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Angler impact on the Brown trout *Salmo trutta* population size and structure in the lake, Øvre Heimdalsvatn

Marit Knutsdatter Strand
Teacher Education in Natural Sciences

Preface

This master thesis completes my five years as a student at the Norwegian University of Life Sciences (NMBU), on the Teacher Education in Natural Sciences.

The idea for this thesis came from Professor emeritus Reidar Borgstrøm, and he has been my supervisor together with Professor Thrond Oddvar Haugen. I would like to thank them both for all the help and guidance regarding my master thesis.

Thanks to John Edward Brittain and Reidar Gran, they were both helpful when I was sampling. The Norwegian Natural History Museum and Brittain provided shelter and equipment at Osbui, which made the estimation of population size and structure possible. I would also like to thank Professor Vidar Selås and Ronny Steen for sharing their data from the university course NATF100. The Faculty of Environmental Sciences and Natural Resource Management, in general, have been helpful with social and professional counselling.

In addition to all the professional help, I would like to thank the Student Society of Ås for being my sanctuary with joy, hard work, and friends – all providing me with memories for the rest of my life. My roommates at Bohemen, family and loved once have all given me the support I needed to finish.

Ås, 12.05.2017

Marit Knutsdatter Strand

Summary

Studies of the brown trout (*Salmo trutta)* population in the subalpine lake, Øvre Heimdalsvatn, on the eastern slope of the Jotunheimen Mountains, have been performed since 1957 until today. The exploitation of the population was reserved for scientific purposes until in 1992, when the lake was opened for ordinary angling. At the same time, the experimental fishery by gillnets has been limited during the last decades compared to the gillnet effort during the period 1958–1970. Based on the earlier studies, the trout population size and the exploitation by gillnets have been known, but no studies of the angling activity and catch obtained by the anglers have been performed.

The lake is located in a popular destination for hikers and tourists. Angler effort and catches were estimated by observations and interviews of anglers present at the lake, in addition to reports submitted by anglers to the fisheries management authorities. I conducted 46 visits for interviewing anglers during June, July and August in 2015 and 2016, both covering weekdays and weekends, between 1000–2200 hours. To estimate the trout population size and structure, I used a pilot fleet of eight gillnets consisting of mesh sizes (bar mesh) from 24 to 39 mm, with a high capture probability for trout of age-class four winters and older, hereafter referred to as post recruits, in the range 20–45 cm. Based on capture data from earlier studies, regarding regressions between catch per unit effort with a gillnet pilot and population numbers, I have estimated the population size and structure from catches per gillnet-effort on my pilot fleet, for post recruits.

The angling season range from approximately mid-June to mid-October. According to the interviews and reports, the angler catches consisted of 28.4 kg trout all together, during the fishing seasons 2015 and 2016. The gillnet catches obtained by a university course and my own gillnetting were far larger, 81.1 kg and 72.2 kg in 2015 and 2016, respectively. The estimated number of post recruits of trout were almost 8,000 fish in 2015 and 7,300 in 2016. The age distribution ranged between 4 and 18 winters, with lengths varying between 17 and 46 cm. Compared to studies in the period 1960–1970, the trout population had approximately the same size today, although the total exploitation is much lower now.

Accordingly, neither the anglers nor the gillnetting seem to be a regulatory factor today. Reduced recruitment due to internal regulation is more likely the main regulation. Based on earlier studies, it is likely that the introduction of European minnows (*Phonixus phonixus*) limits the use of the sheltered, stony part of the littoral of trout juveniles, and forces the juvenile trout to use open water and expose themselves for predation. If the goal is to attract more anglers to the lake, more information about the good angling possibilities should be presented, in addition to investigate the preferences of anglers that visit the lake.

Sammendrag

Undersøkelser av fjellvannet Øvre Heimdalsvatn lokalisert rett øst for Jotunheimen, der ørret (*Salmo trutta*) er største art, har vært gjennomført fra 1957 og fram til i dag. Fisket på ørretpopulasjonen var kun tillat i forbindelse med forskning fram til 1992, da ordinært sportsfiske ble tillatt i vannet. På samme tid, har fiske i forbindelse med forskning vært begrenset sammenlignet med garninnsatsen i perioden 1958–1970. Ørretpopulasjonens størrelse og uttak ved garnfiske vært kjent på grunnlag av tidligere studier, men ingen studier har undersøkt aktiviteten til sportsfiskere og deres fangst.

Området vannet ligger i, er mye besøkt av turister. Fiskeinnsatsen og fangstene i vannet ble estimert ved observasjoner og intervjuer av sportsfiskere ved vannet, i tillegg til innleverte fangstrapporter fjellforvaltningen samlet inn. Jeg besøkte vannet 46 ganger i løpet av juni, juli og august i 2015 og 2016, både i uke- og helgedager, i tidsrommet kl. 10–2200. For å estimere ørretpopulasjonens størrelse og struktur, brukte jeg en pilotserie bestående av åtte garn med maskevidder fra 24 til 39 mm, med stor sannsynlighet for å fange ørret på fire år og eldre, heretter kalt post-rekrutter, i lengdeintervallet 19–45 cm. Basert på fangstdata i tidligere studier, der regresjoner for fangst per garninnsats med en pilotserie og for populasjonsstørrelse er utviklet, kunne jeg estimere ørretpopulasjonens størrelse og struktur for post-rekrutter, fra fangster per garninnsats på min pilotserie.

Fiskesesongen varer fra omtrent midten av juni til midten av oktober. Fiskefangstene var til sammen 28,4 kg ørret i løpet av de to fiskesesongene i 2015 og 2016. Garnfangstene til et universitetskurs ved NMBU og mine egne fangster var mye større, henholdsvis 81,1 kg i 2015 og 72,2 kg i 2016. Den estimerte størrelsen til ørretpopulasjonen, bestående av post-rekrutter, var nesten 8 000 fisk i 2015 og 7 300 i 2016. Aldersfordelingen spenner mellom 4 og 18 vintre, med lengder i intervallet 17–46 cm. Sammenlignet med studier i perioden 1960–1970, er ørretpopulasjonen omtrent like stor i dag som etter intenst garnfiskeinnsats da. Dette er til tross for at fisket er langt mindre nå.

Verken sportsfiske eller garnfangst ser ut til å være regulerende faktorer. Indre regulering er sannsynligvis grunnen til redusert rekruttering. Basert på tidligere funn, er det sannsynlig at rekrutteringen av ørret er redusert på grunn av introduksjonen av ørekyt (*Phonixus phonixus*). Ørekyt kan begrense ørretyngelens tilgang på næring og leveområder, som tvinger yngelen ut i åpent vann der den er mer utsatt for predasjon. Er målet å få flere til å fiske i Øvre Heimdalsvatn, bør mer informasjon om de gode fiskemulighetene slås opp, i tillegg til at det bør bli gjennomført et studie på hvilke preferanser fiskerne i vannet har.

Contents

1. Introduction

Recreational fishing has an important value both commercially and recreationally (Aas & Skurdal 1996; Toivonen et al. 2004). There are long traditions for fishing to provide food for survival. Never the less, the habits of anglers have changed the last century, where recreational fishery now is the main motivation for anglers, resulting in the majority of catch of freshwater fish in Norway being caught by anglers (Borgstrøm 2000). In general, studies indicate that recreational fishing has far bigger yields than expected, compared to commercial fishing (Andersson 2016; Post et al. 2002). However, lack of data limits scientific understanding and sustainable management of recreational fishing in many countries. This is due to recreational fisheries surveys being limited in time, place and assessment of consequences (Burgin 2017; Lewin et al. 2006; Venturelli et al. 2016). To obtain more information about the effects of recreational fishing on fish populations, research on angler effort and catch should be brought into consideration, also in Norway.

Brown trout (*Salmo trutta)*, hereafter trout, is the most important freshwater fish in Norway (Borgstrøm 2000; Dahl 1917; Skurdal et al. 1989). In Norway, trout inhabit lakes and tarns all over the country (Huitfeldt-Kaas 1918), and in tens of thousands of these water bodies the trout has been the only occurring fish species, especially in mountain lakes (Jensen 1977; Sømme 1941). Subalpine lakes are located above the tree line and differ from other aquatic systems because they normally have short growing seasons and low temperatures (Vik 1978). The number of fish and amount of nutrients present in the lake, regulate individual growth and population size of fish (Dahl 1917; Larsson et al. 1978). Recruitment, the annual number of four winter old fish, in such lakes depend on the area available for fry to inhabit (Bruun 1988; Jensen 1977), and the summer temperature, amongst other factors (Borgstrøm & Hansen 2000; Borgstrøm et al. 2010; Johnsen et al. 2013). Colonizing trout in mountain lakes can result in overpopulation if not managed.

Large recruitment may lead to overpopulation, which may reduce individual growth, unless anglers help reduce trout density (Dahl 1917; Post et al. 2002). In overpopulated lakes, more angling with large annual yields reduce population size (Burgin 2017; Lewin et al. 2006; Venturelli et al. 2016). Thus, individual growth can increase and give more attractive fish for anglers (Dahl 1917), while at the same time changing the population structure (Klemetsen et al. 2002). On the other hand, over-exploitation can cause negative effects such as changed age-structure, depensatory effects and loss of biodiversity (Brana et al. 1992; Lewin et al. 2006). The major challenge to fisheries management is to reasonably regulate angling for trout, in addition to other salmonids (Aas et al. 2000). There is a need to better understand how fishery affect size and structure of fish populations, in addition to other regulating factors.

Dahl (1917) found that in lakes with high trout density, years of heavy fishing changed the population structure from high densities of old and small fish, to fewer, younger and faster growing fish. Jensen (1972) also found proof of similar effects of large trout catches in other lakes. Ugedal et al. (2007) compared multiple studies of induced heavy fishing to reduce overpopulated salmonid lakes in different parts of Norway, and found both successful and unsuccessful cases. The study summarized that heavy fishing resulted in positive long-term changes in the lake, Takvatn in Troms County, where the arctic char (*Salvelinus alpinus)* was reduced in numbers and the trout population grew larger (Amundsen 1989; Klemetsen et al. 1989; Klemetsen et al. 2002). Amundsen et al. (2002) conducted a large-scale removal of whitefish (*Coregonus lavaretus*) in Stuorajavri in Finnmark County, where the fish stock also consisted of large-sized fish afterwards. Whitefish in the lake, Drengen in the county Hedmark, saw no changes in the population after heavy fishing (Vagstein 2002; cited in Ugedal et al. 2007).

In 1957, Jensen (1977) initiated a study on the lake, Øvre Heimdalsvatn. During ten years, Jensen examined the density of the trout population, and the effect of heavy fishing. The lake had a very large trout population at the start of the study. Jensen fished intensely through gillnet fishing, resulting in large catches and increased individual growth of the trout (Jensen 1977). The biomass was reduced by half, while individual growth rate amongst the trout increased during the same time (Jensen 1977). Other studies have also concluded that population structure is strongly influenced by fishing (Amundsen 1989; Amundsen et al. 2002; Amundsen et al. 1993; Klemetsen et al. 1989; Klemetsen et al. 2002; Ugedal et al. 2007). Still, this concerns fishing with gillnets and seines. There is a need for more knowledge on how angler impact on fish populations size and structure (Burgin 2017). At very high exploitation even by anglers, the catch may be typically composed of few and small fish (Aas et al. 2000; Brana et al. 1992), and this should be evaluated further to see how angling might contribute in fish population management.

However, not only exploitation may influence a fish population, but also interactions with other fish species. Invasive species are altering many aquatic communities and ecosystems worldwide (Gurevitch & Padilla 2004). The food and growth rate of rainbow trout (*Oncorhynchus mykiss)* in some lakes in British Colombia, changed considerably after introduction of the redside shiner (*Richardsonius balteatus)*, a small cyprinid species (Larkin & Smith 1954). The same type of interactions seem to occur between the native trout and European minnow (*Phonixus phonixus*), hereafter minnows. The expansion of minnows in mountain lakes of southern Norway have increased the last century (Museth et al. 2007). Multiple studies show how the introduction of minnows has affected trout living there, reducing food and habitats available for the trout, as well as recruitment and growth rate (Borgstrøm & Brabrand 1996; Borgstrøm et al. 1996; Bruun 1988; Hesthagen & Sandlund 2004; Museth et al. 2007).

Many studies give insight to fisheries management questions concerning gillnetting and introduced species in high altitude lakes. The questions that arise, are how the trout population in high altitude lakes respond to angling, and how anglers affect local salmonid populations. Almodóvar and Nicola (1998) found no consistent differences in growth, age diversity, mortality and recruitment when evaluating the impact of anglers in a river in central Spain. In mountain rivers in Spain, the trout population living in exploited lakes had individuals growing faster, but consisted of fewer large and old trout, than trout populations living in unexploited rivers (Brana et al. 1992).

I wish to understand better how fishery affects a fish population. Studies of the trout population in the subalpine lake, Øvre Heimdalsvatn, have been performed since 1957 until today, however, until 1992 exploitation of the population was reserved for scientific purposes only. In 1992, the lake was opened for ordinary angling, and at the same time the experimental fishery by gillnets has been limited during the last decades compared to the gillnet effort during the period 1958–1970 (Jensen 1977). Based on the earlier studies outlined above, I here examine the population size and structure of the trout population in Øvre Heimdalsvatn, and register the catch by anglers. The lake is easily accessible from the main road over Valdresflye, and close to the popular tourist destination of Jotunheimen, which suggests that the angler activity may be high, with a possible high impact on the trout population. Angling may thus be an important regulatory factor for a population of trout, which has undergone large changes in recruitment during the last decades.

