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Migration and Area Use of European Perch (*Perca fluviatilis*) in the Lower Reaches of the Glomma Watercourse and the Øra Estuary – An Acoustic Telemetry Study

Sondre Haugholt Breian
Natural resource management – Naturforvaltning MSc
Supervisors:
Thrond Oddvar Haugen (NMBU)
Ole Håkon Heier (NJFF)

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Photo credit: Sondre Breian

Preface

This thesis marks the end of my MSc at the Norwegian University of Life Sciences and the start of my career working with fishing and fish conservation.

First, I would like to thank my supervisor Thrond Oddvar Haugen for all your help and follow-up, even though I have worked a full-time job besides this project. Your enthusiasm is contagious, and it’s always fun to be in the field with you. I am looking forward to working with you on different fish-related occasions.

I am also very grateful for the guidance and friendly conversations with my co-advisor, Ole Håkon Heier. Your knowledge regarding fish and fish behavior is almost boundless. You also share my deep and loving passion for perch, especially this unique population and area.

I will also use this opportunity to thank all the people that have been involved in this project for all the help and support along this journey. Rein Riise Dalermoen, Thor Bjørn Rudi Thorkildsen, Reidar Borgstrøm, Ivan Ivanov and Trond Eriksen. The project was financed with funds from: “Vannområde Glomma sør/Maria Bislingen”, Østfold/Viken county municipality, Fredrikstad & Sarpsborg municipality and Norwegian Hunting- and Fishing Association (central and Østfold). Without your help, it would have been impossible.

Lastly, I will give a shoutout to all the people working for our environment, restoring habitats for fish and animals, and are the main drivers behind managing our inland and marine fish stocks to secure sustainable fish populations.

Your work is priceless.

Ås, 2022

Sondre Haugholt Breian

Abstract

The amount of research done on migration patterns for European perch (*Perca fluviatilis*) between fresh and brackish water is limited, and it is uncertain how these populations of perch utilize the different habitats throughout the year and the timing of migration and what are the drivers behind these. This study aims at enlightening some of these enigmatic patterns and mechanisms by monitoring the migration and habitat use of individual perch in the Visterflo-Glomma-Øra system in southeastern Norway.

Acoustic telemetry was conducted for tracking 25 individuals of perch using tags equipped with depth sensors. All individuals were captured using rod-and-line during the summer/early autumn at two different locations: Øra and Visterflo, considered the two main gathering areas for perch in summertime (Øra) and autumn (Visterflo). A total of 30 acoustic receivers were placed throughout the study area, covering both freshwater and brackish-water habitats. These passive receivers logged signals throughout the June-November 2021 study period.

The telemetry data revealed tremendous inter-individual variation in habitat- and depth utilization between individuals throughout the study. 12 of the 14 perch tagged at Øra returned to Visterflo in the autumn while two disappeared from the dataset. Statistical modeling showed that day-to-day variations in water discharge and -temperatures were the main factors triggering return migration from Øra to Visterflo. All tagged perch in Visterflo during June, chose to stay in Visterflo the entire summer.

No perch smaller than 20 cm were caught or observed at the Øra station, and the perch that chose to migrate had faster growth and better condition. This can indicate that the perch has to reach a certain size before migrating to brackish water areas to feed and grow during the summer months. It is still uncertain what makes the perch choose to migrate between Visterflo and Øra. This population is probably genetically predisposed to this migration pattern, but this must be investigated further in comparison to other populations in the same watercourse.

Sammendrag

Mengden forskning som finnes på migrasjonsmønstre for europeisk abbor som benytter ferskvann og brakkvann er begrenset. Det er høyst usikkert hvordan disse populasjonene utnytter de ulike habitatene gjennom året, samt når de velger å migrere mellom disse. Denne studien hadde som mål å få klarhet i noen av hemmelighetene til denne unike og høyt verdsatte abborbestanden i Norge for å forstå atferds- og vekstmønsteret bedre.

Akustisk telemetri ble brukt for å spore 25 individer ved hjelp av tagger utstyrt med dybdesensorer. Alle individene ble fanget med stang og snøre i løpet av sommeren/tidlig høst på to forskjellige steder: Øra og Visterflo. Disse stedene er regnet som de to viktigste samlingsområdene for abbor om sommeren (Øra) og høsten (Visterflo). Totalt 30 akustiske mottakere ble plassert i både ferskvanns- og brakkvannshabitater i studieområdet. Disse passive mottakerne logget signaler gjennom studieperioden: juni-november 2021.

Telemetridataene avslørte store individuelle variasjoner i habitat- og dybdebruk gjennom hele studien. 12 av de 14 abborene merket ved Øra kom tilbake til Visterflo på høsten, mens to fisk sluttet å sende signaler. Analyser viste at dag-til-dag variasjoner i vannføring og temperatur var hovedfaktoren for å utløse migrasjon. Abborene som ble merket i Visterflo i første runde, valgte å bli i Visterflo hele sommeren og høsten.

Vi fanget eller observerte ikke abbor under 20 cm på Øra, og abboren som valgte å migrere og benytte seg av disse områdene, så ut til å ha bedre kondisjon og vekst. Det kan tyde på at abboren må nå en viss størrelse før den tar sjansen på å vandre til brakkvannsområdene for å spise og vokse i sommermånedene. Det er fortsatt usikkert hva som gjør at abboren velger å migrere mellom Visterflo og Øra. Trolig er denne bestanden genetisk disponert for dette vandringsmønsteret, men dette må undersøkes nærmere i sammenheng med andre populasjoner i det samme vassdraget.

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1. Introduction

Migration and utilization of different habitats are, for many animal populations, crucial for survival, reproduction, or maximizing growth (Tamario, et al., 2019). The benefits of such, often, bi-directional movements differ between species, populations, and individuals. Refuge against predation or better food availability are good reasons for migrating, but migration always comes with a risk of increased use of energy, a more significant chance of predation, or stress related to environmental differences between the habitats (Tamario, et al., 2019)

Studying animal species below the water surface is not as straightforward as studying species on land. With a completely different element to deal with, direct observation can only be done with special equipment like scuba diving gear, underwater drones, or binoculars made for such use (Kessel S. , et al., 2014). In line with technological advances in all fields, the ability to use acoustic technology in studies was explored in the 1970s (Kanwisher, et al., 1974). The first study involving acoustic telemetry was an active form of manual tracking of organisms with an acoustic tag. This method of acoustic telemetry was time-consuming and incomplete, so with the evolvement of passive forms of acoustic telemetry, utilizing arrays of passive receivers, an entirely new world of exploring and studying migration behavior on fish became available (Limley, et al., 1988).

Passive acoustic telemetry involves acoustic tags and a network of passive receivers (Kessel S. , et al., 2014). The acoustic tags are most often implanted into the body cavity by surgery, and they transmit coded acoustic signals at pre-defined and most often random intervals, typically between every 30 and 90 seconds. The received signals are logged continuously by the receivers in the network. The data of the movements are then stored in the receiver until they are downloaded manually for later analyses (Kessel S. , et al., 2014). This type of acoustic telemetry provides unique insight into the movement of populations or groups and addresses the differences in the amount of migration between tagged individuals (Baras & Lagardère, 1995). Some acoustic tags are equipped with various sensors such as temperature, pressure, gyro meter and accelerometers, providing information about the depth- and habitat use, which can be used for analyses of vertical movements as well (Leclercq, et al., 2018).

Habitat loss is one of the five important drivers for loss of biodiversity (Rafferty, 2019). The loss of habitats can happen naturally, but the most significant part of habitat loss happens when humans interfere with nature by clearing forests, filling wetlands, channeling streams, and constructions (Rafferty, 2019). For migratory species or populations, the loss of habitat can have an extensive, negative impact on their viability (Goss-Custard, et al., 1995)

Fortunately, many habitats have not been eradicated. Instead, they are reduced in quality because of runoff or pollution by increasing activity in agriculture, industry, or urbanization (Kerr & Cihlar, 2004). Throughout the last years, there has been significant pressure from activities involving construction work and urban development in the lower reaches of the Glomma-Øra estuary, around Fredrikstad. Some of these activities, such as filling of the Seutelva, dredging of ports and fairways, and an increase in the number of moorings in the area, involve possibly negative impacts on aquatic life, especially fish that use these habitats during different life stages and seasons.

The perch population in the lower reaches of the Glomma catchment is believed to hold one of the fastest-growing perch individuals in Norway, with a large number of big individuals (i.e., > 1 kg) in the population. The growth of the perch is known to be affected by biotic drivers like predation, food availability, and competition (Holmgren & Appelberg, 2001) (Persson & Greenberg, 1990) (Persson, et al., 2003). A significant variation in the availability of habitats and food sources benefits omnivore perch that utilizes both pelagic and littoral habitats depending on the diet and the local competition for food (Persson, et al., 2000). This system provides a lot of potential habitats for perch, and a perch above 1 kg in this system is not unusual at all. Because of that, it is a popular area for recreational fishing. It is crucial to gather information about the seasonal migrations and important places of residence to ensure the best conservation of this population.

1.1 Research objectives and hypotheses

This project aimed to look at the Glomma-Øra perch's migration pattern and habitat use from summer to late fall by using acoustic telemetry. In particular, I address the following research questions:

- 1) What triggers the migration from Øra to Visterflo, and are there larger groups that tend to migrate together or single individuals? I will explore if water discharge and temperature in Glomma comprise triggers of migration due to their inferred influence on the Øra estuary conditions.

- 2) How large-, and what areas do perch utilize during autumn in Visterflo?

- 3) Will fish that choose to migrate tend to grow faster, and at what size do they seem to start or stop migrating?

I predict extensive habitat utilization throughout the year, based on food availability and differences in temperature within the study area. Based on both anecdotal observations and scientific studies (Ložys, 2004). It is reasonable to predict that the perch that migrate to brackish water have higher individual growth and better condition than the perch that chooses to stay in freshwater all year due to the inferred high availability of food in the brackish estuary habitat.

2. Materials and methods

2.1 Study area

Glomma is the largest river in Norway, and the most species-rich river system in Norway, with a total length of 623 kilometers (Norsk Skogmuseum, u.d.), and a complete fish species count of 24 measured species in the biggest lake, Øyeren (Lyche Solheim, 2017). The river originates from the mountain area northeast of Røros and reaches the sea in Fredrikstad (Thorsnæs, 2021). The catchment area of the river Glomma is about 41 970 km^2 and covers approximately 12.8 percent of Norway's area on land.

This master thesis was restricted to the lower part of Glomma and Øra area at 59°14'31.4"N and 11°00'13.4"E, which is in Viken county and Østfold municipality (Figure 1). The study area covers a waterway stretch of 27.35 km consisting of a slow-flowing river (Glomma), a freshwater lake (Visterflo), and a part of an estuary that occurs at the river mouth (Øra). Sarpfossen acts as an obstacle to migration for all fish and sets the limit for the upper part of the study area. Fish may be able to swim from Visterflo – Skinnerflo – Kjølbergelva – Gressvik (Figure 1), but this route is relatively shallow (1 meter or less) in some parts and is not included in this study.

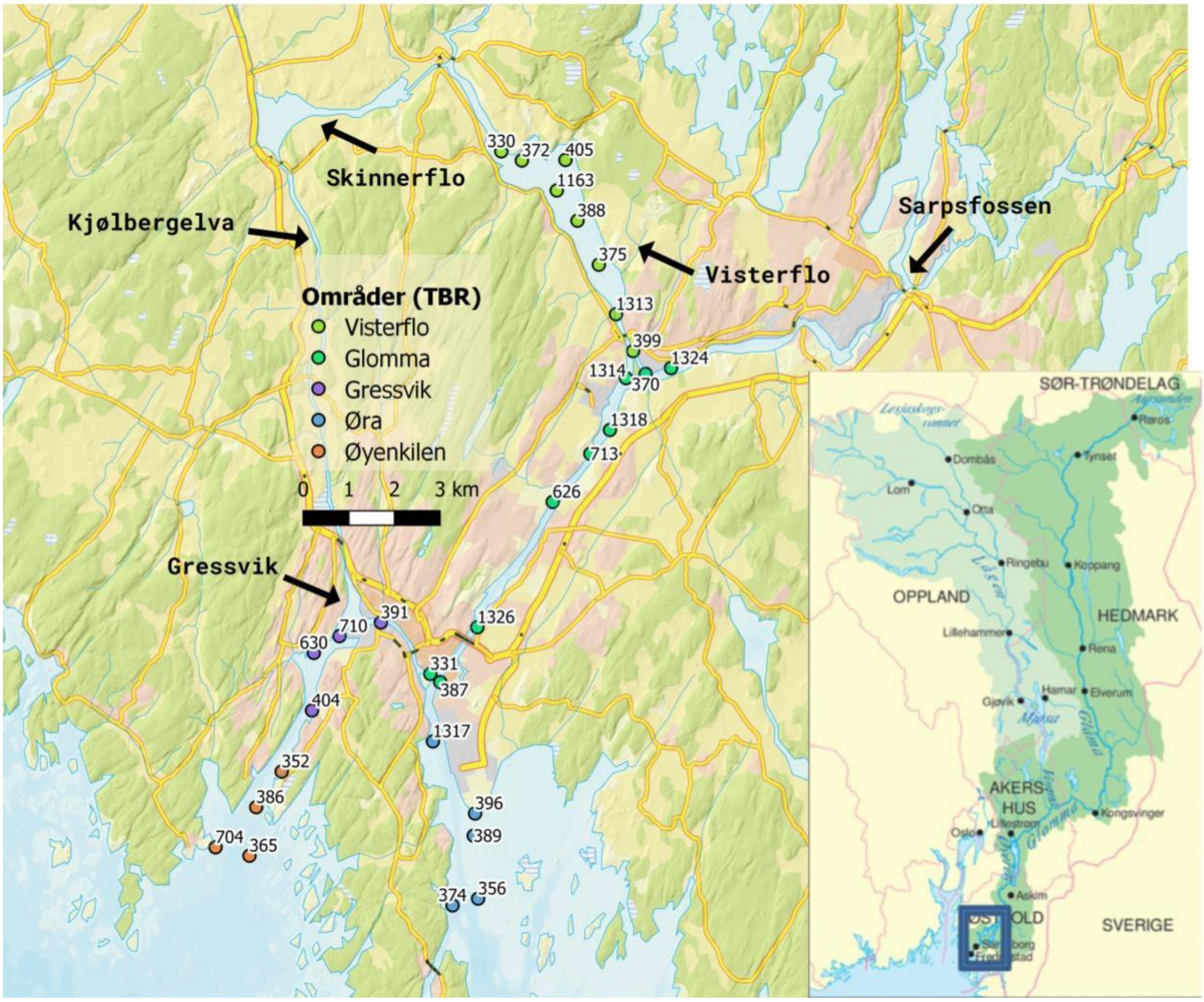

Figure 1 Catchment area for Glomma, study area and locations of the 30 acoustic receivers (TBRs – receiver IDs provided) Made in Qgis.

