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Home ranges and habitat utilisation of the river-resident Atlantic salmon, *Salmo salar*, småblank

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Sammendrag

Hjemmeområder (home ranges) og habitatbruk hos den elvestasjonære atlantiske laksen, småblank, *Salmo salar*, ble undersøkt ved bruk av radio telemetri fra august 2014 til januar 2016 i Namsenvassdraget i Nord-Trøndelag. Målet var å sammenligne hjemmeområder og habitat bruk til småblank i den regulerte elven Namsen, i et område kalt Snåsamoen, og den uregulerte sideelven Mellingselva. Laksens leveområder på dag -og natt tid mellom elvene og variasjoner i sesong i Snåsamoen ble observert. Det ble merket 90 småblank over tre ulike tidsperioder (Snåsamoen høst 2014: n = 33, Snåsamoen vår 2015: n = 20, og Mellingselva høst 2015: n= 36). For å analysere hjemmeområdene ble 35 av de merkede fiskene tilfeldig valgt ut og radio peilet mellom 4 og 5 måneder (Snåsamoen høst: n = 15, Snåsamoen vår: n = 6, Mellingselva høst: n = 16). Det ble observert stor variasjon i hjemmeområder mellom den regulerte elven Namsen ved Snåsamoen og den uregulerte sideelva Mellingselva (Snåsamoen høst: gjennomsnitt = 21 715 m^2, Snåsamoen vår: gjennomsnitt = 29 688 m^2 og Mellingselva høst: gjennomsnitt = 2 362 m^2). Fisk i området ved Snåsamoen hadde en signifikant lavere kondisjonsfaktor enn fisk med samme kroppslengde i Mellingselva. Fiskene med samme kroppslengde hadde også et signifikant større hjemmeområde i elva ved Snåsamoen sammenlignet med Mellingselva. Dette kan tyde på at fisker ved Snåsamoen måtte bruke større områder for å opprettholde sin kondisjonsfaktor. Kondisjonsfaktoren om våren ved Snåsamoen var lavere enn hos småblank merket på høsten i samme område og dette kan være forårsaket av en redusert kondisjonsfaktor gjennom vinteren. Den maksimale avstanden mellom peilepunkter for individuelle fisk, viste en lengre vandring på dagtid (Snåsamoen: høst gjennomsnitt = 301 m, Snåsamoen vår: gjennomsnitt= 191 m og Mellingselva høst: gjennomsnitt = 116 m) sammenlignet med natte peiling, i begge elvene og i begge sesongene (Snåsamoen høst: gjennomsnitt = 104 m, Snåsamoen vår: gjennomsnitt = 136 m og Mellingselva høst: gjennomsnitt = 91 m). Småblank ble observert i elvesubstrat med større partikkel størrelse, og dermed bedre tilgang på hulrom for skjul i Mellingselva sammenlignet med fisk ved Snåsamoen. I Mellingselva ble fiskene observert i raskere flytende vann som ofte er foretrukket av laks sammenlignet med det mer sakteflytende vannet ved Snåsamoen.

Som konklusjon, kan det tyde på at den uregulerte sideelva, Mellingselva er et bedre egnet leveområde for småblank 3 og 4 år sammenlignet med den regulerte elva ved Snåsamoen. Dette kan baseres på forskjellene funnet i størrelser på hjemmeområder, kondisjonsfaktorer og forskjell på substratstørrelse og dermed mulighet på skjul i de to elvene.

Summary

Home ranges and habitat utilisation of the river resident Atlantic salmon, småblank, *Salmo salar*, in Nord Trøndelag, Norway, were studied by the use of radio telemetry during the period August 2014 to January 2016. The aim was to examine home ranges and habitat utilisation of the fish in the regulated River Namsen in the area of Snåsamoen and in the non-regulated tributary Mellingselva. Furthermore, comparisons in space use between day and night time and between rivers and seasons between the regulated river were investigated. A total of 90 småblank were tagged in three separate periods (Snåsamoen: autumn 2014 n = 33 and spring 2015 n = 20, Mellingselva: autumn 2015 n = 36). Of the total number of radio tagged småblank were 35 individuals randomly selected for radio tracking over a period of 4 to 5 months. The selected individuals were then used for home range analysis (Snåsamoen: autumn n = 15, Snåsamoen: spring n = 6, Mellingselva: autumn n = 16). Home ranges were significantly larger in the regulated river in both seasons, compared to the non-regulated tributary (Snåsamoen: autumn mean = 21 715 m^2 and spring mean = 29 688 m^2, Mellingselva: autumn mean = 2 362 m^2). The condition factor of fish tagged at Snåsamoen was significantly lower than of those tagged in Mellingselva, despite similar body length. The fish with same body length did in addition have significantly larger home range at Snåsamoen than Mellingselva, which can result in småblank having to utilise larger areas to obtain their body condition. The body conditions in spring were significantly lower than in autumn at Snåsamoen, which may be caused by a reduction in body mass during winter. The length of river stretch used was longer when considering only day time locations (Snåsamoen: autumn mean = 301 m and spring mean = 191 m, Mellingselva: autumn mean = 116 m) than when considering only night time locations between rivers and between seasons (Snåsamoen: autumn mean = 104 m and spring mean = 136 m, Mellingselva: autumn mean = 91 m). The fish utilised areas with larger particle sizes in Mellingselva than at Snåsamoen, resulting in more shelter availability. Mellingselva had in general faster flowing water velocities which is often more preferred to Atlantic salmon than slower velocities found at Snåsamoen.

In conclusion, the area investigated in the non-regulated tributary seemed better suited for 3 and 4 years old småblank, than the regulated River Namsen at Snåsamoen. This is based on the results from home ranges, body condition of småblank and habitat availability in the two rivers.

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1. Introduction

Atlantic salmon (*Salmo salar*) is a salmonid species native to the North Atlantic Ocean region. The species is distributed from the upper parts of the North Atlantic Ocean south to the coast of Portugal, across the Atlantic Ocean to Greenland, Canada and to the north Easter boarder of USA (Thorstad *et al.*, 2011d). The decline of Atlantic salmon is observed throughout the distribution area (Mills, 2003; Freyhof, 2014), and Norway has an international responsibility for obtaining healthy Atlantic salmon populations (Miljødirektoratet, 2015).

Atlantic salmon are commonly known to be anadromous, which means they hatch in freshwater and can spend several years in freshwater before eventually migrating to the sea. Although anadromous behaviour is the most common life history strategy for Atlantic salmon, individuals remaining in freshwater during their entire life do occur (Klemetsen *et al.,* 2003b). The non-anadromous Atlantic salmon can be divided into two groups. The first group represents a reproductive strategy where male Atlantic salmon choose to sexually mature in freshwater (Thomaz *et al.*, 1997), but where the females migrate to sea. The second group are landlocked Atlantic salmon, where both males and females are freshwater resident throughout their entire life. The landlocked salmon are prevented from successful sea migration due to physical barriers such as waterfalls (Behnke, 1972). Anthropogenic impacts like pollution and hydroelectric production are causing a decrease in landlocked populations, and even extinction in some river systems (Ozerov *et al.*, 2010b). The remaining landlocked populations of Atlantic salmon are found in several rivers in the North East of North America (Boucher, 2004), in addition to nine locations in Europe which are found in Russia, Sweden, Finland and Norway (Ozerov *et al.,* 2010a).

In Norway, at least four populations of landlocked salmon used to exist, but today only two populations remain. River pollution caused the extinction of bleke in Nidelva, and hydropower construction prevents vänerlaks from migrating to Norway from the Swedish lake Vänern (Bremset *et al.*, 2014a). The two populations that still exist are bleke in Byglandsfjorden and småblank in Namsen (Kazakov, 1992). Småblank was first described in scientific literature by Magnus Berg (Berg, 1953). The population density of småblank is unknown, and few observations of the population density is conducted (Bremset *et al.*, 2012b). There is, however, reason to believe the population density has decreased since the 1950's because less småblank has been caught in later years despite the increased efforts (Thorstad *et al.,* 2009b). Unlike the other freshwater resident populations found in Europe, småblank is solely river resident. This means that the småblank populations are not dependent on lakes and ponds, but individuals spend their entire life in river streams (Berg, 1984a). The småblank is one of the few Atlantic salmon populations that has adapted a river resident life strategy in addition to two other known populations, both in North America (Behnke, 1972).

Atlantic salmon is a well-studied species, but few studies are conducted on the freshwater populations (Klemetsen *et al.*, 2003a). Småblank rarely grows larger than 290 mm (Berg, 1984b; Thorstad *et al.*, 2011a), and often utilises fast water velocities and large particle sizes. Freshwater resident småblank and anadromous Atlantic salmon parr are about the same length, though the largest småblanks are slightly larger (Bremset *et al.*, 2014b). The anadromous individuals are therefore a good comparison to småblank.

During different freshwater life stages, Atlantic salmon utilise water depth, water velocity, substrate size and shelter availability differently according to body size (Borgstrøm & Hansen, 2000c). The habitat utilisation is important to understand in order to know which areas are suitable for fish in different life stages. The knowledge can be used in conservation of the populations of småblank and other freshwater resident Atlantic salmon which may also have similar habitat preferences. Habitat use of anadromous parr in freshwater are in most studies conducted as day time observations (Jonsson & Jonsson, 2011b). These studies therefore only show where the salmon is found half of the time. The present study implemented night observations as well as day observations to obtain a broader understanding of habitat use of småblank.

The småblanks's riverine moving patterns can be referred to as a home range. Home ranges are defined as areas in which animals confine themselves (Burt, 1943). By performing home range analyses it is possible to determine which areas are important for the småblank's spatial distribution. Burt 1943, formulated the following definition:

> "*Home range is that area traversed by the individual in its normal activities of food gathering, mating and caring for young. Occasional sallies outside the area, perhaps exploratory in nature, should not be considered as in part of the home range*".

The home range of småblank includes search for food and shelter, in addition to spawning grounds, all within the river system. Differences in home ranges within a species may be caused by different feeding strategies (Fish & Savitz, 1983). This study is the first of its kind to estimate home ranges of individuals småblank. Studying distribution of småblank at day and night, as well as in different seasons will help improving management of fish by learning more about how large areas småblank requires. The knowledge could develop mitigating measures in an area with river resident salmon in terms of constructions of e.g. hydropower production.

Hydropower production is known to have a negative effect on landlocked populations (Norrgård, 2011), and may be the reason for the småblank's population decline (Thorstad *et al.*, 2009a; Thorstad *et al.*, 2011c). Dams and weirs in Namsen were built for the purpose of power production, which caused barriers between the populations of småblank (Sandlund *et al.*, 2014). The dams are constructed at the power station intake, while the weirs increase water level where the water discharge is reduced for aesthetic purposes. The result is a change of habitat with lower water velocity, which is more favourable for brown trout (*Salmo trutta*) than Atlantic salmon (Borgstrøm & Hansen, 2000b).

Småblank is, in perspective of management, highly relevant for conservation because the fishes are the only known river resident populations in Europe. Neither females nor males are utilising lakes, which means that småblank are even more vulnerable for anthropogenic changes in the river than fish that also inhibits lakes. Habitat fragmentation and population decrease are threats that can reduce the genetic diversity. This could be the case for småblank which has a lower genetic variation than anadromous Atlantic Salmon (Sandlund *et al.*, 2014). High genetic diversity provides a stronger population that are better adapted to changes (CBD, 2011). By managing småblank's distribution area, it would be possible to safeguard both the species and the genetic diversity of the populations.

Based on a radio telemetric method, this study investigated home ranges, distance of river stretch used and habitat utilisation for småblank in the regulated River Namsen at Snåsamoen and the unregulated tributary Mellingselva. The following research questions were addressed in the thesis:

- How large home range does småblank utilise, and do the range differ between a regulated mainstream and a non-regulated tributary and between seasons?
- Is there a difference in distance of river stretch used by småblank between the two rivers, between day and night and between season in the regulated river?
- In which size of substrate and level of water velocity are småblank most likely to be observed?

This is the first time radio telemetry is implemented in a study of småblank. Meaning, radio transmitters were used to track småblank and observe the areas fish utilise at day and night time. This method produces a qualitative dataset where position of småblank is located with high accuracy.

2. Material and methods

2.1 Study area

The River Namsen runs from Store Namsvatnet 450 m.a.s.l to Namsos city where it meets Namsenfjorden. The total length is 229 km with a catchment area of 6 300 km^2 (NVE, 2015a). Nine hydropower plants are today producing electricity in the catchment area with a mean annual production of 1 831 GWh (NTE, 2015). Electricity production started in 1946 when the first hydropower plant was constructed in Fiskum (Hjulstad, 1993). Småblank can be found in River Namsen from Namskrokan to Nedre Fiskumfoss which extends 85 km, and the rivers tributaries (Bremset *et al.*, 2011b).