The aim of this thesis is to investigate the angler impact on the trout population size and structure of trout. I predict that (i) the angler catches of post recruits are high, (ii) causing the survival rate of post recruits to be low, (iii) leading to few old trout present in the population. In addition, (iv) overpopulation will not occur due to the recruitment of trout being low. These predictions are assessed by using data from earlier research in addition to my own, observations and interviews of anglers and population estimates in August 2015 and 2016.

2. Method

2.1 Study site

The lake, Øvre Heimdalsvatn, is my study site. The lake is located in Øystre Slidre municipality, is situated 1,088 m a.s.l., and has a catchment area of 23.6 km^2. The lake surface area is 78 ha (Vik 1978). The length is 3 km, breadth at the widest location is 0.4 km, and maximum depth 13 m (Larsson et al. 1978), while the mean depth is 4.7 m (Lien 1978). The main inlet stream comes from the tarn, Brurskardtjern, at 1,309 m a.s.l. The outflow stream ends up in the lake, Nedre Heimdalsvatn. The bedrock in Øvre Heimdalsvatn is part of the great Caledonian slide complex called "Jotundekkene", and consists mainly of Precambrian, lime poor rocks (Skjeseth & Kloster 1978).

The lake has a long period of ice cover from mid-October to early June, with snow reducing light penetration and plant production in the lake during summer (Jensen 1977; Larsson et al. 1978). Inflowing streams supply the lake with groundwater, and precipitation cause eroded materials to leach into the lake (Grøterud & Kloster 1978). Abundant bushes and trees such as dwarf willow (*Salix* spp.), dwarf birch (*Betula nana)* and mountain birch (*Betula tortuosa)* contribute with allochthonous organic matter (Larsson et al. 1978; Østhagen & Egelie 1978)(Figure 2.2). The bottom substrate consists of some big rocks, gravel, fine sand and mud (Bruun 1988). The biotic factors affects the species living in the lake, alongside abiotic conditions such as temperature rise in spring and spring spate (Larsson & Tangen 1975; Larsson et al. 1978). Historically, the air temperature in Øvre Heimdalsvatn has ranged from around -30 °C during winter to above 20 °C during the summer, with a mean annual temperature at -1.2 °C (Grøterud & Kloster 1978). From January 1, 2015 until December 31, 2016 temperature data recorded by NVE (2017) is given in Figure 2.1. Derived from these data (NVE, 2017), the average temperature was 0.6 °C in June and 9.2 °C in July in 2015. The average air temperature was higher in June and July 2016, being 9.5 °C and 10.3 °C, respectively. August was warmer in 2015 than in 2016, with 18.9 °C the first year and 9.2 the second (Table 2.1).

Table 2.1 Average air temperature in June, July and August in the years 2015 and 2016 at the study cite, Øvre Heimdalsvatn.

Temperature in °C			
Year/Month	June	July	August
2015	0.6	9.2	18.9
2016	9.5	10.3	9.2

Trout and minnows are the only fish species in the lake (Lien 1978). Trout has probably been there for at least thousand years (Vik 1978), while minnows were first observed in the lake in 1969 (Lien 1981). Minnows spawn in June (Museth et al. 2010), while trout spawn in September–October (Jensen 1977).

The ownership of the lake has changed many times, but was transferred from the Ministry of Agriculture to the municipality Øystre Slidre in 1982 (Prop. 88 L (1981–82) 1982). The Øystre Slidre Mountain Board administer the fishery, along with the research management at the Norwegian Natural History Museum. In the lake, Øvre Heimdalsvatn, both angling and gillnetting are performed. Angling is open for everyone, but anglers have to pay a fee, while gillnet fishing in the lake is restricted to scientific projects and some university courses. The catch obtained by the gillnet effort is recorded, while the catches obtained by anglers are not regularly monitored. Reidar Gran does the supervision for the Mountain Board, and he told me April 19, 2017 that the fishery has been a complex matter. According to him, the challenge is to combine the interest of local and visiting anglers, in addition to the research. Angling was allowed in Øvre Heimdalsvatn from 1992 for both local and visiting people. All gillnetting has been done by researchers or under strict monitoring, and catches are recorded. A field station is put up by in the east end of the lake, called *Osbui*, managed by the Norwegian Natural History Museum.

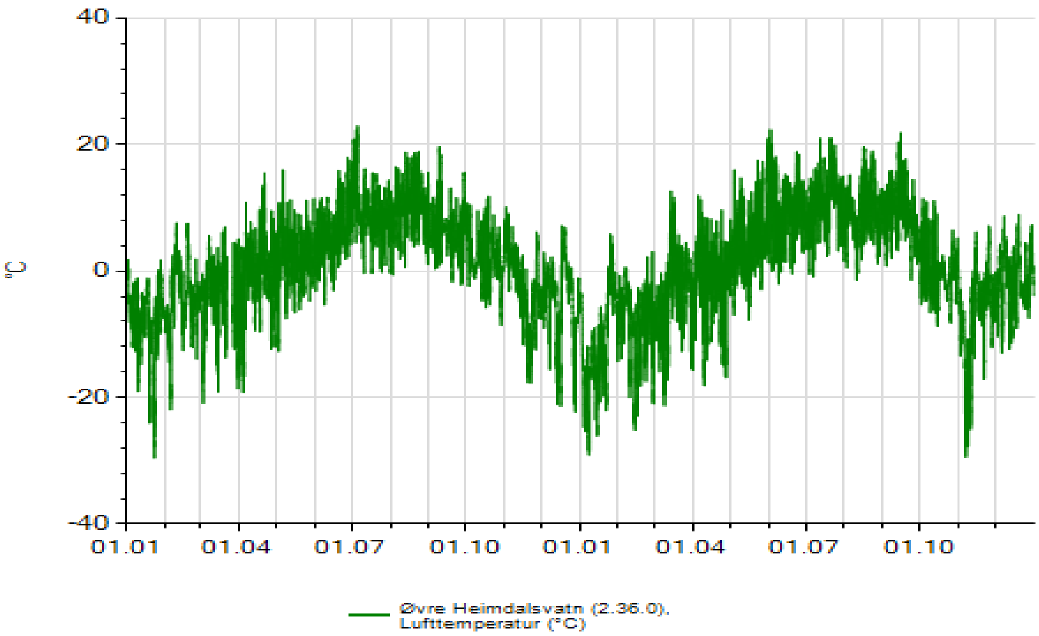

Figure 2.1 Air temperature in °C from Øvre Heimdalsvatn January 1, 2015-December 31, 2016 (Norges vassdrags- og energidirektorat (NVE) 2017).

Today, gillnetting is forbidden for everyone, except for researchers. The comprehensive studies done at the lake makes it an important reference lake (Brittain & Borgstrøm 2010; Vik 1978). There are many long lasting studies in the lake and its catchment; the trout studies conducted by Jensen (1977) from 1957 until 1972, the International Biological Program looking at the entire ecosystem from 1968 until 1974 (Lien 1978; Vik 1978), and the minnow studies of Lien (1981) from 1975 until 1977. In addition to this, there have been multiple studies done in recent times looking at the trout population, the zooplankton community and more. Reidar Gran further told me April 19, 2017 that the local fishery administration has collected angler reports from 1992 until 2013, and that these have been handed on to those conducting research on the lake. The local fishery administration collected angler reports in 2015 and 2016 while my study was conducted.

Anglers can come to the lake by multiple trails in the surrounding mountain area (Figure 2.2). However, there is only one main access point which is a nearby parking lot. This parking lot is a two kilometers walk from the west end of the lake. The mountain board offers a cabin open to anyone visiting the lake, called *Sandbakkbu*. Fishing licenses can be bought at most stores at the closest village Beitostølen, 25 kilometers south of the lake. One can also buy a license by sending a text message or using an application on a mobile phone, or by filling out a form in one of the information boxes put up by the lake. The fishing license can be bought applying for a period of 24 hours, 48 hours, a week or the entire season, and apply to large parts of the municipality Øystre Slidre. There is no phone reception in the valley where the lake, Øvre Heimdalsvatn, is located.

Figure 2.2 The marked hiking trail along the lake, an example of the vegetation on the north side of the lake, Øvre Heimdalsvatn, and in the background, some calves grazing, August 28, 2015 (photo: Marit K. Strand).

2.2 Data collection

Anglers were asked to deliver angler reports during the two seasons of my study. An information board stands by the main access point of the lake, and tells visitors about the latest research done on the lake. Research and increased knowledge about the trout population is meant to encourage anglers to report their catch. The local fishery administration knows who fish in the area due to the mandatory fishing license, but the license covers many different lakes. How many that fishes without a license, the administration knows little about. Gillnet fishing was conducted by a university course and me, but only my own catches were used to estimate the population size, structure and survival rate of trout. My study of the angler impact on the trout population consists of five parts:

1. Observation and interviews
2. Angler reports
3. Gillnetting and gillnet catches
4. Estimation of population size and structure
5. Estimation of survival rate

2.2.1 Observations and interviews of anglers

Collecting data on anglers in the field instead of using a questionnaire sent out by post/email is more efficient when we know little about the anglers and their preferences in advance (Aas & Kaltenborn 1995). Because the fishing license covers multiple lakes, I needed to talk to the anglers in the lake, Øvre Heimdalsvatn in person to be sure that they had been there. To determine the fishing intensity by anglers, I visited the lake from July 7 to August 30, 2015 and from June 22 to August 30, 2016 conducting 20 visits during the first year, and 26 the second year. I registered the number of anglers, their catch as creel stock of fish, and interviewed them about their effort, inspired by the method in the creel survey of Heggenes (1987). I registered my sampling effort in days even though I never stayed at the lake the entire day while sampling. All angling effort observed or registered in interviews were registered in angling days, even though how many hours the different anglers spent angling in the lake, varied from approximately one to eight hours per day. This is to make the estimate of angler effort easier to calculate and compare with angler reports (Attachment 7.3). Catch per unit effort (CPUE) of the units angling days, is denoted as $CPUE_1$.

In order to meet a representative number of anglers, I walked from the access road down the path to the west end of the lake each time I visited the lake (Robson 1961). I used binoculars to spot anglers from various lookout points that covered the entire lake (Figure 2.3). I walked between all the lookout points on each observation day, as recommended by Carlander et al. (1958) and Robson (1961). During my visits, I spoke to everyone I met and interviewed the anglers who agreed to be interviewed.

Before the start of the season, I chose random weekdays and weekends to visit the lake, to obtain random sampling (Robson 1961). Weekdays are defined as Monday–Thursday, and weekends as Friday–Sunday (Table 2.2). To avoid that time of day would affect my results, I visited the lake morning, midday and evening. I stayed for at least 60 minutes each time, ranging from morning at 10:00 until evening at 22:00. I was present in the field 4–13 days each month, which may give reliable estimates for fishing intensity and yield under a randomized sampling design (Heggenes 1987).

Table 2.2 Observation days for the creel survey sampling in the lake, Øvre Heimdalsvatn, the fishing season 2015 and 2016, divided in subsampling groups of weekdays and weekends.

	June		July		August	
Year/Day	Weekdays	Weekends	Weekdays	Weekends	Weekdays	Weekends
2015	0	0	8	2	6	4
2016	2	2	7	6	3	6

During my visits, I interviewed everyone I met who agreed to be interviewed, and that either was going to or already had been angling. I filled out the interview data in a prepared interview form inspired by Heggenes (1987)(Attachment 1). The interview form included questions about their angling effort in relation to number of days they had spent angling in the lake, and their catch (Attachment 7.4). I noted time and place where I met the interviewees, basic information they were willing to give me, and whether they had been there earlier or not. The effort during the different angling days could be anywhere from one to six hours of angling. My questions were close-ended, to avoid interpretation and influence by me (Fowler 1991). I used waterproof paper and a pencil in order to get good notes in all kinds of weather. I had no procedure to approach possible interviewees other than walking to where they were, and telling them about my study. As soon as I had introduced myself as a student wanting to interview them, most anglers were positive to being interviewed.

I noted all the anglers I observed and estimated the total number of anglers *TA* as

$$TA = \frac{AD}{N}$$

Where *A* is number of observed anglers and *D* is the total number of days during that month. *N* are the total number of days I visited the lake. Daily fishing intensity is the average of all angling days observed within the season (Heggenes 1987). The catch per unit effort done by anglers are the number of fish they had caught per day *d*. To get an unbiased estimator of catch rate *CR* of trout, the catch *c* for the complete angling one day *d*, and is denoted

$$CR = \frac{c}{d}$$

This holds true when the anglers interviewed were only evaluated to be a sample of the total number of anglers that visit the lake (Robson 1961). Calculating variability is to detect sources of bias (Lohr 2010). The variation of anglers calculated from my observations is defined as

$$V = \frac{1}{N-1}\sum_{i-1}^{N}(y_i - \bar{y}_U)^2$$

where the standard deviation (SD) is

$$SD = \sqrt{V}$$

and used as a measure of error prevalence (Ricker 1975).

Figure 2.3 A demonstration of how the anglers were spotted using binoculars from the west end of the lake, Øvre heimdalsvatn, August 2, 2016 (photo: Anders S. Sveen).

2.2.2 Angler reports

The local fishery administration that monitor the area, control all angling to make sure the right equipment is used and that anglers have a valid fishing license. They encourage anglers to hand in angler reports after visiting the lake – whether they catch fish or not, to obtain important information necessary to make good management decisions (Connelly et al. 2000) The local fishery administration helped me collect angler reports in 2015 and 2016 while this study was conducted. Earlier studies show that few anglers hand in these reports, and that the quality of the information in them vary (Aas et al. 2000; Hårsaker et al. 2010). When individuals do not submit an angler report, and their characteristics and responses are different from those who do respond, a nonresponse bias occurs (Brown & Wilkins 1978; Connelly et al. 2000). The catch reports from the lake, Øvre Heimdalsvatn, were collected in a box in the west end of the lake, as well as by email. Only one form was handed in by email during the two fishing seasons. The other 19 forms were delivered in the information box close to the parking lot about 2 km from the lake, where the forms were collected by the fishery management and handed on to me. The angler report asked for the name of anglers, their fishing card, address and email, the date, total number of fish caught, the total weight of their catch, and length of each captured fish. Very few anglers filled out everything, but the forms still provided useful complementary information (Attachment 7.5). The angler effort of these reports was registered as angling days (Attachment 7.3). Catch per unit effort (CPUE) of units angling days, was denoted as $CPUE_2$.