Map of catchment area By Kartverket/KF archive

Lisens: NLOD (Norsk lisens for offentlige data)

The lower reaches of Glomma, where it meets the ocean, is highly interesting from a chemical and biological perspective. Even though it mainly comprises of freshwater, it is also influenced by the tides from the sea. Observations of saltwater amphipods and Mysidacea in the river support that claim (Aanes & Kile, 2016). In addition to being interesting from a water chemical point of view, this is interesting for the composition of the fish and invertebrate community. Using gillnets and sediment samples proves that fresh and saltwater species can be found in the same areas during some periods of the year (Båtvik, et al., 2011). Amphipods and isopods are the dominating groups of benthic invertebrate fauna both in terms of number of species and abundance (Båtvik, et al., 2011).

The outlet of Glomma holds the biggest population of brackish water whitefish and one of the biggest perch populations with fast-growing individuals in Norway (Heier, 2018). The river mouth of Glomma is also known as a nursery area for several freshwater fish species (Pethon, 1980). This makes the question about area use and specific conservation highly relevant. Knowing both the ecological state and the migration of the fish populations is important to ensure that they are considered when infrastructural- and other intrusive projects are planned.

The lower part of Glomma is heavily influenced by industry, residential areas, and agriculture (Figure 2). There have been studies on the ecological status of the lower part of Glomma done by NIVA, where this study will take place. They examined the physical-chemical status of the water body, and it was classified as a "moderate ecological state" (Aanes & Kile, 2016). Organic matter is most likely the biggest reason for the given result. The area is described to be heavily influenced by industrial activities as well as contamination from the urban areas surrounding the river (Aanes & Kile, 2016).

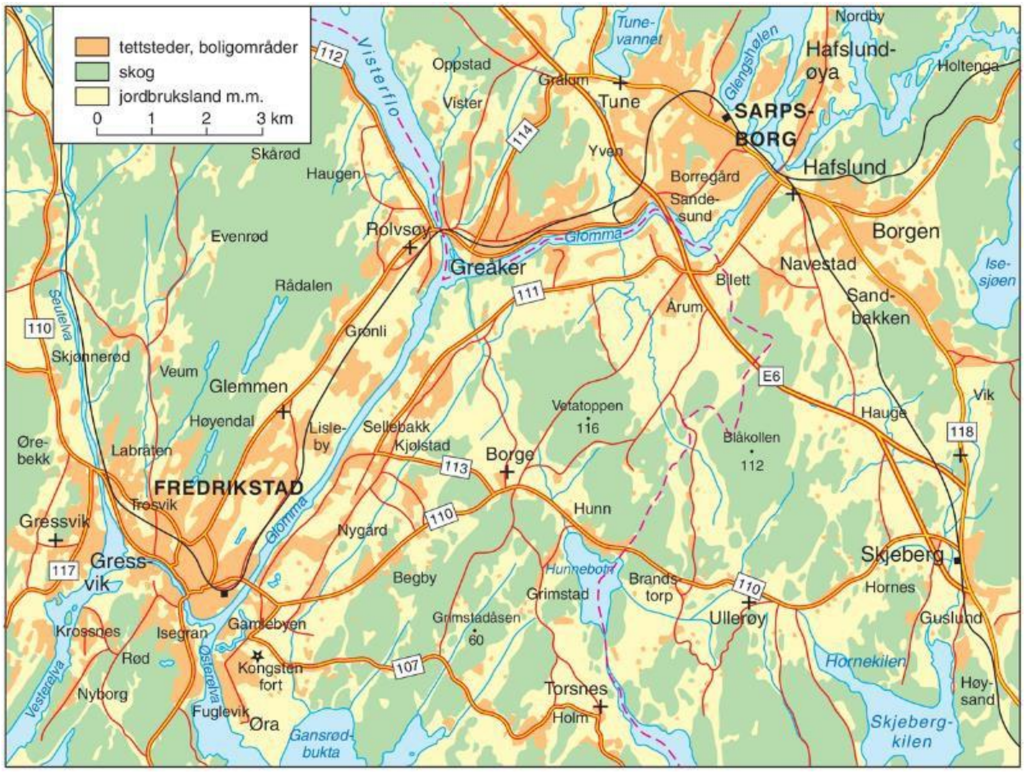

Figure 2 Land use around the lower part of Glomma. Orange symbolizes resident areas, green is forest and yellow is agricultural land. https://snl.no/Nedre_Glomma

2.2 Study species

The species that will be the focus of this thesis is the European perch (*Perca fluviatilis*). The perch belongs to the order Perciformes and the family Percidae and is a very opportunistic fish species when choosing a habitat and prey (Kottelat & Freyhof, 2007). The European perch is characterized by a big, spiny dorsal fin and a second soft-rayed fin. They often have a light or dark greenish color and more or less visible vertical stripes, often darker in color than the rest of the body (Thorpe, 1977) (Kottelat & Freyhof, 2007). Their lower fins usually have a red or orange color. Still, the color variation and intensity can differ between individuals, mainly due to diet choices, watercolor, and turbidity. The perch can reach an age beyond 15 years and a total body length (TL) of 45-50 cm if conditions are good (Studer, 2020).

Perch is naturally found in the eastern part of Norway and eastern parts of Finnmark, Troms, and Nordland (Hesthagen & Østborg, 2004). European perch migrated to Norway from the east about 9 000-10 000 years ago from the giant freshwater lake “Lake Ancylus” and are a part of the group called the “Skåne-Finnmark fishes” (Eggan & B.O, 1983). Even though the perch are mainly found in inland waters, they can cope with brackish water near coastal areas when the water temperature is higher than 6 °C (Studer, 2020).

European perch is a very popular target for anglers. The perch in this watercourse is believed to be one of the fastest-growing perch populations in Norway by body size. It is a very popular fishery after the big perch when they migrate to Øra in July-august, into Visterflo and surrounding areas in the autumn and when the ice settles in Gressvik. Catches of perch above 1 kg are not unusual at all.

Figure 3 A 50 cm perch, caught in Visterflo during spring 2021 (photo: Sondre Breian)

2.3 Fish handling procedure

2.31 Catching procedure

The tagging and handling procedure of the fish in this study were conducted by my supervisor from the Norwegian University of Life Sciences (NMBU) in Ås: Thrond Oddvar Haugen. In addition to that, the procedure required at least one person to help. Ole-Håkon Heier, Rein Riise Dalermoen, Thor Bjørn Thorkildsen and I were helping with handling the fish and the equipment and writing down the measurements during the surgery.

Table 1 Caught and tagged fish in Øra. Each fish was given the ID number of the acoustic transmitter. The floy tag number is the number which was written on the floy tags that was used to externally tag the fish. The age of the fish was determined by reading scales collected from each fish under a microscope.

Date	ID (based on transmitter ID)	Weight (gr)	Length (cm)	Floy tag number	Age
6/25/2021	4481	267	29.5	819	6
6/25/2021	4482	460	34.4	817	5
6/25/2021	4483	396	34	816	4
6/25/2021	4484	284	30.2	815	4
6/25/2021	4485	376	32.6	814	5
6/25/2021	4486	373	30.5	813	4
6/25/2021	4487	233	27.5	812	4
6/25/2021	4488	290	29.5	811	4
6/25/2021	4489	877	41.5	810	7
7/15/2021	4490	559	35	809	5
7/15/2021	4491	865	40	808	7
7/15/2021	4492	426	32	807	4
7/15/2021	4493	1111	42.5	806	9
7/15/2021	4494	1053	43	805	7
7/15/2021	4495	1200	45.5	804	10

Table 2 Caught and tagged fish in Visterflo. Each fish was given the ID number of the acoustic transmitter. The floy tag number is the number which was written on the floy tags that was used to externally tag the fish. The age of the fish was determined by reading scales collected from each fish under a microscope.

Date	ID (based on transmitter ID)	Weight (gr)	Length (cm)	Floy tag number	Age
6/25/2021	4480	367	32.2	825	6
6/25/2021	4479	866	47	824	16
6/25/2021	4478	743	41.5	823	8
6/25/2021	4477	146	24.5	822	2
6/25/2021	4476	341	32	821	5
6/25/2021	4475	218	26.5	820	3
8/31/2021	4496	605	35	829	7
8/31/2021	4497	1141	46	826	11
8/31/2021	4498	1090	45	827	12
8/31/2021	4499	809	43.5	828	9

A total of 25 perch were caught and selected for tagging during three periods over the summer season: June (25th), July (15th), and August (31st). The ten fish captured and tagged in Visterflo (Table 1) were caught on the 25th of June (6 fish) and the 31st of August (4 fish). The 14 fish captured and tagged at Øra (Table 2) were caught 25th of June (9 fish) and on the 15th of July (6 fish). The reason for the skew in tagged fish between the two locations was the goal to tag most of the fish that we considered to be from a migratory population. In other words, the perch that was in the estuary during the period the catching and tagging were done.

All the fish captured and tagged in this study were caught using rods, line, and different lures depending on the situation and fishing spot. The number of anglers per session ranged from two to seven active anglers. The majority of the fish were caught from a boat, and they were caught in depths between 1 and 8 meters in a range of different kinds of habitats. The biggest perches were caught in shallow water, over weed beds.
The gear used was more than heavy enough to ensure a short and effective fight of the fish, and a rubber net without knots was used to net the fish to ensure the safest and most careful handling possible. After netting, the fish was immediately put into 80 l basins (shore fishing) or 150 l live well (boat fishing), with separate oxygen pumps and possibilities for shading to reduce temperature- and visual stress during captivity to a minimum.

3.32 Tagging and handling procedure

2-Phenoxyethanol was used as an anesthetic with a mixing ratio of 4 ml/10 L with water (Kaiser & Vine, 1998). This was done *in situ* and in a bath with approximately 20 L of water and 8 ml of anesthetics. The fish was considered anesthetized when no spinal reflex could be observed (by gripping the caudal peduncle). First, external measurements, tissue samples, and fish scales were conducted. This included measuring the total length (with the mouth closed, all the way to the tip of the tail) to the nearest millimeter and weighing the fish to the closest gram (using My Weigh iBalance 1200).

The length of the fish in this study varied from 245 mm to 470 mm, with a mean length of 360 mm (Table 1 & 2). The weight ranged from 218 g to 1200 g, with an average weight of 605 g (Table 1 & 2). In other words, there was great variability in size structure within the tagged individuals which can be a representative selection of the population. Scales were sampled from just above the lateral line, approximately at the middle of the fish. The tissue samples, taken from the anal fin, were done for later genetic analysis.

The surgery on the fish was conducted in a u-shaped, cut-out foam piece with a wet blanket as a protective layer for the fish. This was done when the perch showed signs of complete anesthesia by not reacting to gentle pinching at the caudal peduncle, belly up, and subtle ventilation was provided through a silicone hose supplying a maintenance dose of anesthetics (approximately 50 % of full doze).

By the implantation protocol of Mulcahy from 2003, we then inserted a small plastic tube into the mouth of the perch to provide a continuous flow of oxygenated water mixed with some of the anesthesia water during the surgery (Figure 4). A small incision of approximately 15 mm was created in the belly using a sharp, sterile scalpel, and the acoustic tag was inserted into the abdominal cavity of the perch. Two stitches of absorbable sutures were used to close the wound after the tag was inserted. After surgery, an external 60 mm T-bar floy tag (FD-94, Floy-tag Inc) was inserted ventrally into the anterior part of the dorsal fin. These numbered tags can provide information such as growth and catch rate/spot. So far (spring of 2022), no fish have been recaptured as far as I know.

Figure 4 Fish handling and tagging by Thrond Haugen (photo: Sondre Breian)

One should always strive for quick procedures when handling fish above water to ensure the highest chance of survival when released. The whole handling procedure of the perch took less than five minutes. After complete anesthesia, the fish were transferred to a big bucket with fresh and well-oxygenated water from the catch area. Each bucket that was used for storing fish, was covered with tarpaulin to provide shading. This measure clearly reduced the stress and increased the chance of survival of the fish. To ensure that all fish recovered adequately from the surgery, the individual perch was observed for at least 10 minutes before being released at the location of tagging.

