Sveriges lantbruksuniversitet
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Examensarbete i ämnet biologi
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SUMMARY

Several techniques are used to sample juvenile salmonids in lotic environments. Electrofishing is by far the most commonly used method on the Scandinavian peninsula. As restoration of stream habitat is becoming increasingly popular, electrofishing is consequently being used to assess the effects of restoration on juvenile brown trout and Atlantic salmon. Electrofishing requires a number of assumptions regarding the movements of the target species. This study scrutinized a few of those assumptions to find out whether current electrofishing-based monitoring methods are appropriate in restored tributaries to the Vindel river in Northern Sweden. By sampling juvenile trout and salmon in two different tributaries, providing them with PIT-tags and releasing them into specific locations of the streams the within-stream-movements of the fish were studied. PIT-tag antennas were used to monitor any potential outward migration from the streams. Several of the tagged fish were detected to migrate out of the electrofishing reaches they were originally caught in. Body length of the fish did, to a small extent, differ between individuals with different migration patterns. Salmon showed a more concentrated period of outmigration compared to trout. One of the tributaries had a considerably larger outmigration from the stream compared to the other. These findings are discussed in relation to future electrofishing-based monitoring.

SAMMANFATTNING

Ett flertal metoder finns tillgängliga för att göra stickprov på juvenila salmonider i vattendrag. I Skandinavien är elfiske den klart vanligaste metoden. Restaurering av habitat i vattendrag är nuförtiden ett populärt ingrepp och elfiske används för att bedöma hur restaureringsåtgärderna påverkar tätheten av unga laxar och öringar. Elfiske kräver ett antal antaganden angående fiskarnas rörelser. Denna studie granskade några av dessa antaganden för att ta reda på huruvida elfiske är en lämplig metod för utvärdering av restaurerade biflöden till Vindelälven i Västerbottens län. Genom att fånga unga öringar och laxar i två olika bäckar, förse dem med passiva sändare och släppa ut dem på bestämda platser i bäckarna studerades fiskarnas rörelser inom biflödena. Antenner placerades där bäckarna rinner ut i Vindelälven för att registrera de fiskar som eventuellt skulle komma att lämna bäckarna. Flera av de märkta fiskarna lämnade de elfiskesektioner de ursprungligen hade fångats i. Längden på fiskarna skilde sig marginellt mellan individer med olika rörelsemönster. Jämfört med öringarna vandrade laxarna ut under en högst begränsad tidsperiod. Antalet fiskar som vandrade ut skillde sig betydligt mellan de två bäckarna. Resultaten diskuteras i förhållande till framtida elfiskebaserade utvärderingar av restaureringsprojekt.

INTRODUCTION

Restoring previously channelized rivers and streams has become a popular practise in the Nordic countries during the last 10-15 years (Nilsson et al. 2015). The goals for the various restoration projects may differ, but many are focused on creating and improving habitats for fish, especially species that are popular for sport fishing (Palm et al. 2009). Whenever a project has goals that involves biological responses, e.g. using restoration techniques to increase the density of salmonids in a stream, evaluation of the project is as important as the restoration itself (Hilderbrand et al. 2005; Morandi et al. 2014). The biological response to various restoration techniques is, by many considered to be the ultimate measure of restoration effectiveness (Roni et al. 2002). Measuring that response in a way that minimizes the risks of producing misleading data, is naturally of great importance. It is commonly suggested that catchment scale or whole river production, e.g. smolt production, is the most reliable approach to avoid spatial variability between reaches and over time. As restoration projects often are restricted by limited budgets, catchment or whole river scale evaluations are seldom conducted. Often, evaluations on salmonid response are based on reach scale monitoring, e.g. by electrofishing. However, depending on the temporal and spatial distribution of the sampling effort, few and small sampling sites may result in a bias in estimates of fish populations (Erkinaro & Gibson 1997). In fact, several of the problems with electrofishing are partially associated with a lack of biological understanding, or limited knowledge about how fish populations fluctuate in time and space (Bohlin et al. 1989). When evaluating organisms of high mobility the risk of gaining biased data is particularly severe. There are several scientific papers reporting on intra-stream movement among salmonids, both young of the year and older fish (Gowan et al. 1994; Carlsson et al. 2004). The common explanations for fish movements are searching for better territories for growth and hiding places for over wintering or to avoid predation, extreme temperatures and other unfavourable environmental conditions (Curry et al. 1993; Burrel et al. 2000; Niemelä et al. 2001; Gowan & Fausch 2002). In addition to the traditional view of sedentary and territorial behaviour, salmon parr also show active exploratory behaviour (Erkinaro et al. 1998).

The fact, that juvenile salmonids move, is seldom discussed in relation to sampling methodology and how results should be interpreted. Most commonly it seems that the traditional view of juvenile salmonids being more or less stationary has been the assumption when deciding the evaluation methodology of restoration projects. To find out whether movement has any implications on the methodology chosen to evaluate restoration efforts it is of high importance to study if juvenile salmonids move within streams, between potential study reaches and between different streams. Annually millions of Swedish crones are spent on brown trout (*Salmo trutta*) habitat restoration in streams and rivers (Nilsson et al. 2015). The restoration actions are primarily conducted to mitigate for the floatway operations conducted during the 19th century (Nilsson et al. 2005). A common objective of restoration is to promote brown trout production that will increase opportunities for recreational fisheries (Palm et al. 2009). To evaluate the effects of restoration on trout populations, electrofishing surveys of stream reaches typically 30-50 m of channel length is the dominant method applied (Nilsson et al. in manuscript; Lepori et al. 2005).