2.2.3 Gillnetting and gillnet catches

Both angling and gillnetting obtained trout catches in the lake, Øvre Heimdalsvatn, during the fishing season 2015 and 2016. In addition to my own gillnet fishing, gillnetting has annually been performed four nights by students from NMBU taking part in a university course (NATF100). This university course uses different mesh sizes and sample from all over the lake. They collect and measure all fish to train their skills in collecting these types of data (Steen 2017, pers. comm.). Their catch data have been evaluated in the trout catches, but only my own catch data were used in the population analysis and estimation of population numbers.

I fished during four nights in August 26–30, 2015, and three nights in August 26–29, 2016. The end of August was chosen because Jensen (1977) performed his fishing for population estimation by catch per effort then. My entire gillnet fishing was with the mesh sizes 16.5, 19.5, 22.5, 24, 26, 29, 31, 35, 39 and 45 mm (bar mesh). All gillnets were randomly set in the littoral zone, and spread along both sides of the lake (Attachment 2). The gillnets were set in the evening and lifted the next morning, after about twelve hours in the water (Figure 2.4). Two and two gillnets were put out together in a straight line from the edge and out to the middle of the lake. All fish caught were trout, and I recorded which mesh size they were caught in.

Figure 2.4 Gillnets that are hung to dry after being used once, and before being used again while gillnetting in the lake, Øvre Heimdalsvatn, August 30, 2015 (photo: Marit K. Strand).

2.2.4 Estimation of population size and structure

Estimated size and structure of the trout population was calculated by yearly average catch per unit effort ($CPUE_3$) by my pilot fleet (Jensen 1977; Ricker 1975). The unit effort used is gillnets inspired by the pilot fleet earlier used in the lake, Øvre Heimdalsvatn by Jensen (1977). Jensen (1977) used 24, 26, 28, 30, 32, 34, 36 and 38 mm (bar mesh) in his pilot fleet, with a high capture probability of trout in the age-classes four and older, referred to as post recruits from now on, in the range 20–45 cm, but all these sizes are not possible to get a hold of any longer. The pilot fleet expresses the series of gillnets used to obtain an estimation of the number of trout in the lake in August 2015 and 2016. My pilot fleet of gillnets consisted of the mesh sizes 24, 26, 29, 31 x2, 35 x2, and 39 mm (bar mesh), which captured on approximately the same length classes as the pilot fleet used by Jensen (1972)(Figure 2.5). Each gillnet was 25 meters long and 1.5 meters deep, and made of light grey monofilament nylon. The total gillnet effort in August 2015 was 53 gillnet-nights, during four nights. In August 2016, the total effort was 52 gillnet-nights during three nights (Table 2.3).

I counted the number of fish caught for the different lengths, what lengths of fish the different mesh sizes caught, and how long different age-classes were. Length distribution in the different age-classes was also registered, to investigate increment and potentially stagnation in growth (Borgstrøm et al. 2010). The number of trout caught in each age-class was plotted. Age composition is a part of the population structure that indicate how many of age-class four winters, hereafter referred to as recruits, the population gain each year (Borgstrøm et al. 2010), how old the trout can get in the lake, and how high the fishing pressure is (Jensen 1977). Change in the fish population of number of post recruits, due to angler behavior might affect average fish size (Aas et al. 2000).

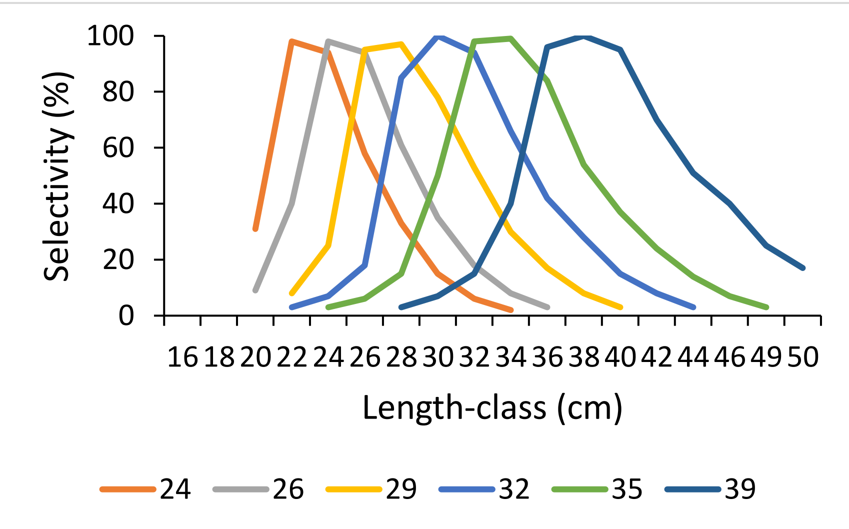

Figure 2.5 Selection values (in %) for nylon gillnets with mesh sizes 24, 26, 29, 32, 35 and 39 mm (knot to knot) according to Jensen (1972).

The fish catches were brought in to the field station *Osbui* for detailed sampling. I registered fish length and weight, and collected multiple scales and the two otoliths, for later age determination (Figure 2.6). Scale samples were taken from the area between the adipose and the back of the dorsal fin, close to the lateral line, as this is where the first scales in trout are formed (Jonsson 1976). However, age estimation was mainly done by reading otoliths, because they give a more accurate measure of age (Power 1978). Each otolith was cut in half, and each half was burned separately before it was studied in a binocular microscope (Christensen 1964). In a few cases, both otoliths were hyaline (unreadable), and in these cases, the scales were used.

I calculated the catch per gillnet-night for each mesh size, and multiplied by ten to get the effort as average per ten gillnet-nights (Jensen 1977). A gillnet-night is one night fishing with a gillnet from my pilot fleet. I used data published by Jensen (1977) concerning $CPUE_3$ in August and number of fish in different age-classes to obtain historical population estimates (Table 2.4). Based on the estimated number done by Jensen, of each age-class the following years, I could determine a regression for the line forming a trend for each different age-class. This is used to estimate the number trout of each age-class in my catches, and to evaluate how the trout population is now compared to when Jensen (1977) conducted his studies. Based on the catches per unit effort by gillnets in my pilot fleet ($CPUE_3$), I plotted the regression models for the relationship between $CPUE_3$ and estimated number in population with data from Jensen (1977). The unknown value x in the regressions is plotted from the $CPUE_3$, meaning the trout caught per ten gillnet-nights on the pilot fleet. R^2 describes how well the regression line fits the real data points, and a R^2-value of zero indicates no correlation, while one is a perfect correlation (Ricker 1975). Standard deviation is calculated using the statistical software R Commander (R Core Team 2016).

Figure 2.6 Example of measuring weight (831 g) and length (42 cm) of a trout caught in the lake, Øvre Heimdalsvatn, August 28, 2015 (photo: Marit K. Strand).

Table 2.3: Gillnet effort (number of gillnets used) of each mesh size 24, 26, 29, 31, 35 and 39 mm during the sampling in August 26–30, 2015 and August 26–29, 2016 in the lake, Øvre Heimdalsvatn.

Year	Date	24 mm	26 mm	29 mm	31 mm	35 mm	39 mm	Total effort (number of gillnets)
2015	26–27/8	2	2	2	4	3	1	14
	27–28/8	2	2	2	4	3	2	15
	28–29/8	2	2	2	2	2	2	12
	29–30/8	2	2	2	2	2	2	12
2016	26–27/8	2	2	2	2	2	2	12
	27–28/8	3	3	3	8	7	3	27
	28–29/8	2	2	2	2	3	2	13

Table 2.4 The catch per unit effort (4w–9w) and estimated number (n4–n9) of trout in age-classes 4, 5, 6, 7, 8 and 9 winters in the lake, Øvre Heimdalsvatn, according to Jensen (1977).

Year	4w	n4	5w	n5	6w	n6	7w	n7	8w	n8	9w	n9
1960	1.77	2387	5.73	2775	6.98	2486	4.06	1511	1.98	959	1.98	496
1961	3.30	3304	2.86	1649	5.18	1765	3.66	1271	2.95	585	1.43	312
1962	2.19	2207	10.3	2149	3.75	928	3.23	724	2.40	394	1.04	145
1963	7.75	4702	3.92	1540	5.42	1168	1.08	401	1.33	389	0.42	98
1964	6.92	5698	8.75	2985	3.37	823	2.60	389	0.67	119	0.10	58
1965	2.86	3983	9.11	3792	3.84	1401	0.89	279	0.54	138	0.00	41
1966	3.16	2536	6.54	2806	6.54	2288	1.25	584	0.15	90	0.07	28
1967	1.48	2127	5.23	1758	5.63	1635	3.83	1013	1.02	232	0.08	38
1968	2.75	2845	3.58	1532	2.50	1052	2.58	729	1.25	301	0.33	44
1969	3.27	3139	3.75	1584	4.42	1355	1.73	478	1.35	179	0.10	32
1970	5.11	4178	7.95	2856	3.52	1000	2.05	586	1.02	204	0.00	47

2.2.5 Estimation of survival rate

Survival rate is calculated from the age composition in the trout population found in the study (Ricker 1975). Based on the assumption that neither fishing, natural mortality nor recruitment, varies much from year to year, the different cohorts can be comparted to estimate the survival rate S, and the mortality rate A (Ricker 1975). The ages representatively sampled was numbered in succession, starting with the recruits, so that successive numbers of fish are N_0, N_1, N_2, etc., and $\sum N$ is the sum all fish. The estimate of Heincke (1913; cited in Ricker 1975) was of the mortality rate A:

$$A = \frac{N_0}{\sum N}$$

When S = 1 – A, the corresponding estimate of survival rate becomes:

$$S = \frac{\sum N - N_0}{\sum N}$$

where N represents the number found of each age, in a representative sample (Ricker 1975). Instantaneous rate of total mortality *Z* is denoted by

$$Z = -log_e S$$

where *S* is the survival rate (Ricker 1975). Based on the estimated number of each age-class of trout, I calculated the $\log_e$ of the total number of each age-class against age, and plotted the catch curve (Ricker 1975). The slope of the curve gives –*Z* (Ricker 1975), and is used to decide total mortality during the two years (Ricker 1975). The mortality rate *A* is calculated using survival rate *S,* by

$$A = 1 - S$$

and further evaluated in my results as a decimal or percentage (Ricker 1975). Statistical analyses were performed using the FSA package in the statistical software R (R Core Team 2016). Control charts are useful in ecological monitoring (Anderson & Thompson 2004). The quality of the estimated mortality and survival during 2015 and 2016, is controlled by computing the upper control limit (UCL) and the lower control limit (LCL). The control limits are chosen so that almost all of the data point will fall within these limits, meaning that the deviation in mortality and survival almost certainly will not exceed the control limits (Anderson & Thompson 2004).

3. Results

3.1 Observations and interviews of anglers

During the two fishing seasons, I conducted eight interviews, registering the catch of 4.2 kg all together. In the fishing season 2015, I only observed and interviewed one angler. He had been angling for two days on a 48 hour fishing license, and captured four trout during one angling day, while catching no trout the second day. The fishing season in 2016 resulted in seven interviews, registering the total effort of nine angling days. An equal number of observations and interviews were conducted in weekdays both 2015 and 2016. I encountered more people on weekends when I increased my sampling effort from six days in 2015 to fourteen days in 2016 (Table 3.1), and also after increasing the number of evening visits in 2016 than in 2015 (Table 3.2). Two of the anglers I met were there one weekday each, while the rest were there during the weekend. Two of the anglers visiting during the weekend had spent two days angling in the lake, while the others spent one day. During a weekend in 2016, I encountered four anglers in a group that were not interested in talking to me, although they confirmed that they were going to angle. In total, I registered one angler spending two days angling in the lake, Øvre Heimdalsvatn, in 2015 and eleven anglers with an effort of thirteen angling days in 2016 (Table 3.3).

The eight anglers I interviewed were all tourists from other municipalities than Øystre Slidre. Seven of the interviewees had visited the lake before, while one was there for the first time. All angled with rod, mostly using lures and spinners. One angler used worms as bate, and one used flies. All anglers were experienced, but not everyone angled frequently. Six of the interviewees were eager to talk and discuss the trout population and angling in Øvre Heimdalsvatn, and they all said they thought few people came here. Five of them had visited the lake before. Those who had been to the lake earlier did not remember much accurate information about their effort and catch. One angler was fishing without a fishing license. The rest of the anglers had a license, whereas three had a license for 24 h, three for 48 h, and one angler had for the entire season. The three anglers with a 48 h license told me they had been angling two days, whereas the rest only spent one day by the lake. Both years there also were hikers in the area, who told me they were not aware of the good angling opportunity in the lake.

Table 3.1 Observations in weekdays and weekends compared to number of registered angling days in the lake, Øvre Heimdalsvatn, during the fishing season 2015 and 2016.

	Weekdays		Weekend	
	Observation days	Registered angling days	Observation days	Registered angling days
2015	14	2	6	0
2016	12	2	14	11

Table 3.2 Number of observation days at the lake, Øvre Heimdalsvatn, either from 1000–1600 hours or from 1600–2200 hours during the fishing season 2015 and 2016.