2.4 Sampling areas

The catching and tagging procedure was done in two different areas (Figure 5). One site was the freshwater lake Visterflo, and the other was Øra at the river mouth of Glomma. This choice was made to ensure that we caught individuals from different habitats and perhaps different populations to provide the best understanding of the perch's migration and movement patterns in the water system.

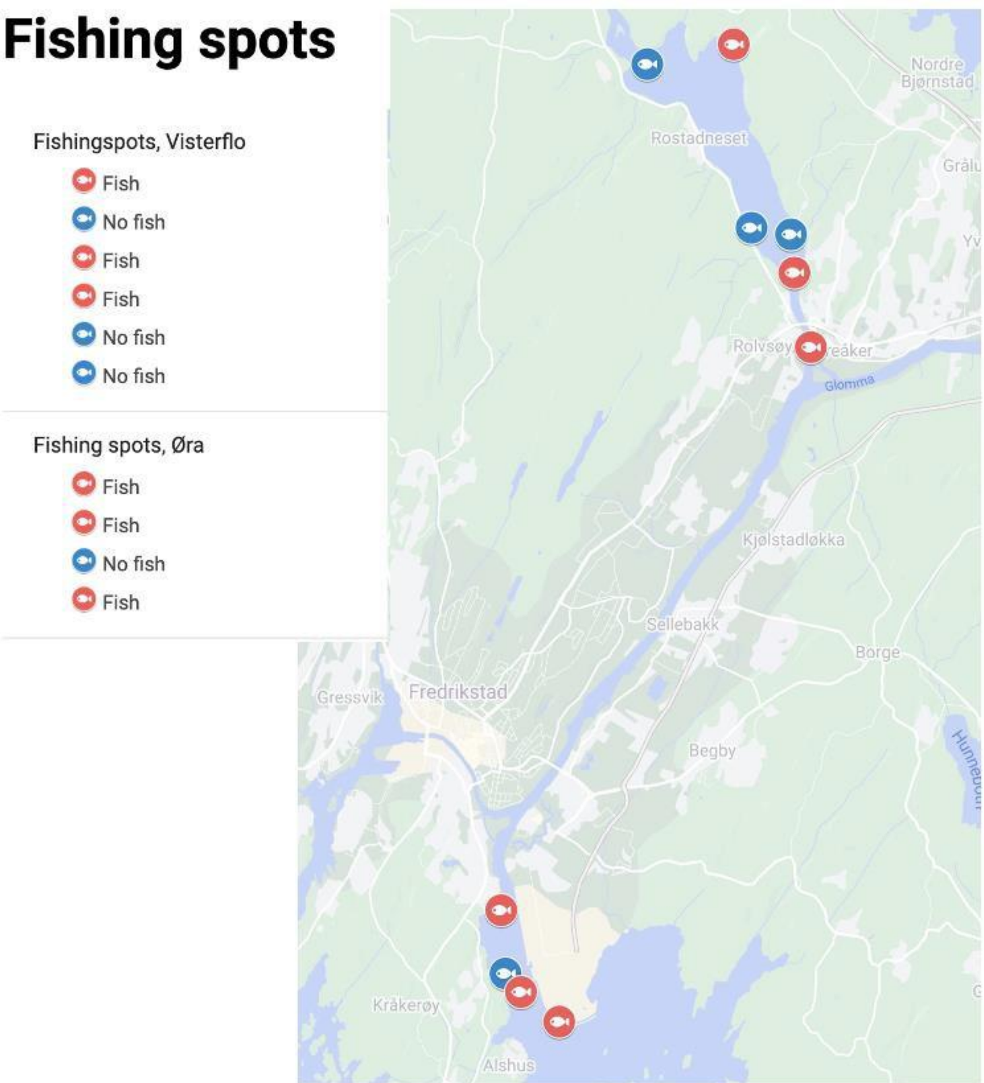

Figure 5 Fishing spots at Visterflo and Øra. Red fish symbolize catch, and blue fish symbolize no catch.

Visterflo

All fish that were captured in Visterflo were caught from a boat. The fishing was done at several different places in the lake, but only a few spots held fish at the time of fishing (Figure 5). At the last tagging round in Visterflo at the end of August, it was clear that much more fish were present, especially in the southern parts close to the outlet.

The lower part of Glomma/Øra estuary

The Øra area is well-known for its fishery during the summer months. Based on catch logs from Ole-Håkon Heier, I decided to do the fishing and tagging process when fish were most likely present (June and July). We fished and tagged perch from four different spots, whereas the most southern one was also fished from shore (Figure 5). The first round was quite early in the summer, and only a few fish were present at the spots. We mainly caught the middle-sized ones (30-40 cm). There was much more fish in the area in the last round, and small and big individuals were also there.

2.5 Scale readings

I collected two to four scales from each fish during the tagging procedure to address the correlation between age and total length (TL) and possible differences in growth patterns between stationary and migratory perch. On fish scales, you find growth rings or circulii (Lagler, 1947). When the fish grows slower, like in the colder months of the year, the distance between these growth rings is shorter. These periods symbolize a yearly circle called annuli (Williams, 1955). The most accurate calcified structures for determining age and growth are otoliths and operculum (Le Cren, 1947) but to be able to release the fish, just the collection of fish scales is considered non-lethal fish (Khan & Khan, 2009). The scales were collected from just above the lateral line and in the middle of the fish (Figure 6).

The scales were first cleaned using lukewarm water with a little bit of soap, before being rubbed between two fingers and a towel to remove access material. When the scales had dried, they were placed between two pieces of object glass which were glued together to compress the scales and make them even and easier to focus on in the microscope. A digital stereoscopic microscope (Leica S9 I) connected to a laptop was then used to obtain photos of the scales for later age analysis.

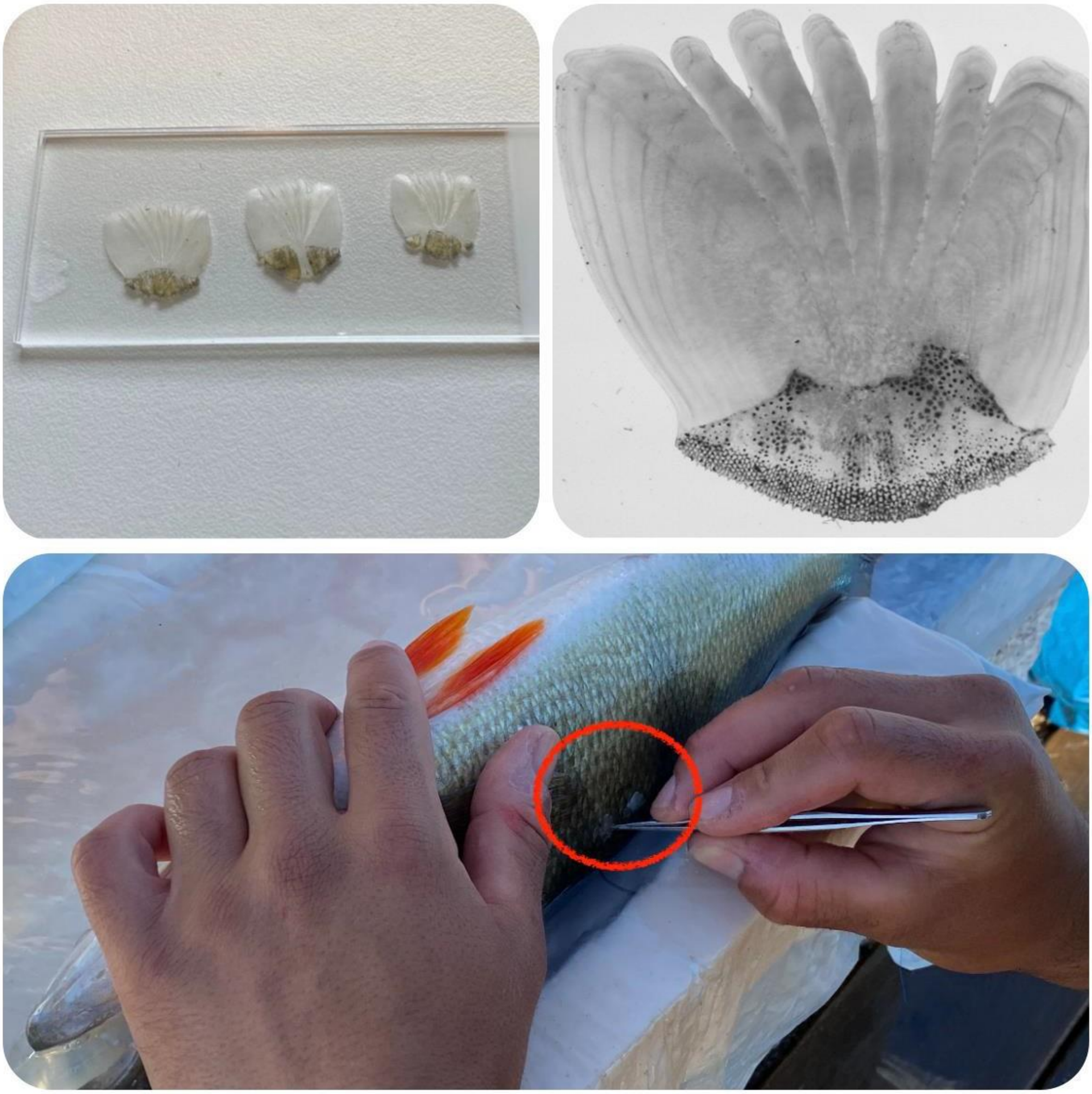

Figure 6 Collection, preparation and reading of the scales (photo: Sondre Breian). The scale in the upper right corner reads to age 8.

2.6 Water discharge data and temperature

Like any river, the water discharge in the Glomma varies quite a lot throughout the year and from day to day. The changes in discharge can explain migration patterns for many fish species (Xu, et al., 2016). The water discharge data were obtained by request from NVE for the following station: Sarpsfossen, the closest upstream station for the study site (Figure 7).

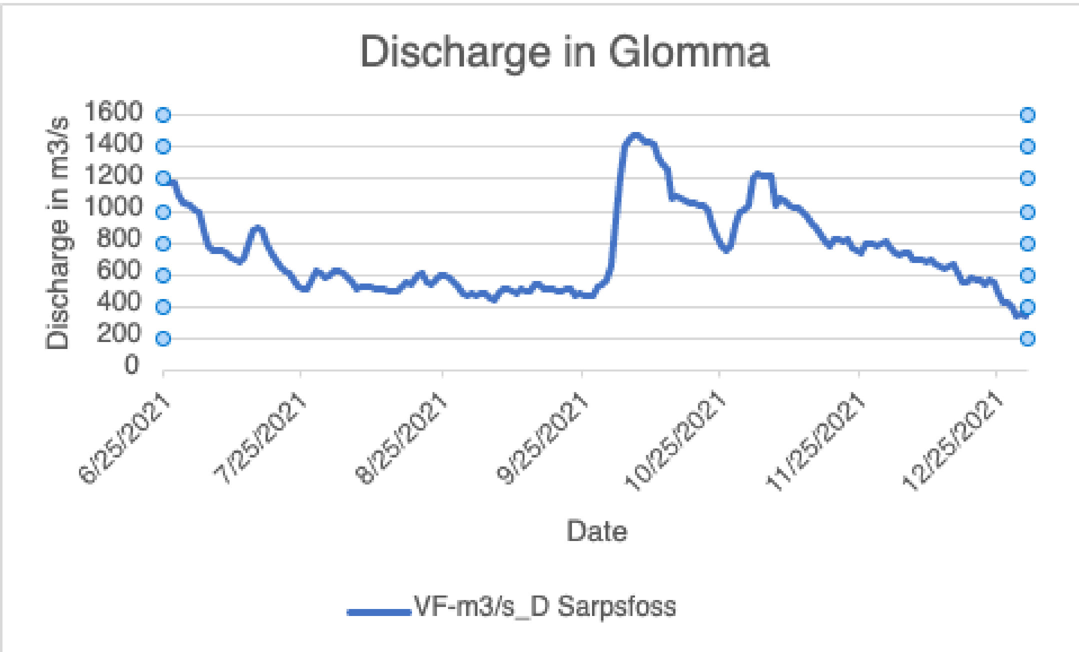

Figure 7 Water discharge for Sarpsfoss in the Glomma during the study period.