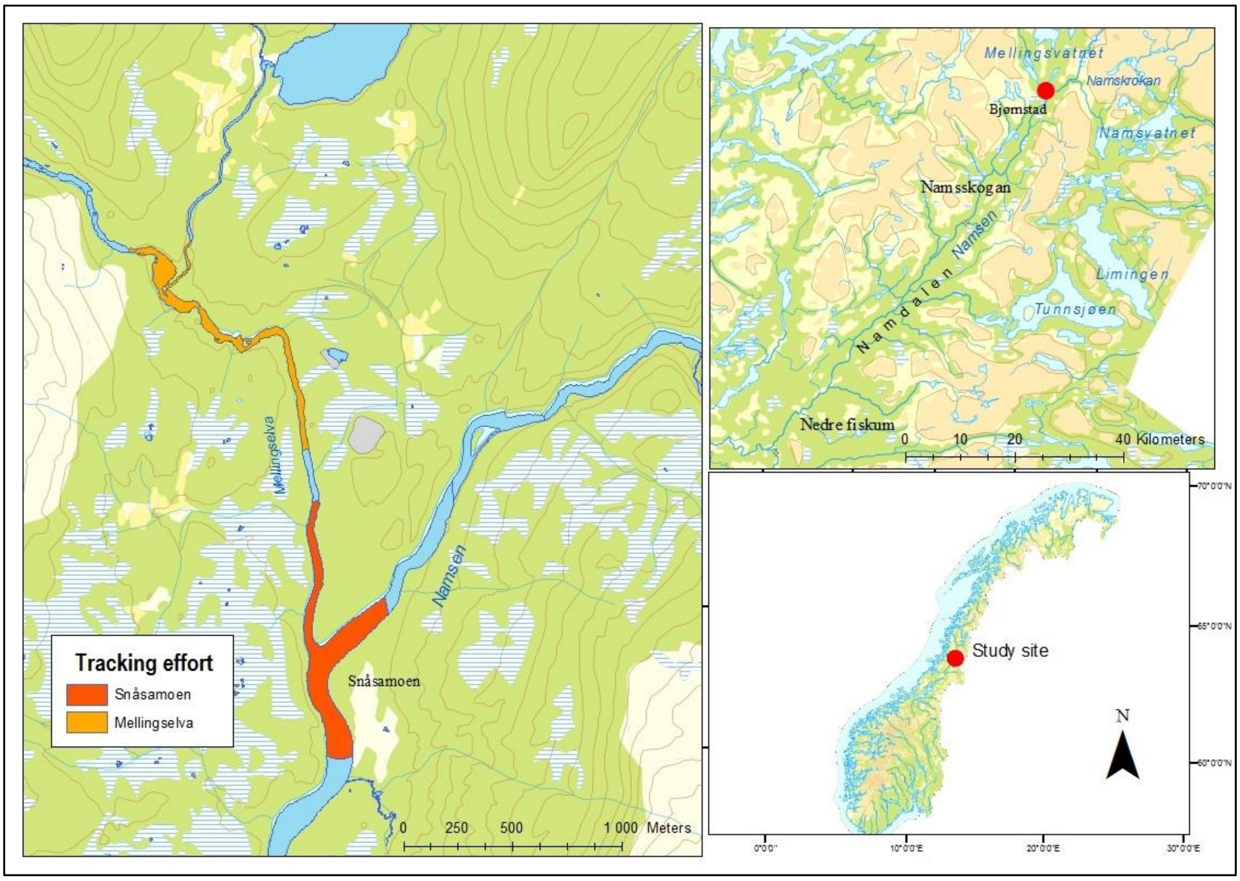

Figure 1 Map of study site, including Øvre Namsen and the area concentrated for radio tracking småblank in Mellingselva (orange) and in Namsen at Snåsamoen (red)

The upper part of Namsen called Øvre Namsen starts at Namsvatnet and extends downstream to Nedre Fiskum. It is a strongly regulated area, and water flowing from Namsvatnet to Tunnsjøelva has a low rate of flow (Thorstad *et al.*, 2006a). This is because water from Namsvatnet is redirected away from Namsen to Limingen and Tunnsjøen to feed the power production in the River Tunnsjøelva. Annually the river system is affected by a spring flood with a water discharge of 150 ms^{-3} at Bjørnstad (NVE, 2015b), which is located 7 km down streams from the study site. This flood normally starts in April/May and can last for many weeks (Reidar Smalås, Fjellstyret, 2015. Pers.comm.15 sept). The water velocity is lowest during winter, and starts increasing in the spring as the snow in the mountains melts.

The two rivers investigated in the study are located in Øvre Namsen, in the lower mountain area, a region with large differences in temperatures between summer and winter (Meterologisk Institutt, 2015). Småblank is distributed from Namskrokan throughout Øvre Namsen, with a varying population density in the river (Bremset *et al.*, 2011a). Relatively high densities of småblank are found in the tributary of Namsen, Mellingselva (Bremset *et al.*, 2014a) and in Namsen at Snåsamoen (Thorstad *et al.*, 2011b) (Figure 1). Snåsamoen is an area with relatively similar particle sizes with little shelter availability. The distance from Namsvatnet to Snåsamoen is 20 km and has an elevation of 200 meters creating riffles and strong velocities (Berg, 1984a). Water depths are similar in most of the area, but in areas with high velocity, the river is slightly deeper.

Mellingselva is one of the largest non-regulated tributaries in Namsen, and an important river for småblank during all life stages (Bremset *et al.*, 2012c; Bremset *et al.*, 2014a). Shelter availability in Mellingselva varies from zero to ten cavities per m^2. The habitat availability is relatively diverse with presence of deep water pools with slow velocity and waterfalls. This leads to a difference in substrate size with areas of sand and other areas with bedrock (own observations according to method described by Finstad (Finstad *et al.*, 2007).

Both the area of Snåsamoen and in Mellingselva, has low levels of pH, nitrogen and phosphorus (Table 1), this is considered to be typical for rivers in the lower mountain areas (Bronmark & Hansson, 2010). Water temperatures fluctuate with season and in 2015, water temperatures reached 23°C at summer and decreased to 0°C during the winter months (own measurements in field 2015) showing no apparent difference between the rivers (Table 1).

Table 1 Environmental variables measured in autumn 2015. nitrogen and phosphorus analysed by Analysesenteret in Trondheim kommune in December 2015. pH, conductivity, oxygen, calcium and temperature measured in field 07.10.15 for all variables

	Snåsamoen	Mellingselva
pH	6.8	7.0
Conductivity (µs/om)	11	25
Oxygen (%)	81	80
Calcium (mg/l)	< 5	< 5
Nitrogen (µg/l)	70	85
Temperature (°C)	12.5	13.2
Phosphorus (µg/l)	< 2	< 2

2.2 Fish capture and radio tagging

Traditional backpack electro fishers were used for catching småblank. This method is commonly used in rivers and has in previous studies been proven successful in Namsen (Bremset *et al.*, 2012a). The electro fisher was set on 700 or 1400 Volt, depending on the conductivity of the water. Generally, conductivity increases with a higher temperature and vice versa. High voltage was required when water conductivity was low due to less ions in the water, and the volt was adjusted down when the number of ions increased.

Fish with a total body length larger than 130 mm were tagged with radio transmitters from the manufactory Advanced Telemetry System (ATS; USA). Large radio transmitters (F1440) weighed 2.1 grams and small radio transmitters (F1420) weighed 1.3 grams, which was inserted on the smallest fish. A total of 92 småblank were caught for the study, but with a loss of two fish. the remaining 90 individuals were used for tracking. The first tagging session was conducted at Snåsamoen in autumn 2014, the second was at Snåsamoen in spring 2015 and the last tagging period was in Mellingselva in autumn 2015 (Table 2). All the transmitters in this study emitted signals at bandwidth between 142.000 and 142.700 MHz.

Table 2 Total body length of småblank tagged in the study at Snåsamoen autumn 2014 and spring 2015. Fish in Mellingselva were tagged in Mellingselva at autumn 2015

Location	Tagging months	No. of transmitters		Total body length (mm)				River condition
		Small	Large	Female Mean ± SD	n	Male Mean ± SD	n	
Snåsamoen	Aug 2014	10	23	167 ± 60	22	160 ± 31	11	Regulated
Snåsamoen	May 2015	0	20	162 ± 24	17	166 ± 25	3	Regulated
Mellingselva	Aug-Sep 2015	3	34	167 ± 66	19	154 ± 32	18	Non regulated

2.3 Anaesthesia and surgery

For implanting the transmitters, fish were anaesthetised in 2-phenoxy-ethanol (EEC No 204-589-7), with a dosage of 0.50 ml\l dissolved in water. The individuals were kept in the anaesthesia between 4 and 4.5 minutes. The surgical procedure lasted approximately 3.5 minutes per fish. A tube with flowing water was placed in the fish mouth for oxygen flow across the gills. Total body length, body mass and biological samples of the adipose fin and fish scales were sampled for further analysis. To avoid influence of post-tagging behaviour to the dataset, tracking was delayed with one day after fish release.

2.4 Radio tracking

Radio tracking was conducted from August 2014 to January 2016, divided in three separate periods. Each tracking period lasted four to five months. Tracking rounds were conducted every third week, and for all tracking rounds, the småblank were tracked at least once. For the total study period two radio tagged fish died shortly after tagging. The remaining 90 individuals were monitored for as long as the fish were in the tracking area and batteries were functional. The total amount of tagged salmon available in the study was therefore 97.8% of the prior sample size.

Picture 1 Receiver, antenna, GPS and habitat form used for radio tracking

For radio tracking, a hand-held ATS receiver was used with a five element Yagi antenna and a 50-ohm cable (Picture 1). To locate småblank, the receiver was tuned to find the direction of the fish based on the equipment's signal strength. When the antenna was directed towards the location of the fish, and when fish were closer, the signal strength would increase. The accuracy from radio tracking was ± one meter. Flooding and deep waters created situations where it was not possible to reach the fish by wading. Field notes where then required to note how far away the fish was located. Each tracked location was registered with GPS locations which had an accuracy of ± five meters.

Table 3 A five category form for water velocity and substrate used for determining småblank habitat utilisation (Berger et al 2007a, Jowett et al 1991)

Category	Water velocity	Particle size
1	Stagnant water: 0 - 0.2 ms^{-1}	Sand: < 2 cm
2	Slow current 0.2 - 0.5 ms^{-1}	Gravel: 2 - 16 cm
3	Moderate current: 0.5 - 1 ms^{-1}	Stone: 16 - 35 cm
4	Strong current: > 1 ms^{-1}	Rock and block: > 35cm
5	Waterfall: Pronounce falling gradient	Bedrock

Day tracking started at least two hours after dawn and night tracking started at least two hours after dusk. This allowed fish to return to their chosen day and night habitats before tracking was conducted. The number of days spent tracking varied from two to five days and nights for each round. Furthermore, the tracking effort was limited by time and therefore the tracking was restricted to a certain area. A total of 101 500 m^2 river surface was covered by the tracking area at Snåsamoen, which included the lower part of Mellingselva where some individuals were observed. In Mellingselva the tracking area covered 70 000 m^2 of the river surface (Figure 1).

2.5 Age, body condition and sex determination

The scale samples were analysed for age determination (Dahl, 1910). Samples that only contained replacement scales were not included in the age analysis as the scales were missing the annual growth rings. Therefore, 72 fish scales were found suitable for age determination. Each scale was put on a 1 mm Lexan plastic plate and pressed with an iron press in order to print the scale. The annual rings of the scales where then read using a Leica MZ16 A light stereo microscope.

Eighty-nine genetic DNA samples from adipose fins were collected for sex determination. The collected adipose fins were sent to the Norwegian Institute for Nature Research for sex and species determination (Karlsson *et al.*, 2013; Quemere *et al.*, 2014). The DNA samples were tested for hybrid brown trout – Atlantic salmon individuals, but hybrids were not shown in any of the tagged småblank.

