Future management of Laisriver Brown trout

– what life history and enhancement strategy should be prioritized?

Framtida förvaltning av öring i Laisälven – vilken livshistoria och förstärkningsstrategi borde prioriteras?

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Swedish University of Agricultural Sciences, SLU
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Abstract

The life history and coexistence of subpopulations of brown trout in the same drainage area are relatively well known. The three forms of trout; sea-run, lake-run and resident, can all be present in the same location at some period of their life cycle, e.g. during the parr stage or at spawning. Despite the presence of all three forms, mostly the sea-run strategy is targeted in management actions from fishery organizations. Commonly this is done by compensatory stocking, even though the survival and fate of stocked individuals are not fully understood. This study investigates the fate of two groups of brown trout in the Laisriver in northern Sweden; stocked sea-run hatchery-reared juveniles and wild adult trout. This was done by tagging and tracking using acoustic telemetry during 2019 and 2020 to 2021. In addition, a genetic comparison of the adult trout with a genetic baseline for the whole Vindelriver system. My results indicate that survival of stocked hatchery-reared juvenile trout is low and that wild adult trout in Laisriver is from a common origin with a genetic profile partly unique to Laisriver and that they can adopt both resident and anadromous life histories. The home range size for the adult trout that has adopted a resident life history reached over 80 km including both stream sections and lakes but was limited to the Laisriver only. My conclusion is that future management actions should aim on enhancing the resident trout stock rather than stocks assumed to be purely sea-run. I suggest that this should be done by habitat restoration measures and improved fishing regulations to protect the important large trout individuals. Finally, I highlight the need for future monitoring of movement patterns of adult trout to increase the knowledge which will lead to further improved management actions in the future.

Keywords: Salmo trutta, acoustic telemetry, spawning migration, hatchery-reared, genetic assignment, sea-run, resident, Laisälven.

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1. Introduction

1.1. Background

Previous research on Brown trout (*Salmo trutta* L.) living in the same catchment reveals a variation in life-history strategy among individuals (Ferguson 1989; Elliott 1994). The strategy variations occur in migration, spawning, and selection of feeding areas. This results in different ages and sizes of trout at the time for migration and spawning (Jonsson & Jonsson 2006). These differences are primarily driven by the type of habitat utilized during the adult stage. A typical trout riverine water system is a river consisting of stream sections, lakes, and an outlet in the sea (Banks 1969; Pakkasmaa & Piironen 2001; Cucherousset et al. 2005). Some individuals leave their nursery area to find other habitats suitable for feeding and growth (Klemetsen et al. 2003). In the feeding habitat, adult trout spend a couple of years until they have reached maturity and migrate back to their natal stream for spawning (Stuart 1957; Pakkasmaa & Piironen 2001; Cucherousset et al. 2005). In contrast, related individuals may spend their whole lives in the natal habitat without any extensive migrating at all, only using different parts of the river depending on the season (Elliott 1994; Pakkasmaa & Piironen 2001; Cucherousset et al. 2005). These different life strategies are categorized into sea-run trout (*Salmo trutta trutta),* lake-run brown trout (*Salmo trutta lacustris*) and resident brown trout (*Salmo trutta fario*). As the names explain, the sea-run trout migrate to the sea, the lake-run brown trout migrate to a lake, and the resident brown trout stays in the natal river throughout its life (Pakkasmaa & Piironen 2001).

As the three life-history strategies are fundamentally different, management strategies aiming to conserve, restore or promote these life-history strategies differ to some extent. In rivers where the three life-history strategies coexist, management is most commonly aiming to conserve, restore or promote the sea-run life history (Lundqvist et al. 2006) as these, often large-bodied individuals (Jonsson & Jonsson 2006), consist a valuable recreational and economical resource. However, the sea-run life-history strategy might not be the most logical life-history strategy to focus on from both a recreational and an economical perspective.

In the Laisriver, in northern Sweden, all three life histories are present (Östergren 2006). However, management measures have mainly been focusing on the sea-run strategy (Jonsson et al. 1999; Palm et al. unpubl.a). In spite of the fact that lake migratory individuals grow large and consist an increasingly popular target for recreational fisheries in the area (Jordbruksverket 2017), hardly any resources are allocated for specific management actions focusing on this life history.

Historical fish management measures conducted in Laisriver have mainly been the release of hatchery-reared trout, commonly by age one or two, from both sea-run and resident origin. Yet, the number of stocked sea-run individuals exceeds by far the number of stocked resident individuals (Hedin & Alkne 1993; Jonsson 2001). Although partly evaluated, the survival and fate of stocked individuals is not fully understood.

