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Sea Trout in Inner Oslofjorden: Population biology, marine recreational fishing and spatial variation in fishing intensity

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General Ecology

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Preface and acknowledgements

This thesis completes my MSc in General Ecology, and, probably, my time at the Norwegian University of Life Sciences. I received a great opportunity to study abroad and last 2 years were a unique experience in my life – filled with challenges, achievements and adventures.

First and foremost, I want to say many thanks to my supervisors Thrond Oddvar Haugen and Jonathan Edward Colman at the Norwegian University of Life Sciences (NMBU), for help and support during the entire process of writing this paper. Without your help there would have been no study. You have been patient, guiding and understanding during the whole process of writing this thesis. You inspired me to work with sea trout even though my former field of study during my Bachelors differed much from it. You helped me when I was struggling with issues that were not related to this study. You were people who I knew I could rely on and who wouldnt turn their backs on me. You taught me a lot and I only have to hope that our cooperative work was as joyful for you as it was for me. Thank you very much.

I would also like to thank all the NMBU staff for helping me with arranging all the necessary documents and paperwork. I would drown in it if not for NMBU workers. They were always nice and helpful and I appreciate it a lot.

Lastly, I want to thank my mother for her support. She helped me raise the funds needed to go study abroad and supported me throughout my masters. Probably, I could have given up on it if not for her constant support and belief in me. The biggest reward for me is knowing that I can make you proud of me and not to let down your expectations.

1. Abstract

Recreational fishing has been known since XV century. Nowadays, Arlinghaus and Cooke (2009) estimate, that around 10,6% of the population in studied countries participate in recreational fishing. However, marine recreational fishing in Inner Oslofjorden is not thoroughly controlled and studied, thus, it is impossible to make assumptions on the ecological effects it can cause. Sea trout is one of the species most studied nowadays due to its high popularity among recreational anglers and due to its economic value. However, as well as about recreational fishing, little is known about sea trout population in Inner Oslofjorden. It is impossible to evaluate population status or marine recreational fishing influence on it without adequate data, thus, serious damage could be done to the sea trout population in this area. My goal in this study was to collect more data both on sea trout and anglers, participating in marine recreational fishing in Inner Oslofjorden. I collected data on sea trout biological variables such as back-calculated first winter length, smolt size and age etc. From interviewing anglers was obtained data on catch rates, catch per unit effort, total number of anglers. Also I looked into the methods of obtaining such type of data and tried to estimate the most efficient way of conducting such studies in the future.

My findings show that sea trout biological variables do not differ much from mean values for the species in general, but they differ from numbers obtained in studies that focused on specific spawning pools of sea trout, which need further studies, but could indicate that habitat conditions and behavior in different fractions of sea trout populations could influence their catchability. Number of anglers was found to differ much depending on which part of Inner Oslofjorden was taken as a study zone, as well as their effort and catch per unit effort. Most anglers were observed in the eastern part of Inner Oslofjorden with northern part being second highest, western – third and the least number of anglers were observed in southern parts. Speaking of methods, using car as a vehicle to move around Oslofjorden looking for anglers was less efficient compared to using boat. Interviews as a form of obtaining angler data proved to be useful, but improvements could be done, for example, implementing mobile applications for anglers in Inner Oslofjorden could possibly increase the amount of data received, which is needed for precise evaluations of marine recreational fishing influence on sea trout population and ecosystem as a whole.

These calculations can be a good basis for future studies, providing data on most popular and “efficient” fishing hotspots as well as methods for gathering data on anglers that participate in marine recreational fishing.

2. Introduction

The anadromous for brown trout, sea trout (*Salmo trutta L.*), is a dominant component of both the anadromous and stationary fish fauna in Norwegian watercourses (Jonsson, 1985). This fish species has an important cultural and socio-economical meaning for and of great cultural and socioeconomic importance for subsistence and recreational angling (Blglinière et al., 1999). However, in recent decades, the abundance of sea trout has significantly declined in many regions (Clover, 2004). Reduced sea trout populations may be caused both by human impacts and a general and large-scale reduction in survival at sea. Populations in middle and western Norway are most severely reduced (Forseth et al., 2018). The migratory life history of sea trout inhabiting different freshwater and marine habitats creates difficulties in the assessment of its population status and identification of production bottlenecks. A further assessment complication is that many populations exhibit partial anadromy where only a variable proportion of the population migrates to sea (Bohlin *et al*., 2001).

Fishing for sea trout is very popular in the Norwegian fjord system Oslofjorden (Thimamontri, 2015). Limited knowledge about how fish populations are sustained may lead to overharvest of sea trout, which has been reported by several studies (Bryan, 1977; Oh and Ditton, 2006), can cause serious damage to the population. For instance, sea trout anglers may catch and keep fish that are too small (i.e., smaller than the minimum legal size), and thus potentially harm the whole population. The ecological effects associated with recreational fishing underlines the importance of investigations into this field. For several species, recreational fishing provides the most important mortality factor, even compared to commercial fisheries (Kleiven et al., 2012), which gives rise to a set of conservational issues. It is important to acknowledge that we know much more about how angling influences fish populations in fresh water, but we know very little about how angling influences the populations of sea trout in Oslofjorden. As mentioned earlier, high exploitation can have detrimental effects, but also selective harvest, trophy fishing, disturbance during reproductive periods, sublethal effects, and environmental disburbances caused by anglers are considered challenges, associated with recreational fishing (Arlinghaus & Cooke, 2009). Despite the popularity of marine recreational fishing in Norway, not much information can be found on its effects on sea trout populations in general and especially on sea trout ecology in Oslofjorden.

The need for studying sea trout population and marine recreational angling is important due to lack of knowledge of catch volumes and angling intensity. Furthermore, little information is available on sea trout populations in Oslofjorden, thus making it difficult to measure how strongly angling can affect it. Even though marine recreational fishing is a million dollar industry that provides livelihoods for a lot of people globally (Arlinghaus et al., 2009), it is hard to obtain good numbers on fishing intensity due to the absence of any official system that could regulate sea trout fishing in the sea. Cordue (2012) describes, that such metrics like “average” exploitation rate of fishery and fishing mortality rate require adequate reference levels to allow valid interpretations. Without these references levels, it is not possible to tell whether observed numbers are “too high” or “too low”, as it depends on many variables such as natural fish mortality in particular fisheries or fishing patterns. Such numbers today are nonexistent for Oslofjorden making it difficult to analyze new data in light of this. Also it is important, that sea trout targeted in Oslofjorden come from a mixture of populations using many tributaries and rivers that empty into the fjord, and thus, parameters of different individuals inside the total population can vary. This makes it challenging for researchers to estimate above-mentioned reference levels. This study is the first that aims to describe for Oslofjorden both sea trout biological variables (smolt age, first-winter size, growth patterns) and also fishing intensity (total number of anglers, fishing effort and catch data). To gather necessary data, a variety of methods was used in this study: roving creel and access surveys, interviewing, gathering and analyzing biological samples, creating linear mathematic models and more.

3. Objectives

The overall objectives of this master thesis are to increase the knowledge on characteristics of sea trout populations in Oslofjorden, along with investigating the fishing intensity these fish get exposed to. The aims are to quantify catch rates of sea trout in Inner Oslofjorden, to quantify the age- and size composition and look into seasonal changes and spatial patterns in catches and catch composition. Furthermore, this study aims to gather data on density of anglers in Inner Oslofjorden, to evaluate their catch effort and catch per unit effort, which is necessary to estimate the fishing pressure, which marine recreational fishing is putting on sea trout population in the area. By back-calculations from scale readings, it is possible to compare both spatial and temporal variations in individual growth trajectories, smolt age and size, and juvenile growth rates. The summary of these studies complemented by data from further researches could provide insights into where the different sea trout individuals recruit from (their natal stream/river) and their individual characteristics. Additional goals of this study were to evaluate data collection methods and find which ones are most efficient, especially comparing methods of movement around Inner Oslofjorden.

4. Methods

4.1 Study species

Figure 1. Brown trout captured by anglers in Inner Oslofjorden during the fieldwork

Brown trout are iteroparous and are identified as a fish with high ecological variability (Klemetsen et al. 2003). The species originated in Europe and spread all over the world throughout its history. The species is successful due to its wide environmental tolerance and migratory behavior, but we know for sure that the main credit for its worldwide distribution goes to introduction by humans (Klemetsen et al. 2003).

Some populations are anadromous; these are called sea trout, and are the focus of this paper. Brown trout can be highly migratory, and thus, not necessarily limited to one river system. Thus, in connection with their wide tolerance, this allows them to drift far from their initial introduction location. Trout have been observed to move over 100 meters a day during migration to spawn (Saraniemi 2008).

The life cycle of brown trout starts in a stream or a river (though in some populations spawning happens in lakes). Spawning normally takes place from September to December but, it also can occur from November to March, which strongly depends on altitude, latitude and temperatures (Armstrong et al. 2003). As they approach the time when they are ready to migrate out to the sea, the parr lose their camouflage bars and undergo a process of physiological changes that allows them to survive a shift from freshwater to saltwater. At this point, the young sea trout are called *smolt*. Smolt spend time in the brackish waters of a river estuary while their body chemistry adjusts (osmoregulation) to the higher salt levels they will encounter in the ocean (Bone et al. 2008). Smolt also grow the silvery scales which visually confuse ocean predators.

Mature brown trout have a mostly silver colored body with large black spots, which are concentrated on the dorsal part of body. These trout can differ much phenotypically, even within the same water system due to their genetic plasticity. Sea trout spend 1-3 years at sea before migrating back upstream to spawn. Commonly brown trout are around 40-50 cm long (Burrill 2014).

4.2 Study area

The study area was about 200 km^2 of water space in Inner Oslofjorden. The study area was divided into several zones and in each zone we selected sampling spots thought to represent “hotspots” for angling. Hotspots were created based on general popularity and accessibility of places for anglers. Sampling was done approximately 6 times a period – 3 times for daytime and 3 times at night. Day and night were defined as 4-6 hour periods within- the lighter and darker periods of the day, and the exact time varied depending on season. There were 2-3 periods during each spring and autumn season starting in 2018. To create maps of the area, QGIS software (QGIS Development Team 2018) was used. On the map, respective zones and hotspots in each zone were marked. Zone number was included in the interview sheet to later identify the number of anglers for each zone. It was also used to estimate fishing effort in each zone.

Figure 2. Northern Europe map with Oslofjorden marked as a red circle. Oslofjorden stretches for 102 km. Oslo is located on the northern end of the fjord and two lighthouses: Torbjørnskjær and Færder mark the southern end. Oslofjorden has Norway’s highest all year temperature: 7.5 degrees Celsius. February is the coldest month in the fjord with -1.3 degrees Celsius, while July normally has 17.2 degrees Celsius.