Time of day	July 2015	August 2015	June 2016	July 2016	August 2016
10–1600 hours	6	5	3	6	5
16–2200 hours	4	5	1	7	4

Table 3.3 Number of observation days at the lake and data on angler effort in angling days according to observations and interviews in the lake, Øvre Heimdalsvatn, during the fishing season 2015 and 2016.

Number of observation days				Angler effort in angling days	
Year/Month	June	July	August	Registered	Interviewed
2015	NA	10	10	2	1
2016	4	13	9	13	7

In June 2015, I did not visit the lake, and therefore have no estimated number of anglers fishing in June this year. In June 2016, however, I visited the lake four times without meeting any anglers and estimate that zero anglers visited the lake June 2016 (Table 3.5). An estimated 6.2 ± 3.4 (SD) anglers visited the lake in July 2015, compared to 28.6 ± 11.0 (SD) in July 2016. In August 2015, I met no anglers, which gave an estimate of zero anglers visiting the lake in total this month, while the estimate for August 2016 is 3.4 ± 2.9 (SD) anglers visiting the lake. According to the standard deviation, the estimated number of anglers visiting the lake may range from zero to forty anglers during the fishing season of 2015 and 2016 (Table 3.4). The interviewees only caught trout.

Estimated catch/effort for anglers is based on fish caught per angling day. My observations from June 2015 give an estimate of no anglers this month, and hence, no fish caught. In July, the catch/effort for the creel survey of anglers ($CPUE_1$) was slightly larger in 2015 than in

2016. Anglers were estimated to catch more fish per effort in July 2016 than in 2015. Still, the average $CPUE_1$ both years varied. The months where I met no anglers, August 2015 and June 2016, give estimates of no catch per effort, due to the effort was zero. The $CPUE_1$-value for July 2015 is less than three trout per angling day, which is the largest catch any of the interviews experienced. July 2016 showed a catch of less than one trout per angling day, while in August 2016 I registered two trout caught per angling day. Estimated catch/effort for anglers I met during the creel survey in August show no angler effort or catch for 2015, while there is an average of one fish per angling day for 2016 (Table 3.5).

Several of the anglers I interviewed were unsuccessful (Table 3.6). Based on the interviews, half of the angling days in 2015 were unsuccessful. In 2016, the interviewed anglers had fished four out of the nine angling days without any catch. The one angler interviewed in August 2016 was successful, giving an estimate of unsuccessful angling days in this month to be zero.

Table 3.4 Estimation of number of anglers with standard deviation (SD) in the lake, Øvre Heimdalsvatn, the fishing season 2015 and 2016.

Year	Month	Observation days	Registered angling days	Average number of anglers	Days in month	Estimated number of anglers ± SD
2015	July	10	2	0,2	31	6.2 ± 3.4
2015	August	10	0	0	31	0 ± 0
2016	June	4	0	0	30	0 ± 0
2016	July	13	12	0,9	31	28.6 ± 11.0
2016	August	9	1	0,1	31	3.4 ± 2.9

Table 3.5 Observation days, registered angling days (effort), interviewed anglers and their catch and catch/effort ($CPUE_1$), and the estimation of the total number of anglers in the lake, Øvre Heimdalsvatn, during June, July and August in 2015 and 2016. The effort of an angler was registered as each day (an angling day) they were day, and all angling days are not necessarily different individuals.

	June					
Year	Observation days	Registered angling days	Interviewed anglers	Estimated number of anglers	Total catch	$CPUE_1$
2016	4	0	0	0	0	0
	July					
	Observation days	Registered angling days	Interviewed anglers	Estimated number of anglers	Total catch	$CPUE_1$
2015	10	2	1	6	4	2.5
2016	13	12	6	29	11	0.9
	August					
	Observation days	Registered angling days	Interviewed anglers	Estimated number of anglers	Total catch	$CPUE_1$
2015	10	0	0	0	0	0
2016	9	1	1	3	2	2.0

Table 3.6 Frequency of unsuccessful angling days based on interviews made in the lake, Øvre Heimdalsvatn, in the fishing season 2015 and 2016.

	June	July	August
2015	NA	50 %	0 %
2016	0 %	44 %	0 %

3.2 Angler reports

In total, there were 20 reports documenting 27 angling days with a total catch of 83 trout. The average catch according to the angler reports is approximately three trout per angling day ($CPUE_2$), based on all catch and effort reported from the fishing season 2015 and 2016 (Table 3.7). The largest number of trout caught was reported in July in both years, where 22 trout were caught in 2015 and 37 in 2016. These catches increase the average catch per effort, because catches in September and October were only one and two trout per angling day ($CPUE_2$). The angler reports show that seven different anglers spent ten days fishing in the lake, Øvre Heimdalsvatn, during 2015, catching a total of 28 trout weighing 9.1 kg all together. In 2016, twelve angler reports were registered from eleven different anglers, catching 55 trout with total weight 15.1 kg, during the total effort of 17 angling days. The total catch per angling day is approximately 900 g. Three angler reports were submitted without including the weight seven trout caught. The weight of these seven fish are included in the results, as the average weight of all other trout in the angler catches, i.e. 280 g (Table 3.8).

One angler that caught 22 trout with a total weight of 5.0 kg for July 30, 2016 had the largest reported catch. This angler also reported meeting another angler catching thirteen trout, who did not intend to hand in an angler report. The second largest catch was 10 trout weighing 3.0 kg all together, caught July 9, 2015, due to this unknown angler not submitting an angler report. According to the reports from 2015, no fish was captured in 2/10 angling days, while in 2016, 3/17 angling days were reported without any catch. Thus, anglers reported that 13 % of the angling days spent by Øvre Heimdalsvatn in July both in 2015 and 2016, 20 % of the angling days in August 2016, and 33 % of the angling days in September 2016 were without any catch. All angler reported from August 2015 and October 2016 indicate that the angling days spent by the lake resulted in trout catches. No angler reports were handed in during September and October 2015 (Table 3.9). The anglers did not report catching any other species than trout.

Table 3.7 Reported angler effort in angling days, total catch and estimated catch/effort ($CPUE_2$) based on the angler reports ($CPUE_2$) in the lake, Øvre Heimdalsvatn, during the fishing season 2015 and 2016. The effort of an angling day might not be different individuals, but are all different days.

	July		
Year	Reported angling days	Total catch	$CPUE_2$
2015	8	22	3
2016	8	37	5
	August		
	Reported angling days	Total catch	$CPUE_2$
2015	2	6	3
2016	5	12	2
	September		
	Reported angling days	Total catch	$CPUE_2$
2016	3	4	1
	October		
	Reported angling days	Total catch	$CPUE_2$
2016	1	2	2

Table 3.8 Reported angler effort and catch in the lake, Øvre Heimdalsvatn, during the fishing season 2015 and 2016.

Year	Number of anglers	Reported angling days	Reported number of fish caught	Reported catch (kg)	Average number of fish caught per angling day	Catch per angling day (kg)
2015	8	10	28	9.1	3 ± 1.74	0.9
2016	12	17	55	15.1	3 ± 5.31	0.9

Table 3.9 Frequency of unsuccessful angling days based on angler reports in the lake, Øvre Heimdalsvatn, during the fishing season 2015 and 2016.

Year/Month	July	August	September	October
2015	13 %	0 %	NA	NA
2016	13 %	20 %	33 %	0 %

3.3 Gillnetting and gillnet catches

During both the fishing season of 2015 and 2016, the students from NMBU fished in the lake with an effort of 40 gillnet-nights. They reported a catch of 239 fish with a total weight of 30.9 kg and 170 fish weighing all together 32.3 kg in 2015 and 2016, respectively. My own catch on the pilot fleet in 2015 consisted of 140 trout weighing 39.7 kg, while in 2016 the total catch was 126 trout weighing 39.9 kg. In addition to this, I caught 113 trout weighing 10.5 kg on other mesh sizes than the pilot fleet in 2015. The total catch by gillnetting was accordingly 81.1 kg in 2015 and 72.2 kg in 2016 (Table 3.10).

Table 3.10 Total catch by gillnetting in the lake, Øvre Heimdalsvatn, during 2015 and 2016.

	Own gillnetting			NMBU gillnetting		
Year	Gillnet-nights	Number of fish caught	Weight of fish caught (kg)	Gillnet-nights	Number of fish caught	Weight of fish caught (kg)
2015	53	253	50.2	40	239	30.9
2016	52	126	39.9	25	170	32.3

3.4 Estimation of population size and structure

The estimation of the trout population indicate that there were almost 8,000 fish in 2015 and 7,300 in 2016 being post recruits. The length distribution range between 17–46 cm long trout. Captured fish on the pilot fleet were in the length range 19–44 cm in 2015 and in the range 17–46 cm in 2016. Both few fish below 20 cm and above 40 cm, were caught in the gillnet fishing during the two years of my study (Figure 3.1).

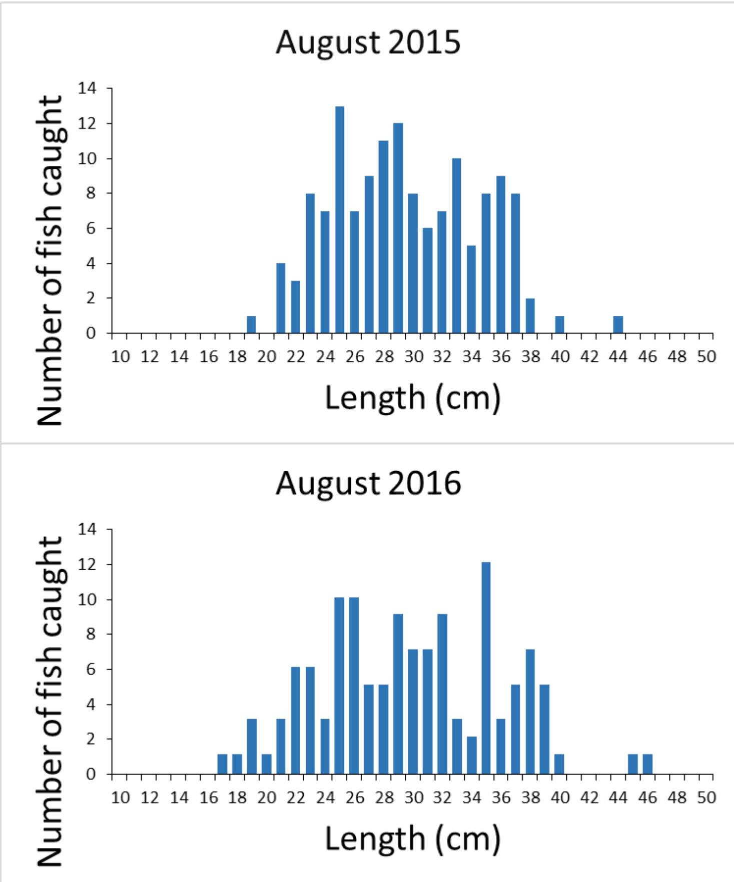

Figure 3.5 Length distribution of trout caught by the pilot fleet in the lake, Øvre Heimdalsvatn, in August 2015 and August 2016.

The length distribution of trout captured on each mesh size in the pilot fleet in 2015 clearly demonstrate that the length interval of captured fish increase with increase in mesh size from 24 to 39 mm. However, the number captured on mesh size 39 mm was very few (Figure 3.2).

Gillnets with 24 mm mesh size caught trout in the length range 21–33 cm, with average length 25 cm. Mesh size 26 mm caught fish with the average length of 29 cm (ranging between 22–37 cm). The mesh size 29 mm caught fish at average length 33 cm (ranging from 27–37 cm). Gillnets of 31 mm captured fish in the range 19–38 cm long fish, but in mostly 32 cm. Gillnets of mesh sizes 35 and 39 mm captured fish with average lengths 33 and 39 cm (in the range 23–49 cm and 37–44 cm), and had less catch than the other mesh sizes (Figure 3.2).

