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ESTIMATE ENVIRONMENTALLY FRIENDLY FISH FARMING IN FOUR LAKES IN TELEMARK

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This thesis is worth 60 study points

Abstract

Fish farms in Norway are expanding following the growing demand for arctic fish. This is also raising concern about environmental issues. This study conducted a water survey in 4 lakes in Telemark, including Tinnjå, Seljord, Fyresvatn and Nisser. The aims are to find out background information about water quality and estimate environmentally friendly fish farming based on total phosphorus and concentration of chlorophyll_a. Fieldtrips in summer 2017 and 2016 demonstrated oligotrophic status of those large and deep lakes. Most of water parameters met good to very good quality according to limits set up by Norwegian Institute for Water Research (NIVA) excepted total nitrogen in Seljord and total phosphorus in Nisser and Fyresvatn in 2017. Potential production of farmed arctic char was estimated by using linear function and exponential function developed by Espend Lydersen (2015) and previous studies. Tinnsjå had highest potential which can produce approximately 1900 tons/year, Fyresvatn could produce approximately 800 tons while that value was not worth considering in Seljord and varied in Nisser. Uncertainty might occur throughout the whole study due to both systemic and random errors and calculation and natural events. This study had supplied useful data for those who are interested in water chemistry as well as farmed fish producers.

Key words: Water quality, total phosphorus, chlorophyll, fish farming.

CONTENTS

FOREWORD

I would like to express my sincere gratitude to supervisor Prof. Espen Lydersen for the support of my master thesis, for his patience and knowledge. His guidance helped me in the time of research and writing of this thesis.

Besides my supervisor, I would like to thank the rest of thesis committee: Prof. Mona Sæbø, student advisor Anette Norheim Fredly, lab assistants and University of South-eastern Norway for free education fees and good study environment.

The thesis was first started in May 2017. The “lab work” part was done in Bø i Telemark in November 2017 and then the thesis was written and submitted from Trondheim in October 2018.

Trondheim 29th Oct 2018

Huy Pham Duc Anh

1 INTRODUCTION

1.1 Issues

Lakes dominate the landscape of Norway which there are more than 450000 lakes. Norway receives plentiful precipitation. Norway's rivers and lakes provide rich freshwater environment that is under less pressure from human activities than many other countries in Europe (Norwegian Environmental Agency. 2017). Furthermore, Norway's fishery industry is growing fast as market is extending. Taking full advantage of this natural favor for aquaculture is beneficial. Nonetheless, challenges are still present. Therefore, environmentally friendly fish farming is being prioritized to minimize harmful effects to the environment.

Bellow is following requests set up for fish farming project in Telemark county (Fyresdal commune and Espend Lysersen 2015):

- ❖ Indigenous populations
- ❖ No traditional breeding program
- ❖ No use of antibiotics
- ❖ Knowledge based and within the frames of environmental sustainability and critical loads
- ❖ Acceptable economic sustainability

This study's main purpose is to estimate environmentally friendly fish farming in 4 lakes: Tinnsjå, Seljord, Nisser and Fyresvatn. In order to reach that ambition, these points need to be obtained:

- Literature study about water quality and fish farming.
- Water quality in four lakes: Tinnsjå, Seljord, Nisser and Fyresvatn in Telemark county was investigated during summer - early autumn of 2017 (water samples were taken once a month from May to October) and analyzed at University of Southeastern Norway, campus Bø.
- Compare with previous data and studies in order to supply background information about environmental load and estimate environmentally friendly production of Arctic Char based on relationship between total phosphorus and chlorophyll_a

1.2 Overview of Norway's Aquaculture

The Norwegian aquaculture industry has witnessed tremendous development over recent years, with a total revenue growth of almost 300% in the last 10 years, and approximately 18.5% growth in 2016. Prices have increased continuously following the growing demand in existing markets and the evolution of new markets (Aquaculture and Seafood - Ernst & Young AS, 2017).

Norway exported 2.6 million tons of seafood worth NOK 94.5 billion in 2017. This is an increase in the value of 3%, or NOK 3 billion, and an increase in the volume of 7% from the record year of 2016 (Norwegian Seafood Council, 8th Jan 2018).

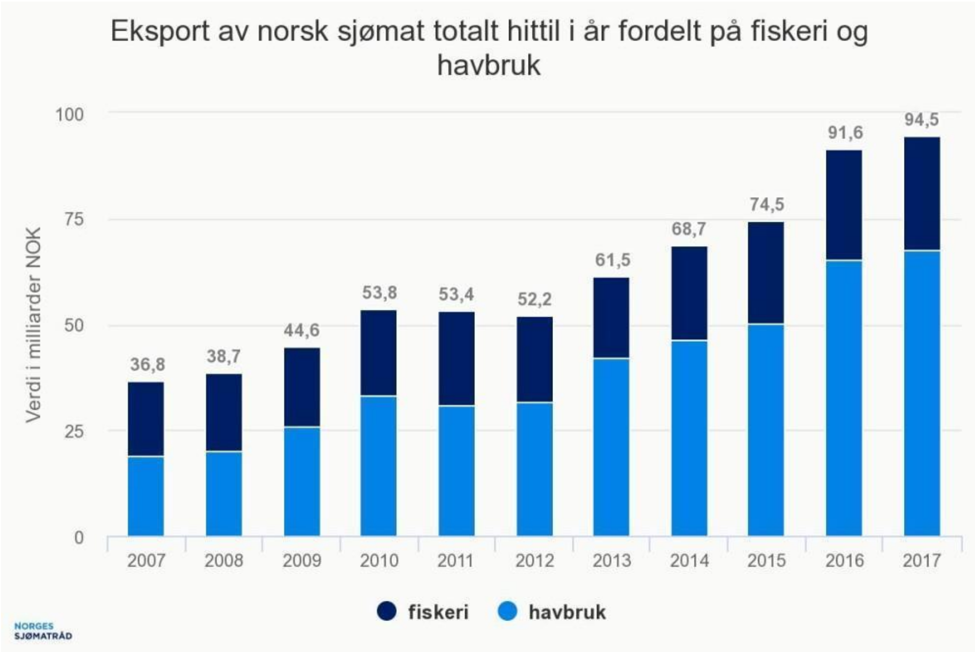


Figure 1- 1: Values of Norwegian Seafood Exported Over Years, Divided by Captured (Fiskeri) and Aquaculture (Havbruk)

Source: Norwegian Seafood Council, 8th Jan 2018

Norwegian aquaculture industry is gathering momentum of a green perspective in the future. Now it is a very important economic sector. As is stated by Norwegian Seafood Council in Jun 2017, "The "Seafood from Norway" - trademark is a collective label that adds value across the Norwegian seafood industry" (Norwegian Seafood Council, 26th Jun 2017).

Main aquaculture sites are located along western and northern coast of Norway. Telemark county lies in southeastern Norway with a short shoreline. Freshwater fish farming has been operating in Fyresvatn and will expand to make Telemark become the leading inland arctic charr farming center in Norway.

Fish farming started in Fyresvatn, Telemark in Jan 2012 when Telemarkrøye A.S got permission from Fylkeskommune to produce approximately 300 tons of fish per year (Fiskedirektoratet). Artic Char is farmed in Fyresvatn. According to project leader - Espen Lydersen 2015, the fish had a good degree of utilization, mortality was low and was consistently high quality. The average weight of slaughtered fish was assumed to be 1.2-1.5 kg.