The trends in water discharge may vary from year to year. Mean discharge for Glomma at Sarpsfossen from 1989 to 2018 shows that the water discharge data for 2021 is quite representative of the mean discharge, except for the big autumn flood in October (Figure 7 & 8)

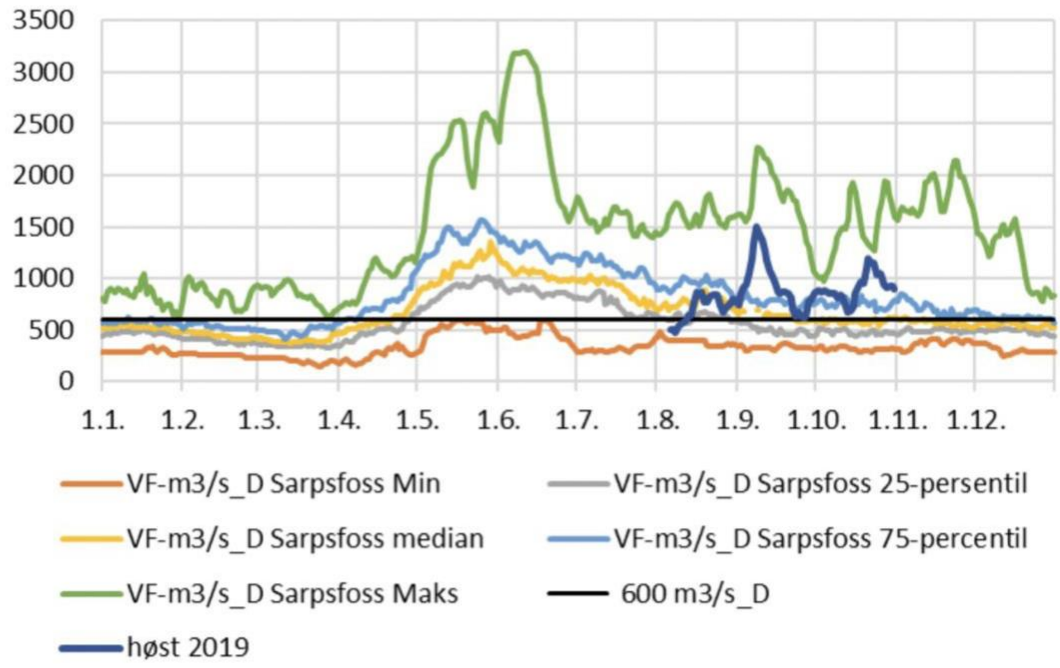

Figure 8 Statistic for mean discharge (m3/s) in Glomma at Sarpsfossen 1989-2018 + Autumn 2019 (dark blue) (Lund & Håll, 2020).

The water temperature was constantly logged throughout the study period by each TBR receiver. The temperature data were later obtained when we synced them to the laptop to download all the data from the receivers. In this study, the temperature was only used in a model to explain migration patterns. I, therefore, only used the water temperature from one TBR (1326) located in the transition area between Glomma and Øra to investigate if the river temperature could trigger migration (Figure 1).

2.7 Tracking procedure

The 25 perch were equipped with D-LP9 transmitter tags from Thelma biotel (https://www.thelmabiotel.com/) to monitor acoustic signals. These cylindrical tags were 23.3 mm in length with a diameter of 9 mm. The dry weight in the air was 4 g, and the estimated weight underwater was 2.5 g (Table 3). This size ensures that a wide variety of length classes can be tagged, ranging from 245 mm (smallest perch tagged) to 475 mm in this study.

Table 3 Physical properties of the transmitters https://www.thelmabiotel.com/transmitters/9mm/

Parameters	Depth tag (ID-LP9L)
Length (mm)	24
Diameter (mm)	9
Weight (air, g)	4
Weight (water, g)	2.5
Effect (dB re 1µPa@1m)	142
Duration (month)	38.5
Code repeat rate (s)	60

These acoustic transmitters transmit unique “pings” with their own identity code that can determine the acoustic receivers' passing and the vertical position due to a built-in pressure sensor. The battery life of these acoustic transmitters with a transmit interval of on average 60 seconds (which was used in this study, varying between 30 and 90 sec) will last for about 426 days. Even though the transmitter stops sending signals, it will remain inside the fish until death.

2.8 Monitoring process

To monitor the movement of tagged perch, I created a network of 30 passive and stationery TBR700s receivers from Thelma biotel throughout the study area (Figure 1 & 9, https://www.thelmabiotel.com/receivers/tbr-700/). These receivers were constantly recording signals from the transmitters via omnidirectional hydrophones.
To ensure that the receivers covered as many relevant places in the study area as possible, we mounted them on locations based on a suggestion from Thrond Oddvar Haugen (Figure 1). This included a particular focus on the Visterflo as the main freshwater lake, the possible transition pathways in the Glomma, and the estuaries outside the outlets on both sides of Kråkerøy.

To secure the receivers, we used both stationary objects such as poles, docks, trees, and buoys, with the receiver connected to a rope with a formwork block of 20 kg at the bottom. The buoy rig was mainly used in the lake in the estuary where the water was deeper, and no objects were present.

To get good coverage of the migration pattern, as well as more detailed data on area use of the perch in Visterflo during autumn and winter in 2022, we used a set of sync tags (6 pieces,) which were connected to some of the receivers in Visterflo. Triangulation of individual X, Y, and Z positions were performed according to the position averaging routines presented in Simpfendorfer et al (Simpfendorfer, et al., 2012). This routine yielded an average 3D position with a 15-minute resolution provided the fish was detected on at least two receivers during a given time slot.

Figure 9 TBR700 acoustic receiver for monitoring of tagged perch (photo: Sondre Breian)

In this thesis, only data from the first phase (fresh & brackish water period) will be analyzed and used due to the restricted period of the master thesis. The most southern receivers up until Rolvsøy collected data from the 24th of June to October the 15th due to the need for 15 of the receivers for another project. The remaining receivers collected data from the 24th of June to November the 23rd. The data was collected when the battery was changed for the second phase (23.11.2021).

2.9 Statistical analyses

After all the data was collected from the receivers (23.11.2021) and downloaded into the Comport software (https://www.thelmabiotel.com/software/), we used the statistical program "R" (R Development Core Team., 2022) to analyze it and provide the results for the thesis. To create the shapefiles for the maps used to visualize movements and placements of the receivers, Qgis was used (version 3.24.2, released 15.04.2022).

When it comes to analyzing the movement patterns of the fish, the "R" package "adehabitatLT" was used. To address the area use and size of the "home range" for each fish throughout the season, the "R" package "adehabitatHR" was used. This is a kernel procedure (kernelUD) where I used the following parameter settings: h=50 & grid=500, on a metric scale. The parameter settings were based on previous analyses of pike movement in Aremarksjøen (Røste, 2021).

To explore the effect of environmental factors that might trigger the migration from Øra to Visterflo, I calculated the probability for migration for two variables: water discharge and water temperature in Glomma, close to Øra. We used a generalized linear model with binomial response (logit-link) and restricted the migration period between day 180 and 280 of the year, which was the period the perch migrated in. Each day the individual perch did not migrate; it got the value 0. When a perch started to migrate, it got the value 1 for the rest of the period until day 280.

Analysis of age, length, and weight can explain individual differences in growth patterns and conditions for migrating and non-migrating fish (Tipping, et al., 1995). To take a closer look at these variables compared to these perch, I created an empirical growth plot to visualize the difference between the fish at the time of capture (June, July, or August).

To better understand the migration speed of the fish, we calculated the migration speed in body length/seconds as well as the time each fish used from Øra - Visterflo. The migration speed can indicate the purpose of the migration and tell if they stop to rest somewhere along the way or choose to migrate continuously.

To present the results more straightforwardly, the receivers were categorized into the following "areas" in the study site: Visterflo, Glomma, Gressvik, and Øra.

The data we collected can be further examined and compared to similar studies. If our hypothesis is right for this population, it may be that the perch that chooses to migrate to brackish water grows faster than the perch that only stays in freshwater systems. It can therefore be interesting to compare the results of this study with future research on big perches in a freshwater system in Norway.

3. Results

Most of the tagged perch in this study (18 of 25) continued to transmit signals to the TBRs throughout the whole study period. All data received from the receivers was of sufficient quality to address the behavior and shed light on my hypotheses, although seven individual fish and five receivers went missing during the study period.

3.1 Movement patterns and habitat choice within the study period

3.1.1 Depth use

The variations in depth use of the tagged perch in this study were quite extensive, with significant long-term variations (Figure 10). Some perch (IDs: 4475, 4477, 4479, 4480, 4484, 4485, and 4488) stopped sending signals before the end of the monitoring period due to either migration outside the study area, predation, anglers, natural death, or faults in the transmitters. The rest of the fish provided usable data for the analyses.

Shallower areas (< 5 meters) were utilized the most in the summer, while most of the fish preferred deeper water (> 5 meters) during the autumn, with some perch exploring depths of up to 18 meters. The maximum depth of Visterflo is around 18 meters (in the middle of the lake, located using sonar and studying bathymetrical maps), which in other terms means that several of the perch in this study utilized the most profundal parts to some extent.

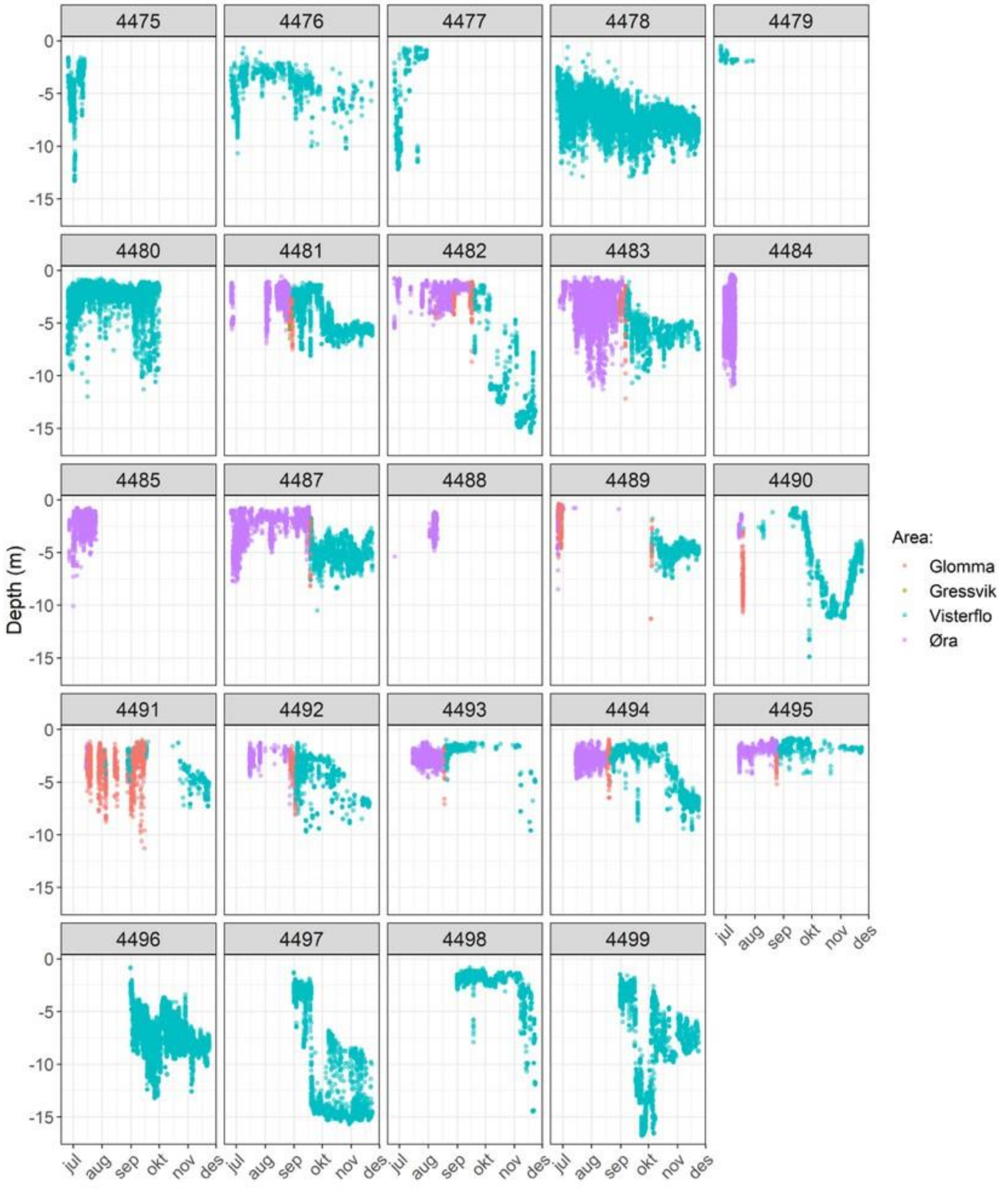

Figure 10 Depth utilization for the 25 perch in this study at Glomma, Gressvik, Visterflo, and Øra from July to the end of November.

Model selection amongst candidate models fitted to depth use data favoured a model with interacting effects between cos((2πT)/24), Area (Visterflo vs Øra) and body length (Table 4 & 5).

Table 4 Model selection table for candidate linear mixed effects models fitted to depth-use data from AT-taged perch individuals in the Visterflo-Øra system during last half of 2021. T =hour of day and cos((2πT)/24) quantifies eventual diel cycles of depth use. Area can take two values: Øra and Visterflo. Length is body length. All models had ID as random intercepts. K is number of parameters, AICc is the n-corrected version of AIC, ΔAIC is the difference in AICc-value between a candidate model and the one with the lowest AICc-value. AICcWt is the relative AICc support amongst all candidate models an LL is the model log-likelihood-value.

Model	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
cos((2πT)/24)*Area*Length	10	1105910	0	1	1	-552945.1
DayNight*Area*Length	14	1106499	588.47	0	1	-553235.4
cos((2πT)/24)+Area*Length	7	1107120	1209.3	0	1	-553552.8
cos((2πT)/24)*Area	6	1107697	1786.99	0	1	-553842.6
cos((2πT)/24)+Area+Length	6	1107771	1860.64	0	1	-553879.5
DayNight*Area	8	1110325	4415.1	0	1	-555154.7
DayNight+Area	6	1110827	4917.19	0	1	-555407.7
Area	4	1112041	6130.69	0	1	-556016.5
cos((2πT)/24)	4	1118466	12555.36	0	1	-559228.8
Length	4	1122368	16458.1	0	1	-561180.2

Table 5 Parameter estimates and the corresponding test statistics for the selected linear mixed effects model fitted to depth-use data (Table X). Random effects: among-ID-variance: 8.493; within-ID-variance: 6.241. T =hour of day and cos((2πT)/24) quantifies eventual diel cycles of depth use. Area can take two values: Øra and Visterflo. Length is body length.