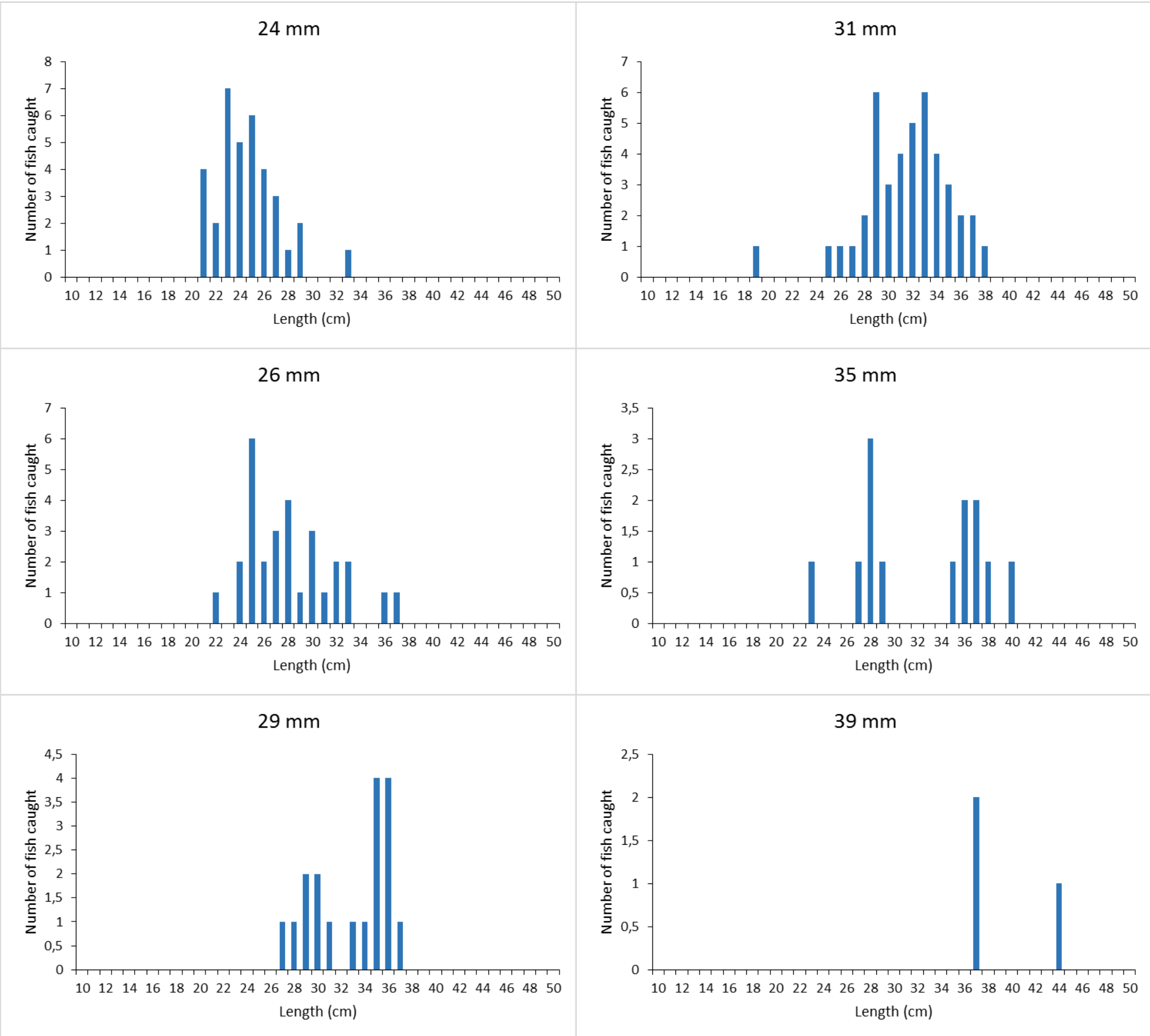

Figure 3.2 Length distribution of total catch on the pilot fleet consisting of mesh sizes 24, 26, 29, 31, 35, and 39 mm used in the lake, Øvre Heimdalsvatn, during the period August 26–30 in 2015.

The catches on the pilot fleet in 2016 show a similar length distribution as the 2015-catches, where the lengths of captured fish increase with increasing mesh sizes. Gillnets of 24 mm caught trout with average length 24 cm (ranging 18–28 cm). For 26 and 29 mm, the catches were averagely trout of 29 cm (ranging from 22–37 cm and 19–39 cm, respectively). The mesh size 31 mm caught fish with average length 33 cm (ranging 17–47 cm). The gillnets of mesh sizes 35 and 39 mm caught more fish in 2016 than in 2015, with average sizes of 34 and 36 cm, (in the range 19–39 mm and 19–46 cm) respectively. Fewer fish were caught by the largest mesh sizes than the other mesh sizes, also this year (Figure 3.3).

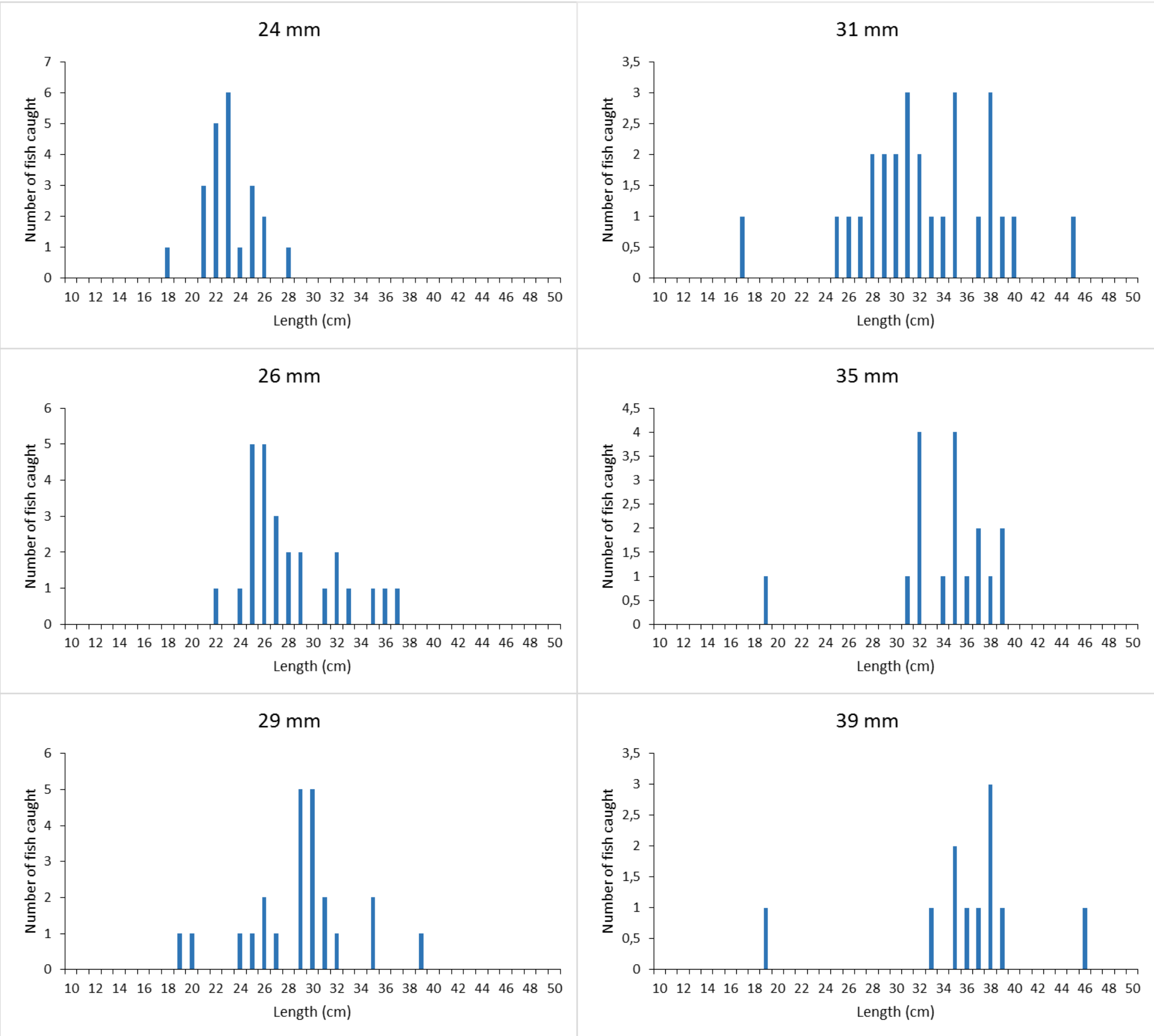

Figure 3.3 Length distribution in cm of total catch on the pilot fleet consisting of mesh sizes 24, 26, 29, 31, 35, and 39 mm used in the lake, Øvre Heimdalsvatn, during the period August 26–29 in 2016.

The trout captured by the pilot fleet in 2015 and 2016 show large variations in length at any given age. For example, fish with age eight winters vary in length between 24 and 44 cm, and in the age-classes seven–nine winters, some fish have much larger length than the majority within these age-classes. Average length of each age-class indicate a stagnation in length from the age of eleven winters, with mean length at the age-classes 11–16, but some vary (Figure 3.4). Compared to length at age four–ten winters in 1958, the corresponding lengths are much larger in 2015–2016, but lower than in 1966, at least for fish older than six winters (Figure 3.5). However, in age-classes seven–nine winters, some individuals caught in 2015–2016 are larger than the mean length at age of the age-classes caught in 1966.

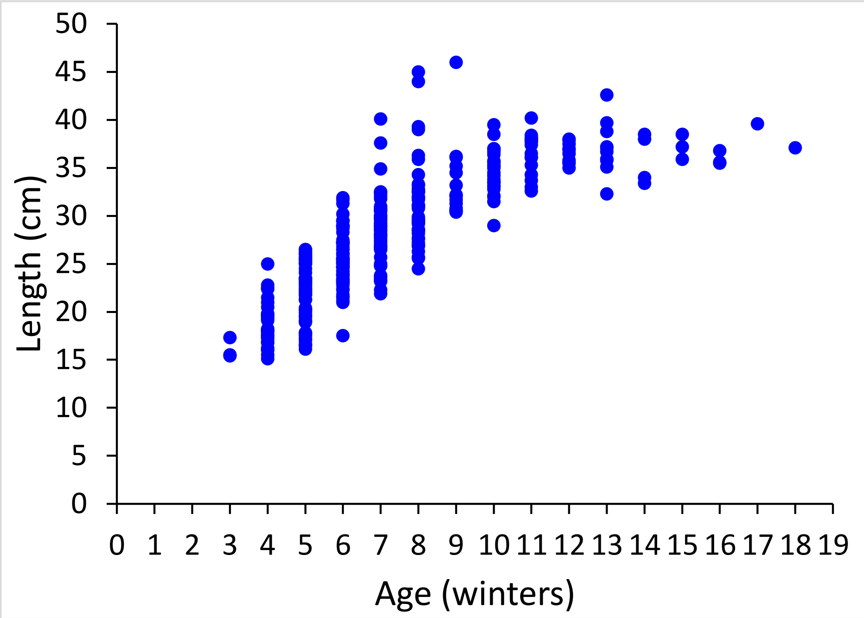

Figure 3.4 Mean length at age of trout captured in the lake, Øvre Heimdalsvatn, in 1958 and 1966 (Jensen 1977), and captured on the pilot fleet in 2015–2016 (own data).

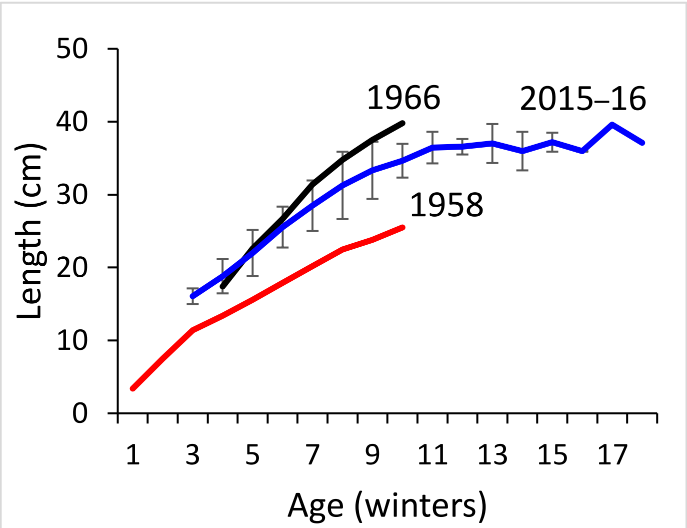

Figure 3.5 Length at age for individual fish captured by the pilot fleet in the lake, Øvre Heimdalsvatn, in August 2015 and 2016, and data for length at age in 1958 and 1966 from Jensen (1977). Vertical lines indicate standard deviation of the mean values.

The age distribution of the trout caught by the pilot fleet show that the six and seven winter old trout dominate the 2015 catches, and that this corresponds to a large number of seven and eight winter old trout in the 2016 catches. After the age of eight winters, the number of trout in the older age classes decrease in both years. The youngest fish caught on the pilot fleet was a three winter old trout captured in a 31 mm mesh size gillnet. The oldest trout was eighteen winters, and was caught in a 39 mm mesh size gillnet. A relatively high number of old fish were captured both years (Figure 3.6).

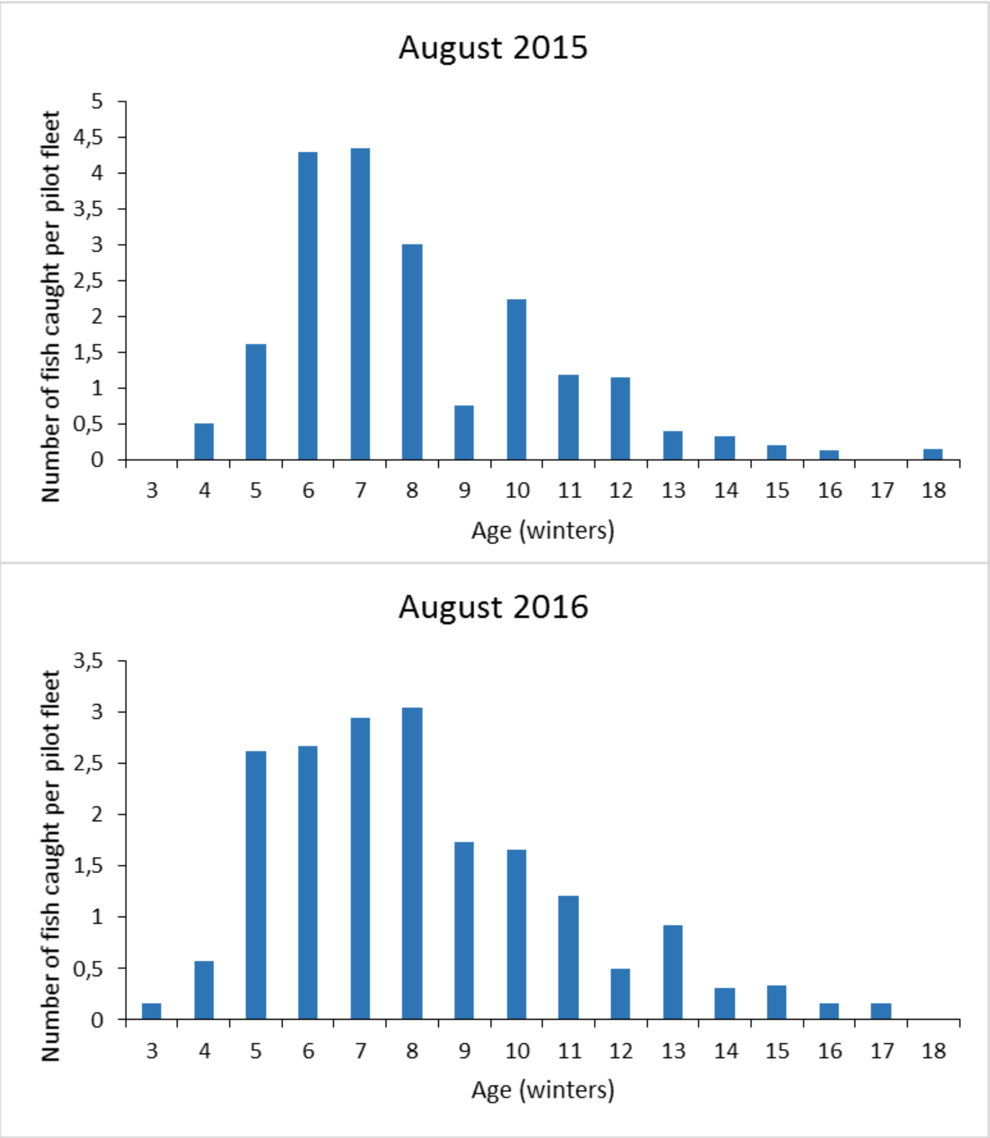

Figure 3.6 Age distribution in winters of trout caught on the pilot fleet used in the lake, Øvre Heimdalsvatn, during the fishing season of 2015 and 2016.