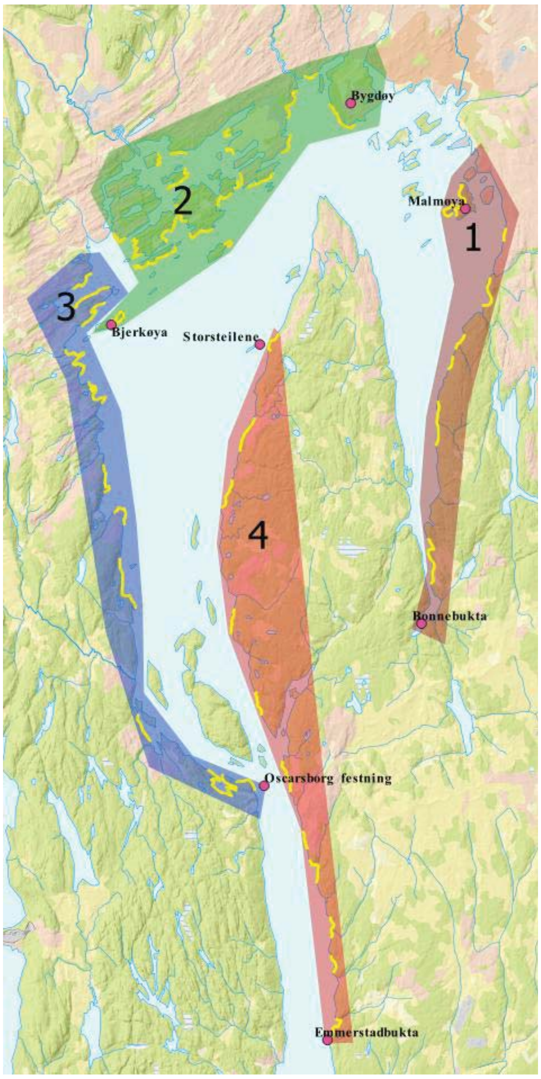


Figure 3. Hotspots where samples were obtained within each of the four sections of Inner Oslofjorden (marked yellow). These were selected as places with highest interest among anglers. Named locations represent edges of each zone. Identifying our position was done with portable GPS tracker, which put a mark on our position every 30 seconds.

Zone 1 covered areas from Bonnebukta to Malmøya island. Landscapes here are mostly beaches or rocks. This territory is mostly popular among locals. Zone 2 covered areas from Bygdøy to Bjerkøya. Here are mostly rocky slopes and docs. This territory is popular among both locals and tourists. Zone 3 covered areas from Bjerkøya to Oscarsborg festning and here we mostly encountered anglers from Eastern Europe who are working in Norway. Landscapes consist of rocks, several beaches and docs. Zone 4 covered areas from Emmerstadbukta to Storsteilene. Landscapes here are mostly rocks with a couple of beaches and docs along the coast. Here anglers mostly consist of locals.

4.3 Sample collection

In order to retreive the necessary data for properly managing and modifying fisheries, several methods have been developed and investigated. Some of these (not limited to) are: roving creel surveys, access surveys, telephone surveys and mail surveys (Pollock et al., 1994; Malvestuto, 1996; Cooke et al., 2000; Hartil et al., 2011). Combinations and different varieties of these surveys are known as complementary surveys (Dorow & Arlinghaus, 2011). Access surveys and roving creel surveys have been used widely to investigate fisheries (Pollock et al., 1994; Malvestuto, 1996). The access and roving creel surveys are both intercept methods, where the fishery is sampled on-site, meaning that anglers are approached and interviewed and biological samples are retrieved. For the access survey this involves sampling at the access points to a fishery, this could be where boats are docked or on parking lots near fishing sites where anglers gather. The roving creel survey on the other hand is a more active variety of survey, where anglers on boats and on shore are directly approached by boat or by foot (Pollock et al., 1994). The access and roving creel survey are used to gather catch and effort data and, if we are allowed – to gather biological samples directly from recently catched fish. In principle, if it is necessary and if our research demands it, any data can be gathered during the interviews; this could be demography, socioeconomy and human dimensions. These surveys can also provide data on the fishing effort. Ideally, for these purposes, aerial photo shooting, where and airplane or drone is used to precisely quantify the number of anglers within an area can be appropriate (Smallwood et al., 2011).

The access survey and roving creel survey are on-site surveys as opposed to off-site surveys, which can include angler diaries, mail, and telephone surveys (Cooke et al, 2000; Dorow & Arlinghaus,2011). Off-site surveys usually rely on anglers having to recall their catch and effort, which can provide bias also known as recall bias. Recalling information for several months can be difficult and thus provide biased estimates (Tarrant & Manfredo, 1993; Vaske et al., 2003; Connelly & Brown, 1995).

Access and roving creel surveys were used in this study to search for anglers both in designated hotspots and out on the waters of Oslofjorden, covering maximum space to obtain fish samples we needed. This study focused on finding general numbers so interviews were focused on the effort more. Anglers were asked about their time spent fishing and about their catch on the day of interview (also in cases when fish were caught and released, it is important to count even such cases).

The biological sampling for this work composed of measuring fish's length and removing scale samples for lab-analyzes. Scale samples were taken between the lateral line and dorsal fin where the oldest scales form. Scales were placed in small envelopes and labeled to keep track of the place and time of catch. Later the scales were read in the laboratory of NMBU to back-calculate fish age and estimated age when becoming a smolt.

4.4 Scale analyses

The scales samples were analyzed at the MINA Ecology lab of NMBU. In the image center, a stereo microscope was used for scale reading. The scales having small central plates were preferred in the analyses, but for some samples, we did not obtain such and used replacement scales. The digital camera Leica DFC 320 was used in the microscope to take photographs of the scales.

The photographs of the scales were analyzed by using the software Image Pro Express 6.3 in the laboratory. The total length of the scale from the center was noted and marked as `Y` and each winter edge as ´V´. After marking, the data were exported to an excel sheet and the snapshot of the scales were taken.

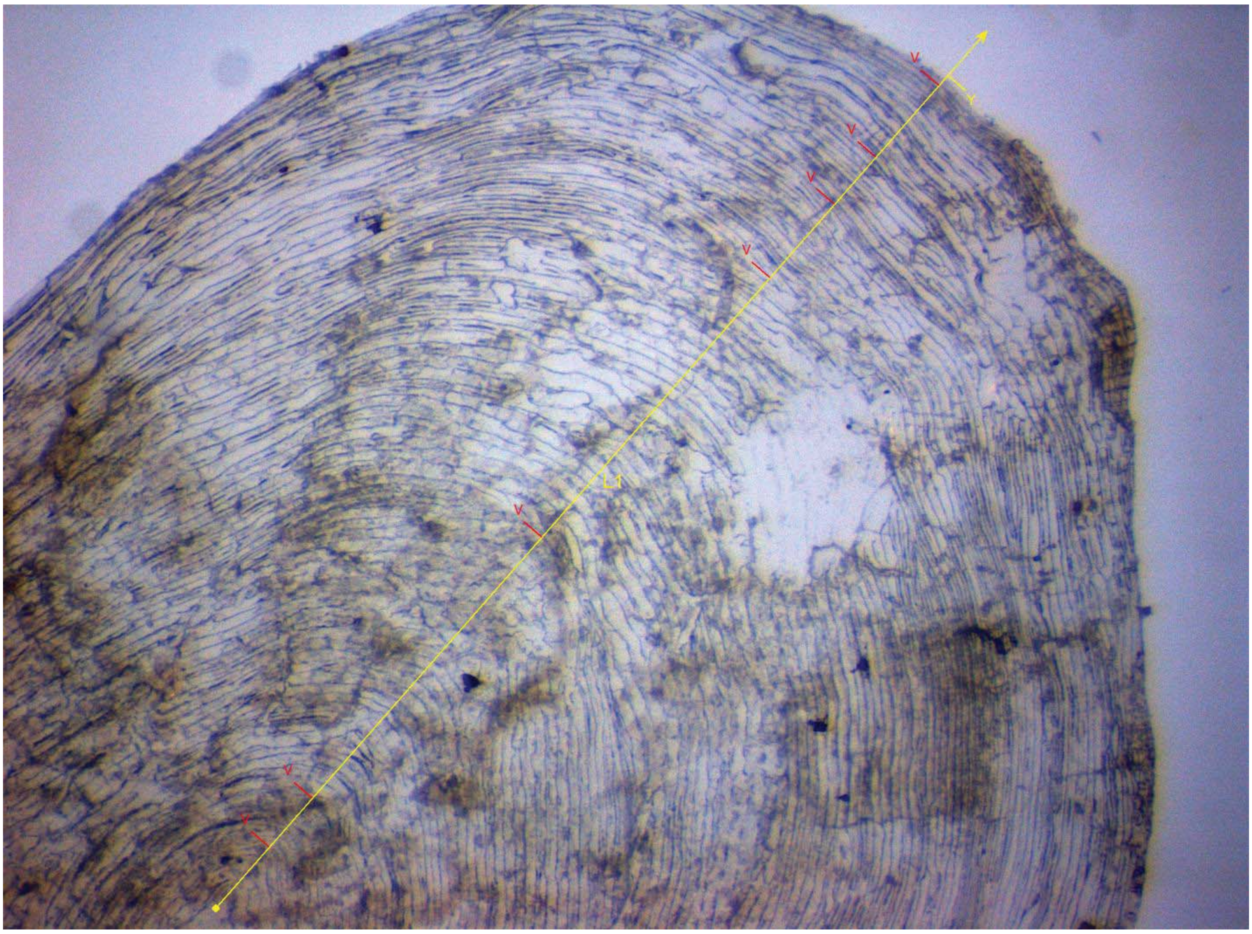


Figure 4. Individual ST3 scale with marked winter edges (V) and scale radius (Y)

Brown trout get their first scales when they are at size around 2-3 centimeters. The center of an older fish's scale, called the focus, represents the scale of the newly hatched fish. As the fish matures, the scales grow in rings around the focus. Each growth ring is called a circulus (plural: circuli). The fish grows faster during the summer when the water temperature is higher and more nutrition is available, and thus the circuli are spaced farther apart. During the winter, growth slows down and the circuli are tighter. When the circuli are close together, they can form a visually darker ring called an annulus (plural: annuli). Each annulus represents a year's growth; by counting the annuli, it is possible to estimate the fish's age (Casselman, 1987).

4.5 Statistical analyses

Statistical analyzes included using of linear models and generalized linear models. R studio and Excel data analyses tools were used for this step of work.

With obtained data I looked at the following metrics and relationships:

A) Back-calculated first-winter length distribution

B) Back-calculated total length as a function of fish's age

C) Back-calculated first-winter length and smolt age (linear model, Searle 1971)

D) Smolt age distribution

E) Smolt length distribution among samples

F) Smolt length as a function of smolt age

G) Number of sea trout caught per hour in each zone

H) Anglers' effort in each zone

I) Number of anglers in each zone

Anglers' effort was calculated from number of hours spent fishing per angler. When the data on fishing hours was lacking, effort was calculated assuming that anglers that did not provide the data fitted into the average effort data (average time spent fishing) for each respective zone.