Seventy-seven fish were measured for body mass and therefore calculated for body condition using Fulton's body condition factor (Fulton, 1904). Fulton's condition factor calculates the morphometrically measurements, mass and body length under the assumption of isometric growth (Sutton *et al.*, 2000). The method is non-invasive to the fish and describes the individuals energetic state (Neff & Cargnelli 2004). The formula represents Fulton's body condition factor (K), calculating mass in gram (W), and total body length in cm (L).

$$K = \frac{100 * W}{L\hat{}3}$$

2.6 Data analysis

2.6.1 Editing GPS locations

The locations for the fish that were not possible to be reached by wading were edited in Geographic Information System (GIS) software Map 10.2 (desktop.arcgis.com/en/arcmap/) in order to achieve a more accurate location than what was feasible in field. Field notes explaining the distance to the fish were used when editing GPS locations in the GIS software. The edited locations and actual tracking locations for each individual where used for home range estimation.

2.6.2 Home range estimation

Home range was determined based on GPS locations collected by radio tracking. A total of 526 GPS locations were used in the home range estimation on 35 fish (Snåsamoen autumn n = 15, Snåsamoen spring n = 11, Mellingselva autumn n = 16). All fish in the estimation included day and night location which calculated the individuals home ranges over several months during day and night time (Table 4). By including day and night locations, a more accurate home range will be achieved compared to studies only observing day locations.

Table 4 Total number and dates of 35 radio tracked småblank conducted at Snåsamoen and Mellingselva

Tacking	Snåsamoen			Snåsamoen			Mellingselva		
round	Date	Day	Night	Date	Day	Night	Date	Day	Night
1	*09.09.2014*	12		*30.05.2015*	6	6	*25.08.2015*	10	1
2	*23.09.2014*	11		*31.05.2015*	6	6	*27.08.2015*	6	
3	*24.09.2014*	3		*22.06.2015*	2	6	*14.09.2015*		10
4	*09.10.2014*	15		*23.06.2015*	6		*15.09.2015*	15	6
5	*10.10.2014*	2	13	*15.07.2015*	6		*06.10.2015*		15
6	*11.10.2014*	15	15	*16.07.2015*			*07.10.2015*	16	
7	*12.10.2014*	15	15	*08.08.2015*	6	6	*21.10.2015*	10	
8	*13.10.2014*	15	15	*09.08.2015*	6		*28.10.2015*		14
9	*14.10.2014*	15	15	*26.08.2015*	5		*29.10.2015*	15	13
10	*15.10.2014*	15	15	*16.09.2015*	5		*30.10.2015*	13	
11	*31.10.2014*	12					*23.11.2015*		11
12	*07.11.2014*	10					*24.11.2014*	14	
13	*24.11.2014*	9					*14.12.2015*		12
14	*08.12.2014*	9					*15.12.2015*	14	
15							*11.01.2015*		5
16							*12.01.2015*	8	
Total		158	88		48	24		121	87

Two criteria were set for the individuals to be approved for the home range analysis. First, all individuals in the home range analysis had to have fifteen locations for large radio transmitters and eleven locations for small radio transmitters during autumn tracking. At spring the required number of tracking locations were eleven. Second, all individuals in the three tracking periods had to have locations lasting for at least four months. A large proportion of småblank (89%) in all the three tracking periods was observed to have occasional migrations outside the tracking area. This resulted in an uneven number of tracking locations for each tracking round because not all fish were detected by radio tracking every round. To standardise the dataset according to the second criteria, the GPS locations were divided into five periods. In each period a defined number of tracking locations were grouped to generalise the home range estimation for the individuals. The location from the first tracking round was included in period 1, and the last period for the last tracking round (Table 5). The reason for tracking over several months is because fish can change their home ranges within season due to precipitation, food availability, competition, etc.

Table 5 GPS locations of småblank used for home range estimation were divided into periods (1 – 5) based on time of tracking. Periods are divided into tracking months for the three tracking periods: Snåsamoen at autumn 2014, Snåsamoen at spring 2015 and Mellingselca at autumn 2015

	Period 1		Period 2		Period 3		Period 4		Period 5	
	May	Aug	June	Sep	July	Oct	Aug	Nov	Sep	Dec/Jan
Transmitters Large/small	Large	Both	Large	Both	Large	Both	Large	Both	Large	Both
Autumn 2014	-	2	-	10	-	1	-	1	-	1
Spring 2014	3	-	2	-	1	-	3	-	2	-
Autumn 2015	-	1	-	4	-	4	-	3/2	-	3/0

A home range estimation makes use of a probability model to estimate an animals spatial use. The estimation depends on choosing the best fitting smoothing parameter (Worton, 1989). Home ranges were estimated using the statistical software R version 3.2.2 (www.r-project.org) and the packages 'adehabitat' (Calenge, 2011b). The package calculates the home range using bivariate normal kernel. Kernel density estimates do not have one single smoothing parameter that applies to all datasets (Laver, 2005b). Choosing the right smoothing parameter is necessary in order to reduce over- or under-smoothing of a home range (Laver, 2005a). For animals being normally distributed in bivariate space, the reference bandwidth 'href' is often used, and is also implied in this study. 'href' is a common reference smoothing parameter that controls the bandwidth of the function in each tracking location. When locations are cluttered together, the bandwidth will normally increase and over-smoothing can occur. Larger 'h' increases the width of the smoothing parameter since the reference smoothing has a tendency to over-smooth data (Calenge, 2011a). In order to reduce the reference bandwidth a defined proportion such as 0.50 can reduce the over-smoothing. Choosing a larger percentage will contribute to a larger over-smoothing of the home range size. A 50% and a 90% bandwidth probability was tested in order to explore which method was best suitable for further analysis in this study. Tests on the 90% bandwidth showed an over-smoothing of the estimation (Appendix) and for statistical analysis the 90% bandwidth was excluded. Further tests were conducted with a 50% smoothing parameter.

2.6.3 Statistical analysis

All statistical analysis was conducted in the R statistical program. For analysing home ranges, the Kernel Utilisation Density Estimator was used to calculate the home range sizes for individual obtaining more than 11 tracking locations (chap 2.6.2). To conduct analysis of variance, t-tests were used to test differences in means of two groups with one variable. Chi-square tests were used to test whether there is a significant proportion between variables. Further, ANOVA, Two-way ANOVA and post hoc ANOVA Tuckey, were used to detect differences among and within multiple groups for tests with two or more variables. In addition, linear regression models were used to test relationship between an independent and dependent variable like home range sizes, body length and body condition.

To explain a model with multiple variables, a model selection tool developed in the package MuMIn (cran.r-project.org/web/packages/MuMIn/) was used. The model calculates and shows which variables are most important in explaining differences in a model. Akaikes Information Criteria (AIC) estimates the model that is best fitted and the lowest AIC value is the best described model. The statistical tools were used to find differences and similarities within and between seasons and rivers. Analyses were used for testing differences in småblanks home range utilisation the two different rivers, Snåsamoen in 2014 and Mellingselva in 2015 during the autumn tracking period and in spring at Snåsamoen. The two autumn tracking periods are referred to as "river" in this study when the two rivers are compared in the statistical analysis. For testing seasonal changes at Snåsamoen, tracking data from autumn 2014 and spring 2015 were compared. These tracking periods are referred to as "seasons" further in this study. The variables that were statistically analysed included body length, body condition, age, sex, water depth, river and season, as well as the variables: day moving distance, night moving distance and home ranges.

2.6.4 Analysis of river stretch used

The distance of river stretch used are referred to as moving distance in the study. A total of 42 småblank were selected according to available tracking data, to analyse moving distances at day and night time as well as to look at differences between seasons and rivers. Fifteen individuals in autumn 2014, eleven individuals in spring 2015 and sixteen individuals in 2015 were used in the analysis. Measurements of the length of river stretch used were performed separately based day time and night time tracking, respectively.

2.6.5 Estimates of habitat utilisation

Substrate size and water velocity were calculated during day and night time tracking according to the five category form (Table 3). Habitat observations were based on a 1x1 meter area of the fish's location. Particle sizes were divided into proportion of substrate present in each category. In situations where more substrate particle categories were present in a location, a numbering system indicated which particle sizes were most common within the square meter. For instance, if a location obtained substrate category 2, 3, 1, where category 2 was the highest present in the location, and category 1 the least present, each category would obtain the value that reflected the presence. Category 2 would gain three points, category 3 would gain two points and category 1 gained one point. If there was only one category present in the location, the substrate received six points.

3. Results

3.1 Biological characteristics

3.1.1 Body length differences between rivers and seasons

Total body length and age were highly correlated (ANOVA, *n* = 72, p-value = < 0.001), and body length increased with age within all tracking periods (Figure 2). The body length of tagged småblank in Mellingselva were larger (mean = 159 mm, range 138 – 199 mm, *n* = 35, SD ± 14) than at Snåsamoen during autumn (mean = 165 mm, range 140 – 210 mm, *n* = 27, SD ± 16). However, the difference in body length in the two rivers was not significant at autumn (ANOVA, *n* = 62, p-value = 0.09), nor did the body length differ significantly between autumn and spring at Snåsamoen (ANOVA, *n* = 54, p-value = 0.63).

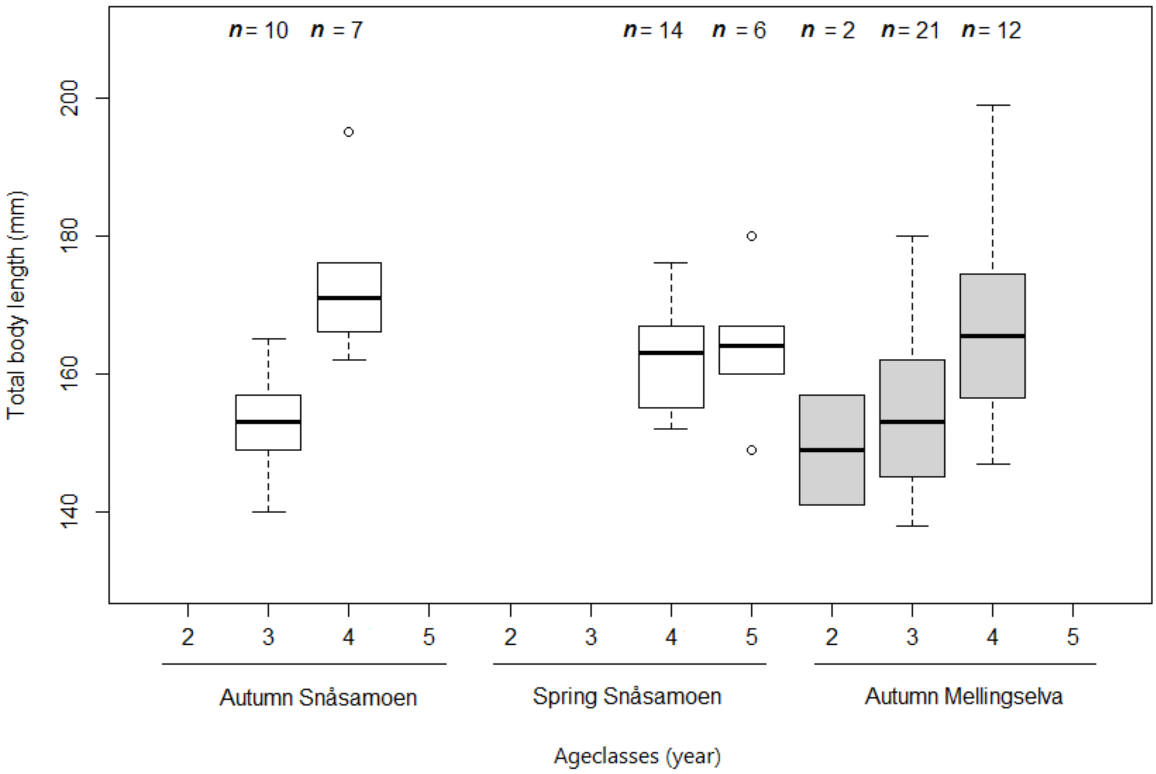

Figure 2 Body length in different age classes of småblank tagged at Snåsamoen (white) at autumn 2014 and spring 2015 and in Mellingselva (grey) at autumn 2015

Males in the river at Snåsamoen had a smaller body length at autumn (mean = 159 mm, range 145 – 176 mm, *n* = 11, SD ± 11) than females (mean = 164 mm, range 140 – 210, *n* = 22, SD ± 19). Three year old males had in average 3.5 mm smaller body length than females at Snåsamoen. In Mellingselva did males have a shorter body length (mean = 154 mm, range 138

– 170, *n* = 18, SD ± 10) than females (mean = 162 mm, range 140 – 199, *n* = 19, SD ± 16). Sex and body length of småblank at Snåsamoen was not statistically significant (ANOVA, *n* = 53, p-value = 0.31) during spring and autumn. During spring, the body length of males (mean = 163 mm, range 155 – 180 mm, *n* = 3, SD ± 12.6) and females (mean = 164 mm, range 149 – 176, *n* = 17, SD ± 18.5) showed no apparent differences (ANOVA, *n* = 20, p-value = 0.40).