Comparing my estimated numbers in each age-class from four to nine years in 2015 and 2016 with the estimates given by Jensen (1977), reveal that the numbers in age-class four and five are in the lower end, and numbers in age-classes seven, eight and nine are in the upper end of the numbers (Figure 3.7). For fish older than nine winters, the regression model for age-class nine winters has been used, giving a total number of fish in age-classes older than 10 winters of 1,652 and 1,521, in 2015 and 2016, respectively. The total estimated number of recruits in 2015 was thus 9,590 in 2015 and 8,779 in 2016.

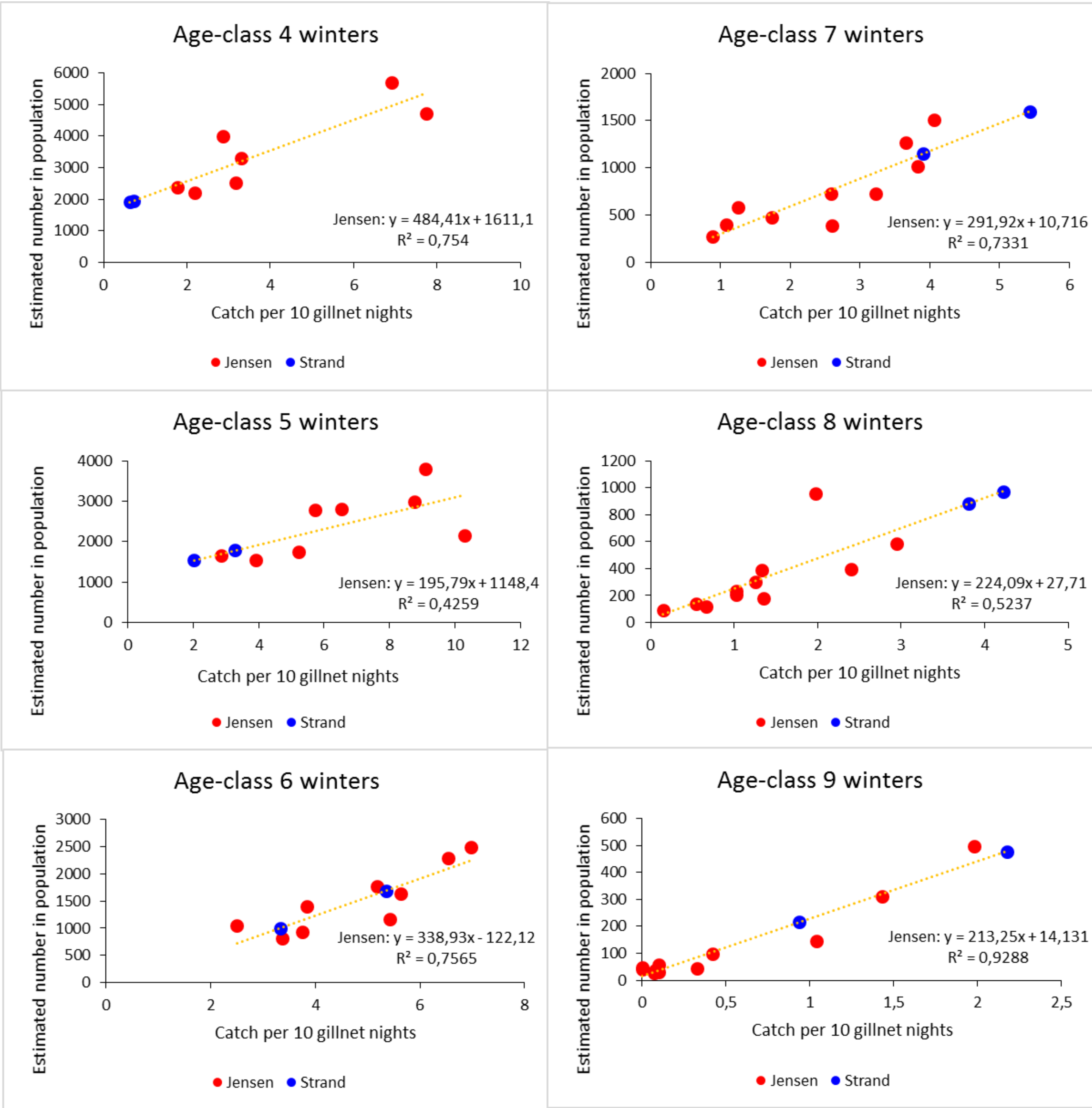

Figure 3.7 Estimated number of trout in age-classes 4 winters, 5 winters, 6 winters, 7 winters, 8 winters and 9 winters in the lake, Øvre Heimdalsvatn, based on $CPUE_3$ by my own pilot fleet August 26–30, 2015 and August 26–29, 2016 (blue dots), and $CPUE_3$ and corresponding number in population in the years 1960–70 (Jensen 1977)(red dots). A yellow line marks the regression for the trend in the 1960–70 data.

Based on these regressions, the recruits are the most numerous in 2015 and 2016, with a clear declining trend in number fish by increasing age in both years, even though the size of the age-classes seem to vary. Fish up to the age of 17 and 18 years were captured (Figure 3.8).

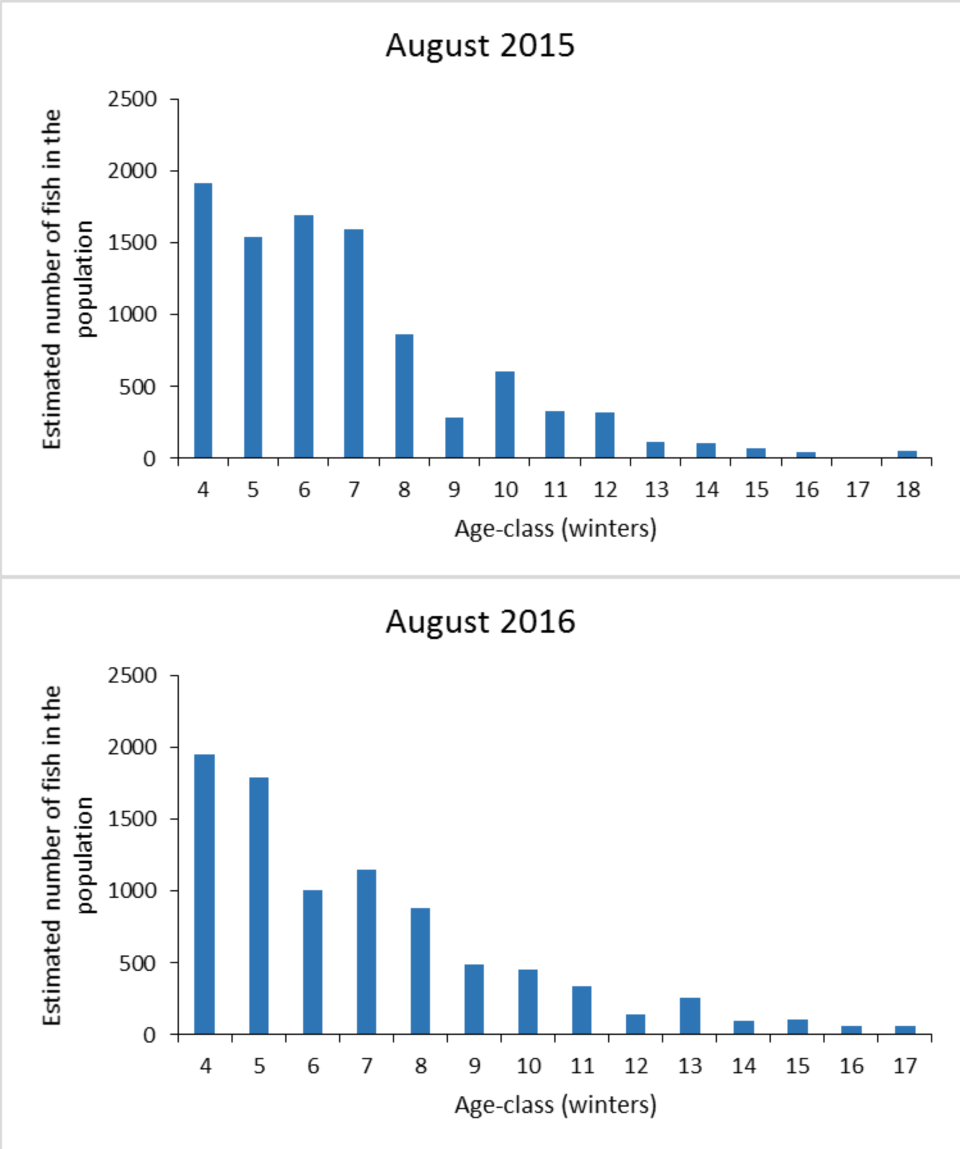

Figure 3.8 Estimated number of trout in each age-class based on catches by my pilot fleet in the lake, Øvre Heimdalsvatn, in the fishing season 2015 and 2016, and the regression models obtained from data in Jensen (1977).

3.5 Estimation of survival rate

The regression between age and estimated number (ln) gives an instantaneous rate of mortality, approximately being Z = 0.30 and Z = 0.29 for 2015 and 2016, respectively. These instantaneous mortality rates correspond to annual survival rates (S) at approximately 0.74 and 0.75, i.e., an annual survival of around 74–75 %. (Figure 3.9). Lower control limit (LCL) and upper control limit (UCL) show that there is no significant difference for the instantaneous mortality rates (Z) in 2015 and 2016 because they overlap (Table 3.11).

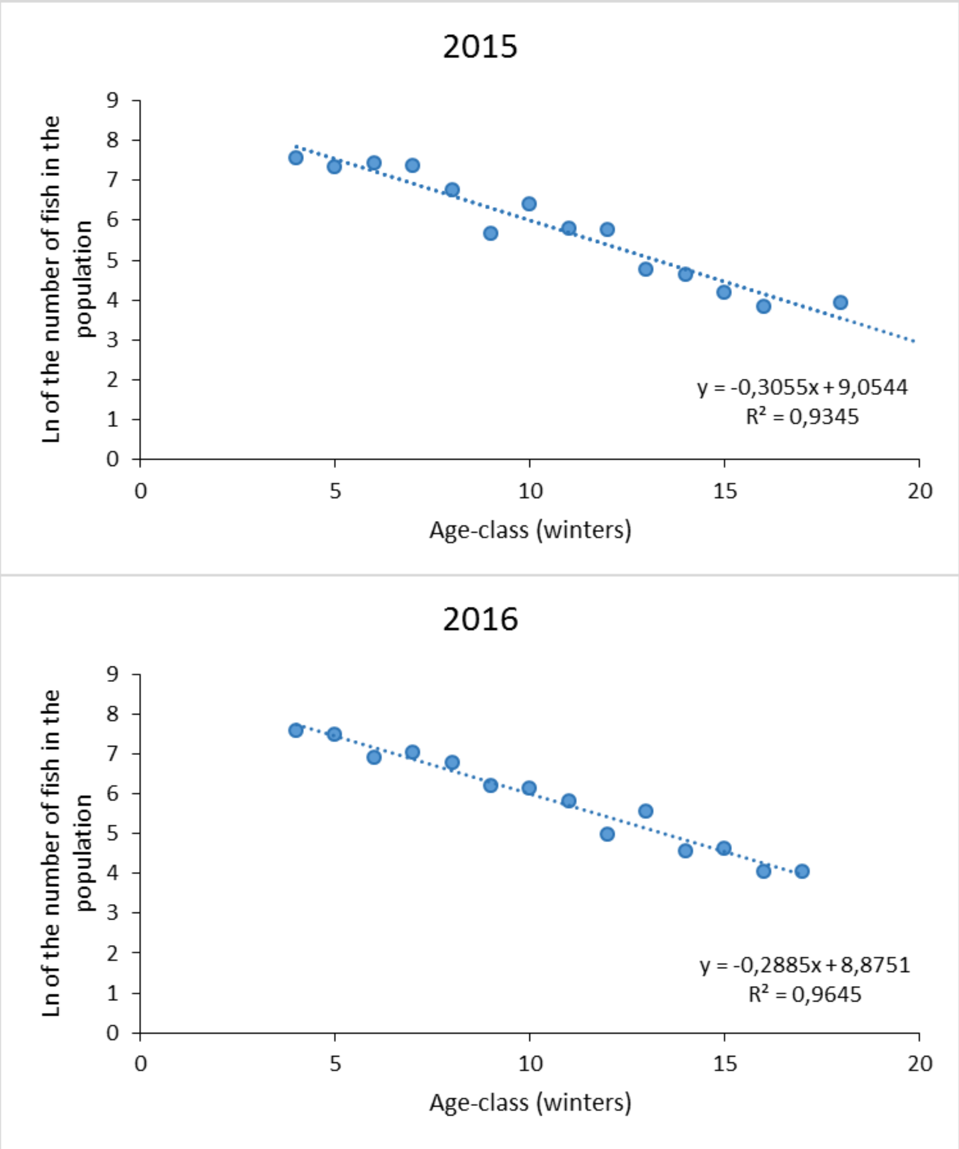

Figure 3.9 Estimated survival of trout in the lake, Øvre Heimdalsvatn, based on catches on the pilot fleet in the fishing season 2015 and 2016 plotted as a catch curve.