Also, as it may be important for further studies of Inner Oslofjorden area, the travel effectiveness of the method of travel (car or boat) while "sampling" anglers in the field was calculated using a generalized linear model approach. N Angler encounters (*A*=0 or 1 for no encounter or encounter, respectively) was fitted as function of survey time (*T*), vehicle (i = car or boat) and sampling zone (j = 1-4) where A was assumed binomially distributed and therefore a logit-link was used in the GLM (McCullagh & Nelder 1989). Candidate models were fitted as either a fully factorial model or less complex combinations of the predictors. Model selection was based on AIC (Akaike, 1974; Burnham, 1998). The fully factorial model looked like this:

$$logit(A_{ij}) = \alpha_i + \alpha_j + \beta_i T_i + \beta_j T_j + \beta_{ij} T_{ij} + \varepsilon_{ij}$$

Where α constitute intercept parameters and β are slope parameters. ε is assumed normally distributed with mean =0 and sd=1, under logit-transformation.

5. Results

5.1 Spatial variation in sea trout catches

Most samples were obtained from anglers in zone 2. In total, 21 sea trout were caught in zone 2 (Figure 5), nine sea trout in zone 3, one sea trout in zone 1 and zero catches were observed in zone 4, with total 31 recorded catches. Most samples were retrieved in April 2018 from anglers fishing from boats. A small portion of samples was retrieved in October 2018, mostly from anglers fishing from land. Sea trout were caught by both fly-rods and spinning rods with comparatively equal success.

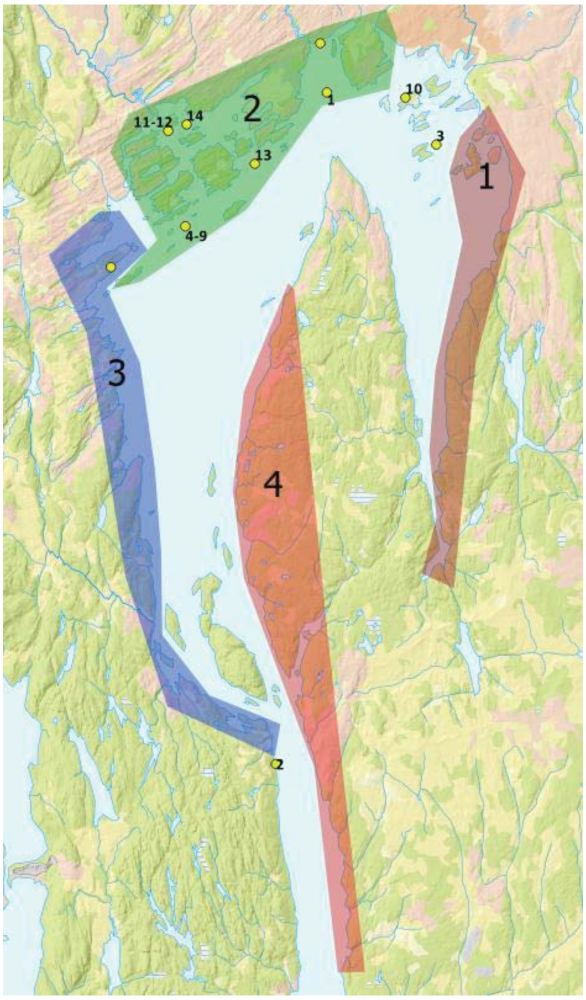


Figure 5. Locations in Inner Oslofjorden where sea trout were caught by anglers in 2018. Labeled spots are the ones where biological samples were obtained.

5.2 Characteristics of the sea trout caught by anglers

Out of 31 observed catches, samples were gathered from 14 sea trout. Sometimes anglers released caught fish or left it in a distant place before samples could be taken. Among 14 samples, length varied from 38.5 cm up to 54 cm. Sampled fish were from three to six years old, with only one individual being three years old and five individuals being six years old what caught.

5.2.1 Individual growth trajectories

Most fish had a rapid increase in body size after their second winter (Figure 6). More rarely, this growth spurt occurred after the third winter, and only one trout accelerated after its' first winter. The growth rate of this outlying trout significantly slowed down after its' third winter. Also, we can see that all sampled trout were of relatively similar sizes before the first winter, but variation in size increased during several following years narrowing down to the age of six where all "survivors" were of relatively same size.

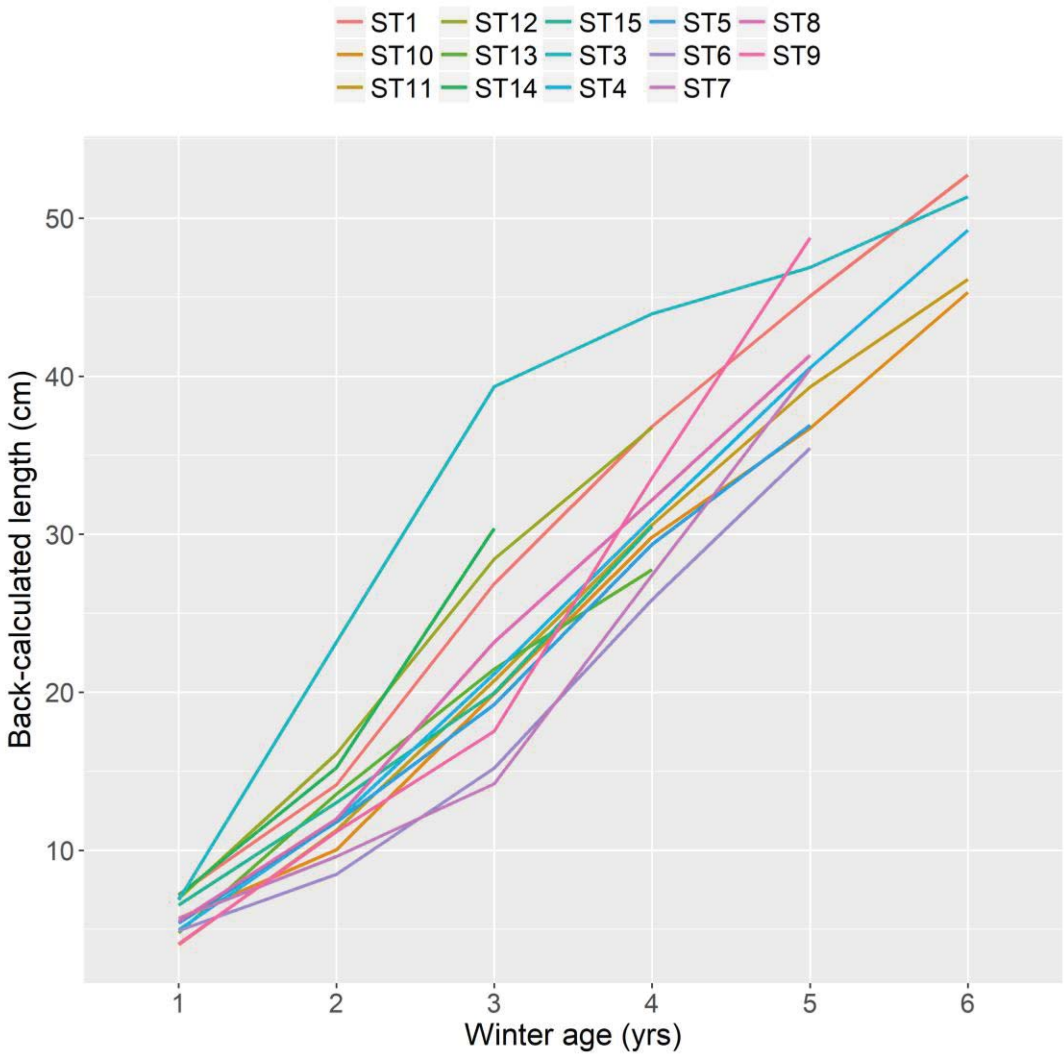


Figure 6. Back-calculated length in centimeters as function of age in years for sea trout caught by anglers in Inner Oslofjorden, 2018. Each of 14 sampled sea trout has an individual line color. Length during every winter was back-calculated from scale readings using distance between annuli and total fish length.

The frequency of back-calculated first-winter lengths among sea trout in Inner Oslofjorden in 2018 showed considerable variation (Figure 7). Most sea trout back-calculated lengths were from 4 to 6 cm at the end of their first winter. Only two values were more than 7 centimeters.

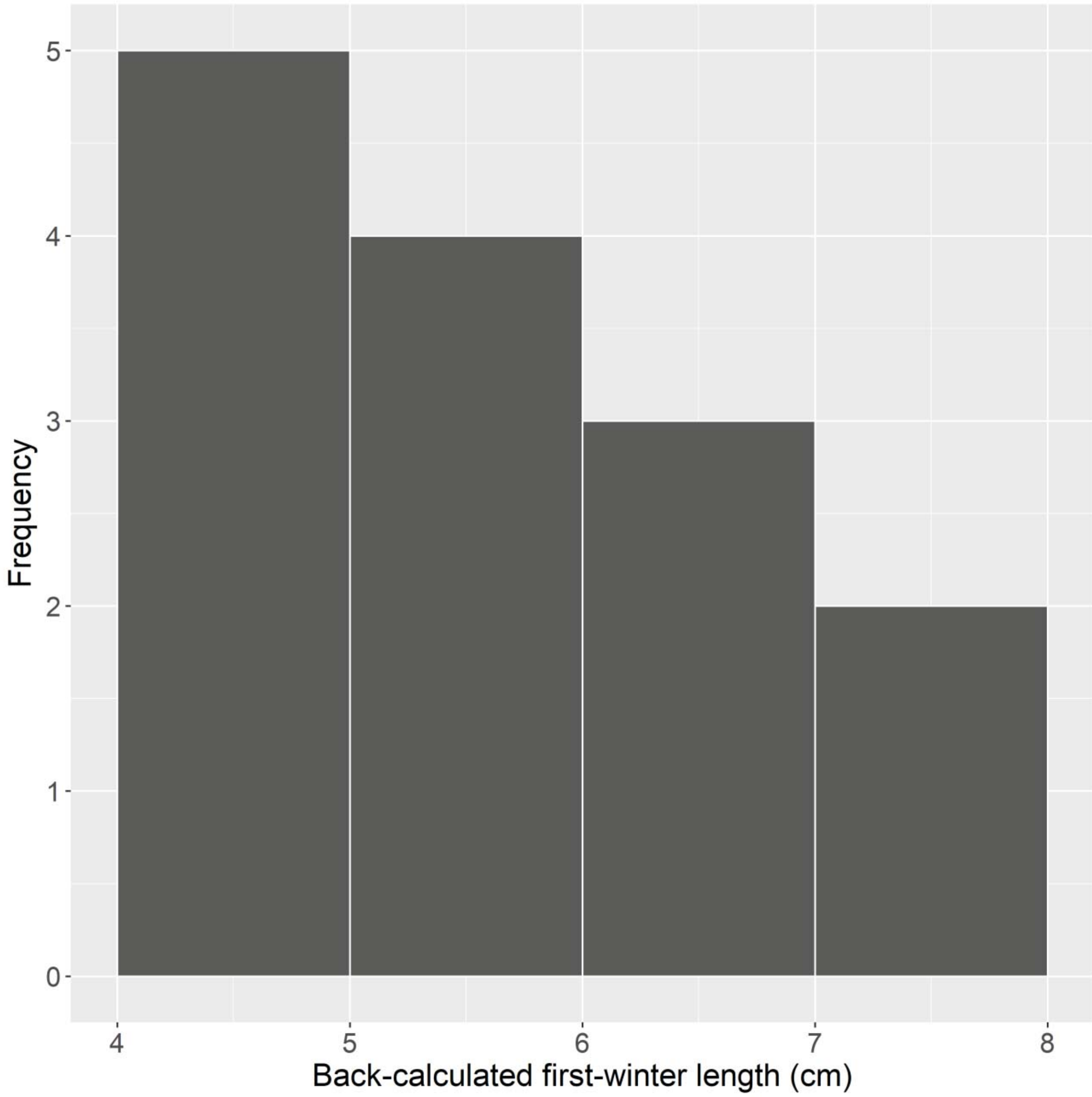


Figure 7. Back-calculated first-winter length distribution in centimeters for sea trout caught by anglers in Inner Oslofjorden in 2018.