Fast growing fishery industry in Norway also brings potential influence to surrounding environment. The Government' s view is that environmental impact should be the most important assessment criterion when deciding how the salmon farming industry can operate and how much it can produce (Norwegian Minster of Trade, Industry and Fisheries, 2015).

2. LITERATURE REVIEW

2.1 Water Quality and Environmental Issues in Fish Farming

Oxygen Dissolved: For salmonids species, the optimal levels of dissolved oxygen (DO) should be at least between 70-80% of oxygen saturation (not below 6.0 mg L-1 and above 9.0 mg L-1) (Mercedes Isla Molleda Et Al. ?).

pH is a measure of free hydrogen protons (H+) in a solution, given on a logarithmic scale from 1 to 14. Although salmonids can tolerate pH values within the range of 5 to 9, optimal growth conditions area pH values between 6.5 and 8.5 (Eva Brännäs et al. 2011). Low pH allows toxic elements and compounds such as heavy metals to become mobile and "available" for uptake by aquatic plants and animals. Again, this can produce conditions that are toxic to aquatic life, particularly to sensitive species like trout. Changes in acidity can be caused by atmospheric deposition (acid rain or acid shock from snowmelt), surrounding rock, and wastewater discharges (UMassAmherst - Water Resources Research Center, ?).

Temperature: For Arctic charr, these limits spans from 0 to 23-24°C (Lyytikäinen, T., Jobling, M., 1998). The optimal feed utilization of juvenile Arctic charr occurs at approx. 9°C, 12°C seems to be the most likely optimal temperature for aquaculture (Uraiwan, S., 1982).

Alkalinity is the water's capacity to resist changes in pH that would make the water more acidic (Brian Oram, Water Research Center, ?). Alkaline compounds in the water such as bicarbonates, carbonates, and hydroxides remove H^+ ions and lower the acidity of the water (which means increased pH). Waters with low alkalinity are very susceptible to changes in pH. Water with high alkalinity is able to resist major shifts in pH. Alkalinity is usually expressed as mg/L of CaCO3 but here it is shown as micromol L-1 (UMassAmherst - Water Resources Research Center).

Turbidity is the cloudiness or haziness of a fluid caused by large numbers of individual particles that are generally invisible to the naked eye (LaMotte, ?). Turbidity was measured by this study with unit NTU. NTU stands for Nephelometric Turbidity Unit and signifies that the instrument is measuring scattered light from the sample at a 90-degree angle from the incident light with single detector (Oregon Water Science Center, ?). Usually drinking water utilities will try to maintain a turbidity level of about 0.1 NTU (LaMotte, ?).

Nitrogen: Nutrients, such as nitrogen (in the forms of nitrate NO_3^-, nitrite NO_2^-, or ammonium NH_4^+) is essential for plant and animal growth and nourishment, but the overabundance of certain nutrients in water causes a number of adverse health and ecological effects (USGS, Water Science School, ?). Agriculture activities, animal feeding and sewage drains contribute most to macronutrients in waterbody. The figure below describes flow and fate of nutrient components from salmon cage system.

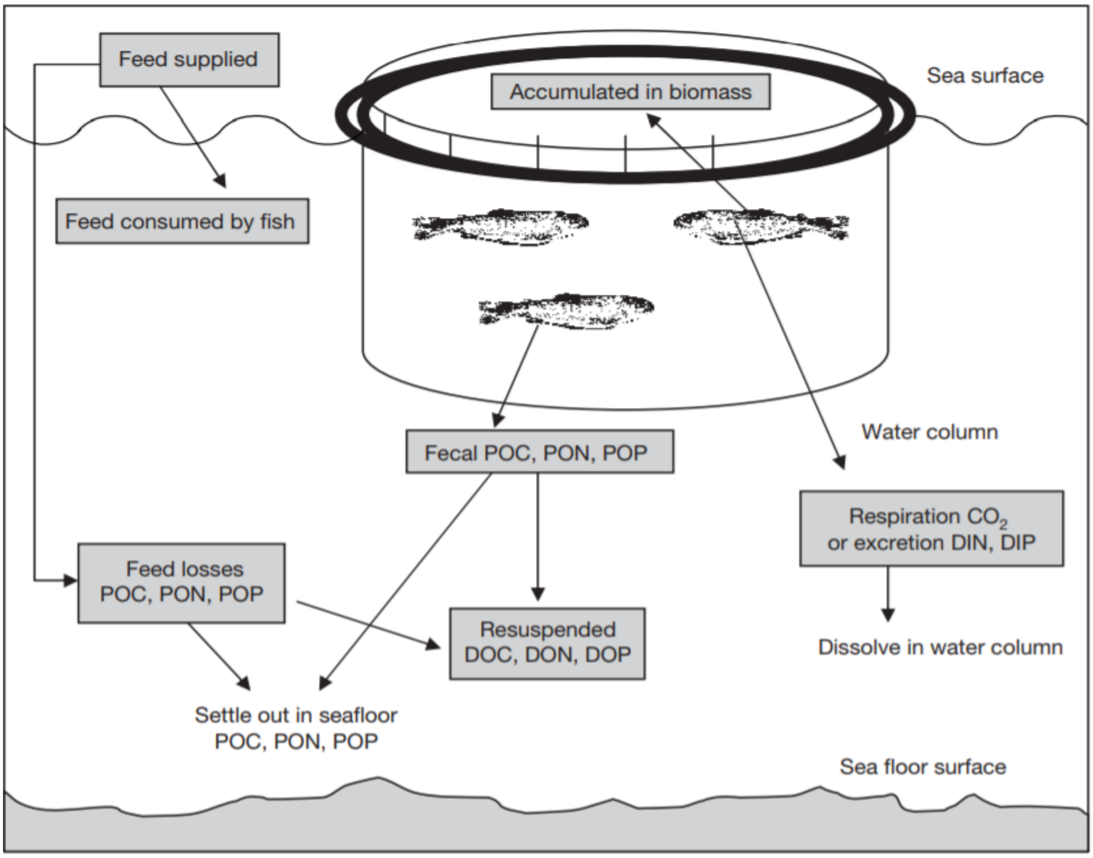


Figure 2- 1: Source and Fate of Organic Stuff in Fish Farm

Source: Xinxin Wang et al. 2012

Dissolved Inorganic Nitrogen and Phosphorus (DIN And DIP, Respectively) Are Released Through Excretion, And Inorganic Carbon (CO_2) Through Respiration. Particulate Organic C, N And P (POC, PON And POP, Respectively) Are Released Through Defecation And Feed Loss. Dissolved Organic C, N And P (DOC, DON And DOP, Respectively) Are Resuspended From Faeces And Feed Particles (Xinxin Wang et al. 2012). The fish create and expel various nitrogenous waste products through gill diffusion, gill cation exchange, and urine and feces excretion; in addition some nitrogenous wastes are accumulated from the organic debris of dead and dying organisms, uneaten feed, and from nitrogen gas in the atmosphere (Mercedes Isla Molleda et al, ?). Total Nitrogen (TN) is the sum of nitrate-nitrogen (NO3-N), nitrite-nitrogen (NO_2-N), ammonia-nitrogen (NH_3-N) and organically bonded nitrogen (ASA Analytics).