Table 3.11 Estimated rate of total mortality (Z) and survival (S) of trout in the lake, Øvre Heimdalsvatn, based on catches on the pilot fleet in the fishing season 2015 and 2016. Lower control limit (LCL) and upper control limit (UCL) limit exceeding events.

	Z			S		
	Estimation	LCL	UCL	Estimation	LCL	UCL
2015	0.30	0.25	0.36	73.73	69.54	78.17
2016	0.29	0.25	0.32	74.95	72.38	77.62

4. Discussion

Based on the predictions made in the introduction, I found that (i) the catches by anglers as well as total gillnet catches are low in the lake, Øvre Heimdalsvatn. Due to the low exploitation by both gillnetting and anglers in 2015 and 2016, (ii) my estimated survival rate is considerably higher than it was in 1960–70 when Jensen (1977) conducted his studies. In the gillnet catches from 2015 and 2016, (iii) there was a larger proportion of old fish than during the period 1960–1970. Only the prediction that (iv) the trout stock is not overpopulated, is strengthened. This is most likely due to the much lower recruitment today than during the period 1960–70, as also found by earlier studies in the lake (Borgstrøm et al. 1996; Borgstrøm et al. 2010). The catches from both anglers and gillnetting are small, compared to what Jensen (1977) assumed to be a sustainable, annual harvest from the lake.

4.1 Catch by anglers

Angler effort and catch of trout in the lake, Øvre Heimdalsvatn, seems to be low. To reduce the bias, I evaluated the findings in the observations and interviews along with the angler reports. In total, 27 angling days were reported and I observed no more than 15 different angling days as angler effort, during 46 visits to the lake. A similar creel survey conducted by Heggenes (1987) in the rivers Tinnelva, Lågen and Glomma with low angler effort, had an annual sampling effort ranging from 18 to 46 visits resulting in no less than 113 anglers interviewed and 179 anglers observed during the years 1978–1984. This might indicate that the fishing intensity in Øvre Heimdalsvatn is extremely low. Other studies found that angler catches are larger than expected in recreational fisheries (Andersson 2016; Lewin et al. 2006; Post et al. 2002), but my results indicate the opposite for this lake, although the lake is easily accessible from the main road over the Valdresflye. The consistency of the effort of anglers may give a sampling error or variation in data, but my high number of visits to the lake should reduce this (Heggenes 1987; Malvestuto et al. 1978).

Studies conducted over multiple years may need to be as equal as possible each year to reduce bias in the results. Comparing my investigations from the fishing season 2015 and 2016 should be unbiased because the surrounding conditions for handing in an angler report was the same both years and neither the information to the anglers nor any fishing regulations changed. Still, comparing the two years is challenging when the timing of my visits and observations varied between the years, even though I visited the lake on random days to ensure a representative estimate of the angling effort.

Fishery managers should be more aware of the angling experience and angler satisfaction (Aas & Kaltenborn 1995). Average temperature for June–July in 2015 was much lower than June–July in 2016, and there were more anglers visiting the lake, Øvre Heimdalsvatn, in 2016 than in 2015 according to both observations, interviews and angler reports. Air temperature and weather conditions might therefore have reduced the motivation for anglers to visit the mountain lake during the summer 2015. The low number of angler reports support this conclusion.

Aas and Kaltenborn (1995) found that catching fish is the most important motivation for anglers. Accordingly, several of the anglers in the lake did not catch fish at all. Anglers with high catch orientation are less satisfied on their fishing trips in general, while tourist anglers are less concerned about their catch (Aas & Kaltenborn 1995). Tourist anglers are more satisfied with their fishing trips. Based on both interviews and angler reports, all anglers were from municipalities far away. Expectations of catching small trout in Norwegian lakes are common (Ugedal et al. 2007), and this might keep anglers from going to the lake, Øvre Heimdalsvatn. Catch per effort based in the interviews and the angler reports ($CPUE_1$ and $CPUE_2$) show a greater success in July than during the other months, which have approximately similar degree of success. A varying angling effort is expected during the fishing season (Heggenes 1987; Hårsaker et al. 2010), but higher trout catches in July support the fact that these anglers are more motivated to visit, and potentially return, than anglers visiting during the other months. Still, how long anglers visit affect the probability of me interviewing them (Robson 1961), and anglers visiting during their holiday probably spend more time than other anglers. Aas (1992) found that time is an important inhibitor to fishing or increased fishing activity. Never the less, the anglers visiting might be motivated by stress release and the experience of nature (Aas & Kaltenborn 1995). Øvre Heimdalsvatn is located in a beautiful mountain area (Figure 5.1).

The preferences of local and visiting anglers are different (Aas & Skurdal 1996). The fact that most anglers at the lake, Øvre Heimdalsvatn, are tourists, is supported by the findings of Aas (1995), that most angle while on holiday. The absence of local anglers in my results from the lake might also be due to the fact that local anglers are allowed to fish with gillnets and other fishing equipment in nearby lakes in the municipality with the same fishing license (Gran 2017, pers. comm.). Either way, far more anglers probably go there than what angler reports indicate (Aas 1995). Unsatisfied anglers are less likely to return, and the fishing intensity might be reduced after a while (Aas & Kaltenborn, 1995).

Estimated catch/effort for anglers based on fish caught per angling day is not very precise, when the hours spent angling is not included in the estimation. Heggenes (1987) used angler-hours and angler-hour per hectare as measure for the fishing intensity, but the rivers in his study had a higher fishing intensity, giving more observations and interviews. Linløkken (1995) also evaluated angler effort in two inland rivers, by registering angling effort in hours, and how many hours spent angling. With the small amount of data from the lake, Øvre Heimdalsvatn, the results are more consistent when the measuring unit is days, due to the angler reports not containing information about time spent angling. Heggenes (1987) found that more anglers visit during the weekends, and that short trips are generally under-sampled. Robson (1961) and Aas and Kaltenborn (1995) found that the probability of interviewing anglers depended on their efforts in terms of how many hours or days spent angling. More anglers observed and interviewed during the weekend than during the weekdays, might indicate that more anglers visit in weekends, but also that they spend more time than anglers visiting in the weekdays (Aas 1992). Whether it is worth the effort to sample outside July and August is a matter of consideration. There is a need for unrealistic high numbers of visits to meet anglers visiting outside these months, when the number of anglers are so low. Until better sampling methods are found, we need to accept some imprecision for the estimated catch by anglers outside the peak season (Heggenes 1987), lasting from July to August in Øvre Heimdalsvatn.

Angler motivation to answer interviews and submit angler reports are low. Both my interview form and the angler report form consists of close-ended questions, such that the interviews were relatively easy to conduct, and the angler reports should have been relatively easy to answer without me interpreting the answers (Fowler 1991). Nevertheless, some interviewees and anglers did not wish to answer all my questions, nor fill out the entire angler report. This could be a consequence of recall bias (Andersson 2016), or because they did not wish to answer. I added some extra open ended questions, when collecting information from interviewees that were more talkative. Some anglers also made more notes on their reports than what the angler report form asked for. In general, the interview form and the angler report form should have had more room for information. The angler report should have asked for how much time each angler spent by the lake as a similar study conducted by Linløkken (1995), and if they wished to add any other information. More questions on the visiting anglers' knowledge about the lake, and how they experienced it, would give more information for the fishery administration, given that the goal is to obtain more anglers visiting the lake (Aas & Kaltenborn 1995). Respondents might be more motivated to angle than others, and are interested in contributing to the studies conducted on the lake (Brown & Wilkins 1978).

Thus, more catches in the reports can be both because successful anglers are more motivated to answer and because the anglers overestimate their catches.

Nonresponse bias influence how accurate fishing reports are (Brown & Wilkins 1978; Connelly et al. 2000). As seven out of eight interviewees did not hand in a report, there are likely many non-respondents. Even though some of my sampling days coincide with days angler reports were handed in, only one angler agreed to be interviewed also handed in a report. Anglers are probably less motivated to hand in an angler report after being interviewed, because they might assume that their information is then registered. All interviews were conducted after the anglers had finished their angling, eliminating the major weakness of a creel census, when information from incomplete trips are used to estimate effort and catch (Robson 1961). Nonresponse bias also creates a challenge for obtaining an accurate estimate of fishing intensity (Brown & Wilkins 1978; Connelly et al. 2000).

The estimated number of anglers is a simple calculation that may give a rough estimate of the angler activities and catches. The estimate of six anglers visiting the lake in July 2015 seems low, compared to the estimate for July 2016 with 29 anglers. Still, the high standard deviation for July 2016 estimates makes this the least accurate estimate. Compared to the angler reports, indicating that eight angling days were spent by the lake each year, may suggest that the variation in visits are not as high as my estimates suggest. The low number of angler reports and observations of anglers, however, indicates that the fishing intensity is low and inconsistent (Heggenes 1987). The number of angler reports are higher than the estimated number of anglers visiting the lake all months studied, except for July 2016. How many non-respondents there are, and how many fish they catch, is hard to estimate, but they likely catch less fish than the respondents (Brown & Wilkins 1978). This might imply that the catch per unit effort estimated by angler reports is too high. However, most angler reports are anonymous, and the motivation for reporting any other fish size and number than the actual catch should not be present.

To investigate the angler preferences further, sending out questionnaires to the anglers that handed in the registration form in Øvre Heimdalsvatn might be a good idea (Andersson 2016; Linløkken 1995). A study conducted in the inland watercourse, Femund, where a questionnaire was sent out to 950 random anglers by email, gave a response rate of 58% (Aas et al. 2000). Based on my estimates, I only encountered 30–40 % of the anglers visiting the lake. However, this would also cause biased reports of angling success, as contact information would not be registered for all of them. Conducting a telephone survey to local anglers might contribute to the knowledge on their angling effort (Aas 1992). Furthermore, management efforts to achieve larger fish might also be an alternative to increase fishing intensity (Aas et al. 2000). Still, large trout catches might be more easily obtained in a lake with low fishing pressure. In long term, more angling can result in more large trout, as found by Almodóvar and Nicola (1998).

Despite my prediction (i) that the angler catches was high, they are just the opposite. Angler effort and catches are far lower than predicted, and most likely do not regulate the trout population size and structure.

4.2 Estimation of population size and structure

The annual gillnet catches seem to be far lower than what Jensen (1977) expected to be a sustainable catch. The total annual catches were less than 100 kg during a total of 185 gillnet-nights all together, in both 2015 and 2016. Jensen (1977) simulated that mesh size 32 mm would give the highest sustainable yield. With a yearly effort of 1,600 gillnet-nights using this mesh size, he predicted the sustained yield to be 5.7 kg/ha of trout with mean weight 269 g. Despite the low harvest in the last years, the mean weights of captured fish on the pilot fleet was of approximately the same size as in the study conducted by Jensen (1977), i.e., 283 and 316 g in 2015 and 2016, respectively. Large fishing intensity may determine the trout density (Burgin 2017), but this seems not to be the case in the lake, Øvre Heimdalsvatn. In Finmark County, the lake, Stuorajavri, a stock reduction program was initiated to reduce the density of the whitefish population (Amundsen 1989; Klemetsen et al. 1989). After a period of negligible exploitation, the whitefish population gradually returned towards the size and structure before stock removal (Amundsen et al. 2002). The trout population in the lake investigated in my thesis seems to be of similar size and structure, as after the stock reduction of Jensen (1977), even after decreased exploitation.

Students from the university course (NATF100) have visited the lake annually for several years and gillnetted with the same fishing effort, and therefore have exposed the trout population for the same fishing pressure for many years. Catch by researchers vary more (Borgstrøm et al. 2010), but the annual catches seem to be much lower compared to the annual yield obtained by Jensen (1977). The catch of more big fish might indicate increased individual growth, despite the low angling effort. Just as in Takvatn in Troms County (Amundsen 1989; Amundsen et al. 1993), the stock removal in Øvre Heimdalsvatn seem to have caused long-term effects.

As predicted in the introduction, (iv) the trout population is not over-populated. The fishery, consisting of angling and gillnetting, most likely do not regulate the trout population size and structure. Other studies concluding that anglers help reduce trout density (Brana et al. 1992; Burgin 2017; Dahl 1917; Lewin et al. 2006; Post et al. 2002; Venturelli et al. 2016) are not supported by my findings in Øvre Heimdalsvatn, because the catches both by gillnetting and anglers are low.

4.3 Change in trout population

Based on the catches by the pilot fleet, the population size and structure in Øvre Heimdalsvatn seem to have changed since the studies conducted in the 1960's (Jensen 1977). The average estimated size of the trout population of post recruits during the two years of my study, was 7,600 trout. Jensen (1977) reduced the biomass by about 50 %, resulting in a reduction from 19.5 kg in 1958, to approximately 8.2 kg in 1963. The number of post recruits in 1963 was still approximately the same as in 2015–2016, with about 8,160 individuals.

