Quantification of one spring fish migration in a small coastal stream in the Forsmark area, Sweden.

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Summary

Many of the freshwater fish species that inhabit the coastal zone of the Baltic Sea conduct annual migration towards spawning habitats prior to their spawning. The majority of these species spawn in spring. Even though most of them are able to reproduce in brackish water along the Swedish coast, they seem to prefer freshwater or shallow sheltered bays. Some of the common freshwater fishes that are known to undertake spawning migration in the spring are roach, perch, pike and ruffe.

Freshwater estuaries that run out into the Baltic provide access for fish to areas such as lakes, marshes and streams. Compared with the Baltic these types of waters offer a faster warm-up in spring and better protection for eggs and fish larvae. The faster warm-up allows fish to spawn earlier and also shortens the hatching of the eggs compared to those individuals that stayed at sea. Together, these factors result in higher survival of young fish.

In this study a short and narrow stream was observed to see in what extent spring migrating fish used it. The stream runs out into the southern part of the Bothnian Sea close to Forsmark, Uppland. During a period from March to May in 2004 an attempt was made to catch all migrating fish by using a fyke-net. The catch was registered in species composition, weight classes and amount caught of each of the species. The fish were then released upstream of the catching devise so they could continue their migration.

During a period of six weeks over 18000 fish were caught and released. The largest group was ruffe (Gymnocephalus cernuus) with over 12000 individuals. Roach (Rutilus rutilus), perch (Perca fluviatilis) and pike (Esox lucius) were also caught in the order of 4700, 1200 and 200 respectively. Soon after the ice had broken up in the stream the fish started to migrate up from the sea. The migration continued with varied intensity during the study period.

The large amount of migrating fish that were caught during this study strongly indicates the importance of a small stream entering the Baltic. The access to suitable spawning habitats, in this case Lake Norra Bassängen and its estuaries are important for the recruitment of the coastal populations in the region. It is also plausible to assume that other similar streams along the coast provide important pass ways to suitable spawning environments. It is therefore vital to make sure that fish will be able to use these streams in the future as well; especially since many of the coastal fish populations have decreased in number.
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Introduction

The Baltic Sea is inhabited by some 35 species of freshwater fish. Many of these show an annual migration pattern, the spawning migration is the most pronounced (Johnson, 1982). However, the knowledge concerning spawning migration of the fresh- and brackish water fishes, other than salmonids, is poor. The spectacular swimming performance and the precise homing to their natal spawning streams, in some cases a journey of a thousand kilometres, has stimulated research of the migratory behaviour of the salmonids (Lucas & Baras, 2001). The focus on salmonids in research is also likely due to the fact that they have been historically more important economically and are distributed worldwide (Lucas & Baras, 2001). However, shorter spawning migration has been observed for many freshwater species. Movement of a few kilometres or a couple of hundred meters may be of great importance for their spawning success and survival (Northcote, 1998). Homing and returning to a natal stream or a specific part of a lake is vital for the reproductive success to be maximized. The natal environment is suitable for spawning and conditions are optimal for the development of eggs and larvae. A synchronized return of sexually mature fish of the same species is also vital (Leggett, 1977).

Medium to small streams have a high potential to provide important pass ways and spawning habitats to typical warm water species (e.g. percids and cyprinids) that are found along the Swedish coast. Marshes, lakes and overflowed vegetation offer the most important nursing and spawning areas. Even though spawning of warm water species occur in the Baltic, the areas mentioned above are more suitable since they provide a higher water temperature and productivity together with increased protection for eggs and larvae. The upward stream migration in spring can be of significant proportions as well as the outward migration of young of the year fish during summer and fall, depending on location and species. Generally, adult fish leave streams, marshes and lakes not long after spawning (Fiskeriverket 1996; Eriksson & Müller 1982).