Sea trout growth rate in Inner Oslofjorden is very stable the first five years, and then slows down by the sixth year (Figure 8). The variation in size is also the lowest during the first winter, and is largest during third and fifth. Boxes include the majority of observations, horizontal lines show the medians, whiskers show variation in sizes, dots represent outliers. During the first winter, variability in back-calculated length was relatively small, but increased during the following three years, and narrowing down again to the age of six. The assumption here is that only trout that grew enough during their first years of life were able to live for more than five years, as only five trout out of 14 were six years old when caught and being of relatively same size. It is important to know that all the largest trout were caught and sampled in spring 2018 (four in the middle of April and one at the end of May).

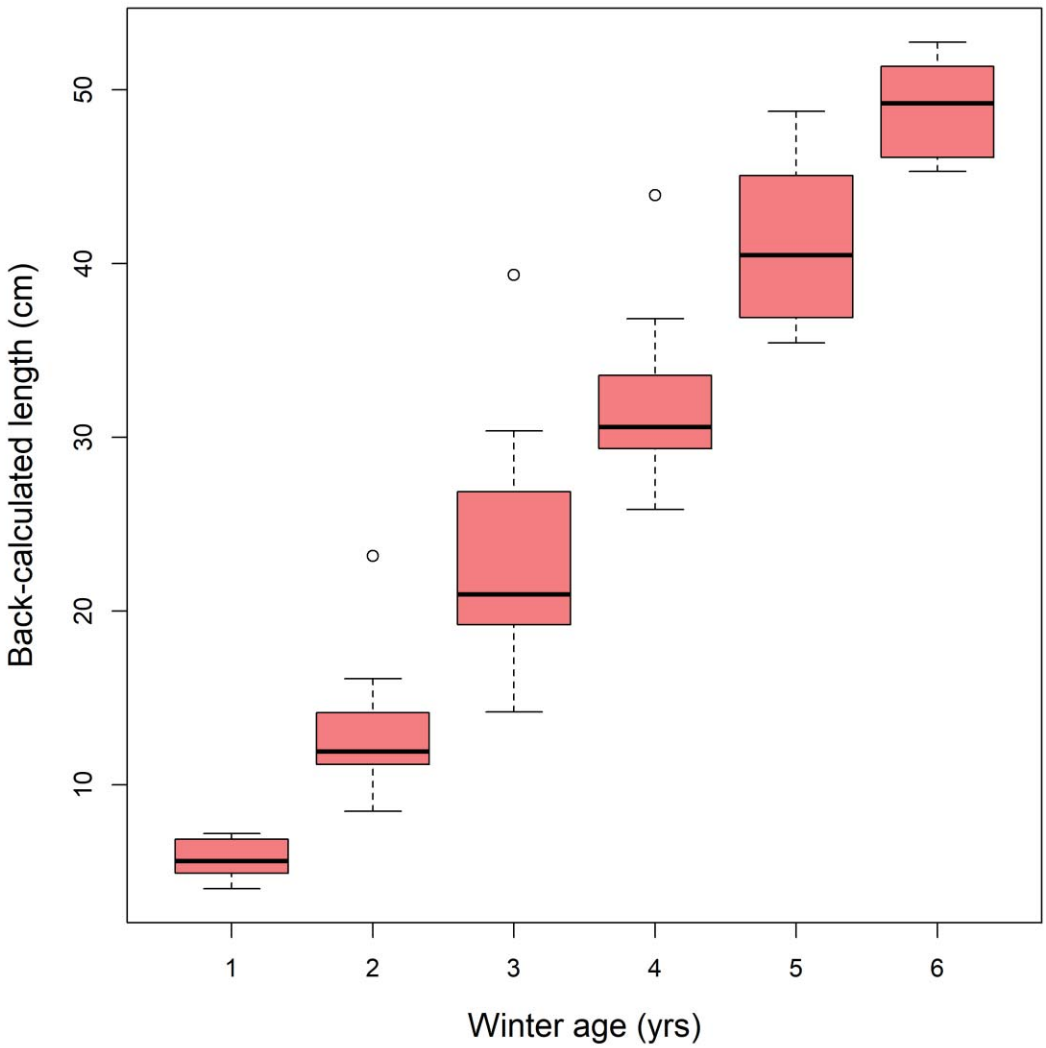
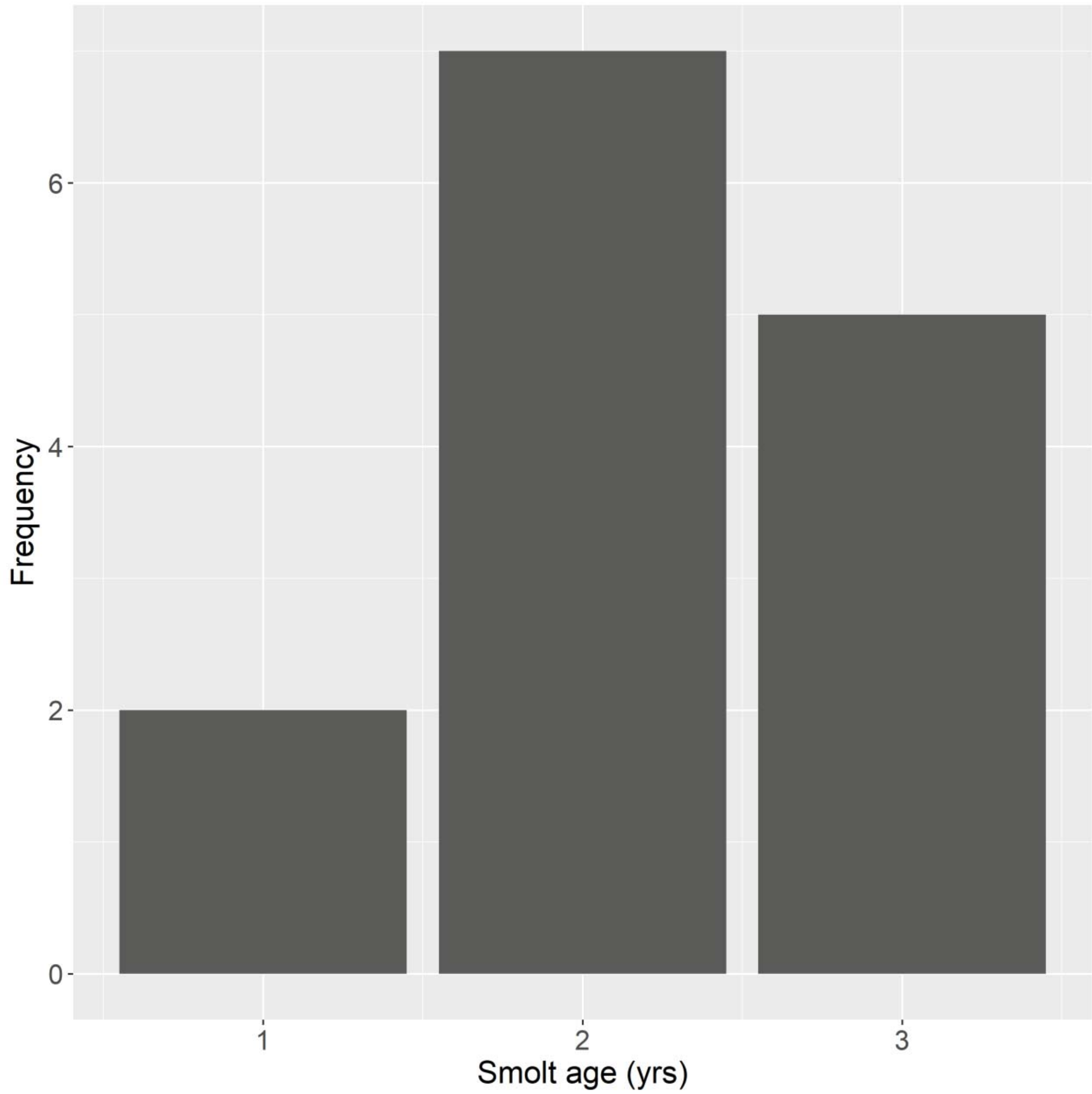
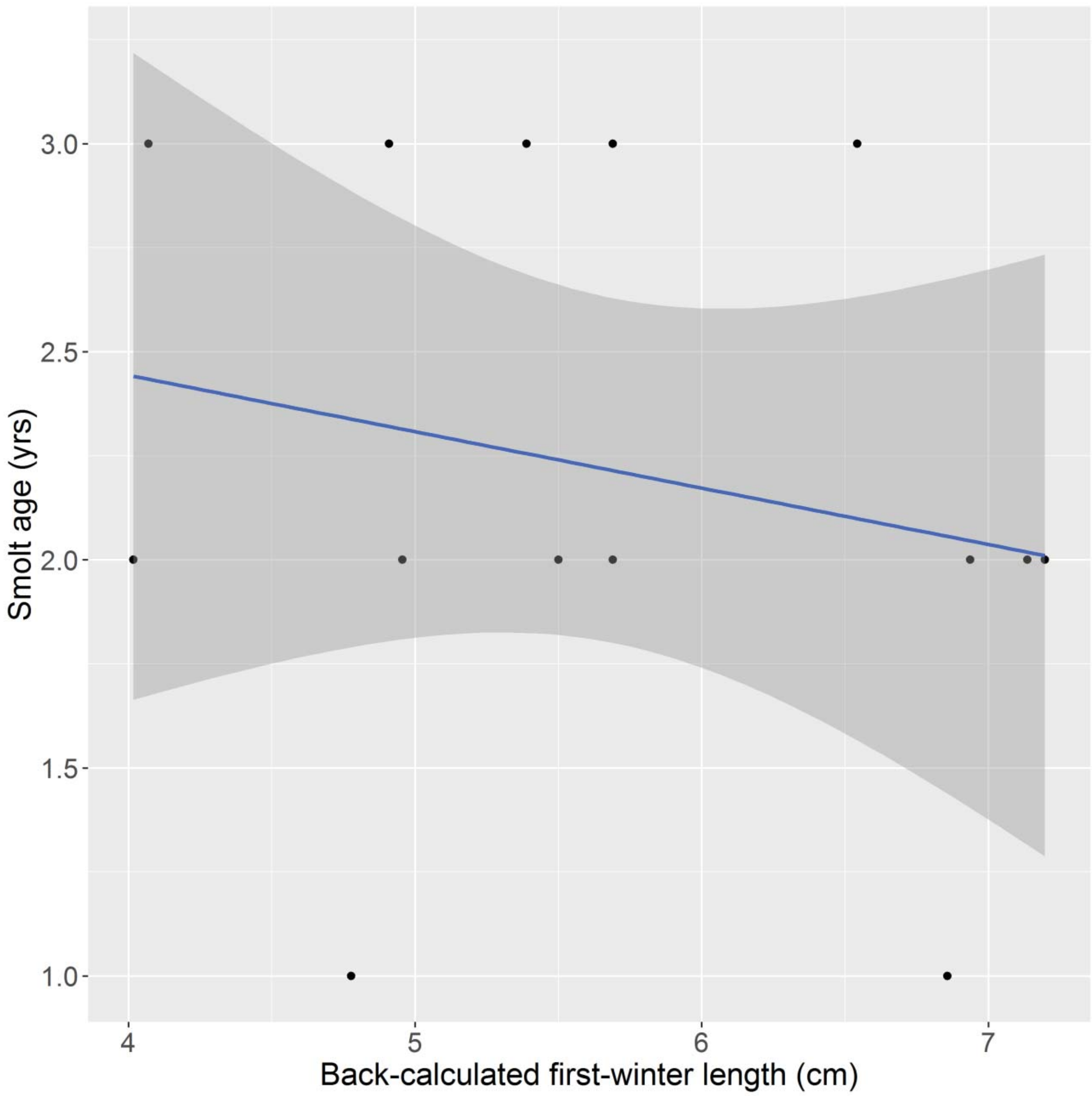