Despite stocking of sea-run trout in Laisriver has been conducted for several decades, little is known about its relative contribution to fishing opportunities in comparison to lake migratory or resident trout.

Furthermore, key information that would improve management of the resident or lake migratory life history, e.g. seasonal migration, is scarce.

1.2. Aim

The aim of the study is to compile the current knowledge about sea-run and resident brown trout in the Laisriver and to discuss prioritization of management measures of these two stocks. Specifically, this study focuses on the following questions:

1. Are adult trout in Laisriver of a sea-run or resident origin?
2. If the adult trout is resident, what is the home range size?
3. Is stocking of hatchery reared trout juveniles a sufficient method to increase sea-run trout in Laisriver?
4. Which life-history strategy, sea-run or resident, should be prioritized in fish management actions?

2. Material and method

2.1. Study area

The study was conducted in Laisriver, the largest tributary to the Swedish national river Vindelriver. Laisriver is a 190 km long river that originates from the mountain area in northern Sweden, over 300 kilometers from the coastline. The water from Laisriver merges into two other rivers, Vindelriver and later on Umeriver, before running out in the Gulf of Bothnia at around 63°38´N, 20°18´E (Figure 1). This includes flowing through the large-scale hydropower station in Norrfors, in Umeriver. The total drainage area for Laisriver is 2960 km^2 and the annual mean water flow is 63.5 m^3 s-1. It runs mostly through forest landscapes and consists of a mixture of slow and fast flowing sections with rapids and cascades.

The river also includes three major lakes, Lake Storlaisan, Lake Granselet and Lake Nedre Gautsträsk. L. Storlaisan is the most northerly located at an altitude of 424 m, it has an area of 27.5 km^2, a depth of 79 m (SMHI 2021), and is approximately 40 km long and 1000 m wide (measured in QGIS version 3.16.2). L. Granselet is located in the middle at an altitude of 390 m, has an area of 2.5 km^2, a depth of 24 m (SMHI 2021), and is approximately 10 km long and 500 m wide (QGIS). L. Nedre Gautsträsk is the most southerly located, at an altitude of 341 m, an area of 10.5 km^2, a dethp of 16 m (SMHI 2021), and is approximately 6 km long and 2 km wide (QGIS). L. Nedre Gautsträsk is also the location where Laisriver enters Vindelriver, which L. Nedre Gautsträsk belongs to.

The fish species present in Laisriver are brown trout, grayling (*Thymallus thymallus* L.), northern pike (*Esox Lucius* L.), Eurasian perch (*Perca fluviatilis* L.), burbot (*Lota lota* L.), whitefish (*Coregonus sp*), roach (*Rutilus rutilus*), Eurasian minnow (*Phoxinus phoxinus* L.), Atlantic salmon (*Salmo salar*) and common dace (*Leuciscus leuciscus*) (SERS 2021).

Historically, both the river and the surrounding area have been negatively affected by anthropogenic actions, such as timber floating (Törnlund 2007; Johansson 2013), phenoxy acid herbicides spraying on deciduous trees (Laestander 2015) and metal contamination from former lead-mining in Laisvall (Rickard et al. 1979; Lidman et al. 2020). Today the river runs within NATURA 2000 areas

(Länsstyrelsen 2007) and is part of the UNESCO biosphere reserve Vindelälven-Juhttátahkka (UNESCO 2019).