Some of the common freshwater species that are known to undertake spawning migration during the spring season are roach (*Rutilus rutilus*) (L’Abée-Lund & Vøllestad, 1985; Vøllestad & L’Abée-Lund, 1987; Johnston, 1982; Eriksson & Müller 1982; Berg, 1982), perch (*Perca fluviatilis*) (Johnston, 1982; Eriksson & Müller 1982; Berg, 1982), pike (*Esox lucius*) (Karås & Lehtonen, 1993; Clark, 1950; Johnston, 1982, Eriksson & Müller 1982; Berg, 1982) and ruffe (*Gymnocephalus cernuus*) (Berg, 1982). The studies have mainly been conducted in smaller residuals and streams that flow into the southern parts of the Bothnian Sea. The homing ability of these species varies. Pike showed a relative high homing among individuals in a study conducted in Ängerån, a small stream that flows into the Gulf of Bothnia. In this study there was a 32 % return of pike tagged the year before (Johnson 1982). An anadromous behavior has also been observed in a perch population in the river Ängerån. In this study foraging and growth took place in the Baltic, but a clear spawning migration up river took place during spring (Berglund 1978; Müller & Berg 1982). Roach has been noted to have a homing precision as high as 92 % in a tributary to a small lake in Norway (L’Abée-Lund & Vøllestad, 1985). The homing behaviour of ruffe has been largely unstudied, although intense spawning migration has been observed in Andersbäcken, a small and short stream that runs into the Bothnian Sea (Berg 1982).
The initiating factor for species making relative short spawning migrations in spring is an increase in water temperature. At our latitudes the temperature rise in the spring is associated with an increase of the length of the photoperiod. The fish need to reach their spawning grounds during a period of a few weeks to synchronize the return of sexually mature fish, and are therefore triggered by the positive change in temperature (Northcote, 1984).

The general arrival pattern at spawning habitats in spring starts with the northern pike, perch and ide (where available), later followed by roach. However, this is not always the case, and the successions can vary from place to place and can be simultaneous (Sandell & Karås 1995). Northern pike (*Esox lucius*) were found to work their way up in small tributary streams to Lake Erie, Ohio, Canada, when ice still covered the pools and the water temperature was 0°C (Clark, 1950). Franklin and Smith (1963) observed pike outside the outlet from Lake George, Minnesota, US, several days before the actual migration started. The entrance into the stream itself occurred in the temperature range from 1 to 4.4°C, where 2 to 3 °C seemed to be the preferred temperature range. The spawning of northern pike takes place in the temperature range 2 to 12 °C (Muus & Dahlström, 1981).

According to Berglund (1978) the start of the spawning run for perch (*Perca fluviatilis*) coincided with a rise in water temperature. It is suggested that the faster rise in temperature in the river Ångerman compared to the sea acts as a trigger for the perch to begin migrating upstream. Upstream migration of roach in a tributary of Lake Årungen started at temperatures between 6 – 10°C (Vøllestad & L’Abée-Lund, 1987). Intense spawning migration in ruffe (*Gymnocephalus cernuus*) has been observed in the small stream Andersbäcken (Berg 1982). The water temperature rose from 6 to 10 °C during the investigated period, and the Bothnian Sea was still covered with ice during that period. During a period between March and June, depending on species and location, most spawning migration towards habitats in lakes, rivers and streams take place (Muus & Dahlström, 1981).

The major objective of this study was to quantify one spring migration in a short and narrow stream, during a period from late March to early May in 2004. The stream runs out into the southern part of the Bothnian Sea, located about one kilometer from the nuclear power plant in Forsmark, Sweden. A fyke-net was used to catch all fishes migrating up the stream, which is the outflow from Lake Norra Bassängen that enters the Baltic Sea. Previous studies of spring migrating non-salmonid fishes migrating up in smaller streams along the Swedish coast have mostly been concentrated to the area along the northern part of the Bothnian Sea (e.g. Berg 1982; Berglund 1978; Eriksson & Müller 1982; Johnson 1982). It is therefore of interest to document what type of fish migration occurs along other parts of the Swedish coast, in this example the coast of Uppland. Further knowledge is also fundamental in order to emphasize the importance of a suitable spawning habitat for freshwater fishes; in a time where many populations are decreasing in number along the Swedish coast. A secondary objective was to observe any fish migration further upstream from the two connected lakes Norra Bassängen and Bolundsfjärden. This was done in order to see if spawning took place in Lake Norra
Bassängen, the first lake the migrating fish reached, or if they searched for other spawning habitats further upstream.