Figure 8. Correlation between back-calculated length (in centimeters) for sea trout caught by anglers in Inner Oslofjorden in 2018 – Y axis and winter age of the fish (in years) – X axis. Boxes entail the majority of observations, horizontal lines show the medians, whiskers show variation in length, dots represent outliers.

5.2.2 Age and size at smolt

There was a trend indicating that the bigger the sea trout is when leaving fresh water, the earlier it smolts (Figures 9 and 10). Half of the sampled sea trout smolted at the age of two, which is a common age for smolting for the species. (Freyhof, 2012). However, some sampled fish smolted at the age of three, and two individuals smolted when they were one year old. Back-calculated first-winter length varies considerably among sea trout that smolted at two years old.





Figures 9 and 10. Smolt age distribution for sea trout and back-calculated first-winter length as a function of smolt age caught by anglers in Inner Oslofjorden in 2018. Dots in Figure 10 (second one) show sampled individuals, grey area shows 95% confidance bounds for the linear model (blue line) fitted smolt age as a function of back-calculated winter length (L_1) (SmoltAge=2.96±1.04-0.14±0.18*L_1 (R^2=0.045, p=0.46).

Most sea trout smolted when they were around 15 centimeters long and at the age of either two or three (Figures 11 and 12). The smallest portion smolted when they had smaller body lengths, with the biggest portion of sampled individuals smolting when they were closer to the size of 20 centimeters. Variation in body size was higher for trout that smolted when they were three years old. Only two individuals smolted at one year age showing no significant difference in back-calculated smolt length.

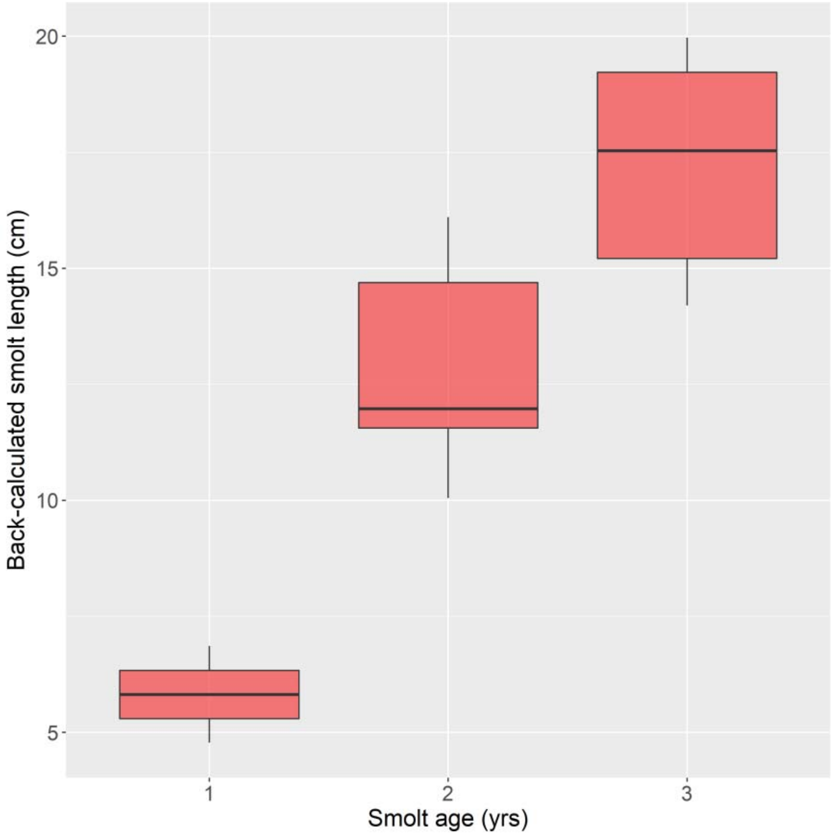


Figure 11. Back-calculated smolt length in centimeters as function of smolt age for sea trout caught by anglers in Inner Oslofjorden in 2018. Boxes entail the majority of observations, horizontal lines show the medians, whiskers show variation in length.

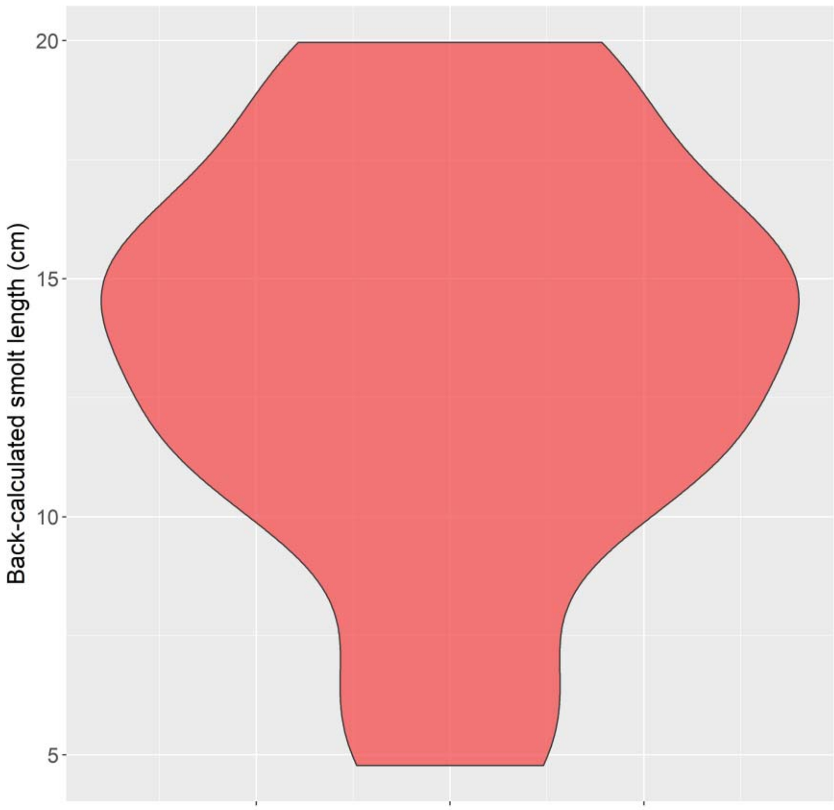


Figure 12. Violin plot of the smolt length distribution among all samples in centimeters for sea trout caught by anglers in Inner Oslofjorden in 2018. The broadest part of the figure shows greater number of trout being of comparatively same size when they smolted.

5.2.3 Individual growth at sea

The older fish gets, the slower it grows, having the most rapid growth right after leaving freshwater and then slowing down during their lifetime (Figure 13). The highest growth rate can be observed when sea trout were one year old, and it slows down and becomes more stable when fish spend from three to four years in the sea.