In order to use electro fishing as a meaningful methodology of measuring the effects of river restoration on salmonid abundance, several assumptions have to be made, e.g. 1) An electrofishing reach, c.50 m, is large enough to encompass the habitat size used for individual fish, 2) Immigration into a given electrofishing reach per unit time is equal to the emigration out of the same reach, i.e. the number of individuals per reach is constant, 3) There is no seasonal migration rhythm during the normal electrofishing period, August–September, 4) There is no effect of individual size, i.e. assumptions 1, 2 and 3 are the same regardless of the size of the fish. So far, the assumptions above have not been rigorously tested. Therefore uncertainties remain on how data, generated by traditional electrofishing, should be interpreted.

Aim

The aim of this thesis was: 1st to describe the movement dynamics of juvenile brown trout and Atlantic salmon in restored tributaries to the Vindelriver, 2nd to discuss the results in relation to the electrofishing methodology that is widely used to evaluate responses to restoration in juvenile salmonids.

MATERIALS AND METHODS

Study site

The study was carried out in two 3rd order tributaries to the Vindelriver in the county of Västerbotten, Beukabäcken (N: 7240543; E: 645158) and Nackbäcken (N: 7191291; E: 692524) (Fig. 1) (Coordinates are according to SWEREF 99TM). Vindelriver and its tributaries are part of a Natura 2000 area (Länsstyrelsen 2005). The streams are predominated by riffle habitats. The discharge in the tributaries varies between 0.18m^3/s and 2.25m^3/s in Nackbäcken, and from 0.19m^3/s to 1.12m^3/s in Beukabäcken (SMHI 2015). Based on the data available in the Swedish Electrofishing Register the density of brown trout is approximately 30.4/100m^2 (varying from 16.7 to 38.9 during 2013) in Nackbäcken and 28.5/100m^2 (varying between 7.5 and 50.2 during the past two decades) in Beukabäcken (SERS 2013). Other species found in Nackbäcken in addition to brown trout (*Salmo trutta*) are Northern pike (*Esox lucius*) and Burbot (*Lota lota*) (SERS 2013). In Beukabäcken Northern pike, Burbot, Grayling (*Thymallus thymallus*) and Atlantic salmon (*Salmo salar*) are found besides brown trout (SERS 2013).

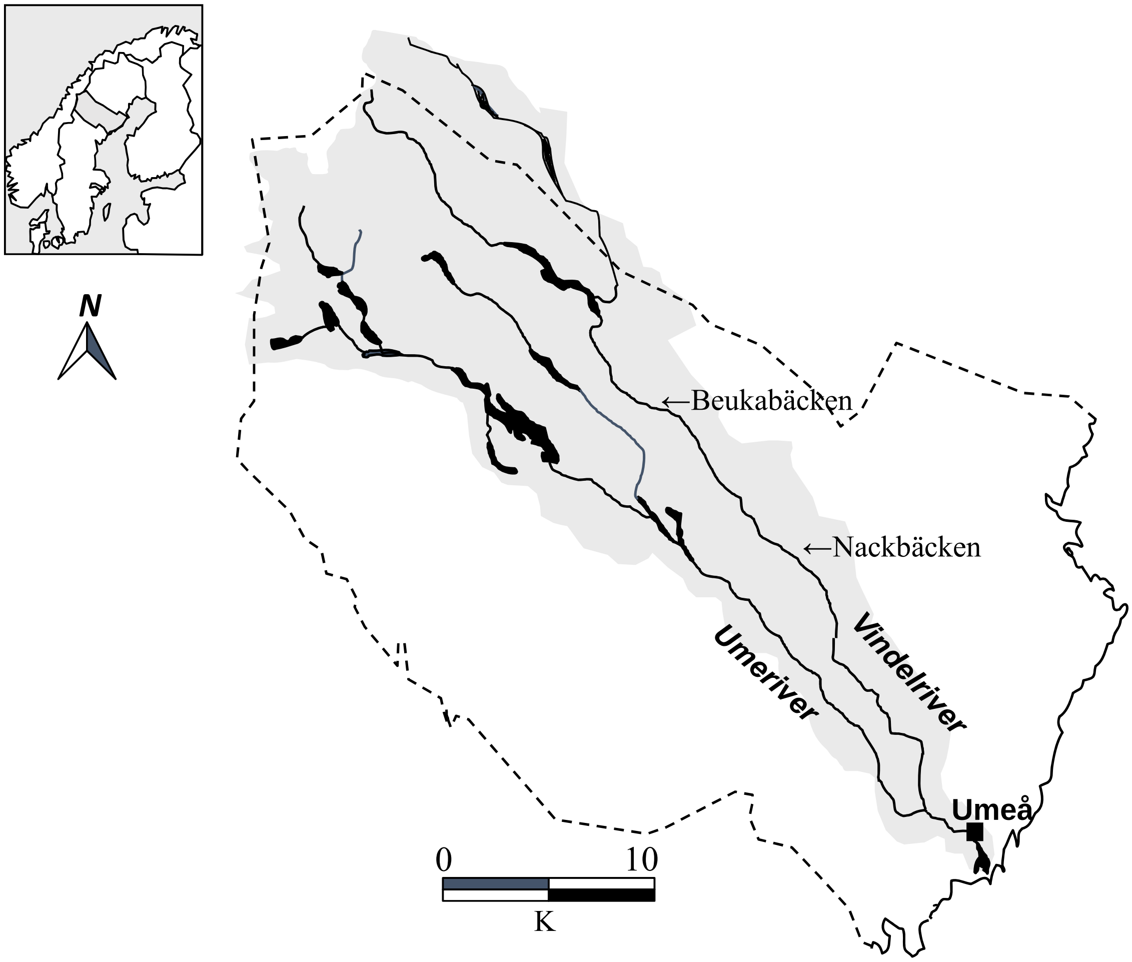

Figure 1. Geographic location of the two tributaries Nackbäcken and Beukabäcken in the Ume- and Vindel river catchment, Sweden.