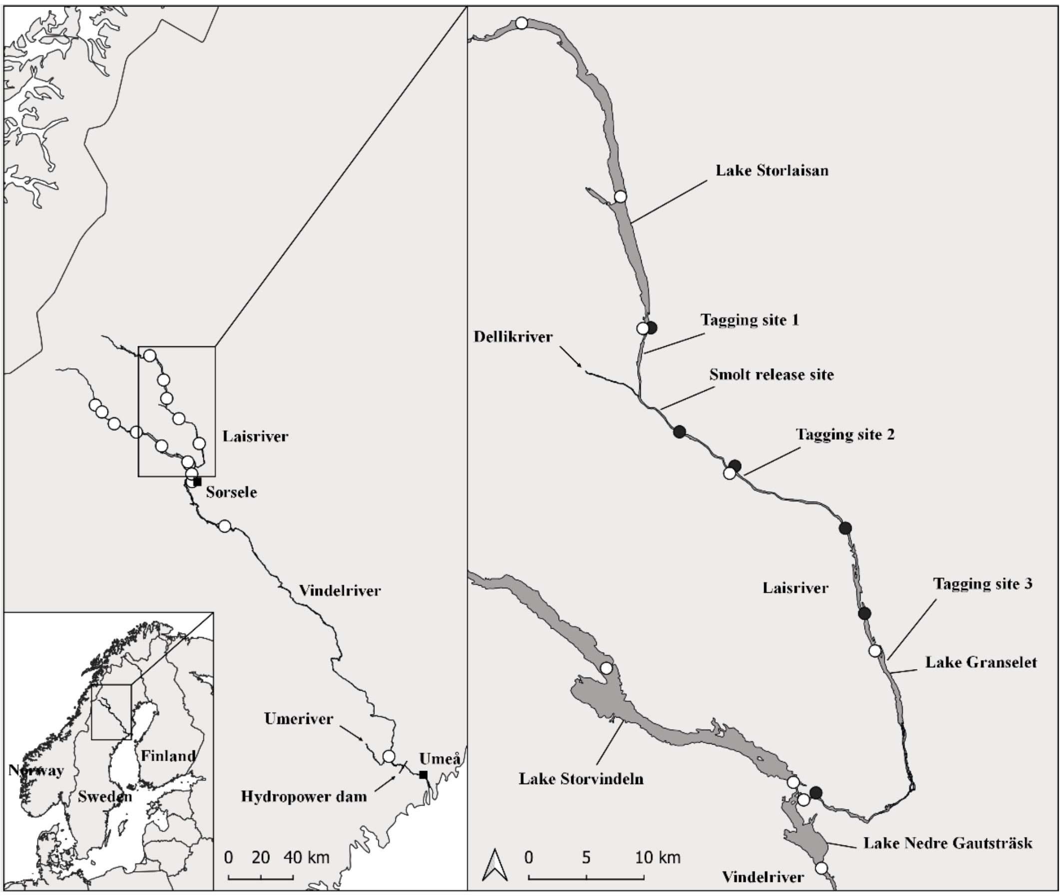

Figure 1. Map over the study area. White circles represent the receivers for the adult trout in 2020. Tagging sites 1, 2 and 3 represent the fishing and tagging site for adult trout in 2020. The black circles represent the receivers for the hatchery reared juveniles in 2019. Smolt release site is where the juveniles were released in 2019.

2.2. Overview of the study

To evaluate the proportion of resident and sea-run trout, two methods were combined. At spawning time in 2019 and 2020 three sections (Figure 1) of the river were sampled. Tissue samples were collected (2019 and 2020) from captured trout larger than 40 cm and tagged (in 2020) before release. By combining genetic information and patterns of post-spawning migration, resident and sea-run individuals could be distinguished.

Patterns of post-spawning migration were obtained by a series of permanent receivers deployed throughout the catchment and a number of manual tracking events from October 2020 through May 2021.

To evaluate if stocking of hatchery-reared trout juveniles is a sufficient method to increase sea-run trout in Laisriver, the fate of 39 tagged hatchery-reared trout juveniles was studied from September 2019 through August 2020. Data of juvenile movement and survival was obtained by series of permanent receivers deployed throughout the catchment.

2.3. Fish tagging

Adult fish

In September 2020, adult fish (mean length 50.7 cm) were tagged at three different locations in Laisälven (Table 1). The sites were located 5, 18 and 35 kilometers downstream of L. Storlaisan respectively. At tagging sites 1 and 2 located between L. Storlaisan and L. Granselet, the fish were caught using an electrofishing boat. At tagging site 3, located in L. Granselet, the fish were caught by angling. Each fish (site 1 = six trout, site 2 = thirteen trout and site 3 = three trout) was surgically equipped with a coded transmitter (V13T1x; Innovasea Systems Inc., Bedford, Nova Scotia, Canada (13 mm diameter, 34 mm length) or V16-4x (16 mm diam., 68 mm length), depending on fish size). Before surgery, done in field, the fish was anesthetized in a 50L water container with 5% of MS222 for two to three minutes. Total length measures and fin tissues were collected followed by implantation of the transmitters. The transmitter was inserted into the abdomen through a three cm incision that was closed with two sutures. Before release, the fish were kept in enclosures with fresh water for a minimum of ten minutes to ensure proper recovery. All handling and tagging methods were proceed with permission from the Animal Ethical Board of Sweden (reference nr: A20-18).

Table 1. Adult trout tagged in Laisriver in 2020 with date, length, sample size and habitat at each site.