Material and methods

Study site 1
The investigation has been carried out in a small stream that runs out from Lake Norra Bassängen, which is located in Uppland, Sweden (coordinates X 1631978; Y 6700198, RT 90). The stream flows into Asphällsfjärden, a bay of the southern Baltic Sea, near Forsmark (Appendix 1). The length of the stream is approximately 175 m, the width varies from 1 to 3 m and the depth varies from 0.3 to 1.0 m during the spring season. However, the width can increase at high flows when the surrounding land is submerged. The stream is divided into four discrete segments. From the lake down toward the outflow it begins with a straight, slow flowing, and channelled part of 75 m. Phragmites australis is abundant along the sides and in the channel itself. The area around the channel is open, with little cover from the surrounding forest after sunrise. The slow flowing part is followed by a small basin, which is led into a short and riffled part of the stream. The last part of the stream consists of two small basins, the first is covered with Phragmites australis and the second is shallow with open water. The outflow is divided into three separate shallow riffled parts, with a maximum depth of approximately 0.3 m.

Catching device
In order to catch all fish ascending from Asphällsfjärden the narrow stream was totally blocked using a fyke-net (figure 1). With this method all migrating fish had to swim into the trap in order to continue further upstream. The fyke-net was 2.3 m deep with a 0.55 m wide opening and a height of 0.53 m. The diameter of the thread was 0.7 mm and the mesh size was 16 mm. On each side of the opening of the trap a net with a height of 0.5 m was attached. The net, which had a length of 2.4 m, made it possible to construct a Y-shaped trap that was set to catch fish migrating upstream to Lake Norra Bassängen.

Figure 1. A schematic picture of the fyke-net used in this study
The fyke-net was placed just upstream the riffled part and about 40 m from the outflow into Asphällsfjärden. The trap was secured to the bottom using wooden poles. In order to prevent the fish from passing the trap, rocks were placed along the underside of the net. The functionality of the trap mainly depended on the flow. Higher flows than the height of the trap would allow fish to pass without getting caught. Drifting material that got stuck on the wings was removed by hand; otherwise the trap would congest and therefore allow water to pass over it instead of through it.

**Fyke-net catch and environmental variables**
The migrating fish species length or size distribution was recorded and divided into groups and classes respectively. During the period of sampling, from 4th of April to 12th of May, the fish was counted and measured each day and thereafter released in slow moving water upstream the trap. Roach (*Rutilus rutilus*) and perch (*Perca fluviatilis*) were divided into three groups depending on size. Ruffe (*Gymnocephalus cernuus*) was only divided into two groups, due to their narrow size distribution. Pike (*Esox lucius*) was classified into three groups depending on weight.

The water temperature was measured each day during the sampling period. Measurements took place 10 cm below the surface, in the middle of a riffled part of the stream just downstream the sampling device.

Fish that deceased during handling were counted on four different occasions during a period with intense fish migration. Mortality for each of the species was recorded by dividing the number of deceased fish by the number of fish caught the same day. A total of 74 of the deceased specimens were cut up to determine spawning ripeness by looking at the development stage of their gonads.

**Study site 2**
Lake Bolundsfjärden, one of the two lakes connected to Lake Norra Bassängen, is located south of Norra Bassängen (Appendix 2). A second trap was placed in one of the three major inlet creeks, entering Lake Bolundsfjärden from southeast. This inlet drains four other lakes in the catchment (Brunberg, et al, 2004) and has a lower water velocity than the stream at study site 1. During the summer months the stream at study site 2 have been observed to totally dry out (T. Carlsson, per. com.). The width varies approximately between 0.5 to 1.5 m during the spring flood. The stream enters Lake Bolundsfjärden through a dense area of *Phragmites australis*.