The riparian zones of both Nackbäcken and Beukabäcken consist of scattered deciduous trees such as willow (*Salix spp.),* birch (*Betula spp*.) and grey alder (*Alnus incana*). The upland areas surrounding the two tributaries are predominated by cultivated forests of scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*). Both Beukabäcken and Nackbäcken have been subjects to channelization during the timber floating era, and both of the tributaries have also been restored since. Restoration efforts have included placing boulders and cobbles back into the streams and creating artificial spawning beds (according to the Hartijoki method (Degerman 2008)). The restoration work has been part of various projects between the years 2004 and 2011. Beukabäcken and Nackbäcken differ in svereal ways. Nackbäcken flows into an area of the Vindelriver which could be described as a lake habitat that might act as a migration barrier for juvenile salmonids. Also the most downstream rapid of Nackbäcken contains a small waterfall which acts as a migration barrier for juvenile salmonids. On the contrary Beukabäcken empties via a low gradient riffle into a low gradient rapid of the Vindelriver. Compared to Nackbäcken the conditions in Beukabäcken makes it easier for migrating juvenile salmonids to enter and exit Beukabäcken.

Tagging of fish

Brown trout and Atlantic salmon were caught using a generator-powered electro shocker (Lugab, Luleå, Sweden) that produced a constant direct current of 800 V. All fish collected were identified to species, counted, measured (mm), and tagged before being returned back into the streams. A total of 3 capture and tagging occasions were conducted in each stream. The date of each occasion in Nackbäcken was 18th of September 2014, 26th of August 2015 and 20th of September 2015. The dates in Beukabäcken were 24th of June 2015, 27th of August 2015 and 19th of September 2015.

Each stream was divided into a continuous series of 50 meter reaches, in total 13 reaches in Beukabäcken and 17 reaches in Nackbäcken. In order to keep track of the sections trees were marked along the linear stream length with distances measured from a given reference point. Each reach was electro fished separately. Tagged fish were released back into the centre of the reach where they were caught. In this manner one after the other 50m reach was electro fished. The tagging of fish was conducted using Biomark HPT12 tags (12.5mm, 134.2 kHz) and a Biomark MK25 implant gun (Biomark Inc. Boise, USA).

Recaptures of tagged fish

Recaptures of tagged fish was conducted with two different techniques, 1. Repeated electrofishing (described above) and 2. Detection with a portable PIT-tag antenna (Biomark HPR Plus) (Biomark Inc. Boise, USA). When using the portable antenna the operator walked upstream from the downstream end to the upstream end of each electrofishing reach. Each detected fish was given a detection point according to the stream linear distance from a reference point. To detect fish exiting the stream a three meter wide permanent PIT-tag antenna (Biomark Inc. Boise, USA) was installed at the outlet of each stream.

Water temperature

Water temperature was measured every six hours near each permanent PIT-tag antenna using temperature loggers (Tidbit, Onset Inc., Bourne, USA). The six hour measurements were transformed in to a weekly mean value.

Analyses

To test whether there was any significant effect of body length on the migration distance, a linear regression was made, treating migration distance (m) as a normally distributed response variable and body length (mm) as the explanatory variable. One regression for each stream (Nackbäcken and Beukabäcken) was made. The regression analyses were conducted using JMP Pro 12 (Anon. 2015). To test whether length had any effect on the probability of changing stream section, a generalized linear model with binomial error was used, treating changing section (yes/no) as a binary response variable and length as a continuous explanatory variable. Separate models were made for each stream. A binominal model was also used to test whether the probability to leave the stream was affected by the length of the fish. Separate models were made for each stream. The generalized linear models were conducted using R (R core team 2015).

RESULTS

Tagging and recaptures

Throughout this study a total of 1235 (498 in Beukabäcken and 737 in Nackbäcken) salmonids were tagged (Table 1). The body length of the captured and tagged fish ranged between 83mm – 165mm (median: 119mm) for salmon in Beukabäcken, 87mm – 450mm (median: 147mm) for trout in Beukabäcken and 103mm – 360mm (median: 136mm) for trout in Nackbäcken. In Beukabäcken 99 trout were recaptured once and 10 trout were recaptured twice while in Nackbäcken 114 trout were recaptured once, 11 were recaptured twice and 2 were recaptured three times.

Table 1. Number of caught and tagged fish on the 1st, 2nd and 3rd electrofishing occasion.

Stream	**Species**	**1st**	**2nd**	**3rd**	**Total**
Beukabäcken	Trout	95	126	192	413
	Salmon	8	38	39	85
Nackbäcken	Trout	348	188	201	737

Fish abundance variability

There was a large variance in the number of individuals caught within each electrofishing reach between each fishing occasion (Fig. 2, 3 and 4). For example during the second fishing occasion there was a reach where only half (50%) the amount of trout were caught compared to the first fishing occasion, while in other reaches more than six times (633%) the amount was caught compared to previous occasions. This variability was found in both streams and regardless if the comparisons were done between the 1st and 2nd, 1st and 3rd or the 2nd and 3rd fishing occasion.