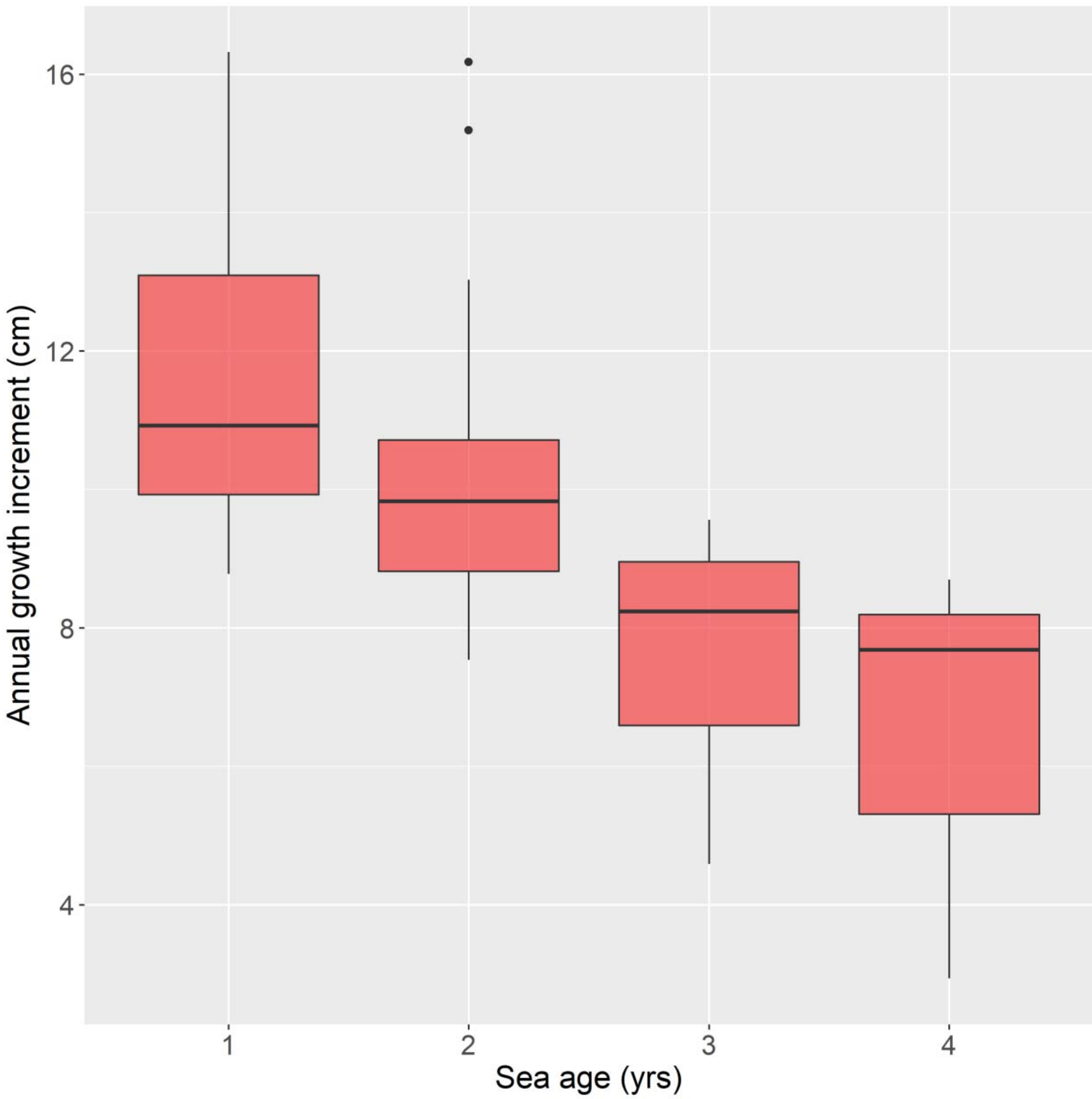


Figure 13. Annual growth increment as function of years spent at sea for sea trout caught by anglers in Inner Oslofjorden in 2018. Boxes entail the majority of observations horizontal lines show the medians, whiskers show variation in annual growth increment among individuals and dots represent outliers in terms of relationship between annual growth increment and ages spent at sea.

5.3 Angling intensity

5.3.1 Encounter rates – access point survey

During fieldwork, both cars and boats were used as a method of movement between hotspots and zones. The probability of encountering an angler is higher when using a boat, reaching almost a "certain encounter" level after 20 minute sampling time (Figure 14). Variance is also much higher when sampling by car for a longer period of time, showing that even when spending around an hour travelling by car you still can encounter 0 anglers, which is opposite to what was observed when using a boat (Figure 14).

Table 1. Model selection table for the eight fitted candidate GLM models exploring effects of survey time, vehicle and sampling zone on encounter probability for sea trout anglers. AIC is Akaike's information criterion, k=number of parameters and ΔAIC is the difference in AIC compared to the candidate model with the lowest AIC.

Model	k	AIC	ΔAIC
Time Sampled*Vehicle+Zone	7	101.16	0.00
Time Sampled*Vehicle	4	104.58	3.42
Time Sampled*Zone	8	117.90	16.74
Time Sampled+Vehicle+Zone	6	118.70	17.54
Time Sampled+Zone	5	120.37	19.21
Time Sampled+Vehicle	3	121.72	20.56
Time Sampled	2	125.53	24.37
Time Sampled*Vehicle*Zone	15	1399.66	1298.50

Table 2. Logit-scaled parameter estimates for the most supported GLM model presented in Table 1.

Term	Esimate	SE
Intercept	-22.04	16.25
Time Sampled	0.40	0.10
Vehicle[Car]	3.16	1.37
Zone2	16.46	16.25
Zone3	16.08	16.25
Zone4	13.94	16.25
TimeSampled*Vehicle[Car]	-0.35	0.10

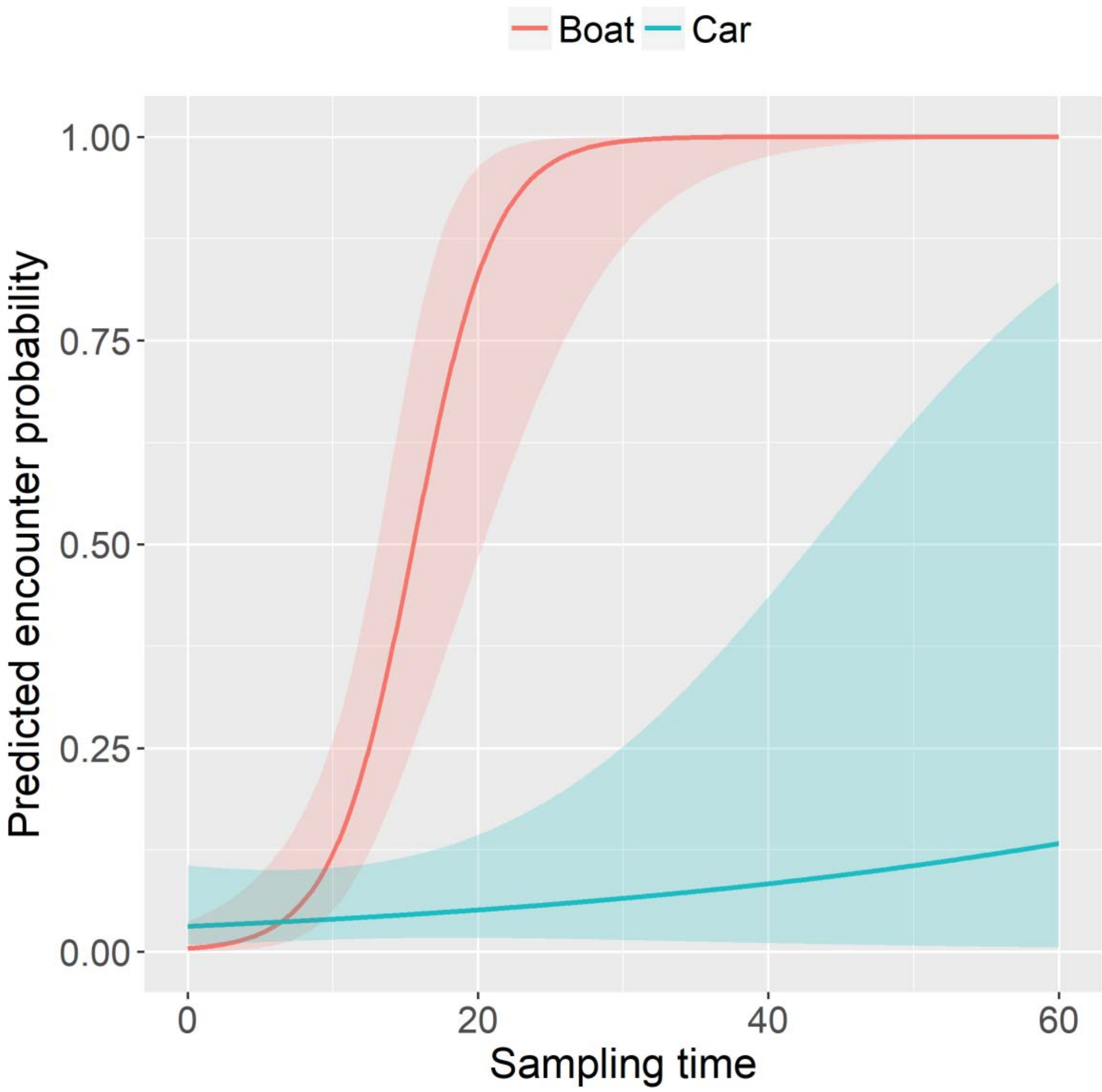


Figure 14. Estimated angler encounter probability per spent time unit (minutes) depending on the vehicle used for the cars or boats when sampling international sea trout anglers in Inner Oslofjorden in 2018. Estimates were retrieved from the selected model provided in Table 2. 95 % confidence bounds are shown as semi transparent bands.

5.3.2. Spatial variation in angler density and effort– rowing creel survey

The total number of anglers was recorded from observations during field trips (Figure 15). Even if an angler was not able to communicate with the observer either due to great distance between them (angler fishing from boat in the middle of the fjord and observer standing on the shore with no means to communicate with the angler) or due to the language barrier, encounter still contributed to the total number of anglers recorded. During an encounter, an interview was taken to obtain data on number of hours spent fishing and total catch data.