3.1.2 Body condition differences between rivers and seasons

Body condition correlated with age in all of the three tracking periods (Two-way ANOVA, *n* = 52, p-value < 0.001). During August 2015, the radio tagged småblank in Mellingselva did have a higher body condition (mean = 0.94, range 0.78 – 1.13, *n* = 36, SD = 0.07) than the fish at Snåsamoen (mean = 0.82, range 0.74 – 0.95, *n* = 21, SD = 0.06; ANOVA Tuckey, *n* = 57, p-value < 0.001) (Figure 3). There were no observations on body condition for five year old småblank in either river, nor for two year old småblank at Snåsamoen in autumn. Age class three (Tuckey ANOVA, *n* = 31, p-value = 0.002) had significantly higer body condition than age class four (Tukey ANOVA, *n* = 19, p-value = 0.01) at Snåsamoen and Mellingselva during autumn (Figure 3).

The body condition factors were statistically significant between the three tracking periods. (ANOVA, *n* = 72, p-value < 0.001) (Figure 3). Body condition in fish between the seasons showed a difference where fish in spring had a lower body condition than autumn (ANOVA Tuckey, *n* = 39, p-value <0.001). The fish at Snåsamoen had a lower body condition score in spring with a mean of 0.67 (range = 0.49 – 0.80, mean = 0.67, SD = 0.08), compared to body conditions in autumn.

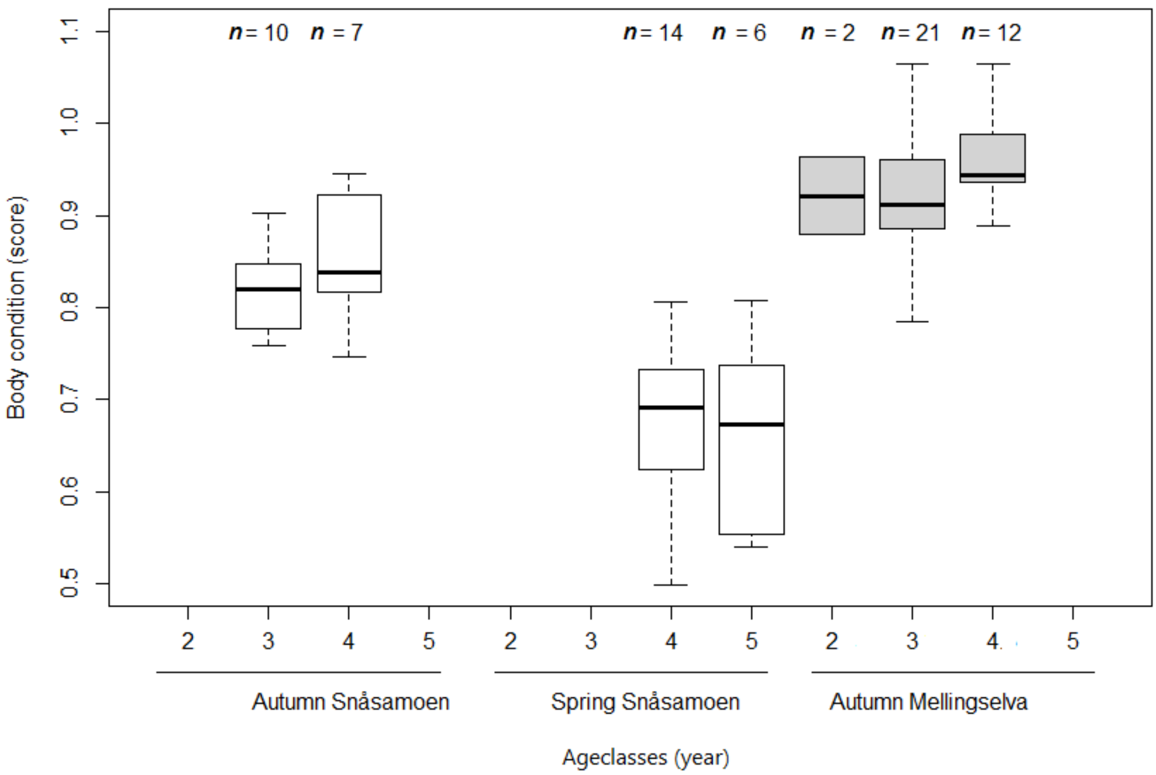

Figure 3 Body condition showed in age classes from 2 to 5 years of tagged salmon at Snåsamoen (white) at autumn 2014, spring 2015 and in Mellingselva (light grey) in autumn 2015

At Snåsamoen, there was no difference in body condition of males and females in autumn 2014 (ANOVA, *n* = 22, p-value = 0.83) or in spring 2015 (ANOVA, *n* = 13, p-value = 0.85), but differences in body condition between sexes in Mellingselva at autumn 2015 were close to significant (ANOVA, *n* = 25, p-value = 0.077).

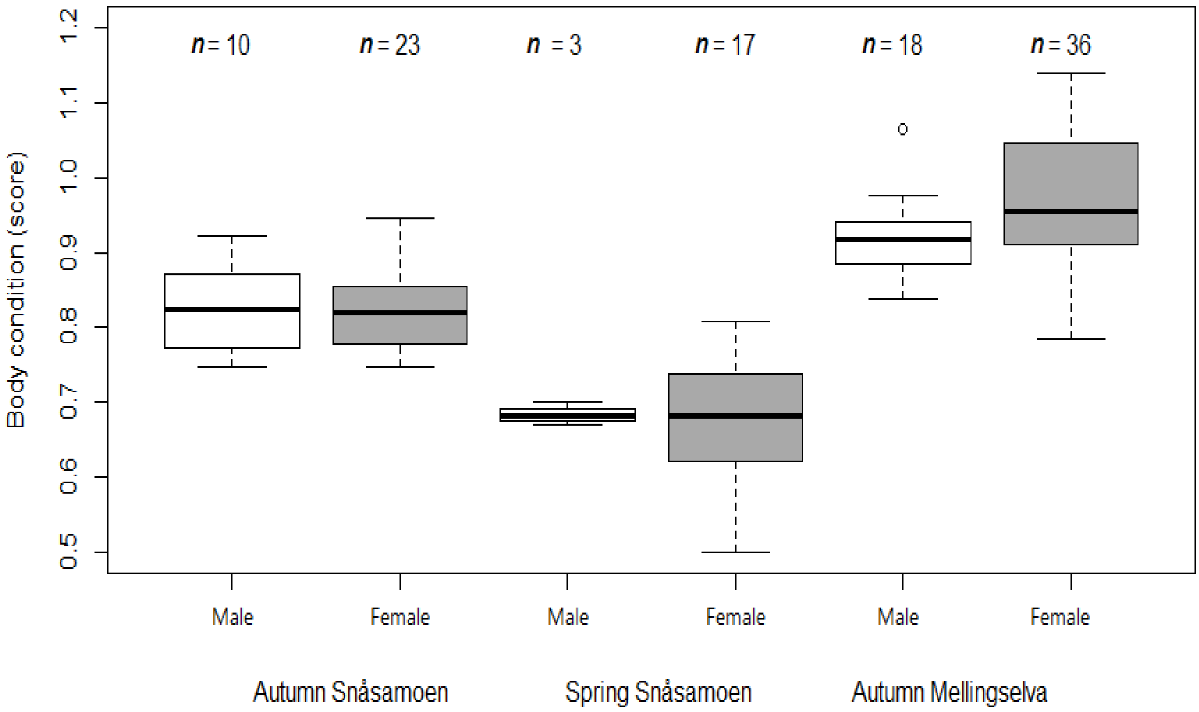

Figure 4 Body condition on males (white) and females (grey) of småblank at Snåsamoen autumn 2014 and spring 2015 and in Mellingselva 2015.

3.2 Home ranges

3.2.1 Comparison between rivers

The home ranges of tagged småblank in autumn at Snåsamoen (mean = 21 715 m^2) were significantly larger than during autumn in Mellingselva (mean = 2 362 m^2; ANOVA, $F_{1,33}$ = 4.90, p-value = 0.035) (Table 6).

Table 6 Mean, number of småblank (*n*), standard deviation (SD) and minimum – maximum estimations of home range sizes in the periods Snåsamoen autumn 2014, Snåsamoen spring 2015 and Mellingselva autumn 2015

	Snåsamoen 2014 August – December	Snåsamoen 2015 May – August	Mellingselva 2015 August – January
Mean Home range (m^2)	21 715	29 688	2 362
n	14	6	15
SD	33 818	26 122	2 315
Range (min – max)	73 – 98 912	6 507 – 70 655	84 – 8 404

In the best fitted model, which has the lowest ΔAIC, (adjusted R^2 = 0.56, p <0.001) did home ranges correlate with body length and body condition both at Snåsamoen and Mellingselva (Table 7). The ΔAIC showed that the four best models (ranging between ΔAIC 0 – 1.99) were almost equally good. The river variables were important in explaining home range and larger home ranges were found at Snåsamoen than Mellingselva. Body lengths were similar in småblank with similar age in all tracking rounds, but the body length differed between Snåsamoen and Mellingselva because older fish were tagged at Snåsamoen. Lastly, an interaction with body condition and river was important in home ranges, because body conditions were lower at Snåsamoen than Mellingselva. The second best model included the same variables as the best fitted model, but did in addition contain an interaction on river and body length. The third model did not include river and body length interaction or body length. The fourth model included correlation on body length, body condition, sex and river.

Table 7 Model selection for estimating the home ranges of 31 småblank at Snåsamoen and in Mellingselva. four best models using model selection where ΔAIC is below 2. The model estimates the parameters from a linear model based on body condition (C), interaction on river and body condition (RC), river (R), sex (X), river and total body length interaction (RL). AIC weights represents the relative likelihood for the model, while ΔAIC represents the value that shows the best fitting model. This represents the four models that were best fitted

Model	AIC	ΔAIC	AIC weights	df
[R, L, C, RC]	621.56	0	2.83	6
[R, L, C, RL, RC]	622.58	1.01	1.70	7
[R, C, RC]	623.05	1.48	1.35	5
[R, L, C, X, RC]	623.56	1.99	1.04	7

3.2.2 Comparison between seasons

Home ranges at Snåsamoen during spring were larger than home ranges during autumn in the same river (Table 6). The best fitted model, which had the lowest ΔAIC, (adjusted $R^2 = 0.37$, p-value = 0.02) indicated that there was a correlation in home range with season and body condition. Home ranges were larger in spring season than autumn season at Snåsamoen, in addition, body condition was poorer during spring than autumn tagging (Table 8). Lastly, an interaction in season and body condition was important in the first model. The second best model included body length where larger fish had a larger home range. The third model included sex as a variable together with body condition and season correlation.

Table 8 Model selection for estimating the home ranges of 20 småblank at Snåsamoen in spring and autumn seasons. The models estimate the parameters from a linear model tested body condition (C), season (S), interaction on season and body condition (SC) and total body length (L). The AIC value is based on Akaike information criterion (AIC). AIC weights represent the relative likelihood of the model. degree of freedom (df) while ΔAIC represents the values that shows the best fitting model. This is presented with three models that were best fitted

Model	AIC	ΔAIC	AIC weights	df
[C, S, SC]	441.00	0,00	0.32	5
[L, C, S, SC]	442.79	1.78	0.13	6
[C, S, X, SC]	442.98	1.97	0.12	6

3.3 Moving distance between tracking seasons

The moving distance of river stretch used varied from 6 meters (m) to 1 530 m for individuals in the study. The individuals also had a great variation in standard deviation values within all tracking periods (Figure 9). The mean moving distance at Snåsamoen was 317 m (range: 16 m – 851 m) at autumn. During spring, the mean distance was 321 m (range: 95 m – 422 m), and in Mellingselva in the autumn mean distance was 115 m (range: 12 m – 500 m).

Table 9 Mean, number of småblank (*n*) and standard deviation (SD) of distance of river stretch used in the tracking periods: Snåsamoen in autumn 2014 and spring 2015, and for Mellingselva in autumn 2015.