Phosphorus: Originates from the same sources as nitrogen. Phosphorus (P) is an essential nutrient for living organisms. For instance, phosphorus is found in DNA (the genetic material of living organisms), used to form cell membranes, and is utilized at the cell level (as ATP, adenosine tri-phosphate) to generate energy (Virginia Water Resources Research Center, 2007). Phosphorus in water exists in two main forms: dissolved (soluble) and particulate (attached to or a component of particulate matter). Ortho phosphorus is the primary dissolved form of phosphorus and is readily available to algae and aquatic plants. Particulate phosphorus can change form during chemical and physical activities in bottom sediment (Minnesota Pollution Control Agency, 2007).

These different nutrient components have the potential to influence different parts of the marine ecosystem. Inorganic nutrients such as DIN and DIP are readily available for phytoplankton and macroalgae (Troell M, et al. 2003). Two nutrients in human-derived sources, phosphorus (P) and nitrogen (N), are of most concern in eutrophication. In freshwaters, P is the least abundant among the nutrients needed in large quantity (macronutrients) by photosynthetic organisms, so it is the primary nutrient that limits their growth (Schindler, D. W. 1977). Large growths of algae are called algal blooms and they can severely reduce or eliminate oxygen in the water, leading to illnesses in fish and the death of large numbers of fish (United States Environmental Protection Agency, ?).

Phytoplankton: The word "phytoplankton" comes from Greek and means literally "wandering plant". Phytoplankton plays various key roles in the water bodies and climate systems, supporting the marine food chain and participating in chemical cycles, including CO2 recycling (Watson, A. J., et al. 1991). The photosynthetic pigment **chlorophyll_a** is a distinguishing constituent of phytoplankton and has a universal distribution among all the minute algae and synthesis of chlorophyll a as a procedure, is sensitive to nutrient supply and deployment (Brönmark, C. et al. 2005)

Nutrient components and chlorophyll_a: In 1974, Schindler published a paper illustrating P-limitation in a lake in Ontario, Canada. Many other researches also gave a strong relationship between total phosphorus and chlorophyll_a. For example, in a study of 19 northern lakes, Dillon and Rigler (1974) demonstrated a strong linear relationship between water column TP concentration at spring turnover and summer chlorophyll-a concentrations ($r \sim 0.9$) (from Virginia Water Resources Research Center, 2007). Similarly, Rast, W. et al. (1983) observed decreasing chlorophyll levels in 10 lakes that experienced phosphorus-loading declines (from Zipper et al. 2004). Thus based on the nutrient requirements for P, N, and C, phosphorus is most likely to limit growth, and nitrogen is next likely to limit growth. Other elements, such as silicon, calcium, or iron, can be limiting but are not required in as large of 10 quantities as phosphorus, nitrogen, and carbon (Wetzel, R. G. 2001).

Oligotrophic and eutrophic lake: According to New Hampshire Department of Environmental Service, 2010 and Parameters stated by “Lake George Association”. Tropic level of lake is made based on these criteria and parameters:

Oligotrophic		Eutrophic	
Description	Parameters	Description	Parameters
Low nutrient enrichment Little planktonic growth Few aquatic plants Sand or rock along most of shoreline Coldwater fishery High dissolved oxygen content	Secchi disk clarity >5m Total phosphorus < 10μg/L Chlorophyll _a < 2 μg/L	High nutrient enrichment Much planktonic growth (high productivity) Extensive aquatic plant beds Much sediment accumulation on bottom Low dissolved oxygen on bottom Only warm water fish species	Secchi disk clarity <2m Total phosphorus >20 μg/L Chlorophyll _a >8 μg/L
Mesotrophic	Has neutral properties		

Many previous studies had concluded oligotrophication property of deep and large lakes in Telemark.

2.2 Arctic Char as A Farming Specie in Telemark’ s Inland Lakes

Arctic char is closely related to salmon and trout, with which it shares many characteristics, including high content of Omega 3 (Lucy Towers, 2016). Arctic charr (*Salvelinus alpinus L.*) is a holarctic salmonid fish species with both landlocked and anadromous populations (Eva Brännäs et al. 2011). In Scandinavia it is mainly found in the mountain area, but it also appears in deep and large lake further south, i.e. in the Alps. It is the northernmost freshwater fish and A. charr is generally regarded as the most cold-adapted freshwater fish (Eva Brännäs et al. 2011). A. charr has been commercially farmed since the early 90ths and today, the total production is 3000, 2300 and 700 tonnes/year in Iceland, Sweden and Norway, respectively (Eva Brännäs et al. 2011).

Figure 2-2: Arctic Charr (Salvelinus alpinus L.) and Fish Cage in Fyresvatn

Source: Sten Siikavuopio and Espend Lydersen

2.3 Studied Area

Telemark county is based in southeastern Norway, sharing border with Vestfold, Buskerud, Hordaland, Rogaland and Aust-Agder with a short coastline.

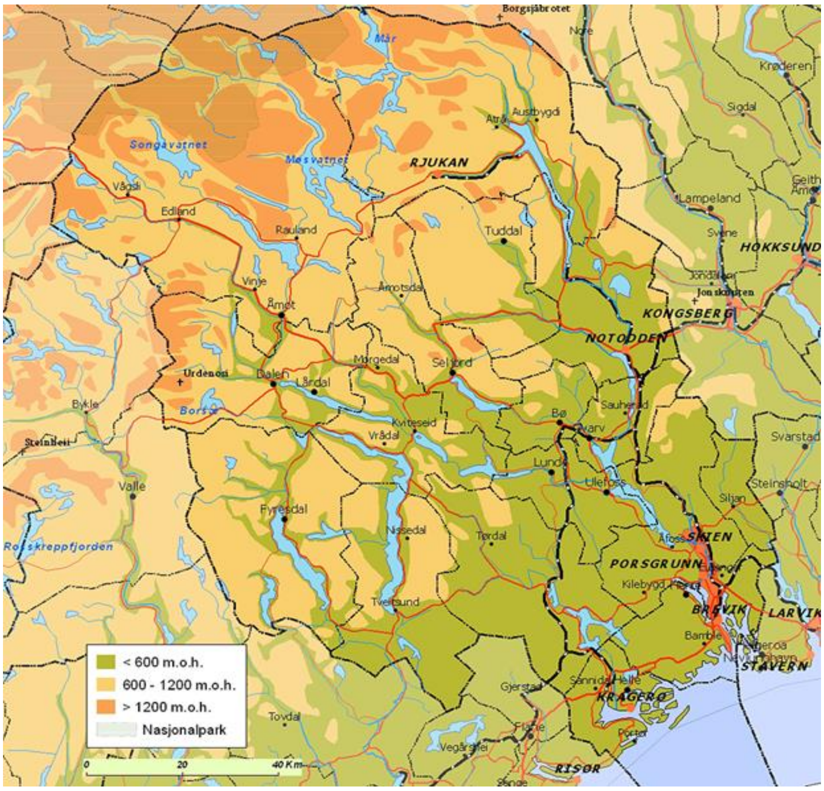


Figure 2-3: Terrain and Administrative Map Of Telemark

Water investigation was conducted in 4 lakes: Tinnsjå, Seljord, Nisser and Fyresvatn. The region is characterized by humid continental climate with warm summer and cold winter with the temperature averages around 6^{o}C, and precipitation is approximately 800mm per year.

