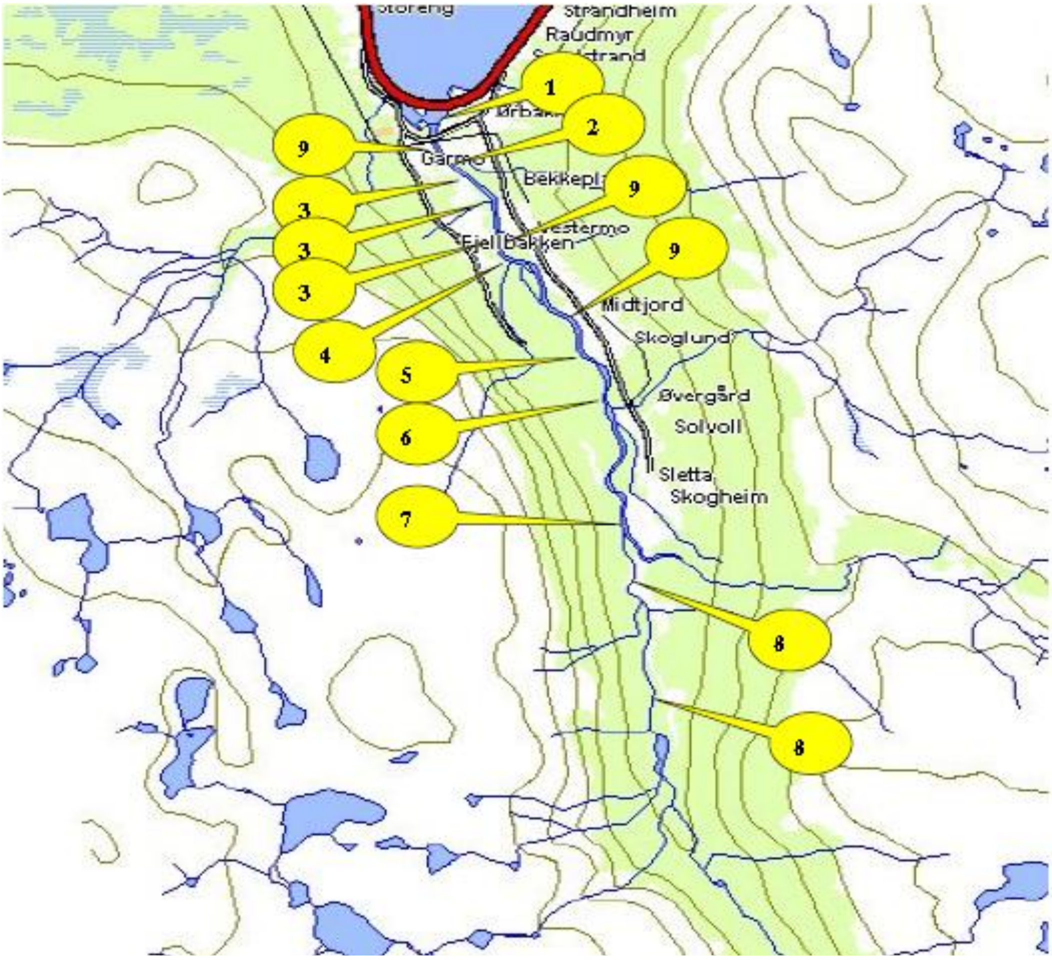

Figure 10. Locations of originally planned restoration measures in the Bognelva river (NVE 2005).

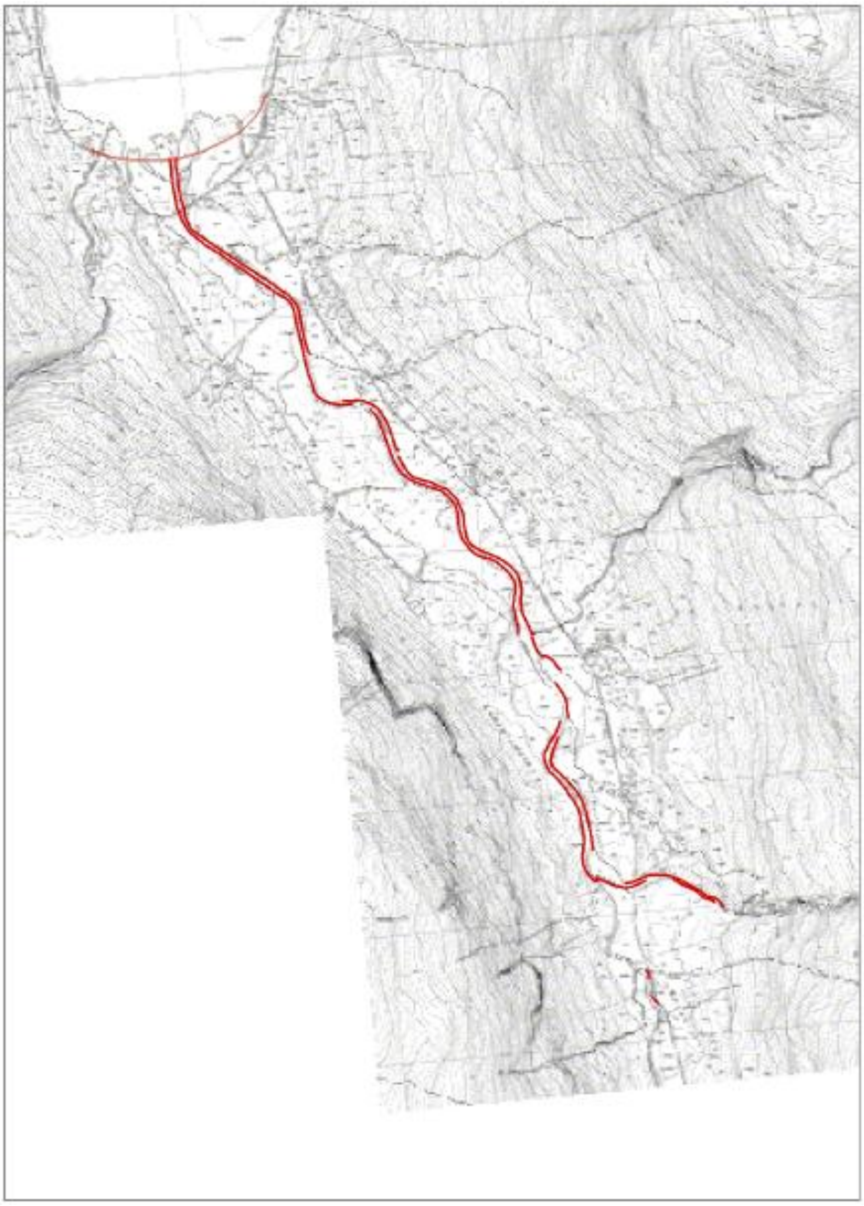

Figure 11. The extent of the channelization conducted along the Bognelva river prior to 2004 (NVE 2005).