**Catching device**
The same type of trap was used as described above in section 2.2.

**Fyke-net catch and environmental variables**
The number of fish, species distribution and total length of fish was registered each day during the sampling period from the 24th of March to the 11th of May. Fish was thereafter released upstream from the trap. The water temperature was also measured each day, except from 27th of March to 1st of April. The temperature was recorded 10 cm below the water surface. Measurements were made in the middle of the stream, close to the trap.
Results

During the investigation period, the 4th of April to the 12th of May, four species of fish were caught at the first study site on their migration upstream from the Baltic. The four species in the trap were: ruffe (*Gymnocephalus cernuus*), roach (*Rutilus rutilus*), perch (*Perca fluviatilis*) and northern pike (*Esox lucius*). Nine-spined sticklebacks (*Pungitus pungitus*) were observed passing through the fyke-net, but due to their size, none of them were trapped. At the second study site the burbot (*Lota lota*) was caught together with the four species mentioned above.

Study site 1

Pike

Upstream migration at study site 1 started a few days after the ice had broken up in the stream, at a time when Asphällsfjärden was still covered with ice. The first ascending pikes were caught the 6th of April when the water temperature was 5.9°C (figure 2). This was the start of an intense migration that lasted until the 16th of April. However, specimens were observed in the trap until the end of the sampling period. The maximum catch, 52 pikes, was recorded the 10th of April when the water temperature had risen above 9°C. The length distribution of the, in total, 212 ascending pikes varied from 24 to 94 cm with a maximum weight of 8.0 kg.

Spawning was observed on the 11th of April over submerged vegetation in the northeast part of Lake Norra Bassängen. In the beginning of May, pikes that had spawned were observed trying to descend the stream, but were hindered by the fyke-net. At this time a few pikes were still migrating up from the sea to spawn.

![Figure 2. Catch Per Unit Effort (CPUE) of the 212 pike that were caught at study site 1, in the outlet from Lake Norra Bassängen, during the sampling period, from the 4th of April to the 12th of May, 2004. The water temperature, measured each day when the trap was checked, is also shown in the graph.](image-url)
Roach
The first roach was trapped on the 4th of April, but the vast majority ascended the 8th of April and forward to the end of the sampling period (figure 3). The ratio and numeric abundance of larger individuals (>25cm) tended to be higher in the middle of the spawning run compared to the two groups of medium (15 – 25cm) and smaller (<15cm) fish. The length of the 4704 roach individuals varied between 10 and 32cm. The maximum catch of 416 ascending roach was recorded the 8th of April. Roach mortality was at a few occasions high, up to 20% of the daily catch.

![Figure 3. Catch Per Unit Effort (CPUE) of the 4704 roach that were caught at study site 1, in the outlet from Lake Norra Bassängen, during the sampling period, from the 4th April to the 12th of May, 2004. The water temperature, measured each day when the trap was checked, is also shown in the graph.](image)

Perch
Perch were caught every day during the sampling period (figure 4). The more intense migration started the 10th of April and lasted to the 20th of April. Males were overrepresented in the smallest size class and females in the largest size class. The length of the 1257 perch individuals varied between 8 and 45 cm. The highest number of perch to pass through the trap was 144 and was recorded the 11th of April. Perch mortality in the trap was at one occasion 78%. The vast majority of them were males from the smallest size class (<15cm). They were pinched in the trap by the movement from the much bigger pikes.
Ruffe
Ruffe ascended the stream during the whole period of sampling (figure 5). A very intensive migration peak started the 8th of April and lasted to the 26th of April. The lengths of the 12394 ruffe varied between 8 and 19 cm. The maximum catch, 1405 individuals, was recorded on the 15th of April. The highest mortality was 17%, recorded on the 8th of April.
On the 13th of April the stream swept away one of the securing poles for the fyke-net. This resulted in a net barrier that prevented most fish from entering or passing the trap during that day. This affected the results that day, most readily seen on the low number of ruffe caught this date compared to the 12th and 14th of April. A total of 74 specimens were checked for spawning ripeness. Every specimen that was checked for spawning ripeness was sexually mature, represented by perch, roach and ruffe.