	Snåsamoen autumn			**Snåsamoen spring**			**Mellingselva autumn**		
	Mean distance m	SD	*n*	Mean Distance m	SD	*n*	Mean Distance m	SD	*n*
Day distance	301	± 274	16	191	± 113	11	97	± 116	15
Night distance	104	± 144	16	136	± 93	11	91	± 106	15
Total distance	317	± 281	16	321	± 107	11	115	± 116	15

The moving distance was compared between day and night time at Snåsamoen during autumn which was significantly different (t.test, n = 15, p-value = 0.022). No significant difference in day and night moving distances on tagged fish was shown in Mellingselva at autumn (t.test, n = 16, p-value = 0.86), or at Snåsamoen during spring (t.test, n = 11, p-value = 0.22). Day moving distances did not differ in seasons at Snåsamoen (ANOVA, n = 21, p-value = 0.22).

The moving distance at day time were significantly larger at Snåsamoen (range: 14 – 851 m) than in Mellingselva (range: 6 – 500 m; ANOVA, n = 31, p-value = 0.01). The moving distance at night at Snåsamoen (SD = 144, range: = 7 – 453 m) and Mellingselva (range 6 – 418 m) was not statistically different (ANOVA, p-value = 0.78) in autumn season.

3.3.1 Comparing moving distance and body condition between rivers and seasons

At Snåsamoen the fish that conducted longer moving distances of river stretch used at day time had a higher body condition ($R^2 = 0.44$, $F_{1,12} = 9.511$, p-value = 0.009). In Mellingselva the day distance did not correlate with body condition ($R^2 = 0.01$ $F_{1,14} = 0.17$, p-value = 0.6). Småblank tagged in Mellingselva moved shorter distances, but had a higher body condition than at Snåsamoen in autumn (Figure 5). Difference in body condition did not show correlation at night moving distances at Snåsamoen ($R^2 = 0.02$, $F_{1,12} = 1.33$, p-value = 0.27) or in Mellingselva at autumn ($R^2 = 0.028$, $F_{1,14} = 0.41$ p-value = 0.53).

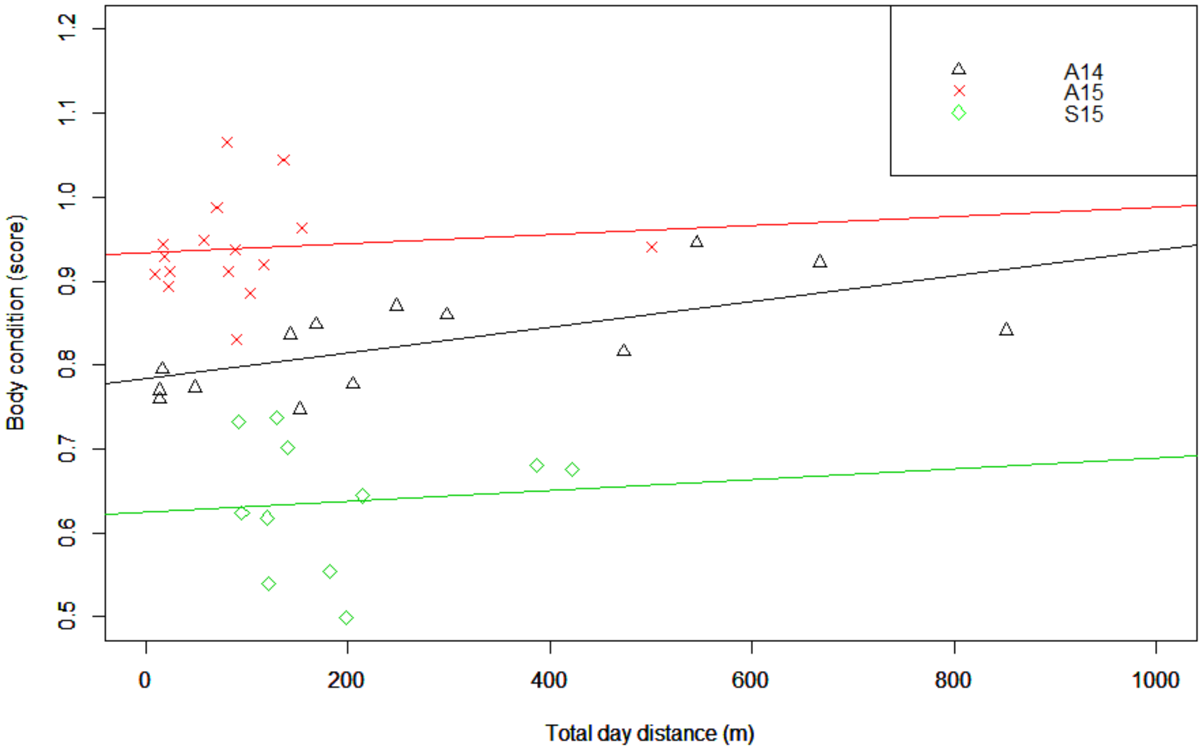

Figure 5 Correlation on Fulton's body condition factor and distance of river stretch used at day time. Three separate tracking periods conducted during spring 2015 (S15) and autumn 2014 (A14) at Snåsamoen and during autumn 2015 (A15) in Mellingselva measured on 35 småblank

There was no correlation between day moving distance and body condition at Snåsamoen during spring (Linear regression, $R^2 = 0.008$, $F_{1,9} = 4.6$, p-value = 0.79). There was neither a significant correlation at night time (Linear regression, $R^2 = 0.084$, $F_{1,9} = 3.5$, p-value = 0.78).

3.4 Habitat utilisation

3.4.1 Substrate

The overall most utilised substrate during day time was stone particles (16 – 35 cm) at Snåsamoen, and block substrate in Mellingselva (> 35 cm; Figure 7). Småblank was observed to dominate areas with stone and gravel substrate (2 – 16 cm) at spring and autumn in Snåsamoen. Småblank generally utilised larger particle sizes of stone and block substrates in Mellingselva at night time compared to Snåsamoen at autumn.

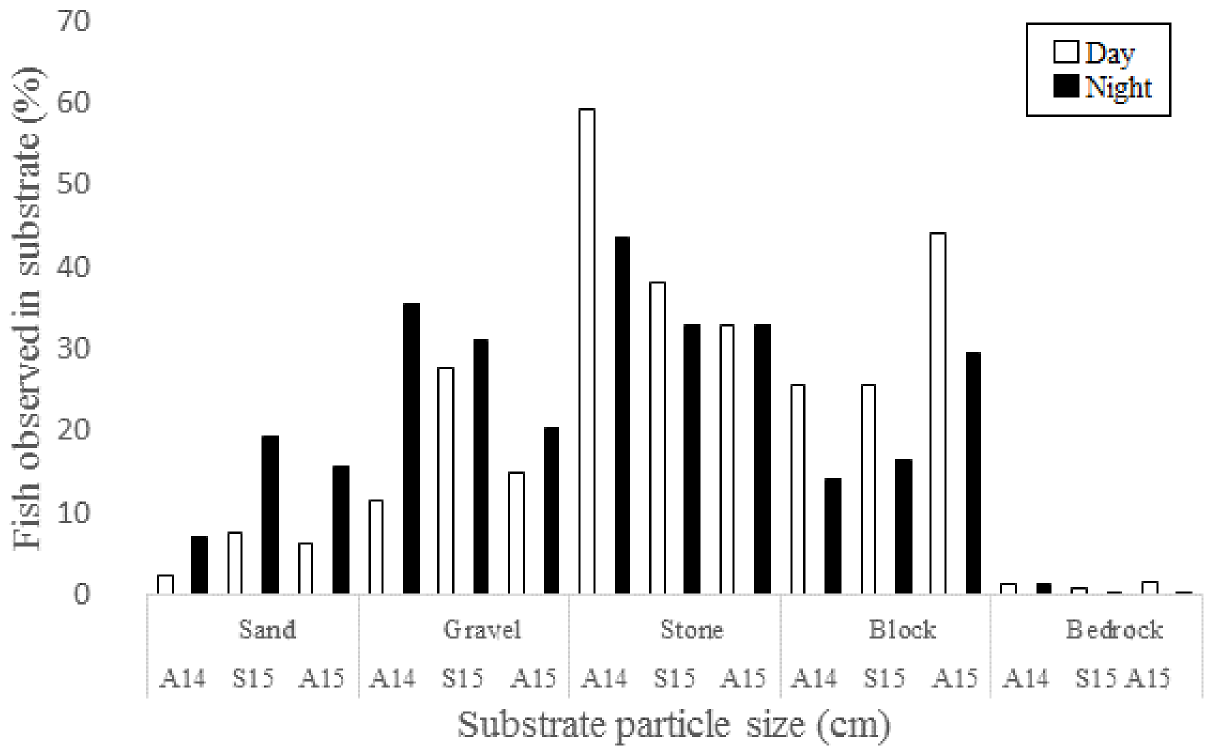

Figure 6 Percentage of time småblank were registered in the different substrate categories: sand (< 2 cm), gravel (2 – 16 cm), stone (16 – 35 cm), block (> 35 cm) and bedrock. Observations included radio tagged fish at day and night time from the tracking periods: autumn 2014 at Snåsamoen (A14) and autumn and spring 2015 (S15), and during autumn in Mellingselva (A15).

3.4.2 Substrate utilisation at Snåsamoen

Småblank was observed to utilise stone substrate 59% of the time in autumn at Snåsamoen during day and 43% of the time during night tracking. The second most utilised substrate at day time was block substrate in 26% of the observations. Unlike day habitat the second most utilised substrate at night was gravel (36%). Thirdly, småblank utilised gravel substrates at day time (12%) and block habitat at night time (14%). The two least utilised substrates were sand and bedrock both during day and night (Figure 6).

The same trend of habitat utilisation was found in spring. The greatest amount of registrations was in stone substrate of 38% at day time and 33% at night time. The second most utilised substrate was gravel substrate for both day and night time with 28% and 31%, respectively. The third most used habitat was block substrate at day time (26%), and sand substrate at night time (19%). The fewest fish registrations were found in bedrock substrate at day and night time of 0.8% and 0.3%, respectively (Figure 6). The proportion of substrate categories utilised in småblank was significant (Chi-square, p-value = 0.04) during day. At night time the småblank did not show any difference of proportion of substrate categories utilised (Chi-square, x-squared = 6.38, p-value = 0.20).

3.4.3 Substrate utilisation in Mellingselva

The highest proportion of registrations of småblank were found in block substrate (44%) at day time and stone substrate at night (33%). The second most utilised substrate at day was stone substrate (33%) and block at night time (30%). Gravel was the third most utilised substrate at day time (15%), and during night time (20%). Similar to Snåsamoen, fewer registrations of observed småblank in bedrock and sand habitats. There was, however, a larger proportion of registrations found in sand habitat at night time (16%) than day time (6%) (Figure 6).

The total difference in substrate categories of registered fish was significant, and showed a larger proportion of tagged småblank to utilise stone substrate than other substrate sizes (Chi-square, n = 63, p-value = <0.001). During night utilisation was there no difference in proportion of småblank utilised in habitat (Chi-square, n = 50, p-value = 0.17).

3.4.4 Water velocity

The overall most utilised water velocity in day time was slow and moderate currents at Snåsamoen at autumn, moderate currents at Snåsamoen at spring and slow current in Mellingselva (Figure 8). Night observations were dominated by småblank utilising moderate current in autumn at Snåsamoen and fast currents during spring. In Mellingselva småblank were observed majority of the time in slow current at night tracking.