Site	Habitat	N Trout	Mean length (cm)	min / median / max length (cm)	Tagging date
1	Stream	6	39.6	35 / 39.25 / 46	2020-09-21
2	Stream	13	53.9	38 / 56/ 67	2020-09-22
3	Lake	3	59	52 / 62/ 63	2020-09-25
Total		**22**	**50.7**	**35/ 51.5 / 67**	

Hatchery reared juveniles

Hatchery reared juveniles, Vindelriver sea-run stock, was obtained and tagged at the Norrfors rearing facility in the vicinity to Umeå. The fish were 2 years of age (mean length 22.6 cm, mean weight 124.8 grams), assumed to smoltify and start their sea-ward migration during the present fall or the following spring. Every fish was surgically equipped with a coded transmitter (V7T-2x (7 mm diam., 19 mm length); Innovasea Systems Inc., Bedford, Nova Scotia, Canada). Before surgery, the fish were anesthetized in a 50L water container with 5% of MS222 for two to three minutes. Total length measures and weight were collected. The transmitter was inserted into the abdomen through a two cm incision that was closed with one suture. After tagging, the fish were kept in enclosures with fresh water for 48 hours to ensure proper recovery before being transported to the release site in Laisriver. After 24 hours of additional recovery in enclosures placed in Laisriver after arrival, the trout were released at locations in the river between receivers 1 and 2 (Figure 1). All handling and tagging methods was proceed with permission from the Animal Ethical Board of Sweden (reference nr: A20-18).

2.4. Fish tracking

Adult fish

Detections from the tagged adult fish were collected by acoustic receivers from September 2020 through May 2021. Eleven permanent receivers (VR2Tx; Innovasea Systems Inc., Bedford, Nova Scotia, Canada) were placed in Laisriver and Vindelriver (Figure 1). In addition, manual tracking was carried out on four occasions by omni-directional hydrophones (VH165 or VHTx-69k) together with a receiver (VR100; Innovasea Systems Inc., Bedford, Nova Scotia, Canada). The receivers is capable to detect and register pings up to approximately 1000 meters, but detection probability rapidly decreases with increased range. The accuracy in detections depends mainly on background noise and physical objects under water such as vegetation, air bubbles and suspended particles (Leander et al. 2019). Since the river width in Laisriver almost never exceeds 1000 m, the receivers in this study are considered likely to detect pings from passing transmitter-equipped fish. However, in turbulent areas, the pings are not considered to pass through, due to high channel heterogeneity in the rapids, such as the occurrence of boulders, multi-channel sections and deep pockets (Leander et al. 2019). When a transmitter was detected from the manual tracking, its position was registered using GPS (Garmin GPSMAP 66st; Garmin Ltd., Kansas City, Missouri, USA).

Hatchery reared juveniles

Detections from the tagged juveniles were collected by acoustic receivers. From September 2019 through August 2020 six permanent receivers (VR2W; Innovasea Systems Inc., Bedford, Nova Scotia, Canada) were placed in Laisriver (Figure 1).

2.5. Genetic analysis

Adult fish

Tissue from one of the pelvic fins from each of the adult trout caught in 2019 and 2020 was collected and stored in alcohol. The tissue was analyzed at SLU in Umeå (Department of Wildlife, Fish, and Environmental Studies) using SNP methodology in a Biomark hd instrument (Fluidigm, San Francisco, California, USA). SNP means Single-Nucleotide Polymorphism, which is the same as single-base polymorphism. Single-base polymorphism is a variation in the genome that affects single nucleotides at specific DNA sites (Vignal et al. 2002). The nucleotides exist in four forms A, T, C and G. For example, the DNA sequence in one individual may be AA**T**GCC while in another individual it may be AA**C**GCC. All tissue samples were tested for variations at 90 positions in every individuals' genome and finally compared to the genetic baseline developed for the Vindelriver catchment by Palm et al. (unpubl.b) using *Assignment analyses*. Palm et al. (unpubl.b) sampled tissue from juvenile brown trout across 24 geographically separated sites evenly spread throughout the catchment. In their analyses, 30 genetically separated populations were found. In addition to their baseline development, they also sampled adult trout ascending from the sea, i.e. anadromous brown trout on their spawning migration, caught at a hydropower plant located close to the rivermouth (Figure 1). The trout sampled in this study were also compared to those anadromous brown trout samples. However, according to Palm et al. (unpubl.b) anadromous brown trout in the Vindelriver catchment is a genetically heterogeneous group separated into 17 genetic subgroups, based on samples from 2012, 2014, 2015, 2018, 2019 and 2020.

3. Results

Adult fish

Detected movement patterns of tagged fish were based on data from eleven receivers in combination with manual tracking carried out in November, January, February and April 2020. From the 22 tagged trout, a total number of 19 individuals were found on at least one occasion (Figure 2). Some individuals moved long distances in the river, and some remained stationary throughout the whole study period. Nevertheless, the stationary individuals had some minor movement detected from the manual tracking. Five individuals from site 2 moved to areas in the vicinity of sites 1 and 3, and one individual from site 1 moved to the lake located upstream. Overall, the data for all the trout revealed movement from 0 – 35 kilometers and the distance from the northernmost to the southernmost known position was 80 kilometers. This home range includes the lakes L. Storlaisan and L. Granselet. None of the 19 detected trout left the Laisriver. Three trout were not detected.