After precise calculation, Jensen (1972) found that his pilot fleet would catch a representative number of trout in the catchable age-classes, from the post recruits. The mesh sizes in my pilot fleet differed from the pilot fleet of Jensen (1977). There is an overlap in the selection values between mesh sizes of related sizes, which might imply that my estimates will not give a large deviation to the estimates from 1960–1970 (Jensen 1977). The smallest mesh sizes, 24 and 26 mm, are the same in both pilot fleets, and thus, the number of small fish caught should correspond. These results indicate what Jensen (1977) also presented as a scenario: Low recruitment would increase the mean size in the catch, but the catches would decrease substantially.

The reduction of high density fish population can cause increased individual growth (Amundsen et al. 1993; Dahl 1917), and hence, give fish that generally are more attractive for anglers. Approximately half of the trout population in the post recruits are at least 30 cm in length today. My results differ from the results in 1958, the population density was high with individuals stagnating in growth at lengths below 30 cm (Borgstrøm et al. 2010; Jensen 1977). Results from the lake, Takvatn, in Troms county showed a similar outcome, where both growth in Arctic charr (*Salvelinus alpinus*) and trout improved when the charr density decreased due to a high fishing pressure, and large fish of both species appeared in the catches (Klemetsen et al. 2002). After the charr population in Takvatn was reduced in numbers, fish which previously had low individual growth might have increased their food consumption (Amundsen 1989), and thereby also increased their growth rate.

The recruitment is lower today than when Jensen (1977) conducted his studies. The number of trout recruits was estimated to be 1,916 in 2015 and 1,955 in 2016, with a mean of 1,935 trout, compared to a mean number of 3,746 for the years 1958–1966 (Jensen 1977). The larger amount of old and big trout opens for regulations of the trout populations internally because the bigger trout may predate young ones (Borgstrøm & Brabrand 1996; Borgstrøm et al. 2010; Klemetsen et al. 2002). However, not only exploitation may influence a fish population, but also interactions with other fish species, as in the study conducted by Larkin and Smith (1954). The minnows are likely causing increased competition and reduced trout recruitment (Borgstrøm et al. 1996; Borgstrøm et al. 2010; Bruun 1988), due to both minnows and young trout occupy the most shallow parts of the littoral zone in the lake, and to a large extent utilize the same food resources (Museth et al. 2010). A large minnow population may therefore force the juvenile trout to leave the refuges in the shallow, stony part of the littoral and thus expose themselves for predation. The increased minnow population gives reason to believe that the impact of the minnow population is greater today than when Jensen (1977) made his trout studies in the lake, Øvre Heimdalsvatn.

Low fishing intensity seem to (ii) cause increased survival rate, and this contradicts my prediction, but follows when prediction (i) also turned out to be wrong. In view of the fact that there are fewer trout recruits in the lake, but at the same time relatively (iii) more old fish compared to the period 1958–1966, this may be a result of low annual recruitment and low exploitation rate, and thereby a high survival rate. Based on the estimated number in each age-class in 2015 and 2016, the annual survival was estimated to around 75 %, while Jensen (1977) operated with annual survivals between 25 % and 44 %, i.e., less than half the survival rate for the last two years. The high survival rates for 2015 and 2016 are supported by the fact that I caught more old fish than Jensen (1977) did.

The annual sustainable catch of trout in Øvre Heimdalsvatn, as described by Jensen (1977), can hardly be obtained today due to the present low annual recruitment. If management measures are done, including a heavy reduction in the minnow population, which seems unrealistic, the trout population in the lake, may give a much higher annual yield than today. Even without introducing any measures to reduce the minnow population, increased angling effort may lead to a higher abundance of trout in the lake.

5. Conclusion

The aim of my thesis was to investigate the angler impact on the trout population size and structure in the lake, Øvre Heimdalsvatn, and to what extent the fishing activity is a regulatory factor. Anglers seem not to regulate the trout population size and structure today. The population of post recruits seems to be relatively dense, despite a low annual recruitment. At the same time, the total catch from the lake is very low, according to the angling observations, interviews and angler reports, as well as the very low gillnet effort and catch. The estimated annual survival was nearly doubled today, compared to the period 1958–1966 when there was a substantial gillnet fishery in the lake, and also indicate that the fishery is limited. Further research on angler preferences and what makes anglers motivated or unmotivated to submit angler reports, should be done. This would contribute to the information local fishery management have on both the fish population, the efforts made, in addition to the number and size of fish caught. In addition, more information about the angling opportunity here, along with good information about angler reports and their value, might contribute to more anglers visiting the lake, and a potential increase in submitted angler reports.

Figure 5.1 The view of the lake, Øvre Heimdalsvatn, from the pier in the east end of the lake with parts of Jotunheimen Mountains in the background August 30, 2015 (photo: Marit K. Strand).

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Attachments

Attachment 1: Interview form

Table A.1 The interview form used in a creel survey in the lake, Øvre Heimdalsvatn, during the fishing season 2015 and 2016.

FACTS			
Date:		Time:	
Lake: Øvre Heimdalsvatn		Whereabouts:	
Name of angler:		Residential municipality:	
Fishing tool(s):		Bait:	
FISHING CARD?			
No:	Yes, type: 24 h/48 h/week/season		
FISHING EFFORT: How many days have you been angling, and for how many hours?			
Catch?	Species:	Number:	Length/weight:
How many visits have been made to the lake this season/year?			
Catch?	Species:	Number:	Length/weight:
Have you been here earlier years?			
Catch?	Species:	Number:	Length/weight:

Attachment 2: Map of gillnet effort covering the lake, Øvre Heimdalsvatn

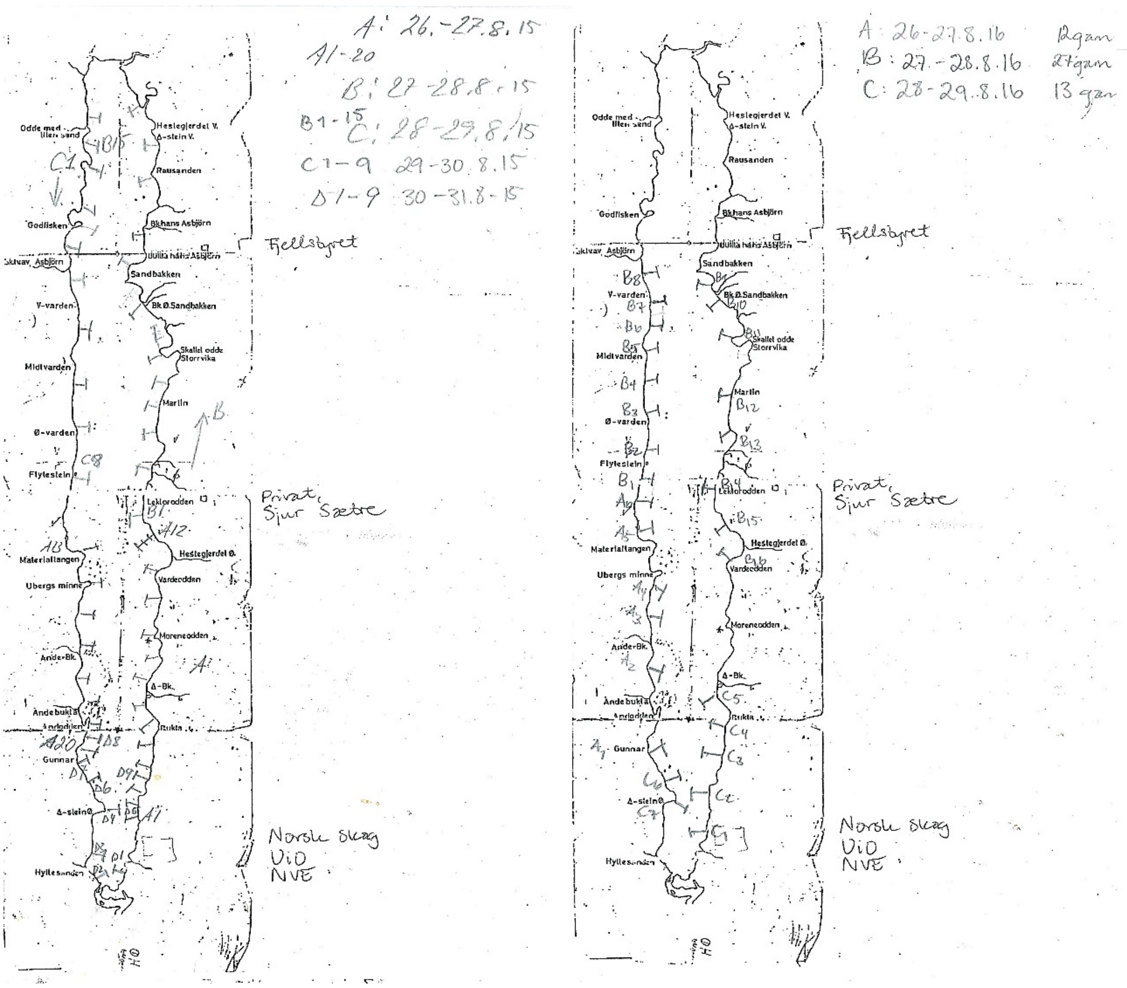

Figure A.1 Gillnet effort covering the lake, Øvre Heimdalsvatn, by fishing with the pilot fleet August 26–31, 2015 and August 26–29, 2016.

Attachment 3: Total collected data in a creel survey during the fishing sea 2015 and 2016

Table A.2 The collected data in a creel survey in the lake, Øvre Heimdalsvatn, during the fishing season 2015 and 2016.

Date	Caught fish	g fish caught	Observed anglers	Reported anglers
07.07.2015	0		1	1
08.07.2015	5		1	1
09.07.2015	10	3000	0	2
10.07.2015	3	Unknown	0	1
11.07.2015	0		0	0
13.07.2015	0		0	0
20.07.2015	1	450	NA	1
21.07.2015	0		0	0
23.07.2015	0		0	0
25.07.2015	2	500	NA	1
27.07.2015	0		0	0
28.07.2015	1	250	NA	1
30.07.2015	0		0	0
01.08.2015	0		0	0
03.08.2015	0		0	0
05.08.2015	0		0	0
07.08.2015	0		0	0
09.08.2015	3	1300	NA	1
17.08.2015	0		0	0
19.08.2015	0		0	0
21.08.2015	0		0	0
26.08.2015	3	1250	0	1
27.08.2015	0		0	0
30.08.2015	0		0	0
22.06.2016	0		0	0

24.06.2016	0		0	0
26.06.2016	0		0	0
28.06.2016	0		0	0
03.07.2016	2	Unknown	NA	1
05.07.2016	0		0	0
07.07.2016	0		0	0
09.07.2016	1	200	5	2
10.07.2016	0		0	0
11.07.2016	0		0	0
13.07.2016	13	2400	3	1
14.07.2016	4	1500	NA	1
16.07.2016	0	0	3	0
17.07.2016	3	750	2	0
18.07.2016	2	Unknown	0	1
19.07.2016	1	400	NA	1
24.07.2016	0		0	0
26.07.2016	0		0	0
28.07.2016	0		0	0
30.07.2016	22	5000	NA	1
31.07.2016	0		0	0
02.08.2016	0		0	0
03.08.2016	3	1000	NA	1
04.08.2016	6	2500	NA	2
06.08.2016	0		0	0
07.08.2016	0	0	NA	1
14.08.2016	2	550	1	0
17.08.2016	0		0	0
19.08.2016	0		0	0
26.08.2016	0		0	0
27.08.2016	0		0	0

28.08.2016	0		0	0
30.08.2016	0		0	0
31.08.2016	3	750	NA	1
15.09.2016	3	750	NA	1
16.09.2016	0	0	NA	1
17.09.2016	1	400	NA	1
09.10.2016	2	500	NA	1

Attachment 4: Angler effort and catch of interviewees in the lake, Øvre Heimdalsvatn, during the fishing season 2015 and 2016

Table A.3 The registered angler effort and catch in a creel survey in the lake, Øvre Heimdalsvatn, during the fishing season 2015 and 2016.

When	Effort (min/h)	Catch	Gathered weight (g)
8.7.2015	90 / 1.5	4	1276
9.7.2016	210 / 3.5	0	0
13.7.2016	180 / 3.0	5	800
13.7.2016	180 / 3.0	3	600
16.7.2016	120 / 2.0	0	0
17.7.2016	360 / 6.0	2	500
17.7.2016	360 / 6.0	1	250
14.8.2016	60 / 1.0	2	550

Attachment 5: Example of an angler report handed in July 3, 2016

Fangstskjema for Øvre Heimdalsvatn

Skjemaet returneres til **Øystre Slidre fjellstyre, Bygdinvegen 1989, 2940 Heggenes**, eller legges i en av **fjellstyrenes fiskekortkasser**. Det er også mulig å sende en skanna versjon av fangstskjemaet til oystre.slidre@fjellstyrene.no. Alle som leverer fangstskjema og oppgir post- eller epostadresse får tilsendt bestands- og fangstanalyser for Øvre Heimdalsvatn. **NB! Hele fangsten må føres opp i skjemaet, uansett fiskestørrelse.**

Navn på kortinnehaver:

Korttype:

Postadresse: **Epostadresse:**

Dato	Totalt antall fanga aure	Samla vekt av fangst	Lengde (cm) på hver fisk i fangsten
03 07	2	?	28 , 34

Takk for at du rapporterte – Øystre Slidre fjellstyre

Figure A.2 Example of a submitted angler report from the lake, Øvre Heimdalsvatn, July 3, 2016.

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

Postboks 5003
NO-1432 Ås
Norway