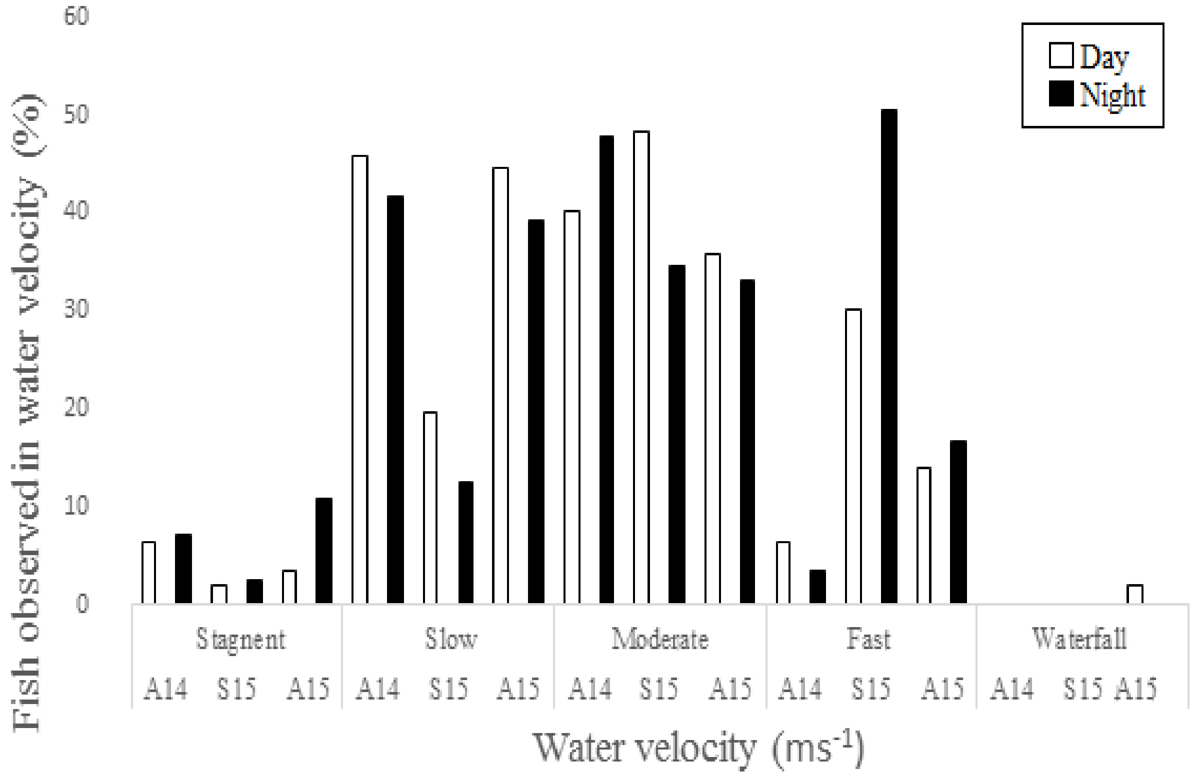

Figure 7 Percentage of fish found in day (white) and night (black) water velocity habitat: stagnant (0 – 0.2 ms^{-1}), slow (0.2 – 0.5 ms^{-1}), moderate (0.5 - 1 ms^{-1}), strong (>1 ms^{-1}) and waterfall (pronounced falling gradient). Figure includes tagged småblank from season autumn at Snåsamoen and Mellingselva, and season spring at Snåsamoen

3.5.1 Water velocity by Snåsamoen

Of all småblank found at Snåsamoen during autumn did 46% of the observations include slow water velocity at day time. At night time the most utilised water velocity was moderate flow (48%). The second most utilised water velocity was observed in moderate currents at day time (40%), and slow velocities during night time (42%). Few fish were found in stagnant waters at day (6.3%) and night time (7.2%). The least utilised category was fast water velocities with 1.4% at day and 3.5% night at Snåsamoen in august. The absence of water falls at Snåsamoen resulted in no registrations for this category.

Tagged småblank were during radio tracking observed in high water velocities in spring. The majority of småblank utilised moderate water velocities at day (48%), and fast water velocities at night (51%). During day observations 30% of the fish were found to utilise fast waters velocities, and 35% in moderate water velocity at night. The proportion of slow flowing velocity observed at day and night time was 20% and 12%, respectively.

A higher proportion of småblank that were found to utilise velocity categories was significant at day time (Chi-square, X-squared = 13, p-value = 0.01). At night time the småblank did not utilise significantly different water velocities (Chi-square, X- squared = 6.38, p-value = 0.20). At Snåsamoen during spring day and night time showed no difference in proportion substrate utilised (Chi-square, X-squared = 15, *df* = 12, p-value = 0.29). The water velocity at day time at Snåsamoen and Mellingselva did not show significance either (Chi-square, X-squared = 15, *df* = 12, p-value = 0.25).

3.5.2 Water velocity in Mellingselva

Småblank in Mellingselva were found in water velocities that were faster flowing than Snåsamoen. The most utilised water velocity in Mellingselva was fast flowing velocity at day time (45%) and night time (39%). Furthermore, moderate water velocities were observed both during day with 36% and night with 33%. Småblank were observed in slow velocities during day and night time with 14% and 11%, respectively. In stagnant water 11% was observed at day time and 7% at night time. Fish present in waterfalls was only observed 2% of the time during day time, and no observations at night time during radio tracking (Figure 7).

The proportion of observed småblank in different water velocity categories at day time were significant (Chi-square, p-value = 0.03) at day time, but during night time no difference in utilised substrate was shown in the different categories (Chi-square, X- squared = 6.38, p-value = 0.23).

3.5.3 Water depths between rivers and seasons

Fish in Mellingselva were found in deeper waters compared to fish at Snåsamoen (ANOVA, $F_{1,56}$ = 17.22, p-value <0.001) (Figure 9). At Snåsamoen average water depth during autumn was lower (mean = 23 cm, range: 15 cm – 50 cm, SD = 9 cm, *n* = 36) than during spring (mean = 35 cm, range: 30 – 39 cm, SD = 3.5 cm, *n* = 18). Fish in Mellingselva were found in (mean = 36 cm, range: 20 – 50 cm, SD = 8 cm, *n* = 25) average 13 cm deeper waters than at Snåsamoen during autumn.

4. Discussion

4.1 Difference in home ranges between seasons and rivers

Home ranges were in general larger at Snåsamoen during spring and autumn, compared to autumn in Mellingselva. According to the best fitted model, the two rivers were important variables in home ranges. The benefits from obtaining a small home range is that småblank is able to familiarise with the area and reduce predation risk. However, if the costs of limiting themselves to a small area exceeds the benefit of obtaining a large area, the småblank would have to increase their home range to improve their fitness (Boitani & Fuller, 2000). Previous papers published on home ranges in stream living salmonid species estimated home ranges remarkably smaller than home ranges in the present study (Miller, 1957; Bachman, 1984; Hesthagen, 1988). The estimations from previous studies were based on observation of fish without any form of tracking device. The large difference in estimated home ranges can be caused by the different method used in observing salmon, where some papers used e. g. mark and recapture methods instead of radio tracking. Another reason for variation of home ranges in this study compared to other studies can be the different home range estimations used in the calculation, e.g. using minimum convex polygon would result in a different outcome than kernel density estimation.

Another important variable in the best fitted model was body length. Snåsamoen had a larger proportion of older and therefore longer fish than Mellingselva. Three and four year old fish were found at Snåsamoen at autumn and four and five year old fish were found in spring in the same river. The fish caugth in spring was therefore the same generation as fish that were caugth in autumn. This means that the fish at Snåsamoen were highly compareable and there was a possibility of catching småblank from the same batch. There were no five year old småblank caught in Mellingselva, nor were there any two year old småblank caught at Snåsamoen. This can result in Mellingselva obtaining a larger number of young småblank, thus being an imporant river for younger fish. As the fish grows larger and older, it is possible a migration occurs from Mellingselva downstreams to Snåsamoen, where older fish were observed.

The body length increased with age until the fish reached four years. Older fish had a linear growth until they reach four and five year old, after this the growth flattened out. This trend was also shown in a study conducted on age and body length on småblank (Thorstad *et al.*, 2006b)

Lastly, body condition was an important variable for explaining home range according to the best fitting model. Småblank tagged in Mellingselva had a greater body condition than the fish tagged at Snåsamoen. The lower body condition at Snåsamoen can be explained by a poorer habitat in the regulated river. The lowest body condition was founded in spring. Home range is suggested to be controlled by size dependent metabolic rate and productivity of an animal's habitat (McNab, 1963). If this applies for småblank, it means that fish with larger home range can obtain a high metabolic rate. Since body condition is low at Snåsamoen, but fish are older and therefore also larger, it is possible that home ranges at Snåsamoen correlated to the food availability. The difference in home range can suggest that the productivity at Snåsamoen was lower than in Mellingselva based on McNabs hypothesis.

The difference in home ranges in autumn and spring at Snåsamoen was explained by body condition and season based on the best fitted model. The findings show that during autumn the home range was lower than spring. There were, however, fewer tracking locations in spring, making it less accurate. Studies conducted on Atlantic salmon shows that fish are known to have lower body condition during spring than autumn (Sutton *et al.*, 2000). The same was shown for fat content in other studies (Berg & Bremset, 1998; Næsje *et al.*, 2006), where fat percentage decreased throughout winter, and regained in spring. In the present study, body condition was measured in the beginning of May and the beginning of August. When autumn sets, småblank had gained body fat throughout summer, which can explain the higher body condition factor in the autumn in both rivers. During winter the body condition decreases, which can explain the low body condition during tagging in May. Body condition was larger in tagged småblank in Mellingselva than at Snåsamoen. In addition, females generally had a greater body condition than males in Mellingselva. The difference in sex and body condition was not present in småblank at Snåsamoen. One explanation for female's larger body condition in Mellingselva could be the upcoming spawning season. Mellingselva is observed to have spawning grounds, and both males and females were observed to be sexually mature during fieldwork in October. During fieldwork, in the middle of November, the fish were observed to be slimmer than the previous month, and there was no sign of further spawning activity. This is most likely due to spawning occurring between October and November.

The home range estimation in this study is based on a limited number of locations and is therefore calculated as the minimum home range sizes. This means that home ranges may have increased with a larger number of tracking locations. There were fewer tracking locations at Snåsamoen at spring than autumn, and there is a possibility that a larger difference would have been shown in home ranges of the increased tracking locations during spring. Changes that occurred in biotic and abiotic factors such as water chemistry, water productivity and population densities in autumn 2014 and 2015 could have affected the outcome of home range. Water chemistry was measured in both rivers in autumn 2015 and the tests showed little difference in pH, calcium, temperature, nitrogen or phosphorus. Water chemistry in autumn 2014 was, however, not measured when home range locations at Snåsamoen were collected. The variables in chemical composition may be important in the variation in water productivity in the river from year to year. Other variables that could affect differences in home ranges were competition within the population or with brown trout, predation, river productivity, food availability, etc, although these were not considered in the present study.

4.2 Distance of river stretch used between seasons and rivers

The distance of river stretched used, also called moving distance in this study, was larger at Snåsamoen than in Mellingselva at day time. However, statistical difference in moving distance was not significant at night time. Most studies on anadromous juvenile salmon claim that parr are more active at night time, when predation is low (Borgstrøm & Hansen, 2000a). This was not the case for småblank at Snåsamoen during autumn, where småblank were measured to have significantly larger moving distances at day time than night time. Movement during night time showed no significant differences in distance in season or river. Despite the effort of finding variables in explaining differences in night moving distance, the variables total body length, body condition, sex and water depth showed no significance. A possibility of why småblank utilised the same areas at night time during all tracking periods may be the result of the fish's having similar feeding strategy in all tracking periods. Observations in the study of fish at night time showed that småblank utilised a smaller area than day time in all tracking periods. The reason for utilising a smaller area at night time may be to obtain a specific feeding strategy. At Snåsamoen during autumn, for instance, the mean distance was 301 m at day time and 104 m at night time. Studies on feeding strategies in Atlantic salmon parr shows that the fish feed most extensively during dusk and dawn when pray are easily detected (Brittani & Eikeland, 1988). During night time the Atlantic salmon parr mainly pray in the bentic zone (Bergersen, 1989; Amundsen & Gambler, 1999), but the feeding rate is shown to be is equally distributed day and night time (Aas *et al.*, 2011). Taking this in consideration, the moving distance of småblank may be controlled by the feeding strategy during day and night.

Day and night distances of river stretch used, must in study be considered as minimum moving distances, because it is most likely that the fish moved in the period between tracking rounds.

In addition, tracking had to be concentrated to an area due to limiting time and budget, and therefore småblank that choose to migrate beyond the tracking area were not detected by the radio receiver. A large proportion of individuals (89%) in all three tracking periods had small migrations outside the tracking area. The fate of fish that were not located again is unknown, it is, however, possible that the transmitter stopped emitting signals due to technical issues, batteries defect or either the småblank was caught by a predator or migrated permanently away from the tracking area.

4.3 Habitat utilisation between rivers and season

4.3.1 Substrate

At Snåsamoen in autumn, the majority of observations on fish was in stone habitat, while småblank in block habitat dominated in Mellingselva at day time. These habitat types are shown to be suitable for the availability of shelter and has been observed to be utilised by anadromous parr (Jonsson & Jonsson, 2011a) and småblank (Norum, 2010). The risk of predation is higher during daytime, and may result in småblank spending most of their time hidden in the substrate. During night time småblank utilise smaller particle sizes in general in both rivers. The trend is also shown in anadromous parr where fish shift to fine particles at night (Borgstrøm & Hansen, 2000c). The proportion of sand and gravel habitat utilised at night time was greater in Mellingselva than Snåsamoen, and field observations confirm a greater availability of sand habitat in Mellingselva.