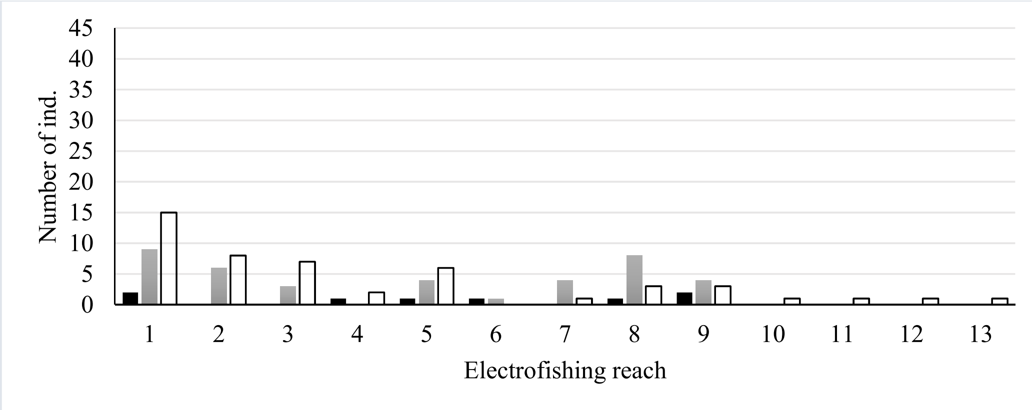

Figure 2. Number of individuals caught per electrofishing reach for salmon in Beukabäcken.   Black bars for June 2015, grey bars for August 2015 and white bars for September 2015.

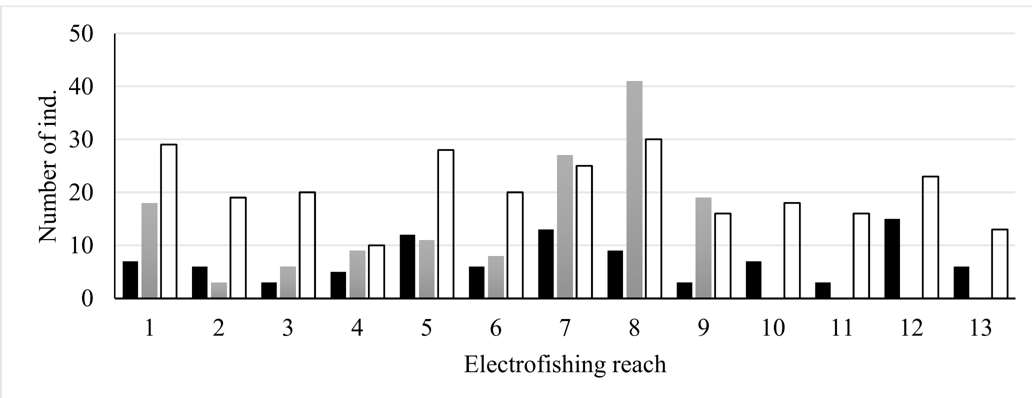

Figure 3. Number of individuals caught per electrofishing reach for trout in Beukabäcken. Black bars for June 2015, grey bars for August 2015 and white bars for September 2015.

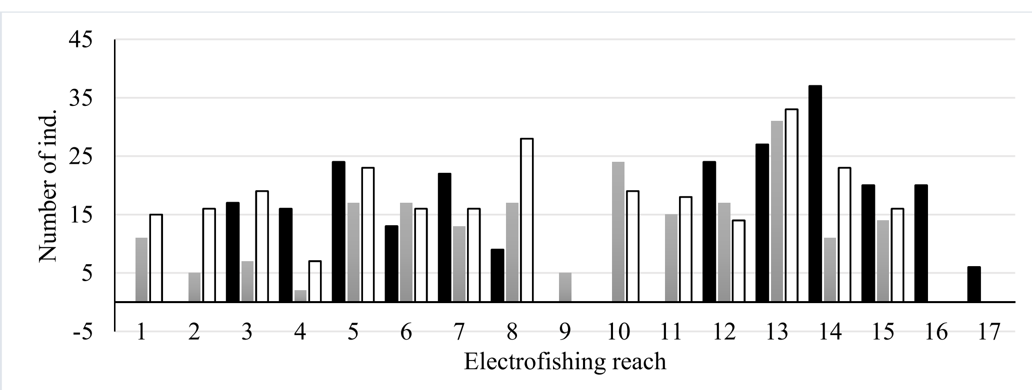

Figure 4. Number of individuals caught per electrofishing reach for trout in Nackbäcken. Black bars for September 2014, grey bars for August 2015 and white bars for September 2015.

Within stream migration

Based on trout recaptures within the streams, the furthest measured migration distances detected were 1425m in Nackbäcken and 250m in Beukabäcken. Due to the design of the study the shortest detectable migration distance was 25m. The median migration distances were 50m in Beukabäcken and 50m in Nackbäcken. There was no statistically significant correlation detected between fish body length and migration distance in trout in either of the two streams (Beukabäcken r^2=0.035, P=0.21, Nackbäcken r^2=0.028, P=0.07) (Fig. 5 and 6). Only 14 salmon were recaptured, 3 of them had migrated 50m while the rest of them had migrated less than 25m.