**Study site 2**
A second trap was placed in one of the inlets to Lake Bolundsfjärden. This was done to see if the fish spawn in Lake Norra Bassängen or continue their migration upstream into the small inlet stream to Lake Bolundsfjärden. Intense migration could indicate that fish from the sea used this stream as well.

**Pike**
Fish was caught at site 2 from the 3rd of April to the 11th of May. The first fish to be seen in the trap was pike. The length of the 58 pikes varied from 12 to 35 cm. Pike was also the most abundant species at site 2.

**Perch**
Perch was the second most abundant species, with 53 fishes varying from 10 to 22 cm in length. The first specimen was caught on the 6th of April, but the majority was trapped during eight days in the middle of April. Anyhow, perch was sporadically seen in the trap until the end of the sampling period. A low number of males released milt when exposed to gentle pressure on the abdomen. Also one female released her eggs when removed from the trap, and most of the bigger perch had swollen abdomens, which indicated gonad ripeness of the females.

**Burbot**
The length of the 11 burbots varied from 11 to 17 cm. The first specimen was caught the 7th of April and the last one was caught ten days later. None of these were sexually mature. The burbot spawn in December to March (Muus & Dahlström, 1981), which makes it most unlikely that these individuals entered the stream to spawn.

**Ruffe and roach**
Three ruffe were observed in the trap. Their length varied between 6 to 7 cm and they were not sexually mature. Also, four roach were trapped, with a length distribution from 18 to 20 cm.
Discussion

An intense migration of several freshwater fish species from the brackish water of Asphällsfjärden to Lake Norra Bassängen was recorded. The migration from salt water into fresh water for spawning has similarities with the anadromous fishes, such as the Baltic Salmon *Salmon salar* (Erikssson & Müller, 1982). As over 18000 adult fish entered the stream between Asphällsfjärden and Lake Norra Bassängen, the stream is likely to have a large effect on the recruitment of young fish in the region. According to Eriksson *et al.* (1982) and Berg (1982) a small stream entering the Baltic can be of significant importance for the recruitment of young fish. No significant spawning migration was observed in the inlet to Lake Bolundsfjärden at study site 2 indicating that spawning takes place in the two connected lakes, Bolundsfjärden and Norra Bassängen.

*Study site 1*

Pike, roach and perch exhibit marked spatial and temporal precision in their seasonal migration (Müller & Berg, 1982) similar to the anadromous behaviour of several salmon species (Erikssson & Müller, 1982). Pike, roach, ruffe and perch are primarily fresh water species, but they also inhabit the brackish water of the Baltic. Both roach and perch are able to reproduce in brackish water with salinity ranging from 5 to 7‰ (Neumann 1977). The salinity of approximately 5‰ in the sea outside Forsmark should allow successful spawning in these areas. However, one can still speculate that even though spawning is possible in these waters, freshwater may still be preferable if the choice is available. The most likely reason for them to seek spawning sites in residuals and streams, in this case the outflow from lake Norra Bassängen and the lake itself, is the early warm up of the stream and lake compared to the sea. This makes it possible for earlier spawning and hatching of the eggs compared to the sea. The water temperature probably stays higher in Norra Bassängen compared to the sea at least until midsummer and this suggests a more rapid embryonal and juvenile fish development. The development rate of juvenile fish in Ängerån was comparable to fish that have their development at sea in the southern part of Sweden (Erikssson & Müller, 1982). Juveniles in this northern water attained the same size in late summer and fall as young fish from southern waters growing up in the sea. Also the presence of suitable spawning sites can explain these migrations. The spawning behaviour of pike can be used to illustrate this, where the pike use seasonally inundated areas or aquatic vegetation in shallow waters for spawning (Muus & Dahlström, 1981). In the surrounding coastal area of Forsmark these areas are rare, but are generously provided in Lake Norra Bassängen.

Kováč (1998) found that all females and males of ruffe (*Gymnocephalus cernuus*), in the Baka side-arm system of the Danube Rivers, Slovakia, exceeding 90 mm and 80 mm respectively were sexually mature. Almost none of the ruffe caught in the present study were smaller than the sizes given in Kováč (1998).