Table 2- 1: Natural Characteristics of Tinnsja, Seljord, Fyresvatn and Nisser

Source: Østrem, G., et al. 1984 and NVE data

*Calculated by NIVA (Norwegian Institute for Water Reseaches)

Lake name	Elevation (m.a.s)	Basin km^2	Lake area km^2	Lake volume km^3	Mean depth m	Max depth m	Annual water input Km^3/yr
Nisser	246,76 – 243,76	1077.7	76.30	7.185	93	234	0.906
Tinnsjå	191,2 – 187,2	3775.2	51.43	9.710	190	460	3.348
Fyresvatn	279,65 – 275,15	878.7	49.63	5,956 *	120	377	0.753
Seljord	116,13 – 115,13	724.7	16.52	0.740	49.5	153	0.428

Water samples were collected at two sites in each lake which are called “North” and “South”. This thesis took and tested water samples of Tinnsjå and Seljord while Nisser and Fyresvatn were taken by another group.

Tinnsjå tops the chart in basin catchment and total volume whereas Nisser has largest lake area and Seljord is least at all criteria. Tinnsjå receives 3.348 km^3 of water per year causing very low retention time. Fyresvatn and Nisser have large water volume but water input is low and that makes very long retention time. Seljord, on the other hand, is significantly smaller and shallower than the others and Seljord has shortest retention time.

Retention time means the time it would take to full up the lake when the whole lake were empty. Longer retention time, more sediment and components will descend and stay in the lake. Nisser and Fyresvatn are very deep whereas water input is not much. This makes more water components to be stored. In lakes having long retention time, more phosphorus entering the lake will be trapped and stored whereas much more phosphorus will be washed away in Seljord and Tinnsjå. This characteristic will be important for fish farming since more phosphorus released from fish cage will flow down to downstream instead of staying longer and accumulate in Nisser and Fyresvatn. Owing to altitude, Seljord is warmer than the others. Lakes lying lower and near the coast such as Norsjø are not chosen because the lakes locating at lower hydrological level have already uptaken nutrients and water components discharge from lakes at higher altitude and that lessens the ability to uptake waste from fish farming or in other word, lower environmental load.

Table 2- 2: Retention Time and Phosphorus Retention in 4 Lakes

Source: Østrem, G., et al. 1984

Lake name	Retention time Tw (yr)	P- Retention coefficient $R = 1/1 + Tw^{-0,5}$	$P_{out} = P_{in}$ (1-R)
Nisser	7.926	0.74	0.26
Tinnsjå	2.898	0.63	0.37
Fyresvatnet	7.973	0.74	0.26
Seljordsvatn	1.729	0.57	0.43

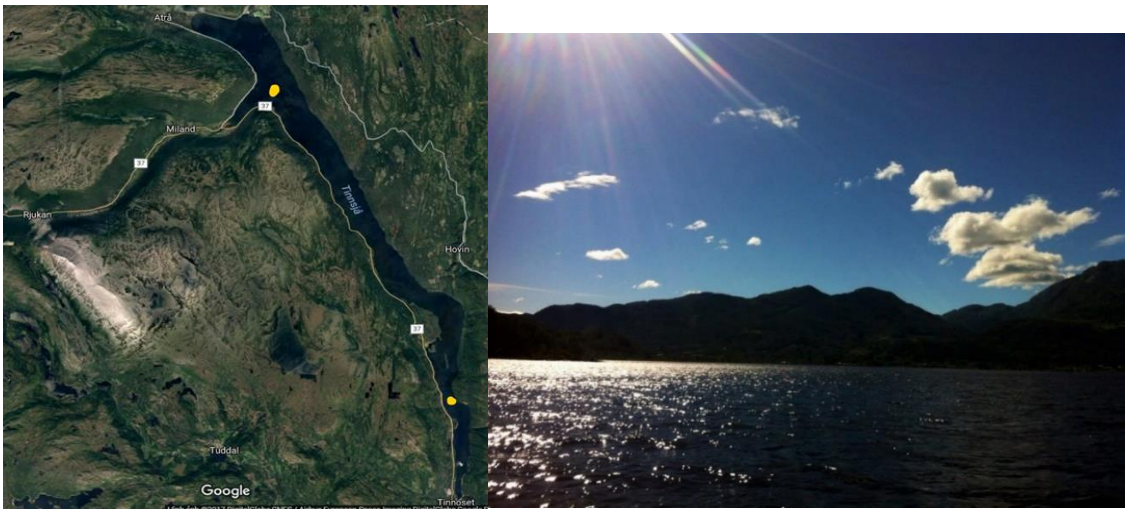


Figure 2- 4: Tinnsjå

Figure 2- 5: Seljordvatn

Figure 2- 6: Fyresvatn and Nisser

Source: Google Mapp

3. MATERIALS AND METHODS

3.1 Field Research and Literature Study

This thesis took and tested water samples of Tinnsjå and Seljord while Nisser and Fyresvatn samples were taken by another group. Field trip was carried out once every month, from 13th Jun 2017 to 17th Oct 2017.

Water samples were taken at different depths: 1m - 3m - 5m - 7m - 9m - 12m and then mixed together (2016 from 1-6m). Samples for analyzing total nitrogen and phosphorus were stored in 200 mL dark glass bottles. Sample for analyzing ions and macro-elements were stored in 0.5mL plastic bottles. Both plastic bottles and glasses must be stored in a styrofoam box to maintain the temperature cool. For chlorophyll_a sample, we poured 5 L of water to the plastic bottle and covered it with a black bag to prevent photosynthesis.

Each lake has 2 sampling sites, duration lasted for 5 months, thus we got 40 samples in total.

Water quality data of 2016 was measured at NMBU and other incoherent data from previous year were collected from official organizations (from Miljøovervåking, 2015, Rådgivende Biologer AS, 2014 and Fylkesmannen i Telemark, 2005).

3.2 Laboratory Methods

Basic water parameters including pH, alkalinity, turbidity, conductivity and pretreatment for chlorophyl_a analysis were done on the fieldtrip day. Then samples which are used to analyze nitrogen and phosphorus were added few drops of concentrated acid sulfuric and stored in the fridge whose temperature is 4 - 5^{o}C. In that condition, the samples are stable for 6 months. All samples (both from Tinnsjå, Seljord and Nisser, Fyresvatn) were analyzed in Nov 2017 at University Of South-eastern Norway, Campus Bø.