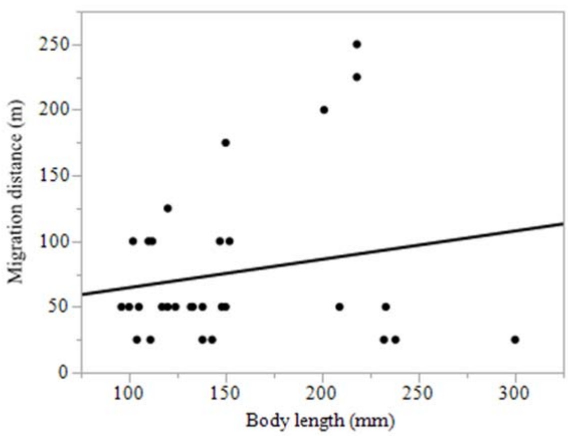

Figure 5. Regression of migration distance (m) and body length (mm) in trout in Beukabäcken (r^2=0.035 and p=0.21).

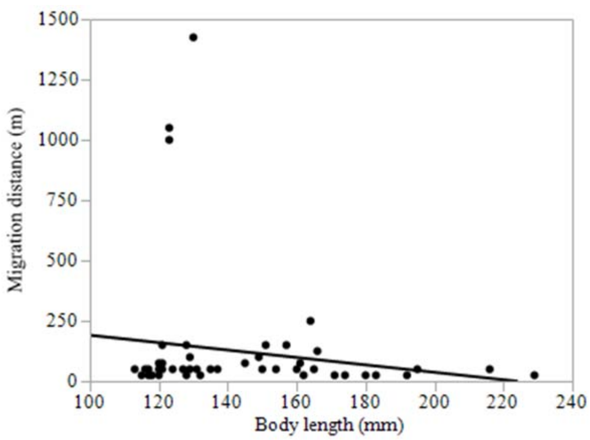

Figure 6. Regression of migration distance (m) and body length (mm) in trout in Nackbäcken (r^2=0.028 and p=0.07).

Inter-reach migration

In Beukabäcken 42% (n=89) of the detected trout had moved from one electrofishing reach (50 m in length) to another. In Nackbäcken the corresponding number was 46% (n=114). For salmon in Beukabäcken the number was 20% (n=14). Individuals from most size classes (body length) showed both migratory and sedentary behavior (Fig. 7 and 8). The average body length among trout that moved between reaches was 156mm in Beukabäcken and 154mm in Nackbäcken. The average body length among the trout that did not move was 153mm in Beukabäcken and 157mm in Nackbäcken. Body length had a significant effect on the probability of changing reach in Nackbäcken (GLM, Df=1.94, P=0.016), with smaller fish being more probable to change reach. This correlation could however not be found in Beukabäcken (GLM, Df=1.84, P=0.206). The number of salmon detected to move or not move between reaches was too few (n=14) to conduct a meaningful statistical test on differences in body length. The average body length among salmon was 129mm for the ones that had migrated and 124mm for the ones that had not.

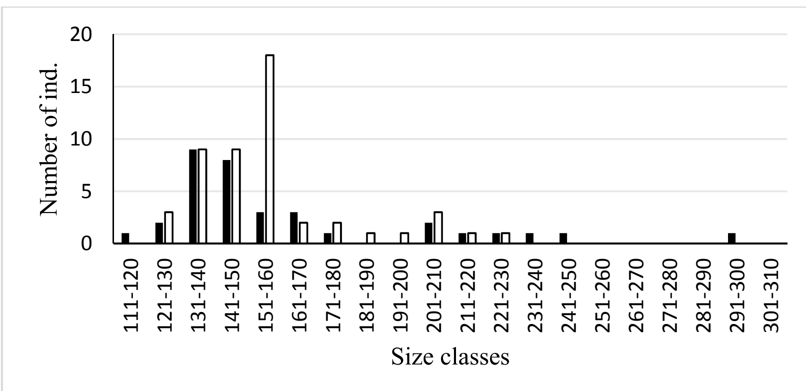

Figure 7. Size distribution of trout in Beukabäcken. Black bars represent trout that had moved between reaches and white bars represent the ones that did not.

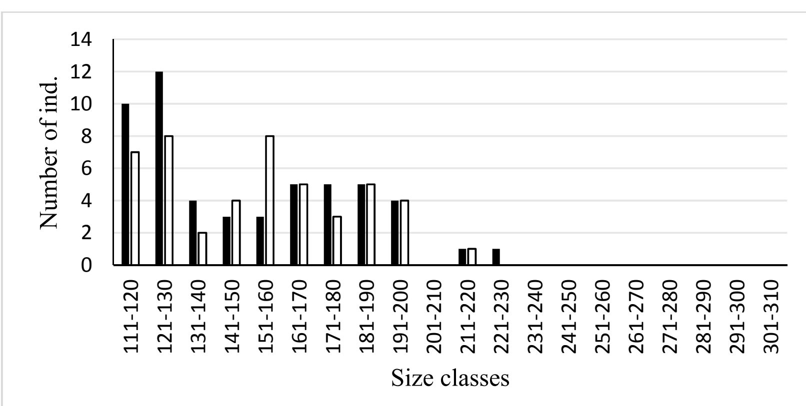

Figure 8. Size distribution of trout in Nackbäcken. Black bars represent trout that had moved between reaches and white bars represent the ones that did not.

Inter stream migration

Except for one trout in week 26, trout and salmon were detected leaving the streams between week 35 and week 46 (Fig. 9), though the bulk of the individuals that left the streams were recorded doing so when the water temperature dropped from 16 to 12° C and during the descent down to 2 °C. Individuals that left the streams were found in most of the size classes (Fig. 10, 11 and 12). The average body length among the trout that did leave the stream was 189mm in Beukabäcken and 174mm in Nackbäcken. The average body length among the trout that did not leave the streams was 150mm in Beukabäcken and 146mm in Nackbäcken. Body length of trout had a significant effect on the probability of leaving the stream in both Nackbäcken (GLM, Df=1.94, P=0.013) and Beukabäcken (GLM, Df=1.481, P<0.001), with the probability of leaving the stream increasing with size (Fig. 13). For salmon in Beukabäcken the average body length among individuals that did not leave the stream was 120mm. The average body length among individuals that did leave the stream was 131mm. Also here, body length had a positive effect on the probability of leaving the stream (GLM, Df=1.92, P=0.002, Fig. 13).