Parameter estimates			Fixed effects test			
	Estimate	Std.		Chisq	Df	p
Intercept	-6.705	3.251	cos((2πT)/24)	4319.686	1	<0.0001
cos((2πT)/24)	2.115	0.053	Area	11025.902	1	<0.0001
Area[Øra]	6.272	0.146	Length	0.001	1	0.9756
Length	0.026	0.088	cos((2πT)/24)*Area	13.344	1	0.0003
cos((2πT)/24)*Area[Øra]	0.351	0.179	cos((2πT)/24)*Length	1096.512	1	<0.0001
cos((2πT)/24)*Length	-0.043	0.001	Area[Øra]*Length	677.498	1	<0.0001
Area[Øra]*Length	-0.107	0.004	cos((2πT)/24)*Area*Length	2.056	1	0.0416
cos((2πT)/24) *Area[Øra]*Length	-0.007	0.003				

The selected model predicted vertical diurnal migrations were correlated with the size of the perch, which showed that perch of different sizes utilize the depths quite differently from each other. Overall, the perch seemed to prefer the shallower areas in the summer season at Øra (Figure 11) while moving to deeper water when they entered Visterflo.

The perch's minor variations in vertical diurnal migrations were observed for the dataset's longest length class of fish (45 cm). At Øra, the big perch seemed to use a deeper area (> 3 meters) than the smaller ones. In Visterflo, they tended to stay at the same depth or shallower than the smaller perch. The most significant variations in vertical diurnal migrations for the perch were found in the data from the smaller fishes. The smaller the fish, the larger the vertical daily migrations were. The fish stayed in the shallowest areas in the early morning and late evening and moved to the maximum depth around mid-day, 12-13 o'clock.

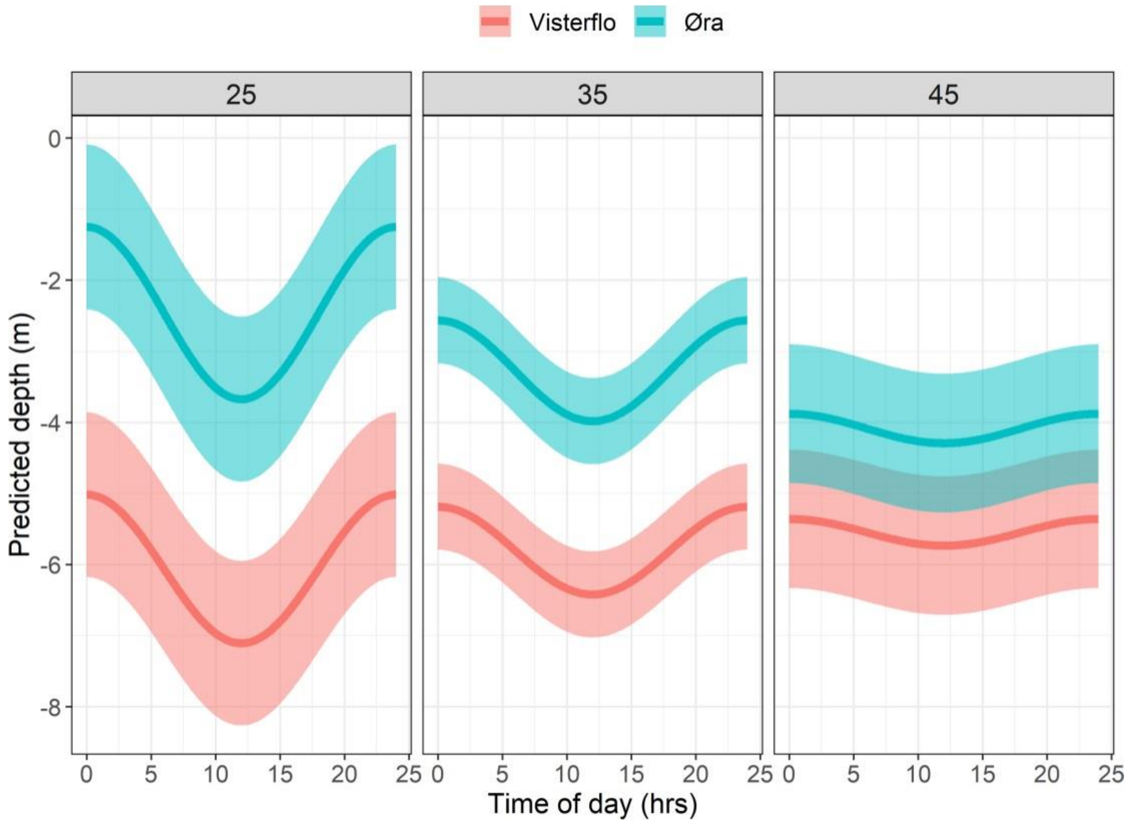

Figure 11 Predicted depth use for the perch in the following length classes: 25, 35, and 45 cm during a whole day (midnight to midnight). Predictions were derived from the selected depth use model in Table X and X+1. Shaded areas correspond to 95 % confidence intervals.

3.1.2 Habitat use

The migration path and habitat use throughout the period was also extensive and impressive. Many of the perch caught and tagget at Øra were registered by almost every receiver placed out from the right side of Kråkerøy to Visterflo (Figure 12) and utilized both Øra, Glomma, and Visterflo in the study period.

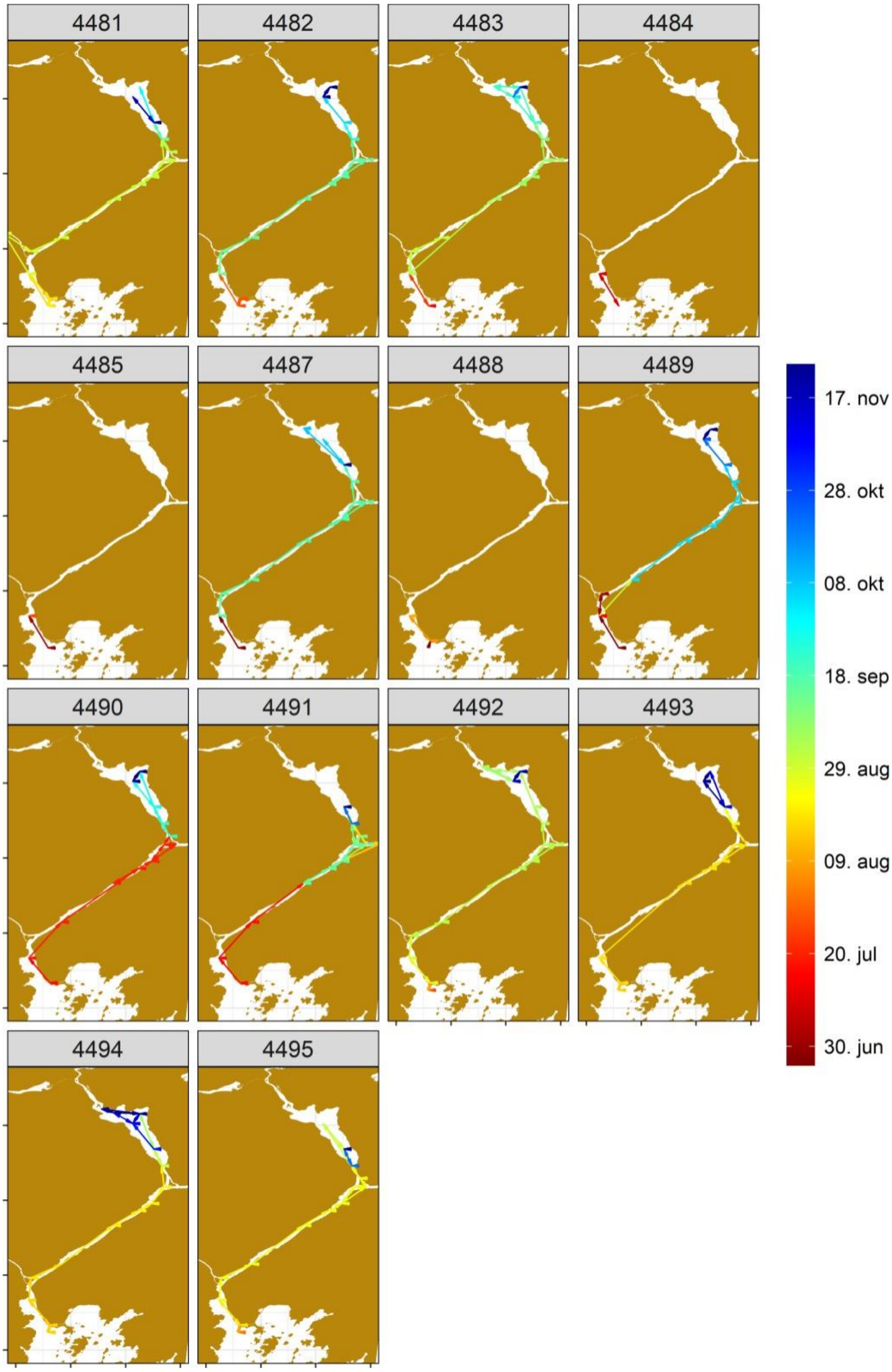

Figure 12 Migration path throughout the study period and area for the perch tagged at Øra presented by fish ID.

The perch caught and tagged in Visterflo, stayed in the lake the whole study period (Figure 13). The majority of the fish utilized most of the lake, except one fish (ID 4479) which also stopped sending signals at the start of August (Figure 10)

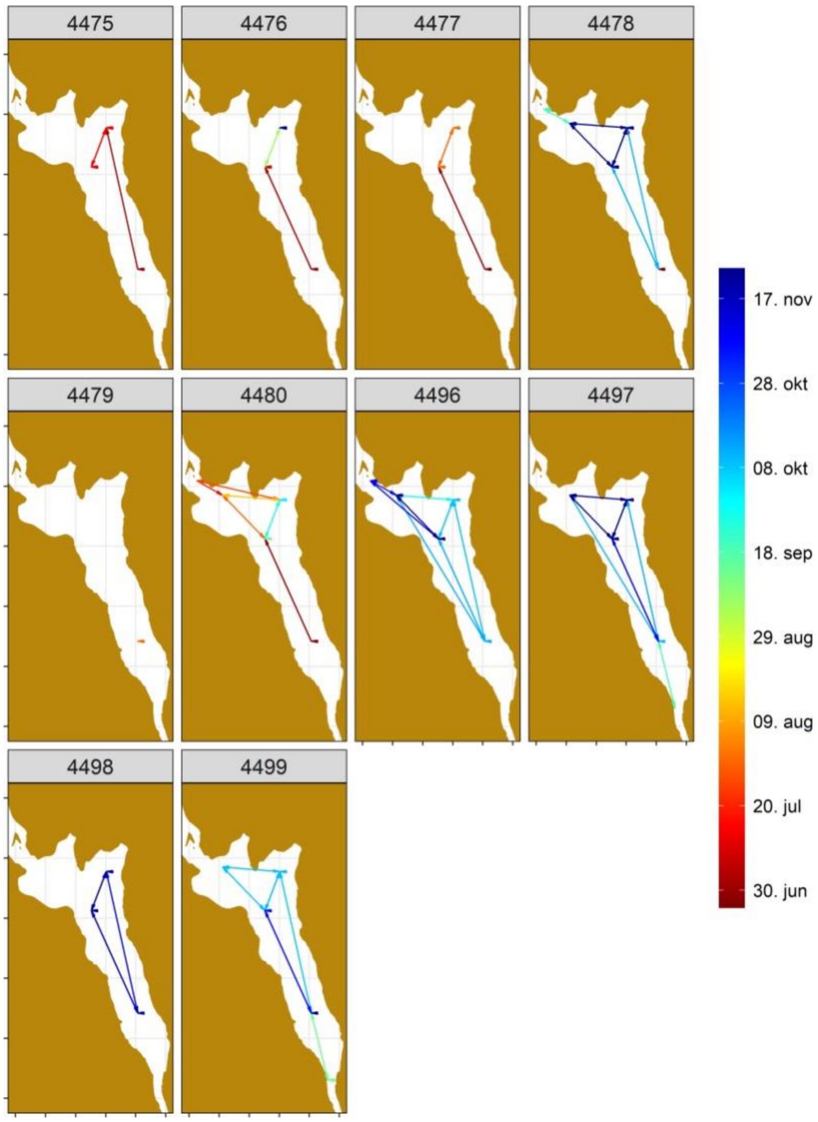

Figure 13 Migration path throughout the study period in Visterflo for the perch tagged in Visterflo presented by fish ID.

3.2 Timing of migration, triggering factors, and migration speed.

3.2.1 Migration period

During this study, the maximum discharge in the Glomma River was 1477 m^3/s. The maximum temperature in Glomma that was registered was 22 °C. There were two distinct discharge peaks during the start of July and the start of October, whereas the main migration happened in the time period with the lowest discharge. The temperature had a peak in late July, and slowly decreased to around 16 °C when the perch migrated.