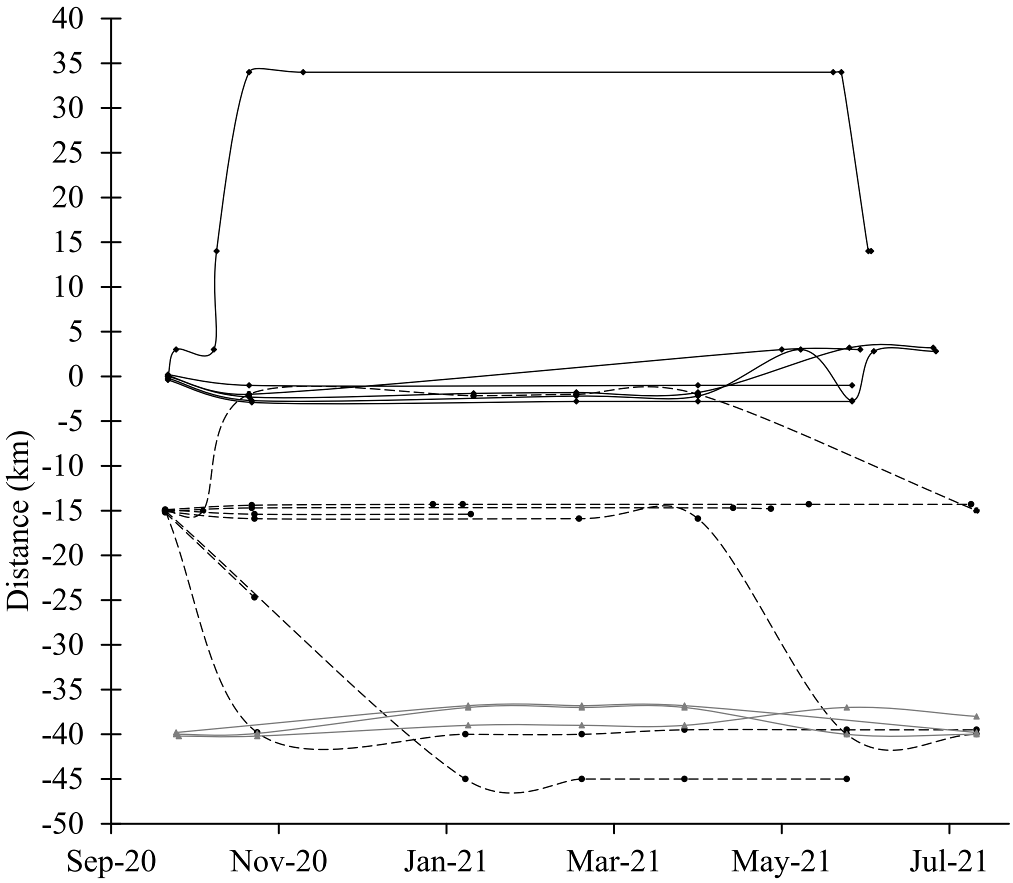

Figure 2. The locations and movement for the adult trout in Laisriver 2020 – 2021. Data registered from manual tracking and from the receivers. Each line represent one individual and the dots are the detections from a manual tracking occasion or at receivers. Trout from site 1, location set to 0 km, n = 6, shown as solid black lines, trout from site 2, located 15 km downstream, n = 13, shown as dashed black lines and trout from site 3, located 40 km downstream, n = 3, shown as solid grey lines. Total n = 22. Lines from individuals migrating at the same time and location may overlap. The last dot on a line represent the latest detection. Distance on the y-axis, positive values indicate upstream movement, negative values indicate downstream movement.

Hatchery reared juveniles

Data from the receivers in 2019 revealed intense movement from the beginning of the trial (Figure 3). A large majority of the fish was detected immediately after being released. After six days no more detections were found except for one fish that was detected 28 days after release. 5 out of 39 fish were not detected in either receiver 1 nor 2, which indicates that they may have stayed or died somewhere between these two receivers. The remaining 34 fish moved downstream to receiver 2. 18 of these individuals then continued downstream to receiver 3. Five of them continued further downstream to receiver 4, and eventually, three of them reached receiver 5 and entered L. Granselet. However, no individuals reached the most downstream located receiver placed where Laisriver enters L. Nedre Gautsträsk. Notable is, that the last detected individual arrived to L. Granselet on October 24th, 28 days after being released. One day earlier, on October 23rd, it passed receiver 4 located 8 km further upstream. Consequently, this individual spent 27 days moving a distance of 12 km between receivers 3 and 4 whereafter it increased its speed to migrate 8 km in approximately one day.