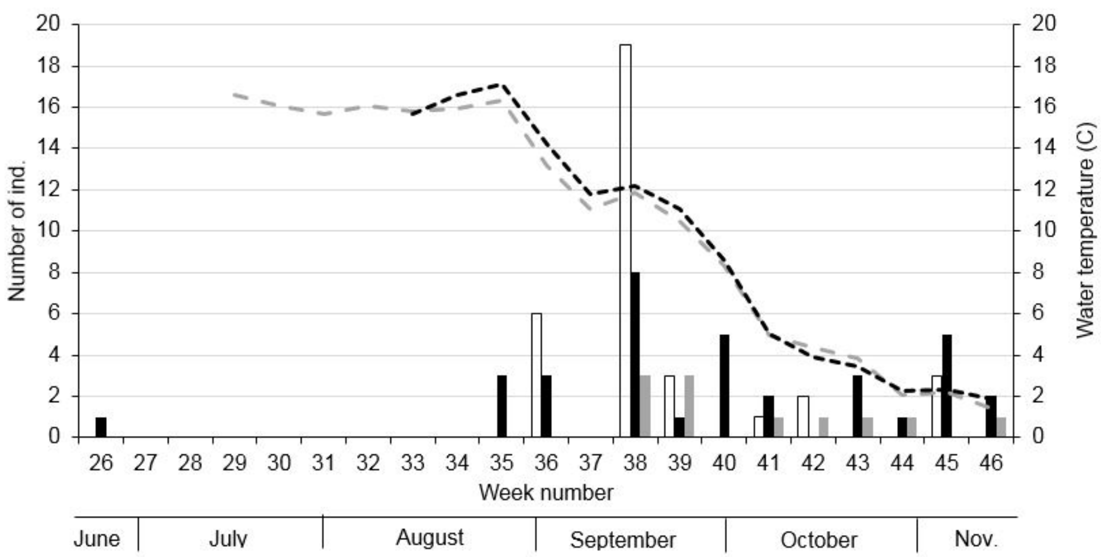

Figure 9. Trout and salmon that were detected by the antennas while leaving the streams. Grey bars for trout in Nackbäcken, black bars for trout in Beukabäcken and white bars for salmon in Beukabäcken. Temperature curve in black for Beukabäcken and in grey for Nackbäcken.

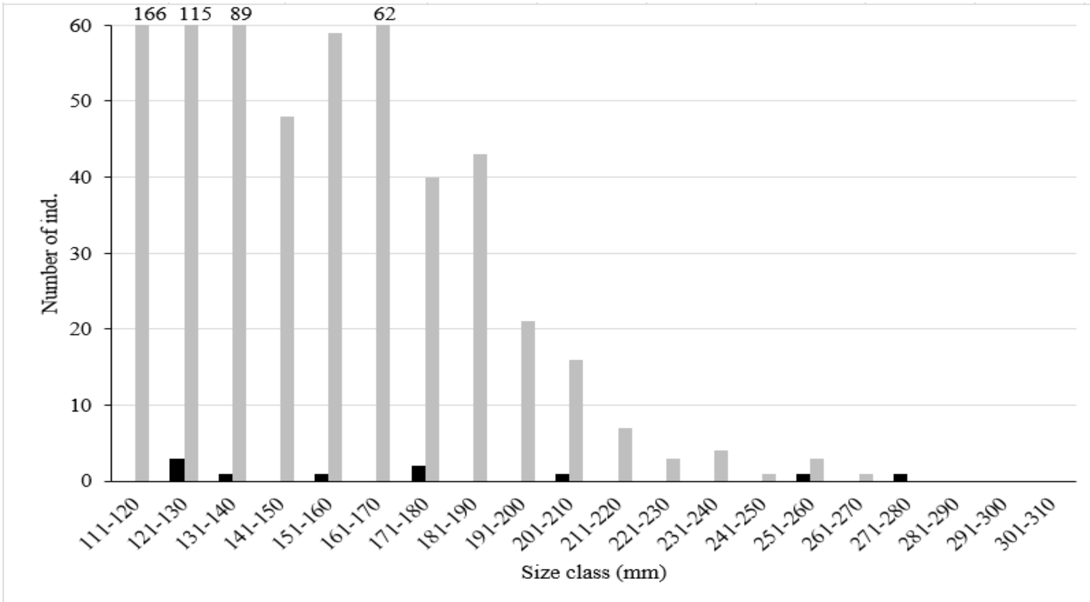

Figure 10. Size distribution of trout that left the stream Nackbäcken (black bars) and individuals that stayed in the stream (grey bars).