The rounded impression of eggs at the abdomen on caught female ruffe also strongly indicates that the majority of ruffe, caught during the sample period in the outflow from Lake Norra Bassängen, was sexually mature. Few pikes that were caught were smaller than the length given in Muus & Dahlström (1981) for sexual maturity. The majority of the bigger pikes (i.e. > 2.5kg) also had the rounded impression of eggs at the abdomen as seen in female ruffe. When small perch (<15 cm) were removed from the trap, males released milt when subjected to abdominal pressure. Also a few female perch, usually
larger fish, released their eggs at a few occasions. This indicates spawning ripeness of the gonads. Pike, ruffe and perch are all species that spawn during the spring season. During the study the temperature in the stream was in the preferred range for spawning, and it is highly likely that the shallow lake Norra Bassängen was in that range as well. The size of the fish, and the samples showing gonad maturity, indicated that the fish were ready to spawn. The fact that these freshwater fishes spawn in spring, and that temperature preferences for spawning was right, it is likely to believe that the majority of the numerous fish observed were on their way to reach suitable spawning ground. The same pattern was observed in several investigations made in Ångerån and Andersbäcken on spring migrating fish (Berg 1982; Johnson 1982; Eriksson & Müller1982; Müller & Berg 1982; Näslund 1978).

Fish that were smaller than 16 mm in height may have passed through the mesh of the fyke-net. This may have affected the length distribution in the catch slightly. However, few observations were made of fish passing through the trap. Most of them were three-spined stickleback (*Gasterosteus aculeatus*), but a low number of small sized ruffe were also seen passing through the trap. According to Berglund (1978) no considerable catch of smaller perch has been made with traps using a smaller mesh size. Thus it is assumed that only low numbers of other species passed without getting trapped since ruffe, roach and perch reach sexual maturity at approximately the same size.

The fluctuating water temperature on the shallow canalized part at study site 1 can easily be explained by sun exposure. Measurements taken with just a few hours difference could be several degrees lower or higher than before. However, the general trend with increasing temperature during the study is still correct. According to several authors the spring migration of pike starts at lower temperature than given in this paper (Müller, 1986; Franklin & Smith, 1963; Clark, 1950). One possible explanation to why the pikes migrated later is that the stream is very shallow and thereby reflects the surrounding temperature. Even though the stream reaches high temperature during the day, the low temperature at night makes the fish more unwilling to enter the stream until the temperature is more stable.

Two papers have earlier speculated in if migration occurs between the connected lakes; Bolundsfjärden, Norra Bassängen and the estuaries to sea. Gunnerhed (2000) mentioned the thickness of the *Fragmites australis* as a possible migration barrier. Borgiel (2004) thought that it is likely that migration of fish occurs between Lake Bolundsfjärden and the sea.

**Study site 2**

The low number of caught fish at study site two, indicate that the fish do not continue their migration further up in the system through this specific inlet. However, since the study was conducted on one out of three inlet creeks that entered Lake Bolundsfjärden, it is possible that further migration has occurred in other creeks. In this report, it is assumed that if migration occurs, it is probably of the same extent as the one measured in study site 2. Most of the caught pike, burbot and ruffe were sexually immature. The burbot reaches sexual maturity after 2-3 years and spawn in the winter (Muus & Dahlström, 1981). The ones caught at study site 2 were at their first year. The large proportion of
sexually immature individuals of burbot and pike indicated that these species did not use the stream for spawning.

Some of the perch and roach had reached the size of sexual maturity. However these were found in low numbers, which could indicate that they enter this small creek for other reasons than spawning. Combined with the fact that low numbers of sexually immature individuals were caught and that the creek lack suitable spawning habitat it is suggested that fish most likely used the stream to avoid predation and for foraging.

**Final conclusions**
The intense migration observed in this study, together with similar studies, clearly shows the importance of small streams for the spawning of freshwater fish in the Baltic. There is a strong biological significance in the large number of fish caught in the study. The importance of a small stream for recruitment of coastal populations was also shown in a study conducted in the northern Bothnian Sea (Eriksson & Müller, 1982). According to their calculations the river Ångerån approximately produced 100 000 – 150 000 of juvenile fish, which enriched the coastal fish fauna in the northern Baltic.