Table 3- 1: Method References/Norwegian Standards Used for Analyzing Water Parameters in This Study

Indexes	Unit	Reference	Short Description
pH		NS 4720	
Turbidity	Transparency (m)	NS-EN	1. Measuring lake transparency and color with

	NTU	ISO 7027	sichi disk on the field (figure 8). 2. Then turbidity was measured with equipment
Alkalinity	µ eq/L	NS 4754	Alkalinity is usually determined by potentiometric titration with hydrochloric acid.
Tot-N	µg N/L	NS-EN 4743	Determination of total nitrogen after oxidation by peroxodisulphate. Organic and inorganic nitrogen compounds are oxidized to nitrate by peroxodisulphate in basic environment.
Tot-P	µg P/L	NS-EN 1189	Determination of phosphorus - Spectrometric method with ammonium. Ammonium molybdate and potassium antimony tartrate react in an acid medium with orthophosphate to form a heteropoly acid – phosphomolybdic acid – that is reduced to intensely colored molybdenum blue by ascorbic acid. Absorbance of the (blue) solution is measured at 880 nm. The colour is stable for around 12 hours.
Chlorophyll_a	µg/L	NS 4766	Determination of chlorophyll a by spectrophotometric measurement in acetone extract. The measure itself relies on their spectroscopic characteristics: light absorption or fluorescence. Filtration - Storage - Pigment extraction - Centrifugation - Spectroscopic Measurement. Filtration was done on the field trip date. Water sample was filled through a filter paper with a gravity generated by a hydrologic pump in order to trap chlorophy_a and then stored in aluminum folio in the freezer.

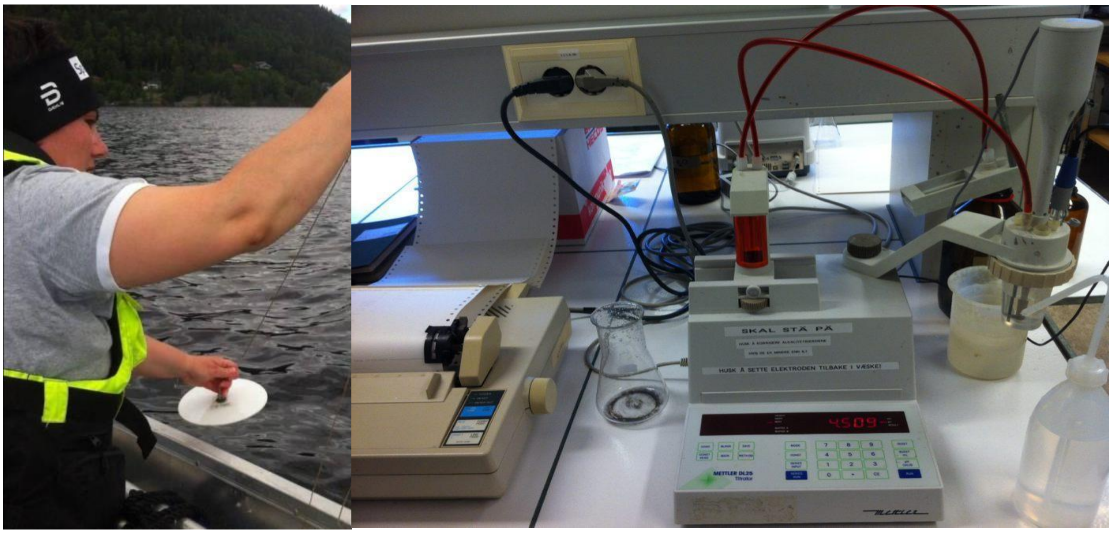


Figure 3- 1: Sichi Disk and Instruments for Alkalinity Analysis at USN in Bø

3.3 Estimate Potential Production

3.3.1 Estimate Phosphorus Storage in Deep Lakes

According to Rognerud et al (1979), the following equation describing relation between total phosphorus and retention time can be used to estimate the amount of phosphorus will be held in the lake.

$P_{in} = 1.59 * [P] * e^{(0.067*Tw)} * Q$ (equation 3-1)

Where: Tw is retention time (year)

Q: Yearly discharge (m^3/year)

[P]: Concentration of total phosphorus (μg/ L)

Lakes having less water input will take more time to fill up the lake, hence longer retention time and this also determines phosphorus storage of lake with subsequent higher retention of phosphorus. Less water input means less phosphorus to be entered. For instance, small lake like Seljord has short retention time (1.729yr), around 57% of phosphorus entering the lake will be retained.

Limit concentration of phosphorus for natural surface waterbody is now only 5 μg/L since NIVA (Norsk Institutt For Vannforskning) considers that is a very good condition. Hence, the potential of phosphorus uptake of the lake is the gap between 5 μg/L and the current average concentration of phosphorus of the lake.

It is well established that when the weight ratio between N and P < 12. P will be limited for algal growth in lakes (Berge, D. 2010). Thus, as the N:P weight ratio in many of the large Telemark lakes normally in 2017 was much higher than 12 (results presented in part 4.2), undoubtedly P is the algal growth limited factor in these lakes (Rognerud, S. et al. 1979). Therefore, phosphorus is a major eutrophication factor in Telemark's lakes and the potential fish production here is estimated based on the concentration of total phosphorus.

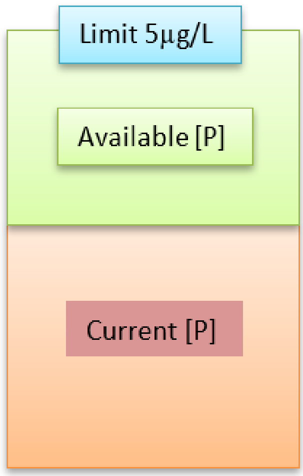
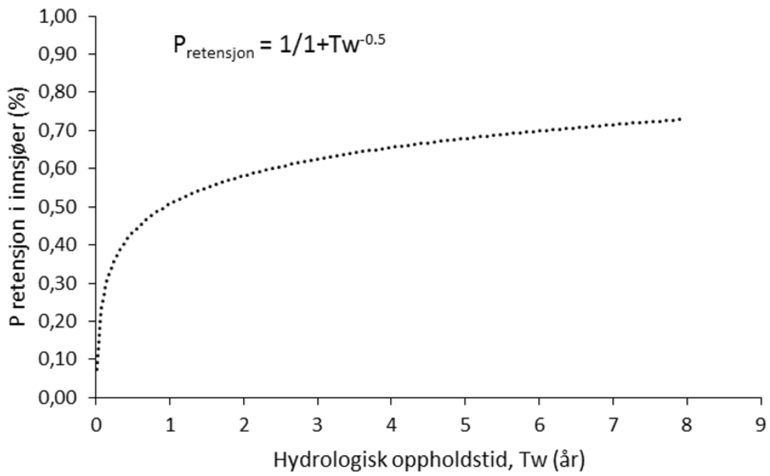


Figure 3- 2: Theory for Estimating Fish Farming Production Based on Total Phosphorus



Figur 1. *Sammenhengen mellom hydrologisk oppholdstid i innsjøer og retensjon av fosfor i innsjøer*

Figure 3- 3: Relationship Between Retention Time and Phosphorus Storage in Lakes

Source: Vollenweider, R.A. 1976 and Rognerud, S.et al. 1979

Table 3- 2: Water Quality Index

Source: Statens Forurensningstilsyn, 1997 (Updated New Total Phosphorus)

	Very Good	Good	Moderate/Accepted	Bad	Very Bad
Total P (µg/L)	≤ 5	5-11	11-20	20-50	>50
Chl_a (µg/L)	≤ 2	2 – 4	4 – 8	8 – 20	>20
Total N (µg/L)	≤ 300	300 – 400	400 – 600	600 - 1200	>1200

Transparency (m)	>6	4 – 6	2 – 4	1 – 2	<1
pH	>6.5	6 – 6.5	5.5 – 6	5 – 5.5	<5
Turbidity (FTU)	<0.5	0.5 – 1	1 – 2	2 – 5	>5
TOC (mg/L)	<2.5	2.5 - 3.5	3.5 - 6.5	6.5 - 15	>15

3.3.2 Background Data for Mass Balance of Main Nutrient Stuff in Fish Farming and Estimate Potential Production

Farming discharges nitrogen, phosphorus and organic carbon to the environment. This study consulted references from Johnsen 2016 and Berge 2010 to assume the average discharge of nutrient stuff from fish farm.