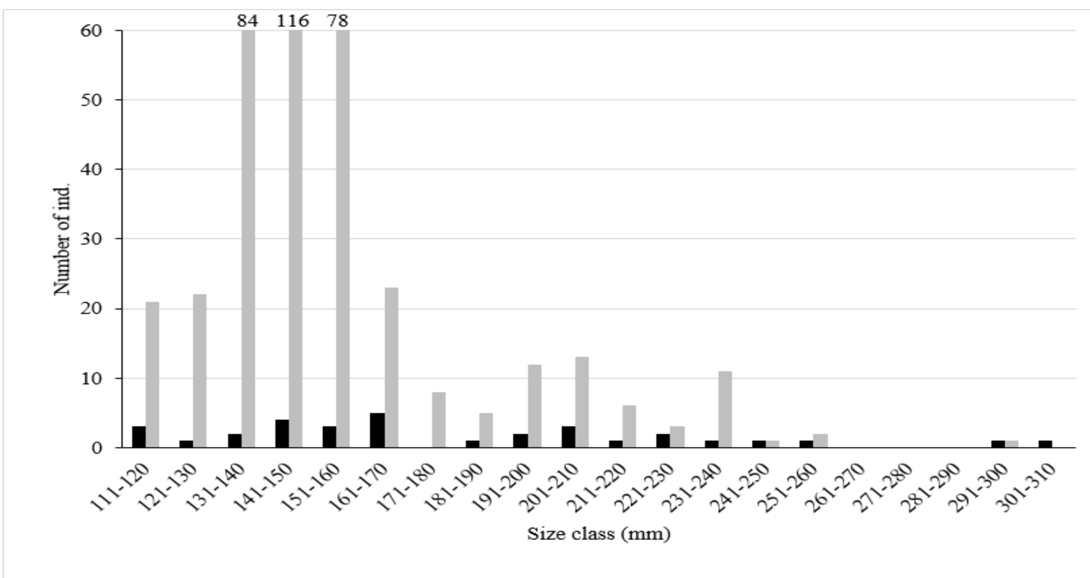

Figure 11. Size distribution trout that left the stream Beukabäcken (black bars) and individuals that stayed in the stream (grey bars).

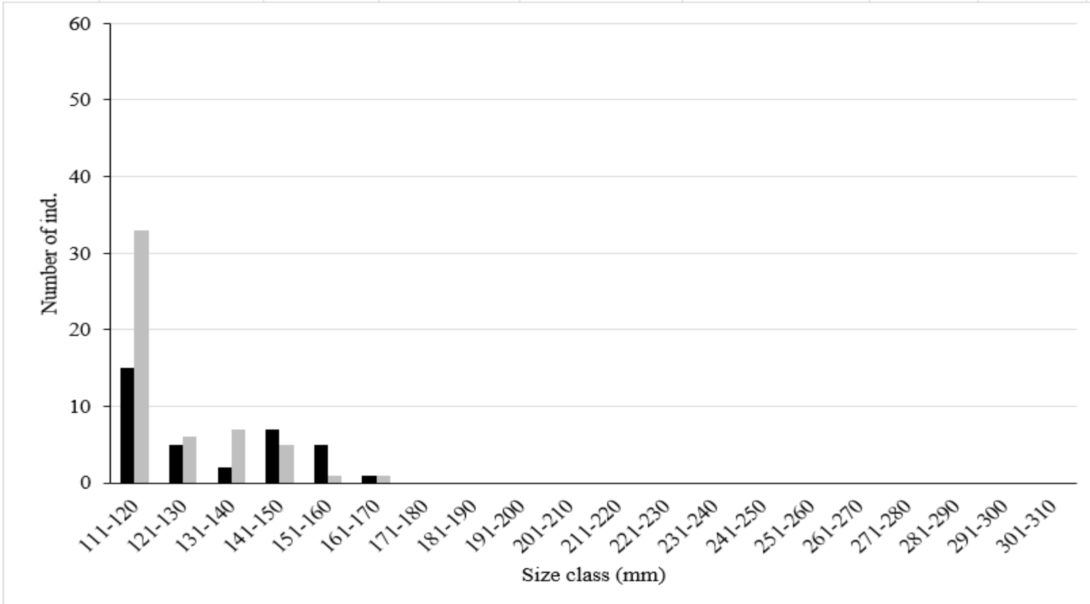

Figure 12. Size distribution of salmon that left the stream Beukabäcken (black bars) and individuals that stayed in the stream (grey bars).

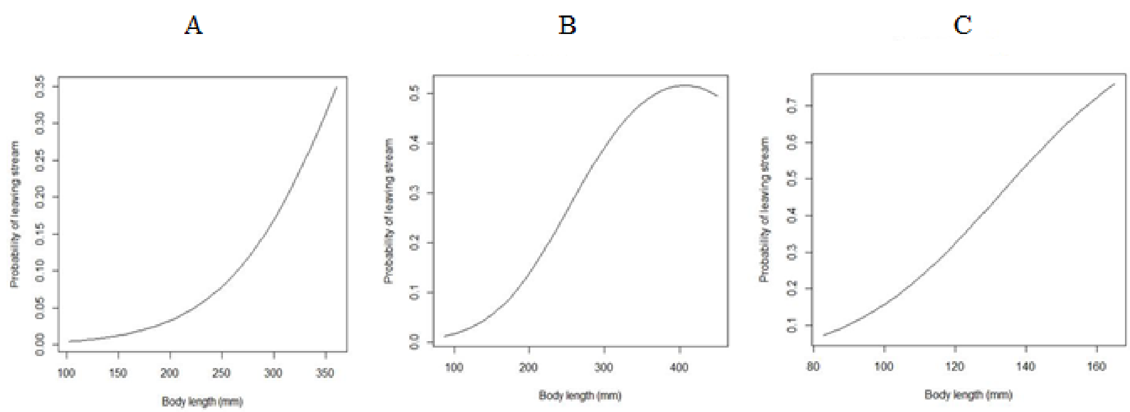

Figure 13. Probability of leaving the stream as a function of body length for trout in Nackbäcken (A), trout in Beukabäcken (B) and salmon in Beukabäcken (C). The lines are the fitted values of a binomial GLM.