4.2.2 Water velocity

Småblank located in Mellingselva utilised faster water velocities than fish at Snåsamoen during autumn. Juvenile salmon often choose areas with a surface velocity of 0.2 – 0.65 ms^{-1} (Degraaf, 1986), while larger parr utilise both slower and stronger streams (Morantz *et al.*, 1987). The majority of fish in the study utilises currents between 0.2 ms^{-1} to more than 1 ms^{-1}. Studies conducted in anadromous Atlantic salmon parr observed that the salmon are more likely to utilise slow velocities at night time and shift to stronger currents at day time (Borgstrøm & Hansen, 2000d).

The fishes in the study were observed to utilise faster water velocities at night time than during day time in both Mellingselva and Snåsamoen. Småblank at Snåsamoen was most likely to be found in moderate water velocities, while in Mellingselva småblank utilised fast flowing velocities. The result is linked with the river characteristics where the habitat at Snåsamoen contained smaller particle sizes and lower velocities than in Mellingselva. A poorer bio productivity in the river may be linked with slower velocity at Snåsamoen (Borgstrøm &

Hansen, 2000e) and with fewer pray reduces the production of fish and its body condition. Slower velocity at Snåsamoen can therefore be a reason for småblank's lower body condition and high home range in the river. Juvenile Atlantic salmon feed in large extent on drifting and benthic invertebrates, and the feeding is correlated with water velocity because insects in slower velocities are easier to detect (Lancaster *et al.*, 1996). When småblank choose to utilise slower flowing waters at day time, it can be the response of increased preying on invertebrates.

Småblank utilised faster water velocities at day time than at night time in both rivers. This finding is contradictory to findings conducted on day and night velocity for juvenile anadromous parr (Borgstrøm & Hansen, 2000c). This trait may be unique for småblank, or, there may be a competition with brown trout forcing småblank to utilise the faster flowing habitat. In a master thesis by Norum, observed småblank was found in stronger velocities than brown trout. In addition, did Norum argue that småblank inhibiting slower water velocities also were in risk of competing with brown trout for space utilisation (Norum, 2010).

In Mellingselva the fish was in general found in higher water velocity than at Snåsamoen. During fish catchment the småblank in Mellingselva were caught in a section of the river with faster water velocities, compared to the fish catchment conducted in the river stream at Snåsamoen.

4.3.3 Water depth

Småblank were found in overall deeper waters in Mellingselva than at Snåsamoen during autumn. The larger fish in Mellingselva were found to utilise several deep pools in the tracking area. Deep pools were not present at Snåsamoen, and explains why deeper utilisation was only found in Mellingselva.

The water depth measured during manual radio tracking showed that fish at Snåsamoen utilised deeper waters in spring than autumn. This can be due to the spring flood that lasted longer than usual in 2015 due to precipitation and semi-cold weather (Meterologisk Institutt, 2016). The water depth is mainly controlled by the seasonal fluctuations in river systems.

During tracking, småblank were hidden in the substrate and therefore rarely seen. The exact depth of where småblank was located in the water column was therefore not certain, but a study on småblank found the fish to stay close to the bottom of the river where water velocity is lower compared to the surface of the water layer, most likely to save energy (Norum, 2010).

4.4 Future conservation and research of småblank

Freshwater fish are constantly exposed to environmental changes whether these are anthropogenic or natural. One of the threats to resident freshwater Atlantic salmon is hydropower production (Borgstrøm & Hansen, 2000d). In Namsen the småblank's biggest threat is most likely hydropower production because of the change in water velocity due to construction. In the present study, differences of two rivers were investigated, where Namsen at Snåsamoen were under the influence of water regulation and Mellingselva was a non-regulated tributary. The differences in home ranges, body condition, distance of river stretch used and habitat utilisation indicated that there were differences in the rivers and how småblank utilised these rivers.

Småblank is known to have similar behavioural characteristics as juvenile anadromous parr, in terms of utilised substrate utilisation, home ranges and water velocities. Management strategies developed for conservation of anadromous Atlantic salmon could therefore also prove successful for småblank, although at present, there is a lack of long term studies on småblank (Bremset *et al.*, 2012c). Monitoring småblank in long term studies, would prove useful in understanding the vulnerability of the fish to anthropogenic impacts, and in planning and evaluating mitigation measures. Extended studies on utilisation and spatial distribution could also be useful in future studies. An extended study of the present study, should include a detailed mapping of the river's water velocity, substrate and vegetation growth. By mapping the river bed and water velocity it will be possible to determine how large proportion of different habitats are found in the river. Analysing the productivity of invertebrates and competition for shelter, food and spawning ground would also be useful in learning which areas are more productive for småblank.

The study looked at how large areas småblank utilised from spring to summer, and towards autumn and winter in the regulated river Namsen. For conservation of småblank the areal use of river is important to take into consideration. The study showed a very large individual difference in home range, which means that both stationary and migratory småblank were found at Snåsamoen and Mellingselva. By managing småblank's distribution area, it would be possible to safeguard the species required area.

In conclusion, the study indicates that the non-regulated tributary Mellingselva was a better suited river for småblank at age 3 and 4, than the regulated Namsen at Snåsamoen. This is based on the results from home ranges, body condition of småblank and substrate availability in the two rivers, and within season. Småblank at Snåsamoen had a larger home range and lower body condition during both autumn and spring compared to autumn in Mellingselva. In addition, the river had slower water velocities and less shelter availability at Snåsamoen than in Mellingselva.

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Appendix

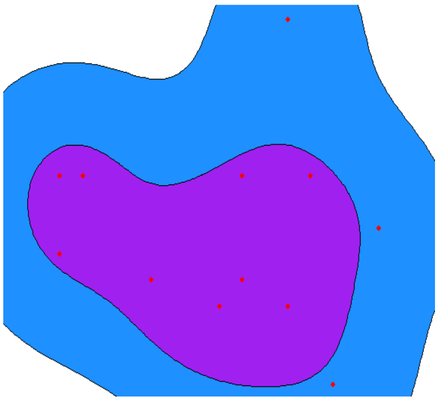
Estimated home range sizes of 35 individuals caught in the periods: Autumn 2014 (A14) at Snåsamoen (ID 1-25), Spring 2015 (S15) at Snåsamoen (ID 45-62) and autumn 2015 (A15) in Mellingselva (ID 64-85). Each estimation includes the home range estimation of one individual with the smoothing parameter of 50% and 95%.