There was a great variation in the perch's timeframe to migrate from Øra area to Visterflo (from mid of July to the start of October). The first perch decided to relocate on day 196, and the last perch migrated on day 262.

Most of the perch migrated around September, and there were some perch that migrated during the same period, but as the graph indicates (Figure 14), all the ten perch from Øra migrated on separate days.

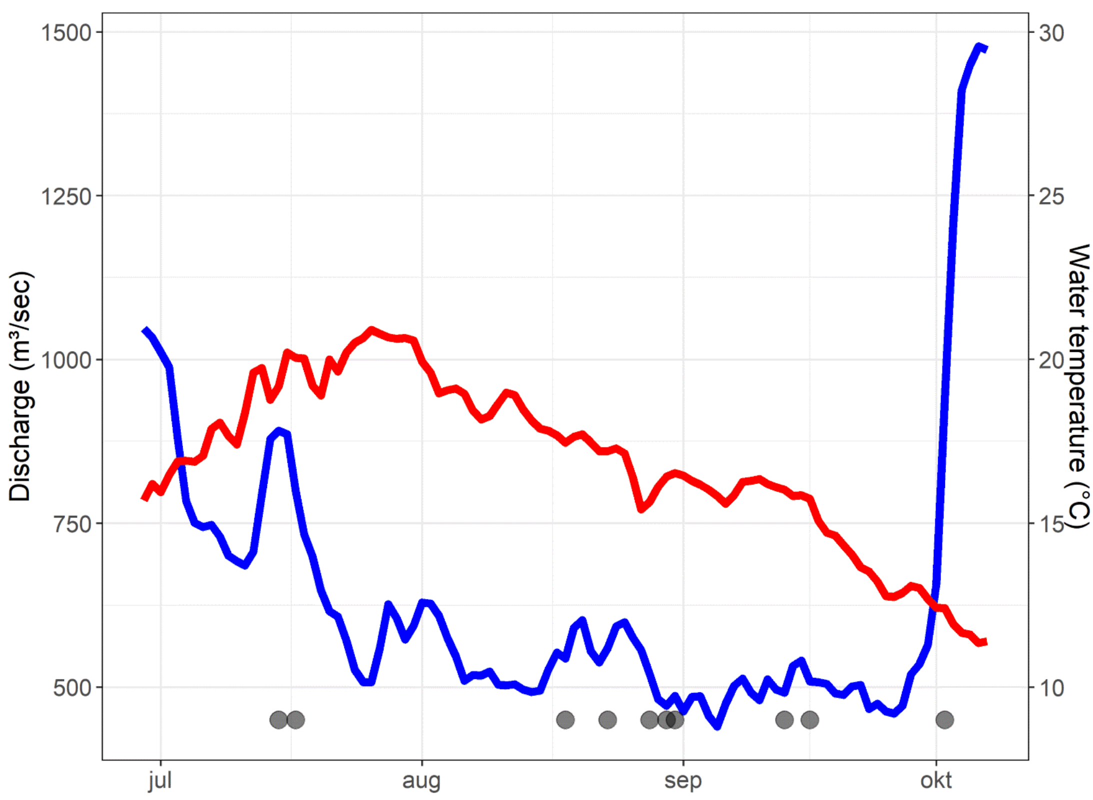

Figure 14 The migration time of the ten migrating perch at Øra (grey dots), compared to the temperature and water discharge from July to October. The red line symbolizes the temperature changes, and the blue line indicates changes in discharge.

3.2.2 Migration triggers

Model selection among candidate generalized linear models fitted to migration onset data favored a model with interaction between day-to-day change in discharge and water temperature as predictors (Table 6 & 7). The selected model predicted that the highest probability for migration was when the change in water discharge was high and water temperatures low (Figure 15). with an increasing discharge and a relatively high temperature (above 15 degrees but below 17.5 degrees). The lowest probability was predicted with decreasing discharge and higher temperatures (above 17.5 degrees) (Figure 15).

Table 6 Model selection table for candidate linear mixed effects models fitted to discharge recorded at Sarpsfossen and temperature data from receiver ID 1326 from June to end of November. K is number of parameters, AICc is the n-corrected version of AIC, ΔAIC is the difference in AICc-value between a candidate model and the one with lowest AICc-value. AICcWt is the relative AICc support amongst all candidate models an LL is the model log-likelihood-value.

Model	K	AICc	Delta_AICc	AICcWt	LL
Temp*deltaQ	4	998.36	0	1	-495.16
Temp	2	1019.81	21.45	0	-507.9
deltaQ	2	1312.52	314.16	0	-654.25
Discharge+rel.deltaQ	3	1325.36	327	0	-659.67
rel.deltaQ	2	1330.43	332.07	0	-663.21
Discharge	2	1384.76	386.4	0	-690.37

Table 7 logit parameter estimates and corresponding likelihood-ratio effect test for the selected model for estimating daily migration probability from the Øra area (Table Y). DeltaQ is the day-to-day difference in water discharge and Temp is water temperature as measured by receiver ID 1362 (Figure 1)

Parameter estimates			Effect test					
Parameter	Est	SE	Term	Df	Chisq	ResDf	ResidDev	p
(Intercept)	9.952	0.769	Temp	1	365.45	1008	1015.8	<0.0001
Temp	-0.606	0.045	deltaQ	1	13.43	1007	1002.37	<0.0010
deltaQ	0.093	0.026	Temp:deltaQ	1	12.05	1006	990.32	<0.0010
Temp*deltaQ	-0.005	0.001						

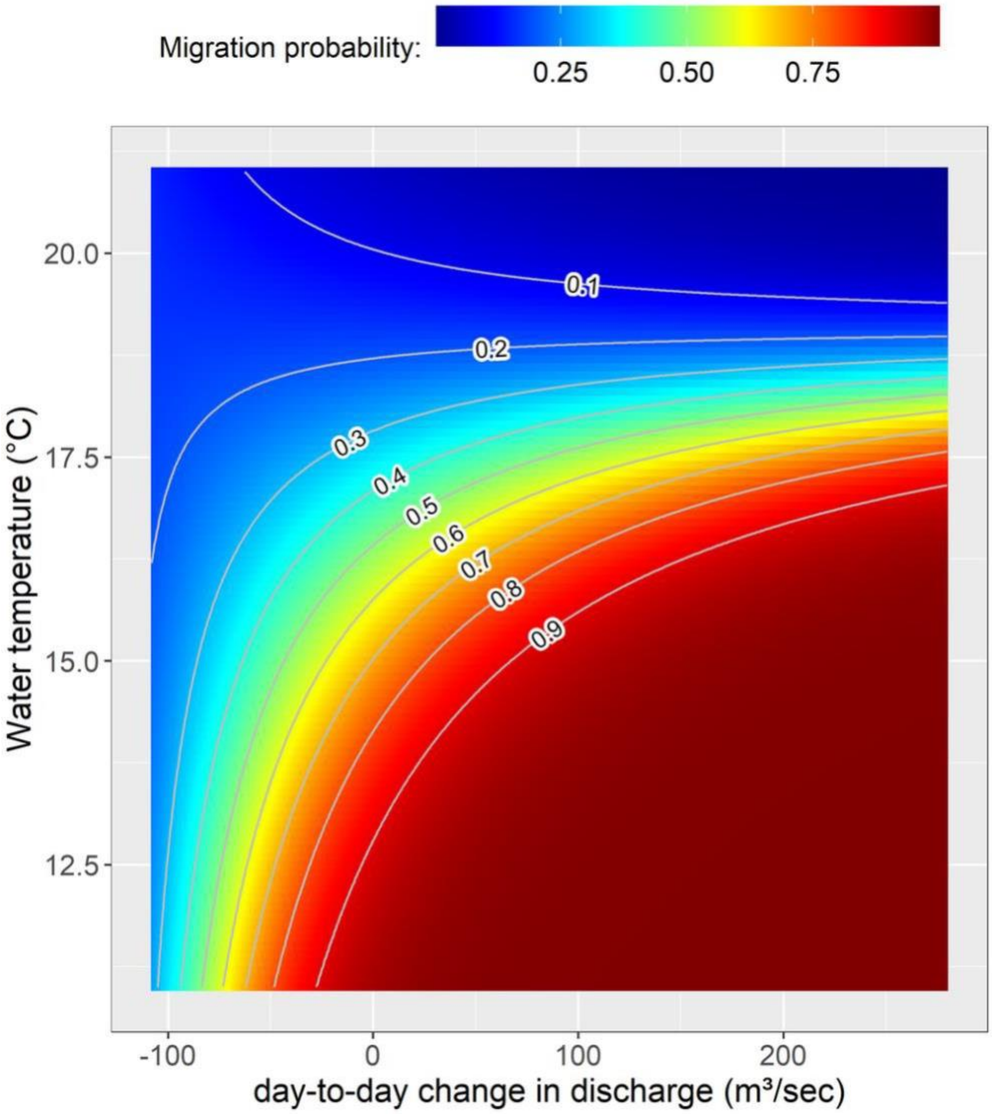

Figure 15 Predicted migration probability in response to changes in the discharge in Glomma and temperature at receiver 1326.

3.2.3 Migration speed

The migrating fish used on average 3.41±5.52 (±SD) days from leaving the Øra area to arriving in Visterflo.

The migration speed ranged from 0.01 to 0.53 body lengths/second (0.215 ± 0.171, SD) There was not observed clear correlation between the size of the fish and the individual migration speeds.

3.3 Area use

To better visualize an example of the differences in utilization and size of the home range on a weekly basis, we plotted the data from 50%- (Figure 16) and 90% utilization area (Figure 17) for an individual perch (ID: 4480) on a map over Visterflo. This example is showing that the placement and size of the home range vary greatly throughout the summer and autumn, even though it is not following all the trends when compared to the results of all the perch combined (Figure 18 & 19). This perch was most active during the warmer months and became significantly more stationed when the water temperature dropped, except from the time period between week 35 – 38 where this individual showed a slightly increase in home range size.

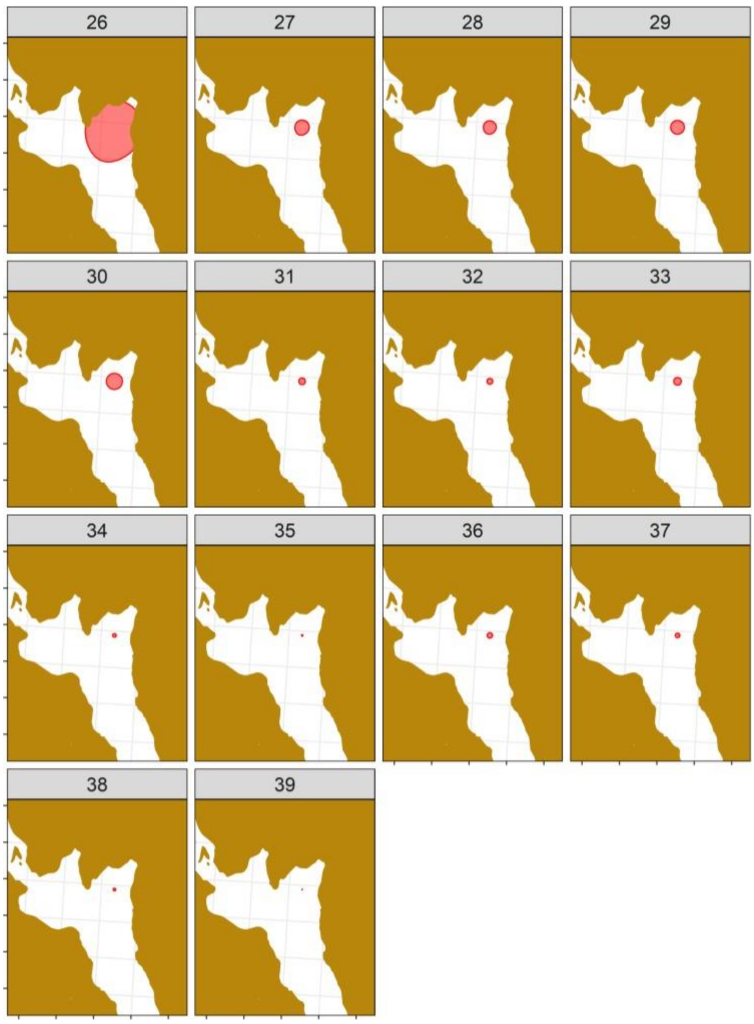

Figure 16 The weekly extent of the home range used 50% of the time in Visterflo by the perch with ID: 4480.