DISCUSSION

During the electrofishing occasions the size of the catches varied between the different electrofishing reaches. Since all the fishing took place within the limited time of 2 months in Beukabäcken and 12 months in Nackbäcken, the variation in catch size is an indication of extensive movement between the electrofishing reaches. The antennas revealed that the migrations out from the streams were initiated when water temperature dropped below 16 °C, which happened in early September, and continued through November. The practical implications of these findings in relation to electrofishing-based monitoring is explored by addressing the four questions below.

1. **Is movement of juvenile individuals negligible and not needed to be considered?**

   There are many reasons for juvenile trout to migrate within and between streams. For example Näslund et al. (1998) noted that intraspecific competition causes brown trout to move within a stream, Roussel & Bardonet (1997) recorded diurnal and seasonal movements in 1+ brown trout between pools and riffles and Brännäs et al. (2003) reported a higher level of activity when food was not abundant. Furthermore Forseth et al. (1999) found that juvenile brown trout migrate to shift habitat as a response to declining growth rate. Also Carlsson et al. (2004) suggest that their recorded intrastream movements in juvenile brown trout has to do with foraging opportunities. Given findings from previous studies and the results from the present study, movement of individuals is an aspect that needs to be considered when conducting electrofishing-based monitoring. The results also indicate that one should be careful when drawing general conclusions about salmonid density within specific reaches and how it might change over time. In accordance with the results from this study, Höjesjö et al. (2007) also detected that juvenile brown trout moved considerably between reaches 50-100m in length. This is an incentive for monitoring programs to increase the length of electrofishing reaches to at least 100m. A factor that seems to trigger and dictate salmonid's movement out of the stream is the water temperature and therefore indirectly the date. Electrofishing-based monitoring that aims to generate time series at specific reaches must be particularly careful when selecting date for sampling and that the sampling date should be consistent throughout the time series. The importance of consistency in the selection of sampling dates is also pointed out by Niemelä et al. (2001). Date is however not a guarantee to avoid for environmental variability as discharge and water temperature might vary considerably at the same date between different years. To avoid for variability due to fish movement in catch per unit effort, at specific reaches electrofishing should not be conducted later than August in streams of northern Sweden.

2. Do salmon and trout show different movement patterns?

25 out of the 34 (74%) salmon that were detected leaving Beukabäcken, did so during one week while the water temperature was 12-14 °C and the remaining 9 (26%) salmon left during the following 7 weeks. The temperature range is similar to what has been reported for salmon in the nearby Ume river area where Fängstam et al. (1993) has reported an initiation of downstream migration at 10-11° C. For trout there was no such distinguished peak. Instead trout in both Beukabäcken and Nackbäcken left the streams during the 10 weeks as water temperatures descended from 16 °C to 2 °C. In accordance with Hesthagen (1988), who detected a significant downstream movement of juvenile Atlantic salmon in autumn and that only 73% was recaptured within release sections, the results from the present study suggest that one should be especially careful when monitoring salmon since they seem to leave the stream during a very short time period. Depending on whether the electrofishing is conducted before or after the migration peak, results may vary considerably. Selecting the proper date for sampling is therefore more crucial in salmon monitoring compared to trout monitoring.

3. Is movement only needed to be considered in certain sizes of individuals?

For salmon movements within streams are important in all stages of their life cycle (McCormick et al. 1998). Any movements, like shifting from summer feeding territories to winter habitat, spawning movements of sexually mature individuals, and establishing feeding territories, could be long enough movements to affect the results of monitoring. The actual lengths of intrastream movements must be further studied, in addition to what was found in the present study, Halvorsen and Stabell (1990) found that both sexually mature and immature brown trout that was caught and displaced by 200 m returned to their home areas at the same rates. To further highlight the complexity of linking migration behavior to size Forseth et al. (1999) found that 0+ and 1+ brown trout that migrated from stream to lake were smaller than the ones that remained in the stream but that 2+, 3+ and 4+ trout that migrated were significantly larger than the ones that remained in the stream. The present study did find a small, but significant, effect of body length on the probability of migrating between electrofishing reaches as well as an effect of body length on the probability of leaving the streams. However it is not possible to distinguish between migratory and not migratory individuals only based on body length as individuals from all size classes conducted inter- and intra-stream migrations. The practical aspect of the findings highlight that it is not possible to avoid variability in catch per unit effort in electrofishing, due to movement, by sampling only specific size classes.

4. **Is trout movement patterns identical between streams?**

   Although a similar extent of intrastream movements, a fivefold higher proportion of tagged trout left from Beukabäcken than did from Nackbäcken. This might possibly be explained by the two main characteristics that separate Nackbäcken from Beukabäcken in terms of suitability for migration; 1) Nackbäcken flows out into a section of the Vindelriver which could be described as lake habitat which might act as a migration barrier, 2) the most downstream part of Nackbäcken contains a small waterfall that could also act as a migration barrier. Physical parameters like these can differ a lot from one stream to the other even if they are located close to each other and are part of the same catchment. Due to this fact specific populations might have developed different movement behaviors. Besides physical factors fish density is an example of parameters that vary between streams and could have an effect on fish movements as noted by Hesthagen (1988). While Hesthagen (1988) reports less movement in less densely populated habitats, this study found that Beukabäcken, which is the less densely populated out of the two streams, had more movement when it comes to outward migration. These results highlight that the extent of movement in one species may differ between parts of the same catchment and only detailed monitoring can separate streams with a high degree of movement from streams with a low degree of movement.

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