Table 3- 3: Average Concentration of Phosphorus in Commercial Fish Feed and in Fish Body

Unit	N in Feed	P in Feed	Unit	N in Fish	P in Fish
%	6.4	1.05	%	2.76	0.54
g/kg	0.064	0.0105	g/kg	0.0276	0.0054

1.3 tons of feed is needed to produce 1 ton of commercial fish. Thus, we present nutrient excrete in this table

Table 3- 4: Estimated uptake and excrete amount of nutrient per ton of produced fish

	I fór	I fisk	Til innsjøen
	kg tonn^{-1}	Produsert fisk	Utslipp
Fórfaktor	1,2		
Element	kg 1,2 tonn^{-1} fór	kg tonn^{-1} fisk	kg tonn^{-1} fisk
N	76,8	27,6	49,2
P	12,6	5,4	7,2
C	960	816	144

The study held by Braaten et al. 1992 assumed that 39-41% of discharged phosphorus will be dissolved in form that is available for biochemical processes in water.

Table 3- 5: Overview of Allocation of Nitrogen and Phosphorus From Research About Rainbowtrout at Fishery Biological Institute Hirtshals

Source: Braaten, B. et al. 1992

Nærings stoff	Tilført mengde fôr	Innebygget i fisken	Fekalier og fôrspill %	Utskilt i oppløst form %
N	100 %	30 - 39 %	13 - 15 (20 - 23)	49 - 56 (77 -80)
P	100 %	27 - 35 %	38 - 45 (59 - 61)	27 -29 (39 - 41)

4. RESULTS & DISCUSSION

4.1 Background Parameters About Water Quality of Studied Lakes

Surface temperature (at 1 meter under surface down to 12 meters deep) varied from 8.3°C in Oct in Nisser to 17.6°C at the surface of Seljord in August in 2017.

pH: Two lakes located further south, Fyresvatn and Nisser, had relatively lower pH than the northern lakes (Seljord and Tinnsjå). pH of Fyresvatn had dropped slightly below point 6 during 5 summer months in 2017, which is sign of light acidic environment. Surveys conducted by NMBU in 2016 and other data sources from Miljøvernavdelingen in 2015 and Rådgivende Biologer AS in 2014 altogether showed a same trend of pH variations (figure 12). The likely reasonable answer for low pH in South further lakes could be blamed on acid rain caused by industrialization period in Central Europe. However, pH of Nisser and Fyresvatn was not too low that can create harmful effects to fish.

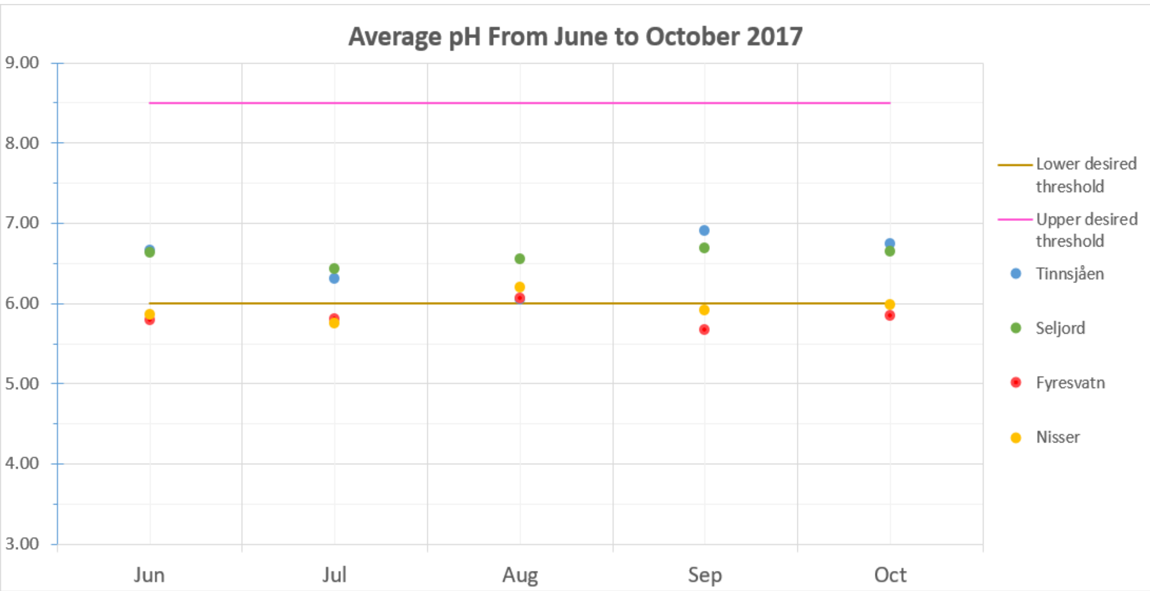


Figure 4- 1: Monthly Average pH in 2017

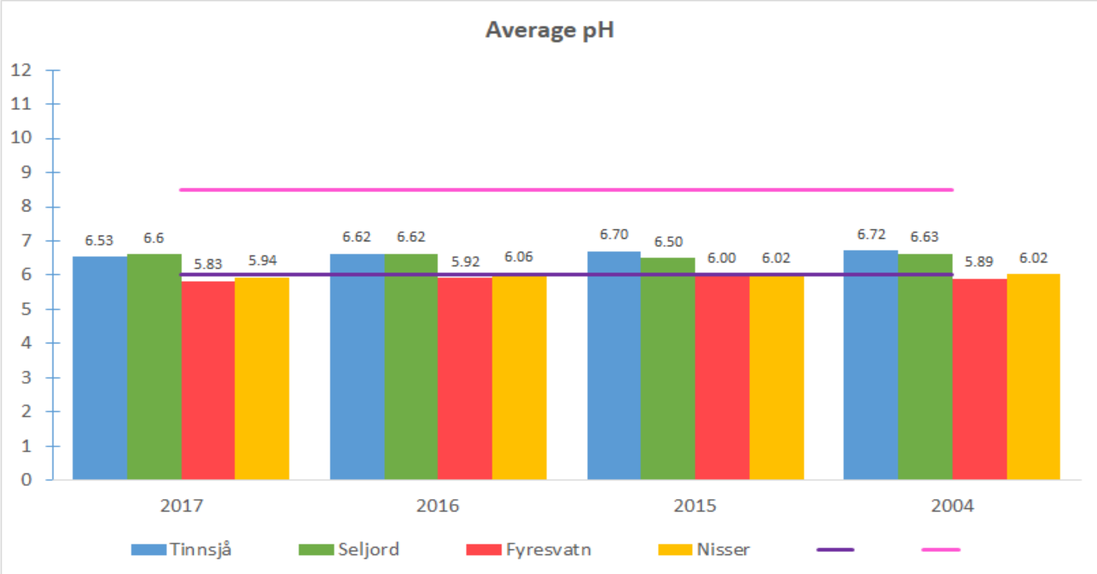


Figure 4- 2: Yearly Average pH

Our turbidity values from summertime 2017 respectively demonstrated low dissolved components and suspended solids in these large and big lakes. In general, lakes at high latitude usually have lower turbidity because of the fact that weathering, yearly temperature and annual runoff are not either high or intensive as tropic level, which results in a thin soil layer. Most of turbidity values got in summer 2017 fell below very good condition while June and Oct had little higher turbidity owing to snowmelt and heavy rain period (figure 13).