ID 1

Home range 90%: 292 m^2

Home range 50%: 97 m^2

Total body length: 150 mm

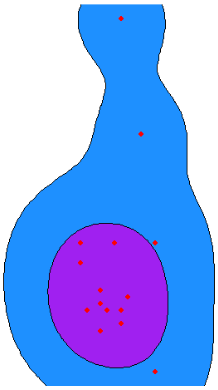


ID 2

Home range 90%: 1301 m^2

Home range 50%: 303 m^2

Total body length: 150 mm

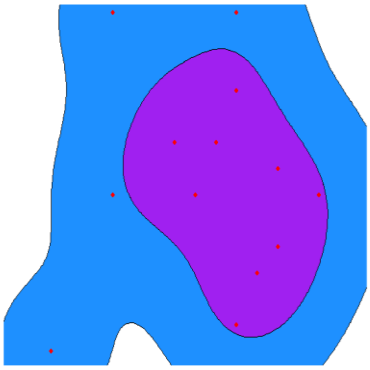


ID 4

Home range 90%: 248 m^2

Home range 50%: 73 m^2

Total body length: 155 mm

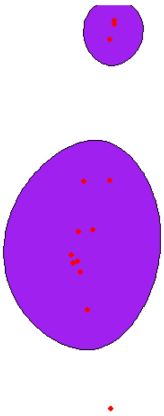


ID 9

Home range 90%: NA

Home range 50%: 82 040 m^2

Total body length: 157 mm

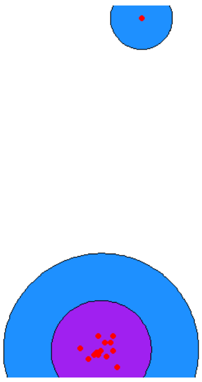


ID 10

Home range 90%: 7 775 m^2

Home range 50%: 1 863 m^2

Total body length: 164 mm

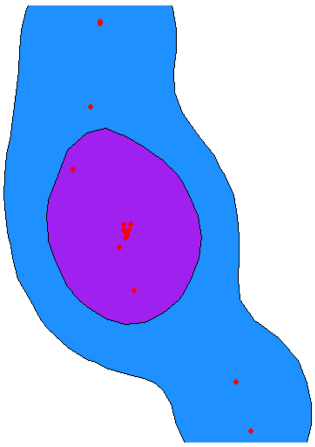


ID 11

Home range 90%: 29 682 m^2

Home range 50%: 7 177 m^2

Total body length: 169 mm

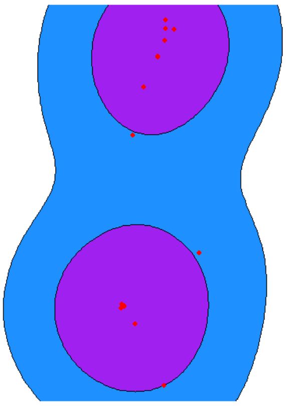


ID 12

Home range 90%: 300 401 m^2

Home range 50%: 98 912 m^2

Total body length: 171 mm

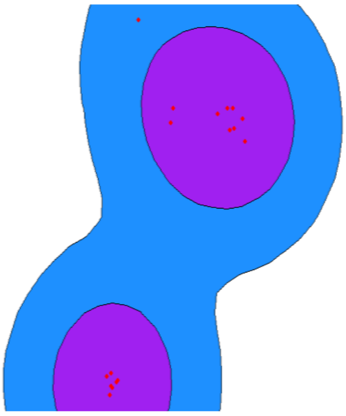


ID 14

Home range 90%: 46 605 m^2

Home range 50%: 14 362 m^2

Total body length: 165 mm

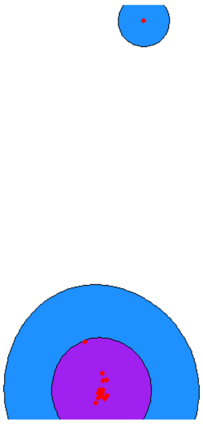


ID 16

Home range 90%: 20 045 m^2

Home range 50%: 4 861 m^2

Total body length: 154 mm

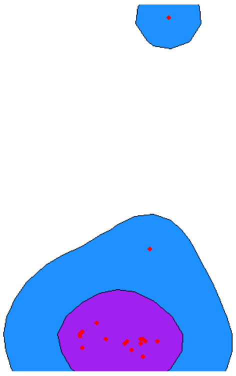


ID 17

Home range 90%: 7 591 m^2

Home range 50%: 1762 m^2

Total body length: 176 mm

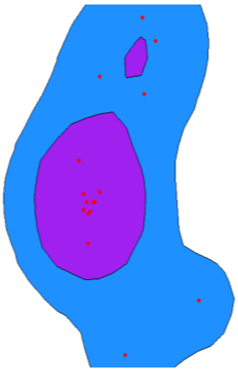


ID 19

Home range 90%: 20 125 m^2

Home range 50%: 4 798 m^2

Total body length: 163 mm

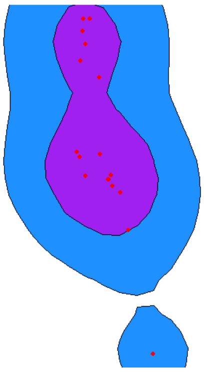


ID 20

Home range 90%: 227 387 m^2

Home range 50%: 66 071 m^2

Total body length: 162 mm

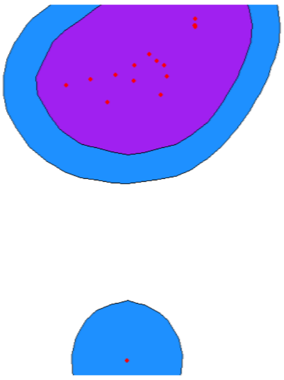


ID 24

Home range 90%: 33 240 m^2

Home range 50%: 15 807 m^2

Total body length: 210 mm

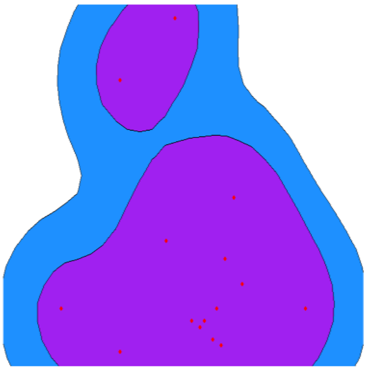


ID 25

Home range 90%: 5 015 m^2

Home range 50%: 2 810 m^2

Total body length: 260 mm

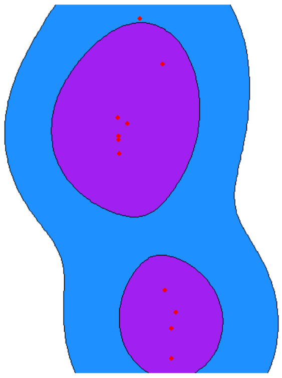


ID 45

Home range 90%: 145 310 m^2

Home range 50%: 48 385 m^2

Total body length: 167 mm

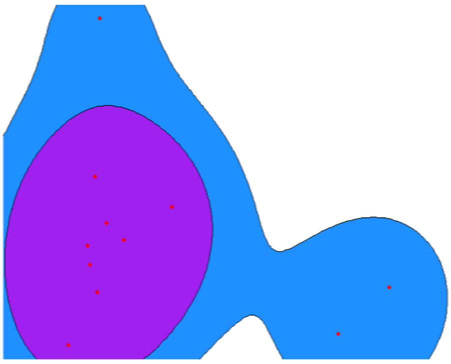


ID 48

Home range 90%: 17 672 m^2

Home range 50%: 6 507 m^2

Total body length: 160 mm

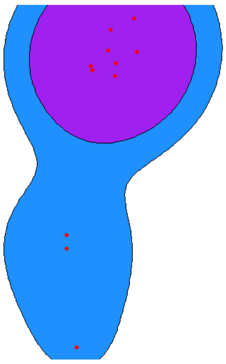


ID 57

Home range 90%: 30 434 m^2

Home range 50%: 11 455 m^2

Total body length: 176 mm

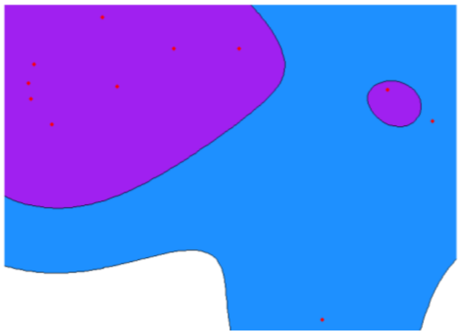


ID 60

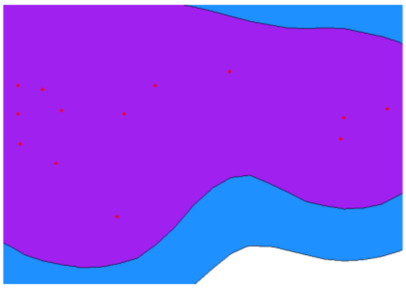
Home range 90%: 25 062 m^2

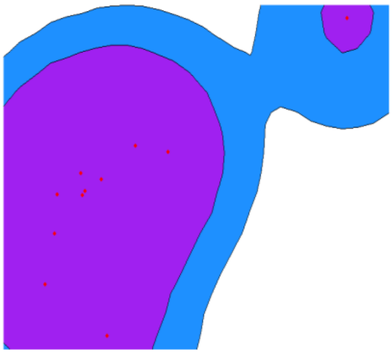
Home range 50%: 7 375 m^2

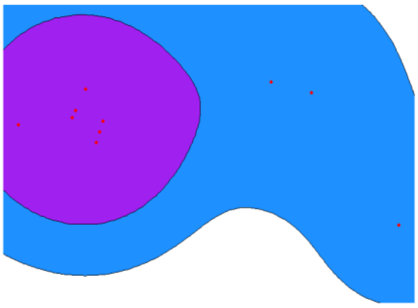
Total body length: 165 mm



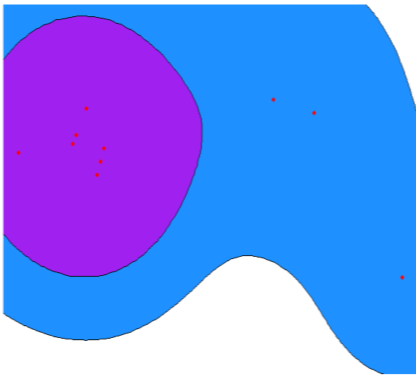
ID 61	ID 62	ID 64
Home range 90%: 57 673 m^2	Home range 90%: 144 764 m^2	Home range 90%: 11 263 m^2
Home range 50%: 33 746 m^2	Home range 50%: 70 655 m^2	Home range 50%: 3 012 m^2
Total body length: 163 mm	Total body length: 167 mm	Total body length: 141 mm

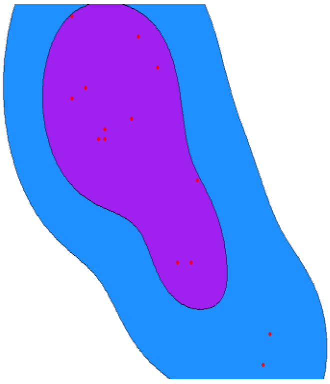


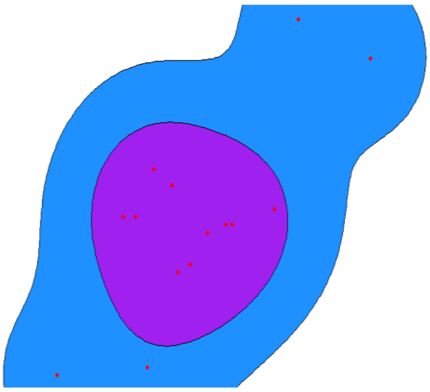




ID 66	ID 67	ID 68
Home range 90%: 11 263 m^2	Home range 90%: 1 451 m^2	Home range 90%: 2 676 m^2
Home range 50%: 3 012 m^2	Home range 50%: 480 m^2	Home range 50%: 708 m^2
Total body length: 138 mm	Total body length: 140 mm	Total body length: 158 mm





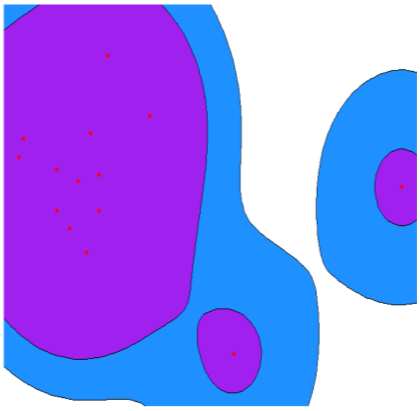


ID 70

Home range 90%: NA

Home range 50%: NA

Total body length: 152 mm

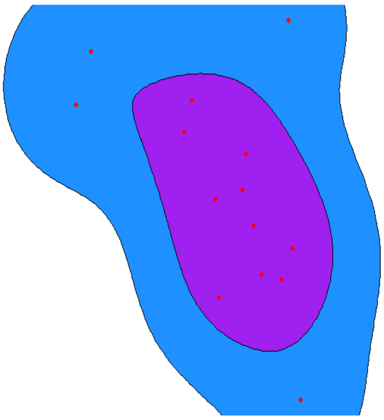


ID 71

Home range 90%: 7 089 m^2

Home range 50%: 3 416 m^2

Total body length: 153 mm

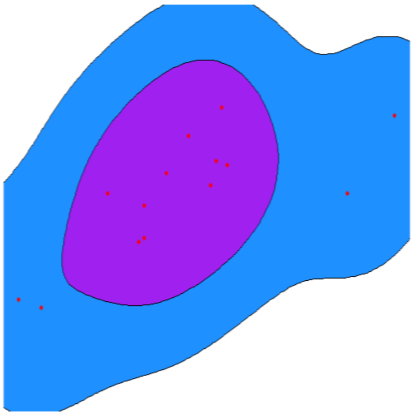


ID 73

Home range 90%: 7 249 m^2

Home range 50%: 2 178 m^2

Total body length: 167 mm

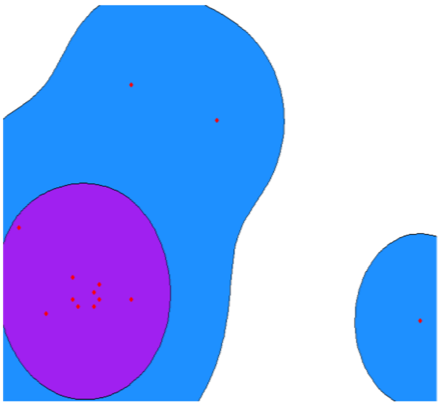


ID 75

Home range 90%: 3 550 m^2

Home range 50%: 776 m^2

Total body length: 150 mm

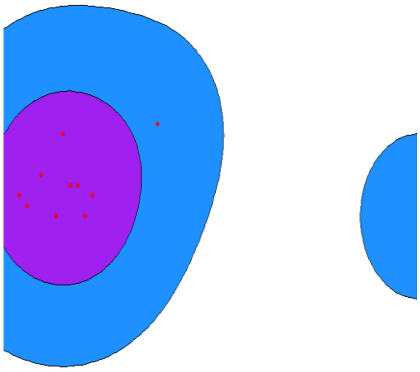


ID 76

Home range 90%: 1 334 m^2

Home range 50%: 312 m^2

Total body length: 147 mm

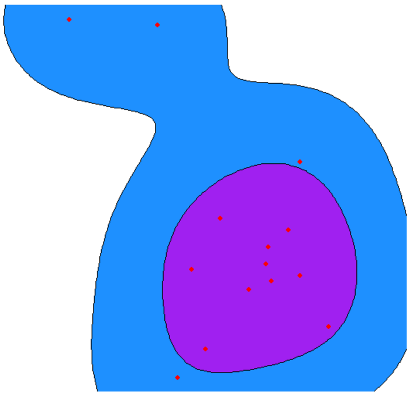


ID 77

Home range 90%: 15 748 m^2

Home range 50%: 3 988 m^2

Total body length: 145 mm

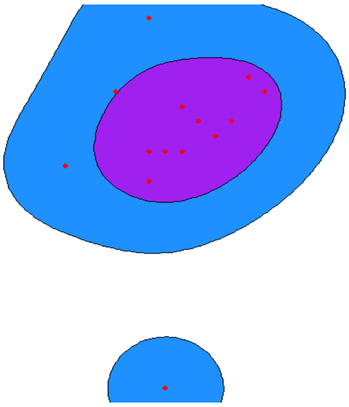


ID 78

Home range 90%: 325 m^2

Home range 50%: 84 m^2

Total body length: 142 mm

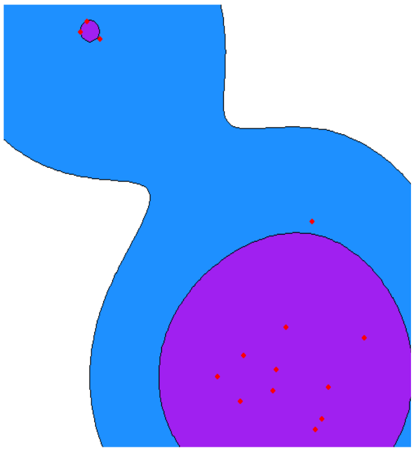


ID 79

Home range 90%: 17 618 m^2

Home range 50%: 4 747 m^2

Total body length: 159 mm

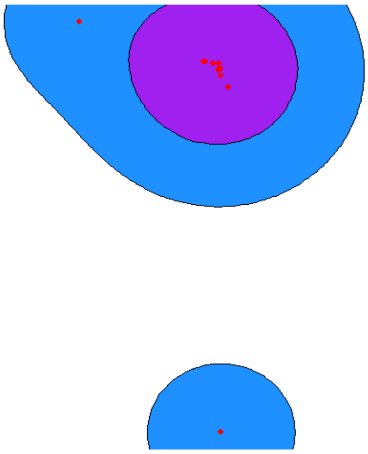


ID 83

Home range 90%: 15 412 m^2

Home range 50%: 3 368 m^2

Total body length: 150 mm

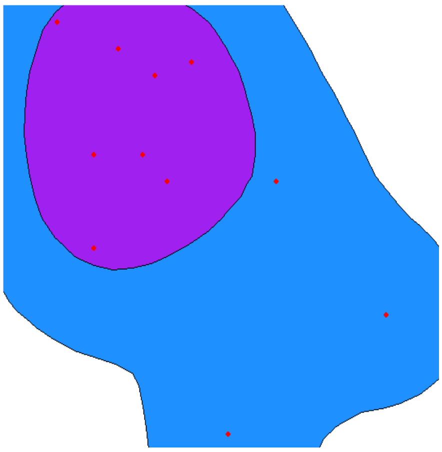


ID 84

Home range 90%: 1 214 m^2

Home range 50%: 319 m^2

Total body length: 153 mm



ID 85

Home range 90%: 1 069 m^2

Home range 50%: 290 m^2

Total body length: 151 mm