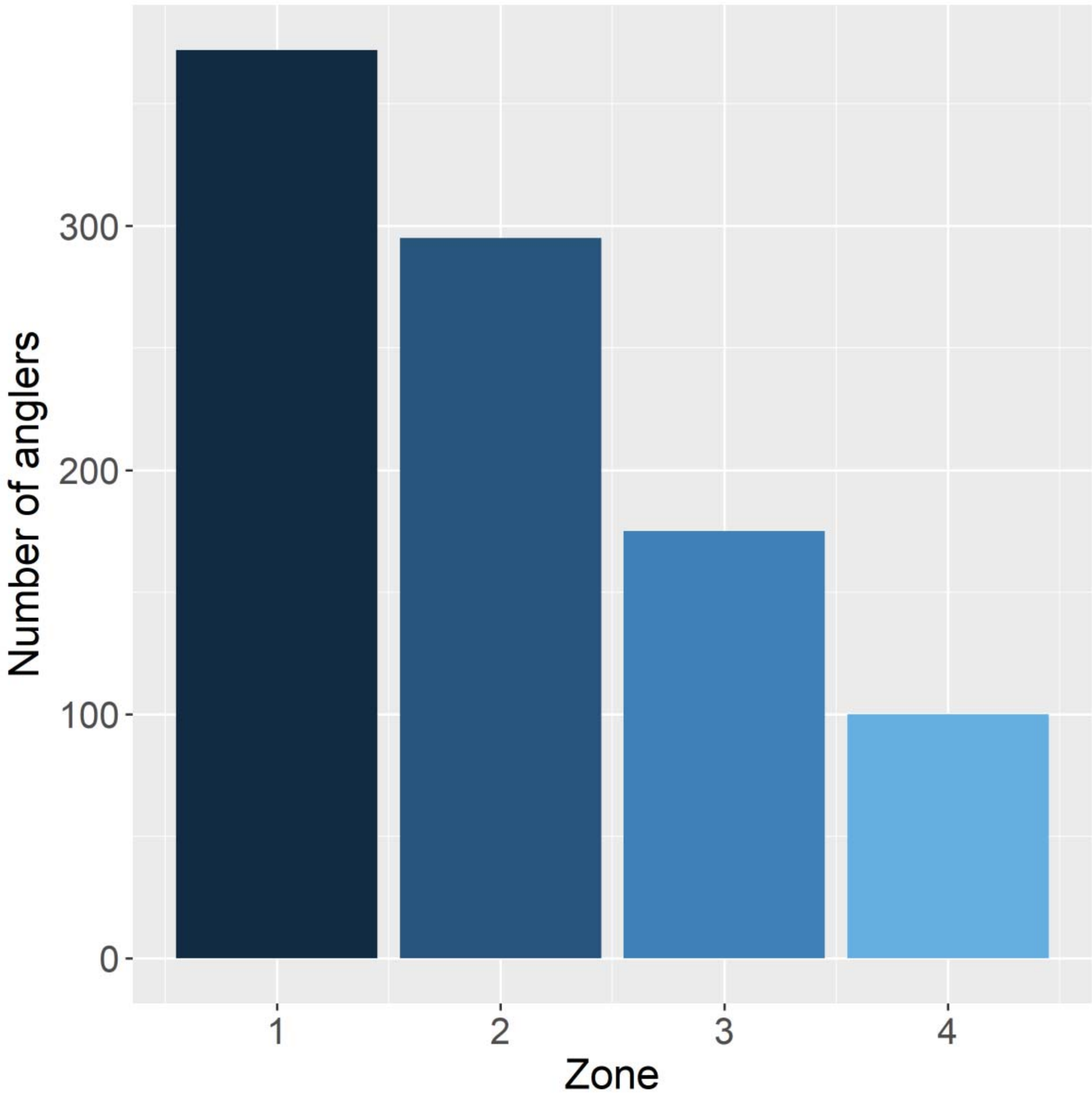


Figure 15. The number of anglers in each respective zone while sampling recreational anglers in Inner Oslofjorden in 2018. Total number of encountered anglers was 942 individuals.

The average number of hours each angler spent fishing in each zone per day varied amongst the four zones (Figure 16). Effort in zones 1, 2 and 3 did not differ much statistically, but anglers in zone 2 put a bit more effort in trying to catch something. Zone 4 showed significantly lower angler effort compared to the other three zones with anglers fishing for an average of 2.19 hours per day. Together with observed, comparative low number of anglers supports a low popularity of zone 4 among anglers (not many come here and those who come do not spend significant number of hours fishing).

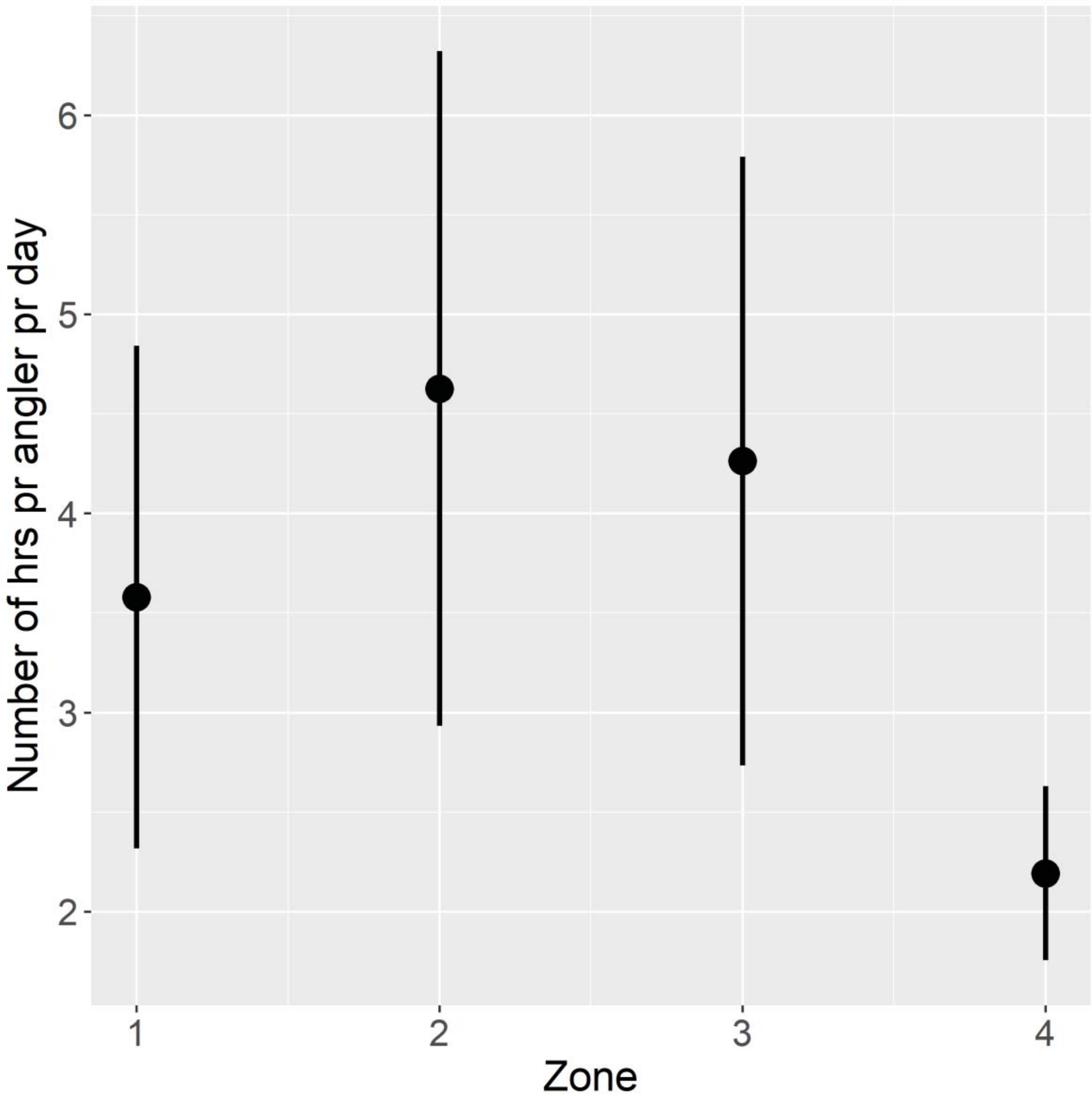


Figure 16. Average angler effort in each respective zone for Inner Oslofjorden sampled in 2018. Circles show mean values and lines represent 95% confidence intervals.

5.3.3 Spatial variation in catch per unit effort

Catch per unit effort can be used as an indirect measure of the abundance of a target species. Average number of caught sea trout per one hour was counted for each angler in each zone (Figure 17). The catch per unit effort was largest in zones 2 and 3 compared to zones 1 and 4. No sea trout catches were observed in zone 4, thus having a CPUE value equal to 0. Variability in individual CPUE in zone 3 is higher compared to zone 2 (Figure 17).

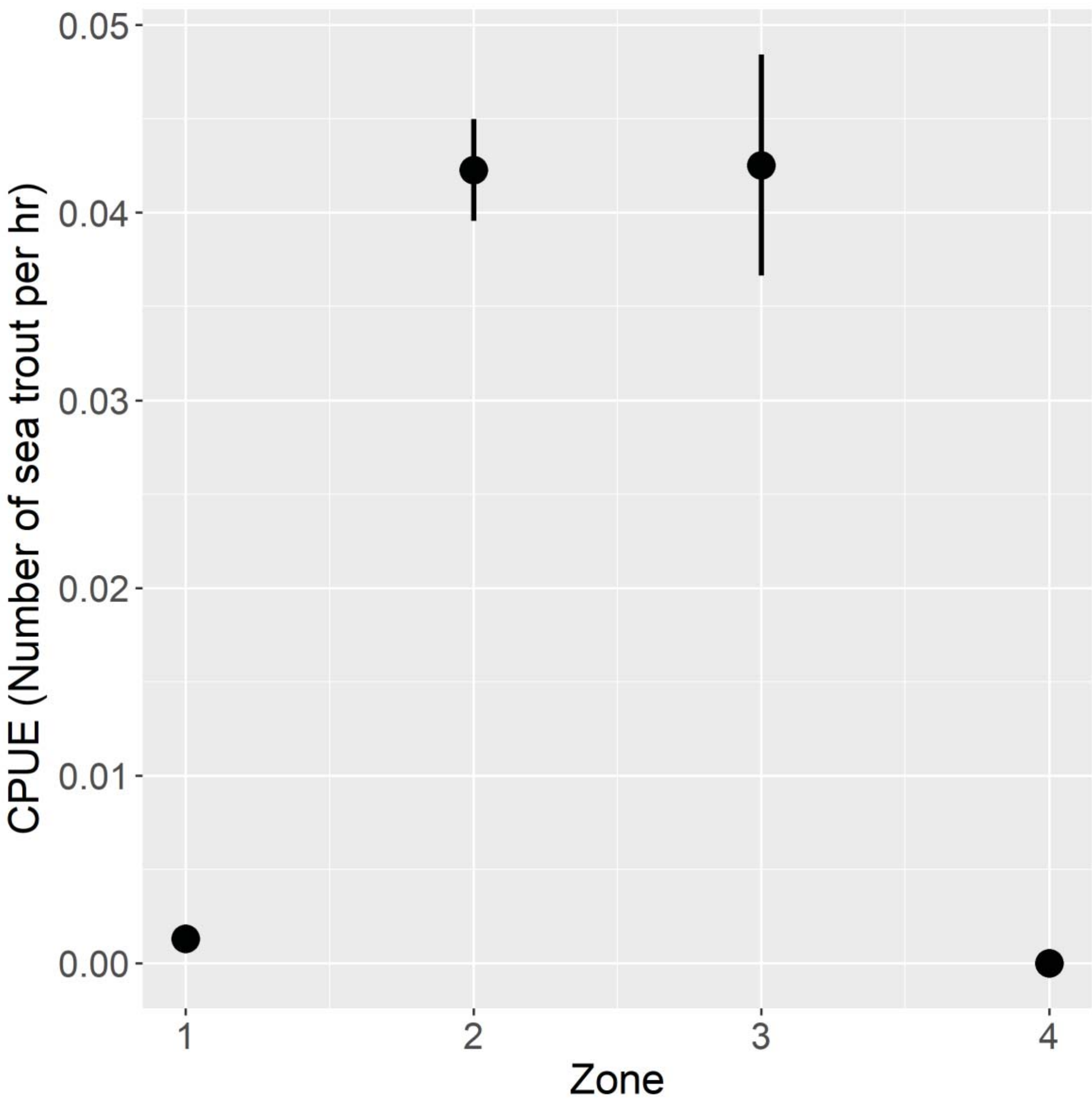
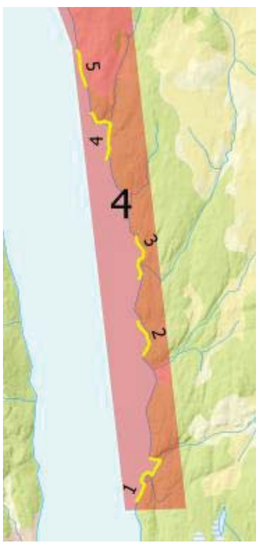


Figure 17. Average number of sea trout caught per hour for each zone sampled for recreational anglers in Inner Oslofjorden in 2018. Circles show mean values and lines represent 95% confidence intervals.