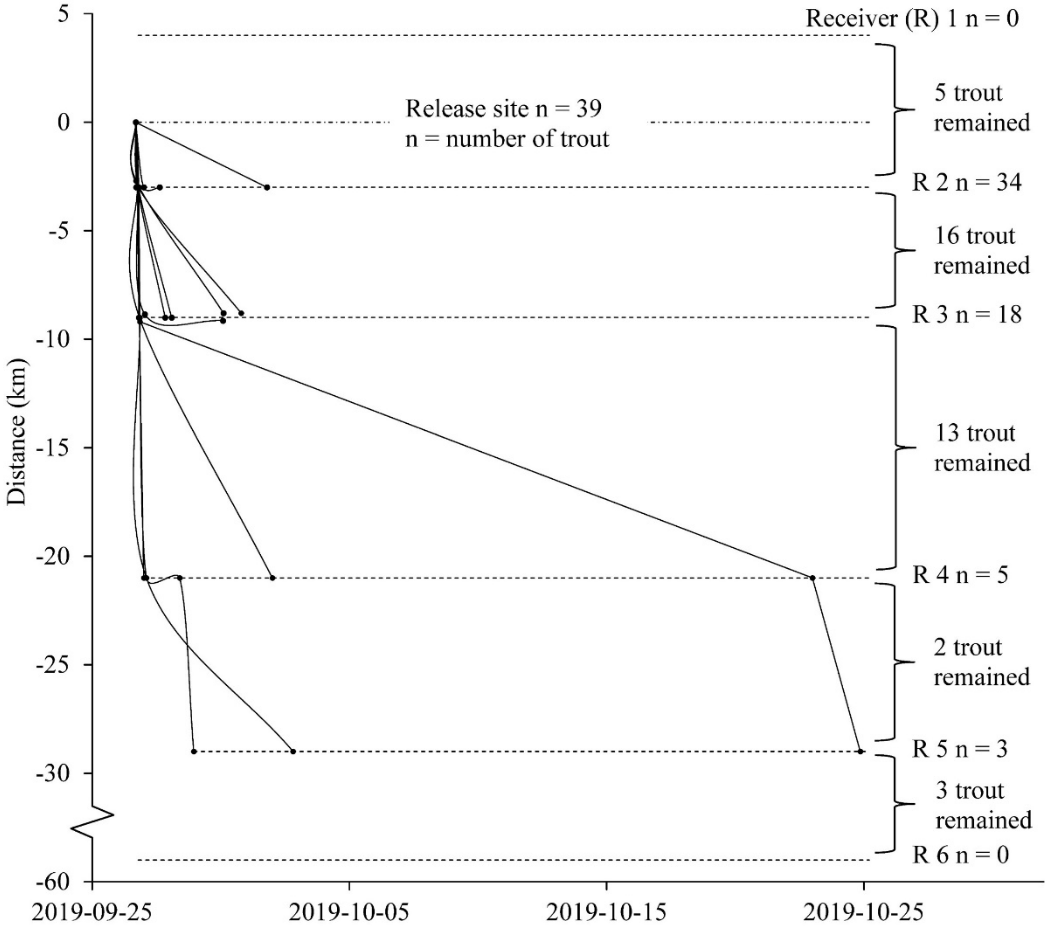

Figure 3. The movement pattern for the hatchery reared juveniles in 2019. Each solid line represent one individual and the dots are the detections at receivers. Lines from individuals migrating at the same time and location may overlap. The last dot on a line represent the latest detection. Dashed horizontal lines represent the location of receivers in relation to release site set to 0 km. Distance on the y-axis, positive values = upstream movement, negative values = downstream movement.

Genetic analyses

Of all sampled trout, 32 individuals had the adipose fin intact, indicating a wild origin (Table 2). Tissue analyzes revealed substantial genetic deviance between the sampled adult trout and most of the 30 genetically separated populations found by Palm et al. (unpubl.b). The population in the genetic baseline that was genetically closest to the sampled trout was the Laisriver population. 31 of the 32 sampled trout were genetically assigned to one single population found in Laisriver. The remaining individual was assigned to another population located over 200 km downstream from the site of catch. In addition, one individual had a cut adipose fin, which indicates a hatchery reared origin, and it was probably released as juvenile over 200 km downstream the catch site. From the anadromous brown trout samples by Palm et al. (unpubl.b), individuals was genetically assigned to the Laisriver population in two out of six sampled years. The portion of Laisriver trout in the annual number of ascending anadromous individuals was 4% in year 2018 and 3% in 2019.