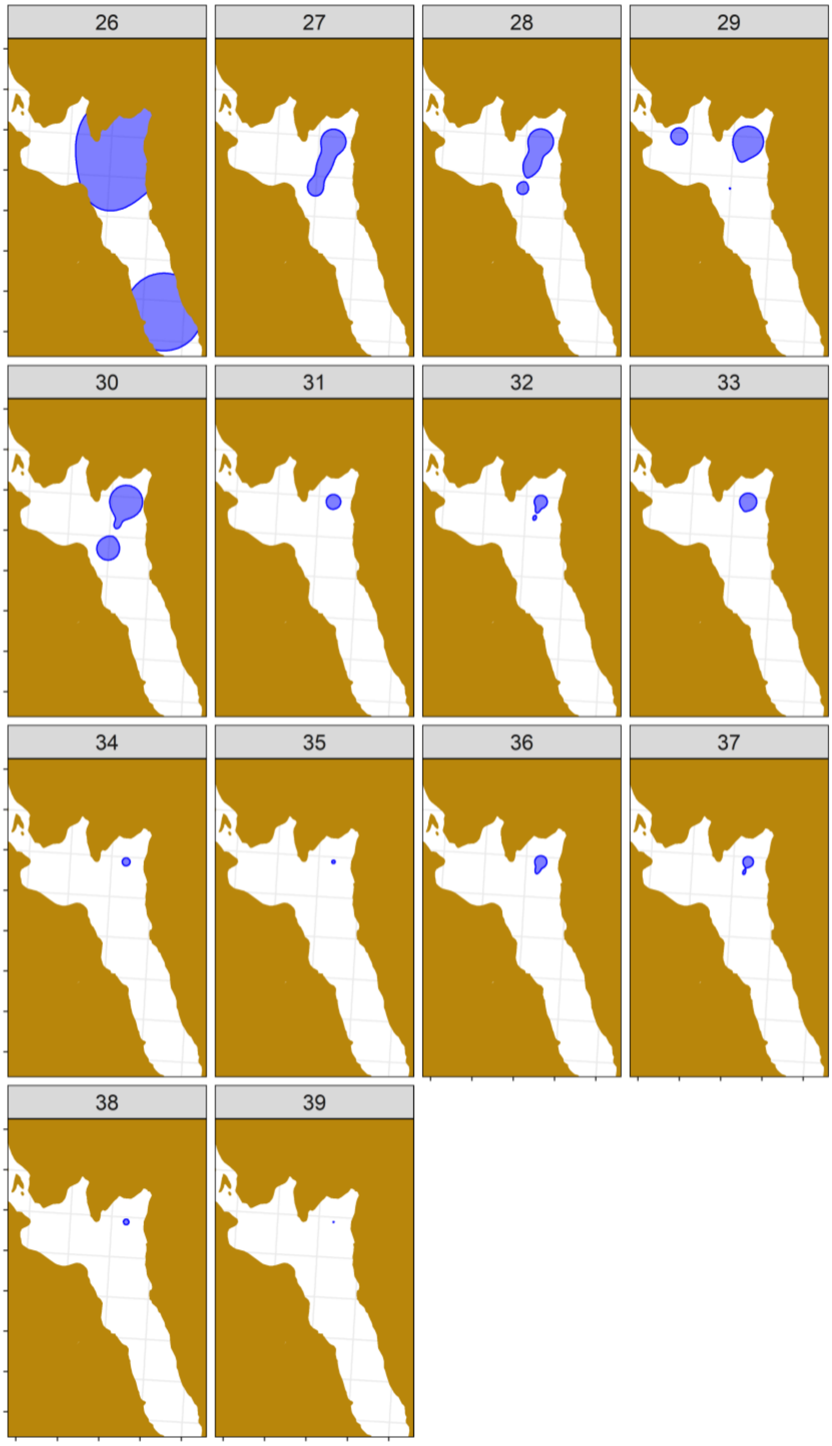

Figure 17 The weekly extent of the home range used 90% of the time in Visterflo by the perch with ID: 4480.

The results for the 95% utilization area plot showed that the size of the home range for the perch varies a lot throughout the summer and autumn (Figure 18).
The most extensive home ranges where the perch spent 95% of its time were observed during week 35-44, and the size of the area used was close to 12.5 ha. Before and after this period, a considerably smaller home range size was observed (below 7.5 ha).

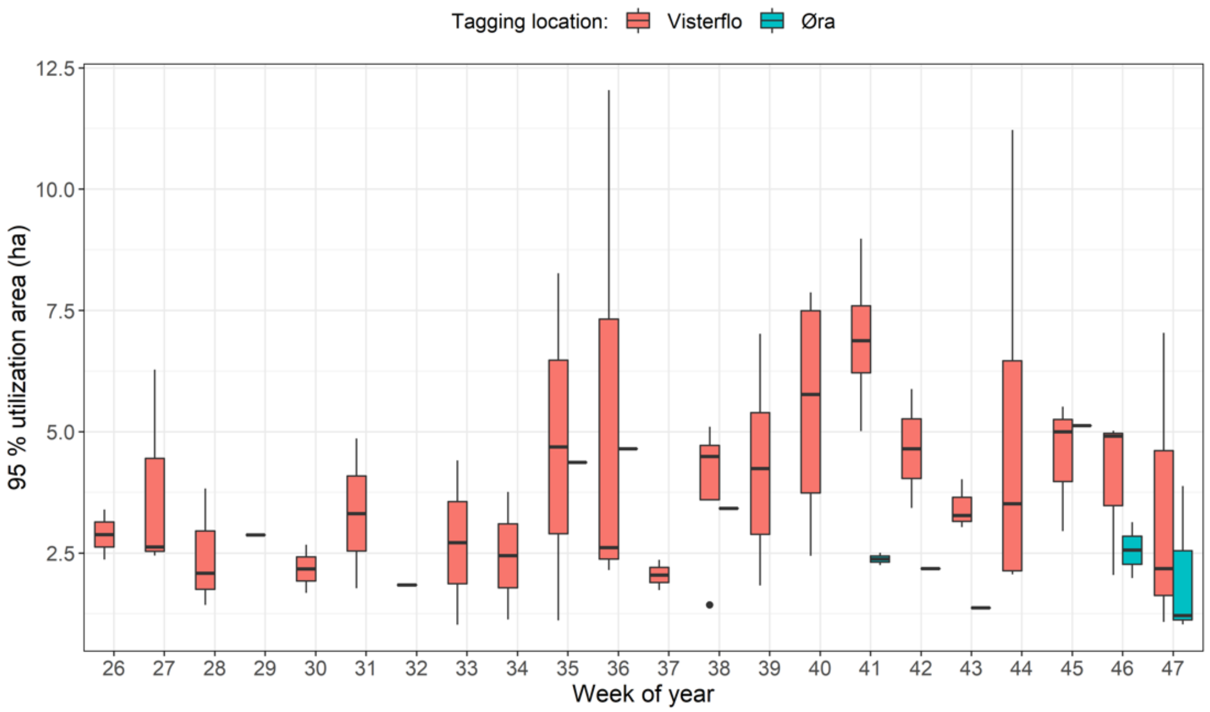

Figure 18 Weekly size of the home range where the perch spends 95% of the time.

The plot with the utilization area where the perch spent 50% of the time showed that the size of the home range differs in the same periods but that the space used is considerably smaller (Figure 19), indicating that the perch has smaller areas they tend to use a lot of the time. The biggest home range within a week was 2,5 ha.

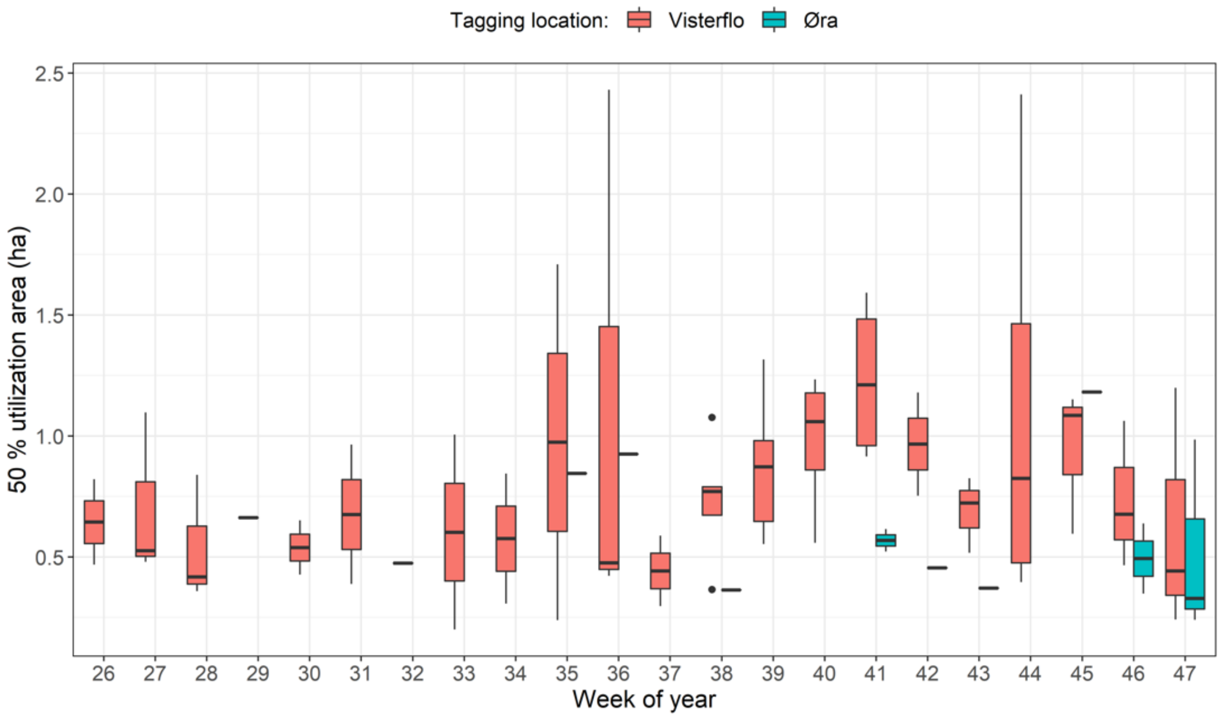

Figure 19 Weekly size of the home range where the perch spends 50% of the time.

3.4 Age, empirical growth, and condition

3.41 Age and growth

The analysis of the perch scales showed an age span from 2 to 16 years for the fish caught in Visterflo (mean 7.9 years) and 4 to 10 years for the perch in Øra (mean 5.7 years) (Table 1 & 2). Data shows that most of the caught and tagged perch at Øra reach a certain size faster than the perch in Visterflo (Figure 20). The youngest and oldest perch analyzed was caught in Visterflo, while the age span at Øra was noticeably smaller.

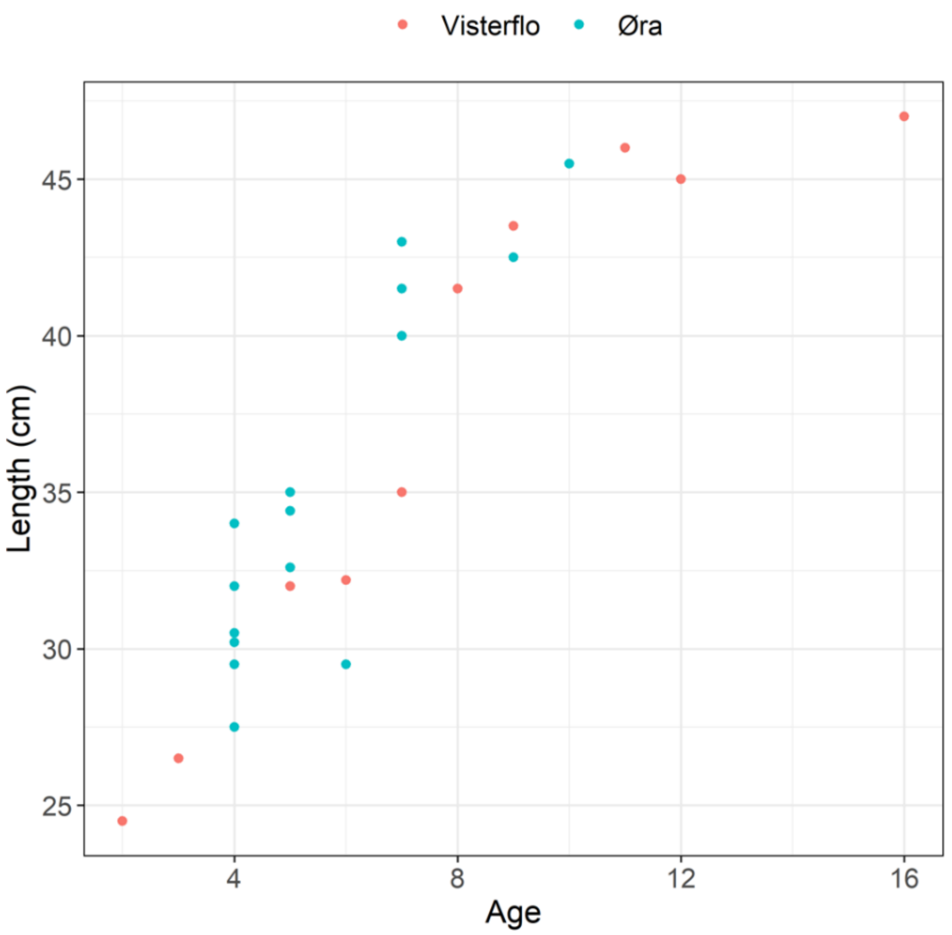

Figure 20 Age determined by scales in relation to total length (TL) for the perch caught in Visterflo and Øra.

3.42 Weight:length-relationship between individuals at the time of capture

To address differences in the condition of the perch caught at the two different stations at the time of capture in June, July, and August, we compared the weight to the total length of the perch (TL). The results showed that perch caught at Øra, apart from a faster growth shown above (Figure 20), also had a better condition than the fish caught in Visterflo (Figure 21).