Because of low turbidity, transparency of those lakes just fluctuated within very good threshold (>6m). Tinnsjå has least organic stuff as its transparency was clear down to 9 → 11 meters whereas Seljord's water was murkier and its transparency varied from -4.5 → - 5.5m. The visibility of a lake reflects the amount of particles and organic matter present in the water mass (Økland, J. & Økland, K. A. 1998). So, we could assume that Seljord lake has more humus stuff than the others. Taking a look at figure 15, we see total organic carbon, total nitrogen and Chl_a in Seljord in 2017 seemed to by higher and that resulted in shallower transparency visibility.

Total organic carbon of these 4 lakes in Telemark surveyed in 2017 was relatively low as ¾ lake did not escalate the limit 3.5 mg/L considered as good condition. Seljord's was lightly over that threshold but was still under 6.5 mg/L - moderate quality.

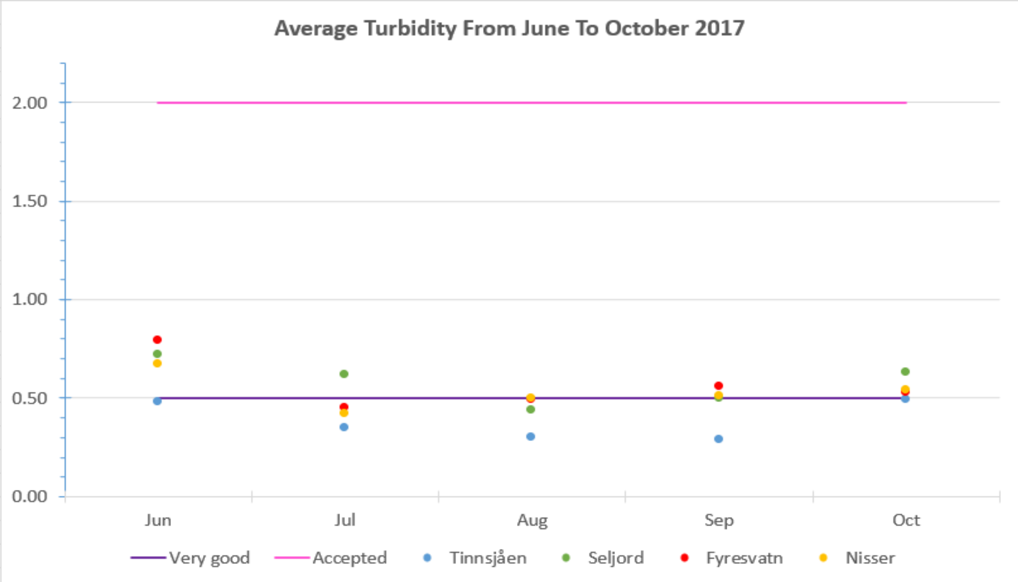


Figure 4- 3: Monthly Average Turbidity 2017

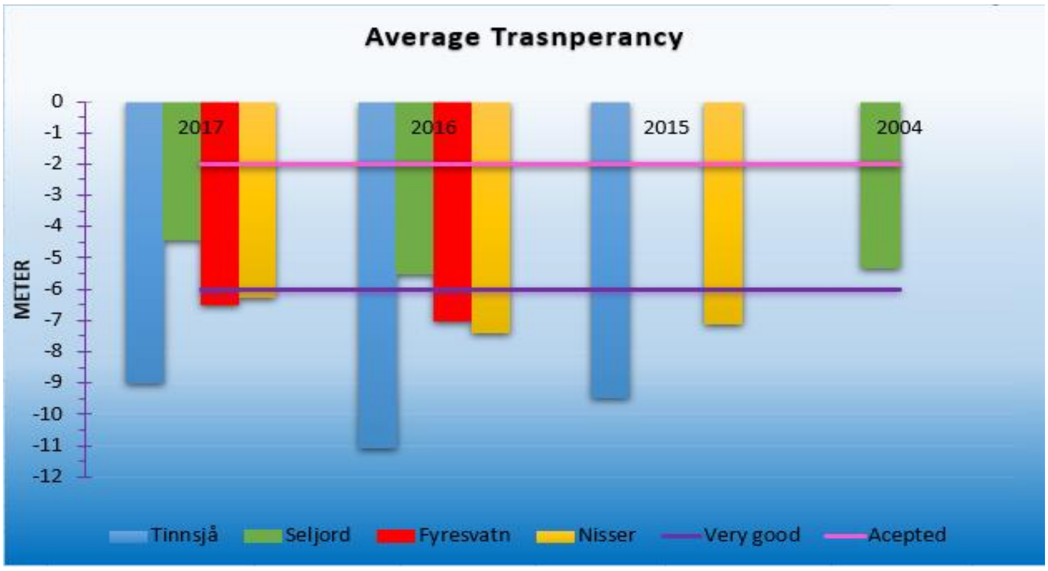


Figure 4- 4: Yearly Average Transparency

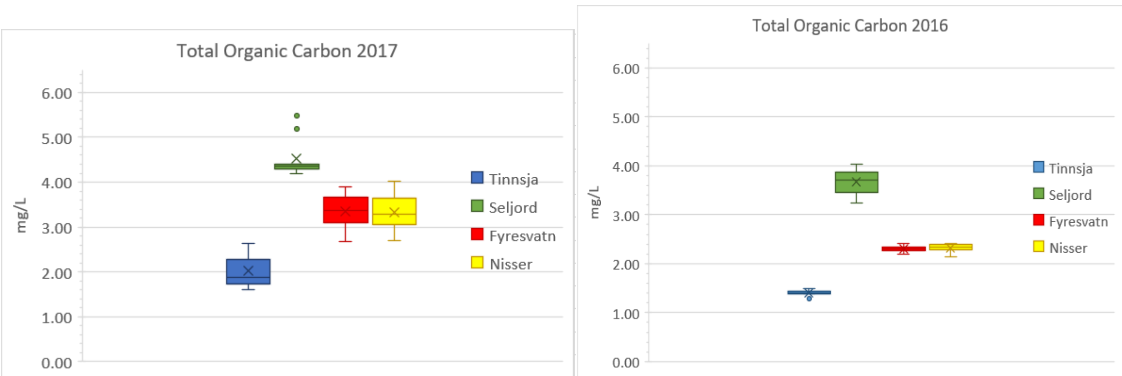


Figure 4- 5: Total Organic Carbon in 2017 and 2016

Total Nitrogen of Tinnsjå, Fyresvatn and Nisser was classified as good condition. On the other hand, total nitrogen in Seljord was relatively high. The average concentration was 657.05 µg/L which fell to the zone moderate/accepted quality. Boxplot figure 16 indicates the mean, median and the dispersal of datasheet. Data points of Fyresvatn and Nisser was stable and did not vary too much, the boxplot looked symmetrical. In contrast, data sheet of Tinnsjå had 2 outliers, one