Table 2. Site number, habitat type and genetical assignment (G.A.) of sampled adult trout of wild origin in Laisriver 2019 and 2020. G.A. to Laisriver refers to genetically assigned to the Laisriver baseline, G.A. to >100 km refers to a baseline found 100 km (river length) downstream from Laisriver and G.A to >200 km refers to a baseline found 200 km downstream from Laisriver.

Site	Habitat	N	G.A. to Laisriver	G.A. to >100 km	G.A. to >200 km
1	Stream	6	6		
2	Stream	23	22	0	1
3	Lake	3	3		
Total		**32**			

4. Discussion

This study generated significant data that could be used in managing Laisriver trout in the future. Especially in prioritizing between what life histories to focus on and what enhancement methods to use. Below the four specific questions stated in the introduction are addressed.

Are adult trout in Laisriver of a sea-run or resident origin?

The result from the genetic analysis indicated that the majority of sampled adult trout was closely related to the genetic baseline for Laisriver trout developed by Palm et al. (unpubl.b). Despite three different sample sites and one site with samples from two different years (site 2 from 2019 and 2020), only one out of the 32 sampled trout was genetically related to another part of the Vindelriver catchment. When genetically compared with tissue samples from upstream migrating anadromous spawners caught near the ocean, it was obvious that trout originating from Laisriver also has the ability to adopt an anadromous life history. Thus, anadromous brown trout in Laisriver do not constitute a genetic population separated from resident individuals. According to Östergren & Rivinoja (2008), the seaward migration of anadromous brown trout kelt in the Vindelriver catchment occurs at fall after spawning or the following spring. In the present study, 19 out of 19 tagged and detected trout individuals did not migrate out from Laisriver after the spawning period or the following spring and summer. As 100% of 19 randomly caught individuals showed no signs of anadromous brown trout post-spawning behaviour it can be assumed that the predominant life history among trout in Laisriver is resident and only a small fraction of the juveniles produced undertake seaward migration. These results contradict some of the findings by Östergren (2006; 2011) who also studied trout in the Vindelriver catchment. Based on telemetry and genetic (microsatellites) analyses he concluded that trout in Laisriver was largely from anadromous origin and that the Laisriver genotype was highly similar to trout in other parts of the catchment. As the sample size in this study is larger and the genetical method used (SNP) has a higher resolution, and therefore more likely to detect genetical differences, I am confident that my results reflect the truth more accurately.

If the adult trout is resident, what is the home range size?

In the time frame from September 2020 to July 2021 the results from the adult trout movement revealed home ranges up to 80 km (river length), limited to only the Laisriver. This home range included the two lakes above and below the tagging sites, and all the stream sections between them. Trout showed variation in migration distance and habitat use, both during winter, spring and early summer. Some individuals did not move at all, some moved to other stream sections or one of the lakes. It was clear that the periods for the most intense movement were in the fall after tagging, i.e. spawning, and in the spring. After tagging, all trout that were detected, moved 0 – 35 km to areas where they remained stationed with almost no migration during the winter. After the winter, movement started to occur again for some individuals. Thus, trout in Laisriver use home areas including both stream sections and lakes, and with sizes large enough to cross several different fishery management areas. This is an important finding in the understanding of how to manage the Laisriver trout, since the regulation in one fishery area, also has an impact on trout in the neighboring fishery areas. In comparison with other systems, this size of trout home range is nothing unusual. In the nearby Ammarnäs population, for instance, trout have similar home ranges including both stream sections and large lakes (Näslund 1993; Spade 2011).

Is stocking of hatchery reared trout juveniles a sufficient method to increase sea-run trout in Laisriver?

The results from the juvenile trout from 2019 showed that some individuals moved downstream immediately after being released in the beginning of the trial. However, they did not pass the downstream most receiver. This indicates a low rate of survival or a resident behaviour. Most likely they died from predation or starvation, otherwise they should have been found on a receiver sometime during the following year. The individuals that did not start downstream migration also indicates a switch to a resident behaviour or instant mortality. This demonstrates that the release of hatchery reared juveniles, i.e. compensatory stocking, is a non-successful management method both for enhancing sea-trout abundance as well as increasing fishing opportunities on resident fish in Laisriver. When enhancing trout population through stocking in Laisriver, stocking of green eggs might be a more sufficient method according to Palm et al. (unpubl.a). However, as resident and anadromous trout in Laisriver originates from the same population, the best way to increase both anadromous and resident trout is probably by improving the self-reproduction through habitat restoration and harvest regulations, i.e. bag- and size limits. When restoring spawning beds Palm et al. (2011) proved that the number of juveniles increases after restoration which would be a key factor to generate a more reproductive system. Type of harvest regulation should be set with the purpose to increase the productivity of the population. For example, it has been shown that first-time spawners do not contribute to the population growth more than their own survival. Repeat spawners, which generally carry more eggs, do on the other hand have a substantial impact on the population growth, hence they are important for future reproduction (Stubberud et al. 2021) and should not be allowed to be harvest. A regulation on a maximum body length of fish that are allowed to harvest would be a sufficient method to protect repeated spawners.