6. Discussion

In Inner Oslofjorden for the study period, 942 anglers were observed with total of 31 catches of sea trout among 4 sampling zones. This includes all anglers, and not just those targeting sea trout. Most catches were observed in zones 2 and 3, which could be because of proximity of Sandvikselva river, reported to have a big and healthy sea trout population (Lamberg & Strand 2019). This river contributes a lot to the entire sea trout population in Oslofjorden and naturally, zones closest to it will be more populated by sea trout (Figure 19). Also recent study reports that sea trout from Sandvikselva disperse over entire Oslofjorden and some of trouts even go further out in the ocean. These findings with further investigation could prove that catching and killing trout in the inner parts of Oslofjorden could reduce abundance of sea trout not only in zones studied in this paper, but across all Oslofjorden. Another important factor to mention is that not much data is available on relative abundance of sea trout in rivers flowing into Inner Oslofjorden that are used for spawning by the species. There are more than 10 rivers, that flow into the area and more than half of them are used by sea trout to spawn and currently there is no reliable data on each river comparative contribution to the population as a whole. Another important point to acknowledge when speaking about spawning pools, is that sea trout both within and between watercourses draining to the same fjord system may differ in morphology, life history, migration behavior, and marine habitat use. This plasticity may influence population resilience in recreational fishing areas in both negative and positive way (Eldøy et al., 2015). Also there is data that indicates that variables such as genetics, ontogeny, morphological and life history characteristics as well as current hierarchy status in a population, might affect the behavior of each individual sea trout in the marine environment (Höjesjö, 1998). Thus, a better understanding of sea trout behavioral strategies both on population and individual level is needed to understand the influence of angling, habitat changes and other factors on the studied species.



During the study, probability of encountering anglers was much higher when using a boat as a vehicle when sampling compared to a car. This could be useful for further studies of marine recreational angling area in Inner Oslofjorden to maximize study efficiency. Generally, it was much harder to access some fishing hotspots by car, when it was necessary to make a huge detour across the area to move from one hotspot to another.

For example, to move between hotspots 3 and 4 in zone 4, you would generally spend around 40 minutes if travelling by car and only a couple minutes using a boat. By car, you would also have to take a detour, including roads with no pavement which limits travel speed greatly. The same argument could be applied to explain the number of anglers in each zone. There are many variables that could be taken into an account, but accessibility seems to be important for an average angler when selecting a fishing spot. Zone 4 in this regard seems to be the least accessible from shore, with many relatively “good” spots lying in places which would take a lot of time to get to. Zone 2 and 1 on the contrary – are easily accessible to everyone, with many areas of shore lying relatively close to roads or settlements. This could explain the highest number of anglers encountered in these two zones, putting a lot of effort into fishing. Though definitely not all anglers target sea trout directly as their primary interest, their total amount caught can nevertheless put a significant pressure on the population in this area.

During the study were faced two important obstacles in obtaining angler data. Abovementioned language barrier was a big issue due to the fact, that many encountered anglers originated from Eastern Europe and could not speak any of languages, which were known to researchers (Russian, English and Norsk). Even when communication was established, interviews with such types of anglers generally took much more time, compared to other anglers. Another obstacle was an overall mistrust in researchers from some anglers. Several encountered people mentioned their suspicion in researchers’ actions and required detailed explanation of the study, which could take a solid portion of sampling trip time.

Though more sea trout catches were observed in zones 2 and 3 compared to zones 1 and 4, many factors could contribute to these numbers. General habitat quality, disturbance by humans’ activities, and competition levels can be very different in the 4 study zones, and these factors are yet to be studied.

Biological data indicates that sea trout age, size and smolt parameters in Inner Oslofjorden are generally close to same parameters of studied species (Eldøy et al., 2015). However, some variables differ from the ones calculated during another recent study of sea trout population in Inner Oslofjorden (Dzadey, 2014). Growth patterns of sampled sea trout are mostly identical with an exception of one individual with a very rapid growth rate at earlier age (Figure 6.). Back-calculated smolth length varied a lot - from 4.7 cm to 19.9 cm (Figures 11 and 12.). Data obtained in this study indicates a more stable growth rate among all the sea trout and much higher variability in smolt age. Smolt age variability could be connected with differences in spawning habitats of sea trout across Inner Oslofjorden as data obtained by Dzadey (2014) was gathered in a much smaller area, compared to the one covered in this study (only a part of zone 2).

Another important comparison can be done with the study of sea trout population in stream Årungselva done by Borgstrøm and Heggenes (1988). In this study, the average length of 0+ sea trout was 7.4 centimeters, whereas in my study the average 0+ sea trout length is 6.1 centimeters (Figures 7 and 8). The estimated growth patterns differ much too between the two studies – 1988 study shows comparatively higher growth rates. These findings could indicate, that none or a very small portion of sea trout sampled in my study originated from the Årungselva stream. Though, it is also possible that fish from that stream are better at avoiding anglers, or their migration patterns are different and they go out further from Inner Oslofjorden. Further investigation of these results is required.

It also seems important, that although sea trout growth rate starts slowing down at the age of 5-6 years, almost all obtained samples were 4 to 5 age old. It could be that caught sea trout in Inner Oslofjorden are still too young and small and could contribute greatly to population production if not caught and killed. Sea Trout can live up to 20 years, and thus an individual younger than 6 years old can be considered young. This is important for conservation purposes. Furthermore we do not know the whole size of sea trout population in Inner Oslofjorden, making it impossible to investigate on how strongly anglers affect the population overall. Though, it is possible to hypothesize, that catchability of each trout depends on personal traits like boldness or "experience". This could explain why many sampled trout in this study were close to minimum allowed catch size (35 centimeters). This hypothesis needs further investigation. If sea trout, that is caught in Inner Oslofjorden is really too small and population dynamics is negative, regulating measures would be advised to conserve the population. Also this would show that it is important to apply more rules to marine recreational fishing in Oslofjorden overall to both create more accessible and reliable data on angler number and catches, and make management of populations easier in the area.

In addition to complexities in acquiring necessary data for studying sea trout, recreational fishing, as a whole, presents another set of problems. Commercial fisheries, in comparison, are not only more regulated, but also generally target larger fish sizes in a population (Sampson 2014). Recreational fishing, in turn, induces wider and more complex trait selection on the target fish stock (Wallerius, 2016) and, thus, it is much harder to find any correlations between population status and angling intensity.

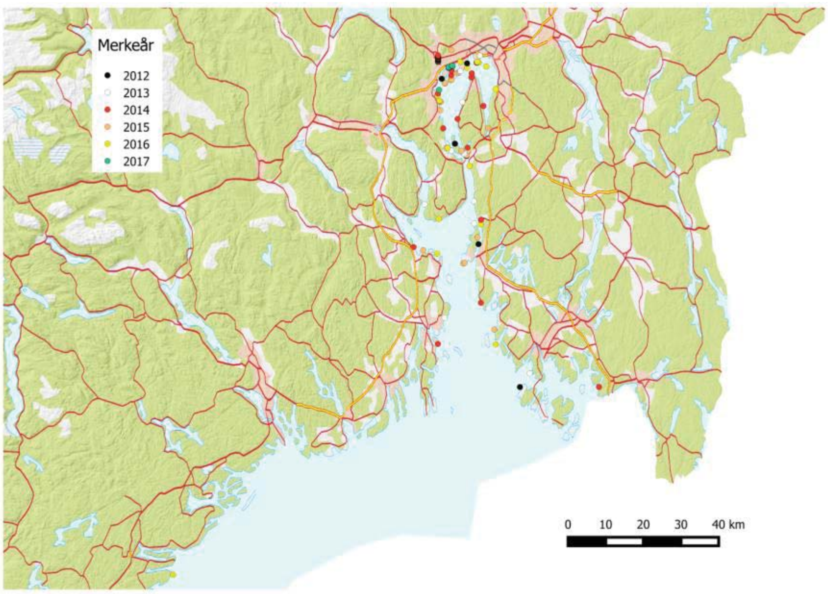


Figure 19. The distribution of recaptured sea trout from floy-tagged sea trout in the Sandvikselva during 2012-2017 period (unpublished material from Thrond Haugen (NMBU-MINA) and Morten Merkesdal (Bærum Municipality Administration)).

7. Conclusion and suggestions for further research

In summary, this study showed zones in Inner Oslofjorden, where most sea trout is caught. During the study, data on total number of anglers, fishing effort and CPUE was gathered which is an important step in estimating the pressure, that marine recreational fishing is putting on sea trout population in this area. For now it is possible to hypothesize that angler pressure on sea trout population is relatively high in zones 2 and 3 of this study, which could be a good starting point for further studies or management actions.

Biological data on sea trout was gathered and did not show any abnormalities in mean individual parameters, though many of the sampled trout could be considered too young and small, which could damage the population overall. Further investigations of a total population size and population dynamics are needed on a larger scale to make certain conclusions.

Another discovery is that boat as a vehicle is more efficient compared to car in such type of study, so boat is a recommended vehicle type for investigation marine recreational fishing and trout population in Inner Oslofjorden. Also for further studies that would include taking interviews from anglers, to solve the problems which were mentioned (language barrier and general suspicion), is advised to develop more advanced interview forms, that would be translated to a wider variety of languages (especially Polish and Lithuanian) and contain detailed data on the conducted research project. This step would save a lot of time and effort during the actual investigation.

Also I would advise creating a single "official" website, accompanied by the mobile application, where anglers could fill in forms similar to the ones, which were used in interviews in this study. This website should be translated into several languages and be advertised among anglers that go out to fish in Inner Oslofjorden. Even if a small portion of anglers would upload their trip and catch data, it would greatly enhance the amount of comparatively reliable data in our possession. Mobile application could allow anglers to upload photos of their catch with automated measurement tech that is already used in several other applications. Thus, it would be possible to get a good portion of data even in times, when no researches are able to go out on field trips and it could allow for deeper education among anglers about the state of ecology of Inner Oslofjorden by making some types of data public (population status of species, total amount of fish caught, etc.). Recent anglers studies in Denmark (Gundelund, 2017) show that mobile applications such as Fangstjournalen used in that respective study can be a valuable source of data for scientists when gathering data on anglers. This very application could be used as a reference for developing something similar for use in Inner Oslofjorden. The data from these applications could be crucial in terms of studying marine recreational fishing influence on ecosystem of the area and further management and conservation.

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