The problematic situation of declining freshwater fish populations and recruitment of young fish, especially of pike and perch, along parts of the Swedish coast has been observed during the last decades (Ljunggren *et al.* 2005). The underlying mechanisms are yet to be determined, but the primary hypothesis is that the zooplankton community has been changed over large geographic areas. Zooplankton is an essential food resource for all young freshwater fish during the first few weeks of their early life stage. However, all coastal areas do not show the same pattern of declining fish populations. The fish populations in regions with access to suitable recruitment areas are generally stable. The majority of areas that have the lowest recruitment of young fish lack shallow coastal zones, areas that are sheltered from the surrounding sea or freshwater estuaries (Ljunggren *et al.* 2005). The low findings of juvenile fish in areas that lack sheltered shallow bays and freshwater estuaries illustrate the importance of small streams, such as the one examined in the present study, which enters the Baltic.

The stream that enters Asphällsfjärden is small and vulnerable. Even minor manipulation could affect the accessibility of the stream negatively. Operations made in the area should be preceded with caution so that fish can conduct their spawning migration in spring and later the seaward migration of juvenile fish in late summer and fall.

It is possible that fish were still migrating from Asphällsfjärden into Norra Bassängen after the end of the sampling period. However, the vast majorities of the fish were most likely caught and recorded during the time span of the study. This assumption is based on the knowledge of temperature and time preferences for the spawning periods of the fish species involved. It is possible that other fish species, which were not looked upon in this study, uses the stream as well, but during other periods.
Further investigations and improvements

It would be of interest to examine the upward migration from the sea in this stream during a period of several years. That would give a good view on how the coastal fish population in this area fluctuates. Closer studies of the migratory behaviour of ruffe would be another interesting task, as our present knowledge about their migration is low. According to Lucas & Baras (2001) the ruffe (Gymnocephalus cernuus) has not been reported as migratory, although it shows some tendency for upriver movement in the spring. However, in the light of this investigation and Berg (1982), the ruffe have shown not only upriver movement, but also migration of sexually mature fish towards suitable spawning habitats.

It would also be interesting to measure the amount of juvenile fish migrating back to the sea from Lake Norra Bassängen. According to Eriksson & Müller (1982) large amounts of young of the year fish were observed in the stream during their seaward migration. The investigation in the present study aimed to catch upward migrating fish, prior and during the spawning period. Since juvenile fish are expected to do their seaward migration in late summer and early fall, it was impossible to study it in this investigation. Catching descending juvenile fish need to be done with other trapping device than a fyke-net (see Eriksson & Müller (1982)).

During this investigation, the fish mortality in the trap reached high levels at a few occasions. It is probably difficult to reach zero percent mortality when handling such a large amount of fish. However, lowering these levels can be done with a few adjustments:

- Check and, if necessary, empty the trap more frequently. During periods of intensive migration, the trap gets full quickly and the risk of smaller individuals being squeezed to death increases.
- The smallest individuals, especially among ruffe and perch, had a tendency to get stuck in the mesh. They often got their heads through the mesh, but got stuck with the rest of the body inside the trap. Using a fyke-net with smaller mesh-size than the one used in this study would solve the problem.

This study has shown how a narrow and short stream can provide important spawning habitats for freshwater fish along the coast in the southern Bothnian Bay. There are several hundreds of other streams of this type along the Swedish coast, which at the most have been studied by visual observation and in some cases by electrofishing. Even though these methods can be of use to assess the possibility of migration, it cannot give the magnitude of the migration that may take place. Further investigations are needed to study freshwater fish migration in those streams that we today have little knowledge about.
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References


Appendix 1. The circle marks the stream that runs out from Lake Norra Bassängen into Asphällsfjärden and the arrow marks the placement of the trap at study site 1.
Appendix 2. The arrows mark the two study sites, study site 1 in the outflow stream from Lake Norra Bassängen and study site 2 in the inlet to lake Bolundsfjärden.