Which life-history strategy, sea-run or resident, should be prioritized in management actions?

The results of this study indicate that the dominating fraction of trout in Laisriver applies a resident strategy. Even the hatchery-reared individual among the tagged adult trout showed a resident behaviour. I strongly recommend focusing on resident trout in future management actions. First of all, the Laisriver trout is a largely genetically unique group, and therefore perhaps adapted to the climate at these latitudes. However, if the Laisriver trout has developed its genome through evolution by time or, is shaped by human impacts from earlier compensatory releases is not yet investigated. Moreover, when introducing other genetic stocks in the river, changes to the genetic variation might occur and it cannot for certain be predicted what the outcome would be. A known outcome from compensatory releases is a reduction of the genetic variation (Vasemägi 2004; Lundqvist et al. 2006), and therefore, one can think that compensatory releases may harm the genetic composition in Laisriver trout. Instead, managers should aim to maintain and enhance the present resident Laisriver trout in the future. This is best done by improving and restoring the environment to help the trout reproduce by itself, and not by stocking. Two main negative aspects of stocking are difficulties to have a full-scale program with the correct genetics and that it requires large financial and work-intensive efforts. To specifically point out two management actions I would suggest to (1) restore the river from its earlier heavily degraded measures from timber floating, and (2) protect the important large individuals by improved fishing regulations. Finally, I will emphasize, according to the data, that if a trout is catched in Laisriver it is most likely a resident individual. However, owing to the plasticity of brown trout with individual variation in life history, an increase of the resident Laisriver trout will also result in an increased number of trout adopting an anadromous strategy, and therefore create benefits to the whole Vindelriver catchment as well as fisheries in the Baltic.

Sources of error and future research

When estimating the size of home ranges and movement of adult trout the methods used, sample size and the time frame studied will influence the outcome.

Firstly, technical issues can give us misleading guidance in acoustic telemetry. For instance, if a transmitter is recorded from the same position regularly, it is hard to separate a dead fish from a living one. Therefore, conclusions should be drawn carefully from situations like that. This could be questioned regarding the stationary individuals from the adult trout in this study. However, some smaller movements for most of the stationary trout were noted from the manual tracking occasions, indicating the trout to still be alive. To prevent issues like this, mortality transmitters can be used, but with more advanced techniques, the more expensive the cost. Although the transmitter usually performs very well (Hellström pers. Comm. 2020), another issue that could be, is that some transmitters may be out of function, which in this study could be the case with the adult trout where three individuals were never relocated after tagging.

Secondly, the larger the sample size, the more accurate results. For example, if 40 out of 40 trout instead of 19 out of 19 are showing a resident behaviour, that result would be more reliable. Or, if it only is a small fraction of the Laisriver trout that takes on a seaward migration, this behaviour is more likely to be detected with a larger sample size. Another aspect to have in mind is that even if the distribution between resident- and sea-run trout is equal, a larger amount of resident trout would have been expected to be found in the river, since they spend their whole lives here. Sea-run trout, on the other hand, are only visiting the river to spawn and only the spawning individuals are here, while the rest remain located in the ocean.

Thirdly, the time frame is a factor of great importance when studying fish behaviour. In this study, the adult trout was only followed from fall to summer, unable to catch seasonal variations and behaviour all year round.

Due to these three factors, no conclusions about the three non-detected adult trout were made, even though they might as well be alive and located in areas between receivers. Also, the movement results from the adult trout should be interpreted as accurate data but, with a little portion of skepticism in mind due to potential year-to-year variations.

In the future I suggest similar studies in the area to be conducted to monitor the tagged trout, and at larger sample size. That will help studying similar or different behaviour and also to study temporal variability, i.e. all year round observations and signs of seasonal variations. Finally, one thing that would increase the quality of the data on a small scale level is to increase the receiver density to increase the detection rate. However, with more receivers, the cost of the study will increase. Therefore, good site selection for receivers might be as good as increasing the number of receivers.

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