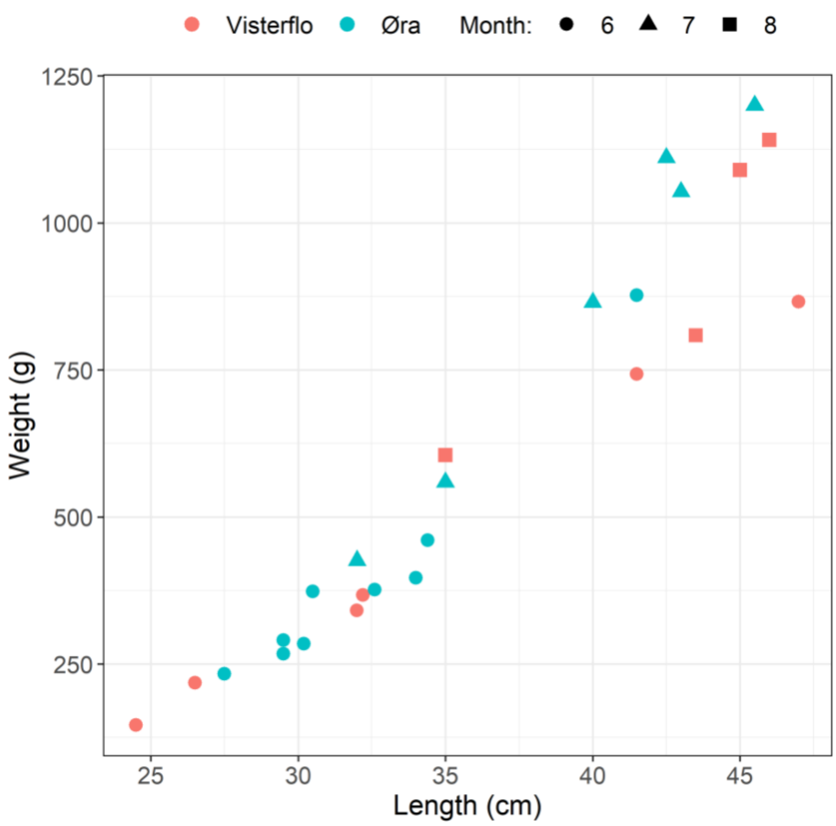

Figure 21 Weight to length ratio for the perch caught in Visterflo and Øra in June, July, and August

4. Discussion

A range of different factors such as place, size, month, and temperature impacted the habitat and depth utilization of the perch in this study. As predicted, the fish captured at Øra were younger in relation to size, and had a better condition, indicating a higher food availability in the estuary and a positive effect of migration. Still, a lot of reasonings remains mysterious about this perch population and the behavioral trends.

4.1 Habitat utilization and time of migration

The majority of the fish migrated in the autumn during August and September. Surprisingly, some fish decided to leave as early as mid-July instead of later in the autumn when the temperature dropped, and food availability is believed to decrease in the estuary.

By analyzing the migration data, most of the perch migrated in a fast phase to Visterflo without stopping in the Glomma. One fish (ID 4491) spent considerably more time in Glomma than the rest of the fish from July to September. It is difficult to say why this perch chose this strategy, but it may have explored the lower reaches of Glomma in search of food where there is believed to be less competition than at Øra. This individual may also have increased the average time used for migration from Øra to Visterflo.

Due to the fact that most of the perch migrates in the same time frame, the migration does therefore not seem “random” and the excellent fishing that anglers report from the southern end of Visterflo (where it runs out in the Glomma) may consequently be perch that have recently migrated up from Øra and are swimming around in the shallower areas to rest after the long journey in the Glomma.

The small perch had more considerable daily variations in depth use than the big perch (25 cm vs. 45 cm). An anti-predator behavior or different foraging strategy may explain this difference by the small perch. The deeper areas may provide more protection than the shallower areas.

During the study, both cormorants and seals were observed in the estuary. In contrast, the shallow areas are probably used for foraging during the low-light hours of the day.

The data on the time of migration can indicate that the perch does not migrate in a few big groups but tends to migrate separately or in smaller groups when the conditions for migration are considered sufficient. Although, this assumption is based on the data from only ten individuals and the amount of data is not big enough to clearly say that they don’t migrate in bigger groups. It may be that we “accidentally” tagged ten perch that choose a more solitary style of migration, while the majority of the fish might migrate in bigger groups. Also, this dataset is too small to prove significant differences in the migration behavior between small and large perch, which are believed to be quite different from each other.

The size and extent of the home range varied significantly between the individuals and during the study period in Visterflo. I couldn’t prove any differences in the area use between large and small individuals, but the dataset is too small to exclude potential differences regarding size completely. The largest areas used were observed when the temperature was higher, and it decreased throughout the autumn, with a slight increase from week 35 - 38. This time period matches with the time period the perch from Øra migrated to Visterflo. The increase in area use may be a response to the receivers picking up signals from these fish in addition to the fish that stayed in Visterflo the whole summer, as well as increased movement due to stress and challenge for territories for the perch that stayed in Visterflo.

The overall reduction in area use in late autumn may be a response to colder water and a slower metabolism (the same for the baitfish), where the need to swim and cover large areas to search for prey becomes less necessary. It seems like most of the perch chose to utilize the deepest parts of Visterflo to some extent during the study period. It's not quite clear why they choose to go so deep, where the availability of food and temperature is believed to be lower. It may be that the perch switches its preferred diet to fish species like smelt and vendace instead of bleak, which are also present in the lake and known to be living in greater depths.

These are the kinds of behavior mysteries that acoustic telemetry can dig deeper into and possibly solve. It will be interesting to look at the winter- and spring behaviors, size of the area used, and migration timing when the data from winter and spring 2022 have been collected and analyzed (planned during the summer).

4.2 Growth patterns and fish condition from the two tagging sites

Several studies have been done on growth metrics for both estuarine populations and freshwater populations of European perch. Earlier studies have shown higher growth rates and more considerable total length for the estuarine populations (Christensen, et al., 2021). The data in this study seems to support this even though they are not significantly different from some fast-growing populations in freshwater locations which have been reported in present studies (Ali & Jones, 1978) (Willemsen, 1977) (Christensen, et al., 2021). Three of four fish caught in Visterflo symbolized with the square dots (Figure 21) have a noticeably better condition than the other fish caught earlier at this station. These fish have probably migrated from the brackish water as there were already many migrating perch present at that time in Visterflo.

There can be indications that the small perch choose to stay in Visterflo/surrounding areas until they reach a more significant size (around 30cm) before migrating to the brackish water areas. During the fish catching procedure for this study and countless private fishing trips, no fish below 27cm have been seen at Øra, which can support this theory. That also indicates that the estuary area is not used for spawning and rearing, just foraging by bigger individuals. Data from the second telemetry phase (November 2021 – July 2022) will hopefully be answering where the main spawning grounds are.

Due to the quality of some scales from the smallest fish, we could not back-calculate growth for each fish to compare early life strategies for the fish caught at the two different stations. Still, the data and plot indicate that the younger perch caught (below four years) are living in Visterflo, which may be an important spawning and rearing area for this perch population. That may explain the absence of small perch at Øra, which is also supported by anglers who fish in these areas.

So, what can be the reasons for the will to migrate when the small perch have no idea of the estuary further down in the watercourse? The most plausible explanation is that some of the perch are genetically predisposed to this behavior and that they choose to migrate together in the spring/summer with the bigger fish who have overwintered in the same habitat. Genetical samples were taken of the fish, and further examination of these in comparison to different populations of perch in the watercourse can reveal if this is true or not. It is further reason to believe that the perch choose to migrate because of the higher availability of food in the estuary, and the increased risk of migrating is outweighed by the potential benefits in growth.

Compared to a study done on the growth of the perch in Øyeren, an inland freshwater lake in the same watercourse (about 42 km further upstream), the perch caught at Øra has a considerably higher growth rate. The youngest perch to reach a body length of 35 cm in Øyeren was 8 years old, while a perch at Øra reached the same length at the age of 5 (Moseby, 2011). Compared to perch in the Drammen fjord in Viken county, which is believed to be a perch population that behaves a bit like the perch in the Glomma, reached a body length of 35 cm at about the age of 6-7 (Haugen, et al., 2009).

The condition analysis can only say something about the condition at the time of capture and does not represent the overall condition of the perch during a year. All the fish were caught post-spawning. After spawning, the big female perch have no roe left (which can make up a considerable part of the total weight of the fish) and they have usually not been able to eat enough to restore their condition. Therefore, the condition in the summertime is usually not the best. That must be taken into consideration if this data is compared to perch in other studies. More data must be collected (preferably over a year) to get a better general view of how the condition varies throughout the year for the perch that chose to migrate and the perch that decided to stay.

4.3 Suggestions for improvements

Studies done using acoustic telemetry are believed to be well suited to observe the behavior of animals in their habitats. If the receivers are placed correctly in the area to be kept, and enough of them are used, the fish's position can be triangulated (Kessel S. , et al., 2014). Many factors can impact the range of detection of the receivers, such as turbidity, waves, water flow, and air bubbles (Donaldson, et al., 2014).
A range test was not performed in this study, but sync tags were used on some receivers to improve the positions over time and space (Heupel, et al., 2006)
To eliminate blind spots for the receivers, we placed most of them relatively close to each other (Figure 1). The TBR receivers in the Glomma were set a bit further apart because their main reason was to detect migration time and speed.

Unfortunately, all the five TBRs located furthest out at sea were lost. It's unclear what caused this, but the most plausible reasons are the autumn flood, something to do with people purposely stealing it, or cutting the rope/buoy with the propeller. The purpose of these TBRs was to determine how far the perch migrated out into the sea. Earlier studies done with gillnets show that perch utilizes many shallower areas quite far out (Båtvik, et al., 2011). Therefore, it would have been interesting to understand better those movement patterns that happen further out at sea, where there is little to no knowledge on how the utilization is distributed and which areas they prefer.

Also, we weren't quite sure which pathways the perch chose to migrate through when placing out the receivers. We only had one detection on the west side of Kråkerøy (Gressvik area), even though we know that there is much perch in the summertime on that side as well. It might be that perch from the Gressvik and the Øra area is two separate populations that utilize different habitats and migration routes. To address if there are different populations of perch in this watercourse, it could be interesting to take a closer look at this. Anglers report of a more varied age structure in their catches in the summer- and wintertime, and it may be that these perch do not utilize the same areas as the Visterflo/Øra perch does. Another acoustic telemetry study could be conducted for this population, which is also influenced by industry and constructions.

During the handling of the fish, we should consider collecting more than 2-4 scales. Initially, we had a plan to back-calculate growth to compare the fish we caught at Visterflo with the fish we caught at Øra. For most scale samples, the quality of the innermost part was too unclear to take a closer look at the growth trend in the first years. On the other hand, the scales were good enough to determine the age of each fish. That left us with the option to just compare the total age with the total length of the fish, to get an idea of how the empirical growth pattern was.

This study only analyzed the data on habitat utilization and migration behavior from the summer of 2021 to the late autumn (November) of 2021. To get a complete picture, a study of at least a full year (summer to summer) should be conducted to take a closer look at the yearly migration to the estuary in late spring/early summer as well as the more detailed data of the habitat use and movement patterns the perch has in the winter. The discharge in the Glomma varies quite a lot from year-to-year dependent on precipitation and temperature, which can influence the perch behavior from one year to another, especially in regard to migration patterns. Also, data from several years are needed to get a solid and representative result for what this population does over time, test if our result is representative, and fully understand all the mechanism that possibly affects the behavior.

4.4 Relevance for fish management and human activity in or close to the study area

To ensure that fish populations are managed in the best possible way, it’s essential to collect information and data for each specific watercourse. In this specific watercourse, the authorities have not been taking fish populations into consideration when planning for activities in or close to the river. The perch population in this area is clearly unique in the Norwegian context, with only two other known brackish water perch populations in Tista and Drammensfjorden, whereas this is the biggest one.

Even though the area's perch population has been relatively stable from 1986-to 2009 (Båtvik, et al., 2011) and the catches by anglers are still good in this area, it is still heavily influenced by industry and urbanization. There is already large construction acitivity, and plans for futher developments like: dredging, building of boat facilities and ports as well as construction close to the shoreline (< 100 m).

Based on the results of this study, we can say that the perch utilizes several different habitats and that these areas probably are essential for a range of different life stages. The littoral and the shallow regions around the Øra estuary are necessary for their food availability and good growing conditions in the summertime. At the same time, the deeper areas of Visterflo are used more often in the transition between autumn and winter and act as an essential refugee area for the youngest perch in their early life. It is possibly an overwintering area for the migrating perch, as well as an important spawning- and rearing area as well. That should be considered when questions about development in these areas are raised.

The findings in this study can act as guidelines for the conservation of this unique perch population for the best of the entire ecosystem and anglers who find great joy in this fishery.

5. Concluding remarks

This acoustic telemetry study conducted on European perch during the summer and autumn of 2021 provided a wide range of interesting data and results for understanding populations of perch that utilize brackish water areas for particular activities such as foraging in the summertime. To highlight the most important findings in this study, the following points can act as a summary:

- The perch showed extensive depth use in different areas throughout the season and a comprehensive area used during the period studied.
- Water discharge and temperature in Glomma triggered migration from the estuary to Visterflo.
- The perch overwintered in the freshwater lake Visterflo.
- The age and length data show that the perch caught in Øra was both younger in relation to length and had better condition than the perch caught in Visterflo in the same period. This indicates that it may be beneficial to use the brackish water areas as a foraging area to grow faster.
- Young perch (below four years) were only caught and observed in Visterflo. This can indicate that the perch use Visterflo as a spawning- and rearing area.

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Norges miljø- og biovitenskapelige universitet
Noregs miljø- og biovitskapelege universitet
Norwegian University of Life Sciences

Postboks 5003
N0-1432 Ås
Norway