was 559.74 µg/L and the other climbed up to 1135.68 µg/L which is a bad sign of water quality. Moreover, one data point of Seljord escalated to 1542.96 µg/L. Fyresvant also had one bad value of total nitrogen (739.50 µg/L). These outliers were likely to be affected by natural events such as heavy rain washing matter on the ground since those outliers were measured in October where the heaviest rainy period in Norway lasts in September and October. Compared to data sheet in 2016 which was done by NMBU lab, outliers we got this year might also be affected by labwork manipulation or contamination had occurred during sampling procedure and handling samples. Total nitrogen in 2016 datasheet was narrower and there was no aggressive outlier. All of total nitrogen values in 2016 also dropped below very good condition at 300 µg/L at all 4 lakes.

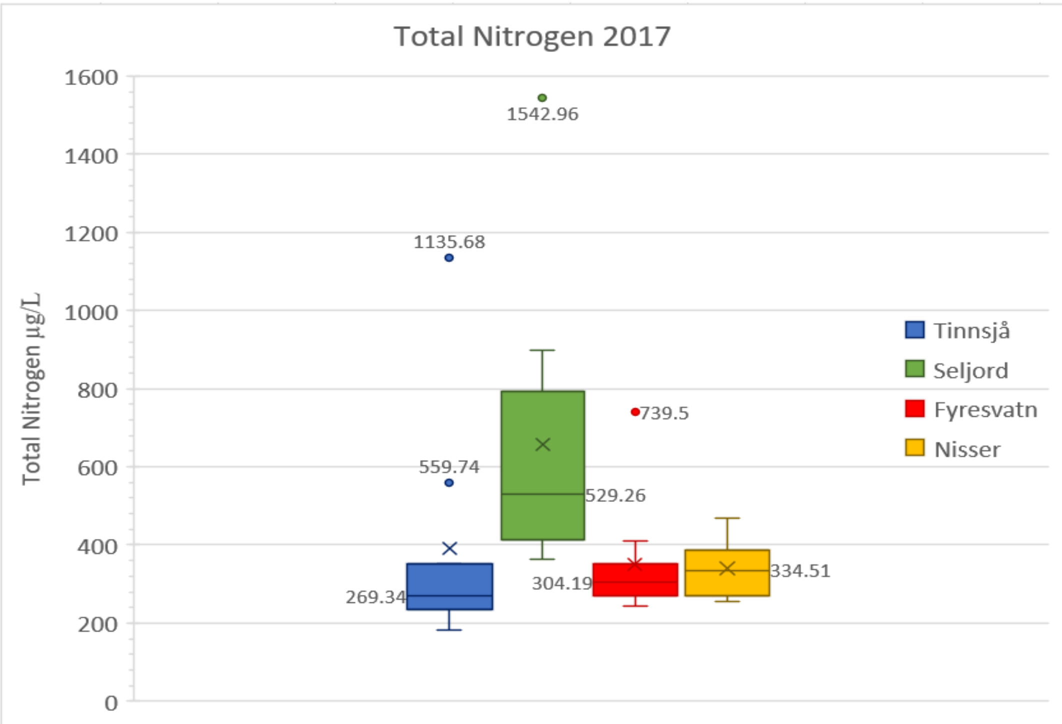


Figure 4- 6: Total Nitrogen 2017 of 4 Lakes

Unit: µg/L	Tinnsja	Seljord	Fyresvatn	Nisser

Minimum	183.08	362.29	243.06	256.17
Q1	234.26	413.51	270.85	269.01
Median	269.34	529.26	304.19	334.51
Q3	352.10	793.02	353.00	386.01
Maximum	1135.68	1542.96	739.50	469.45
Mean	390.52	657.05	350.05	339.59
Range	952.60	1180.67	496.44	213.28

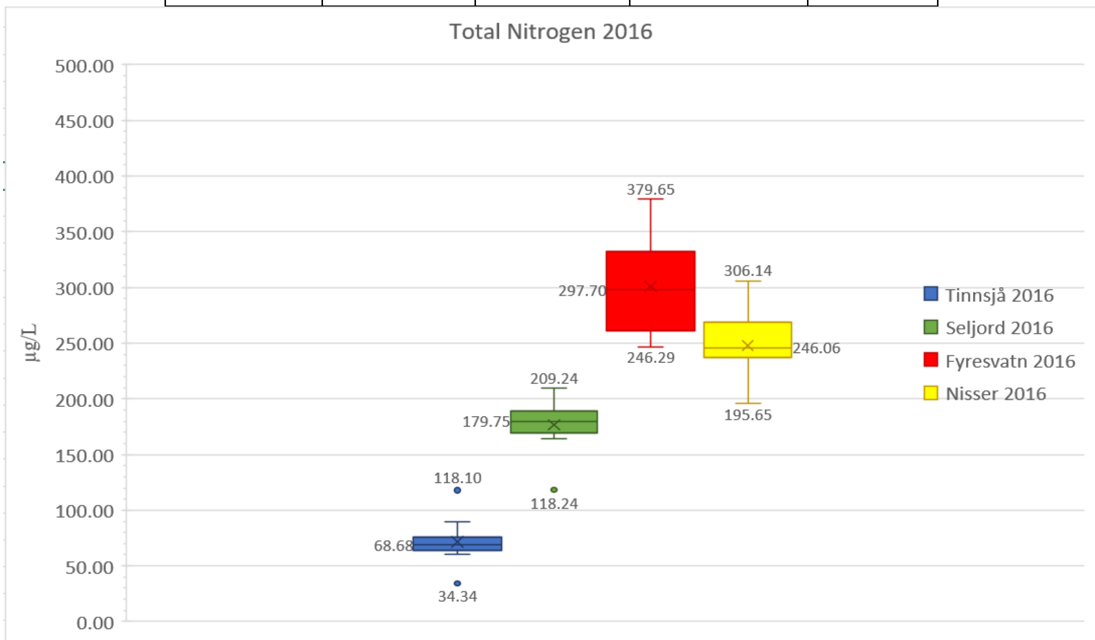


Figure 4- 7: Total Nitrogen in 2016

Unit: µg/L	Tinnsjå 2016	Seljord 2016	Fyresvatn 2016	Nisser 2016
Minimum	34.34	118.24	246.29	195.65
Q1	63.84	169.31	261.22	237.14
Median	68.68	179.75	297.70	246.06
Q2	76.23	188.72	332.50	268.68

Maximum	118.10	209.24	379.65	306.14
Mean	71.64	176.52	301.18	247.66
Range	83.77	91.01	133.37	110.50

4.2 Total Phosphorus, Chl_a and Potential Production

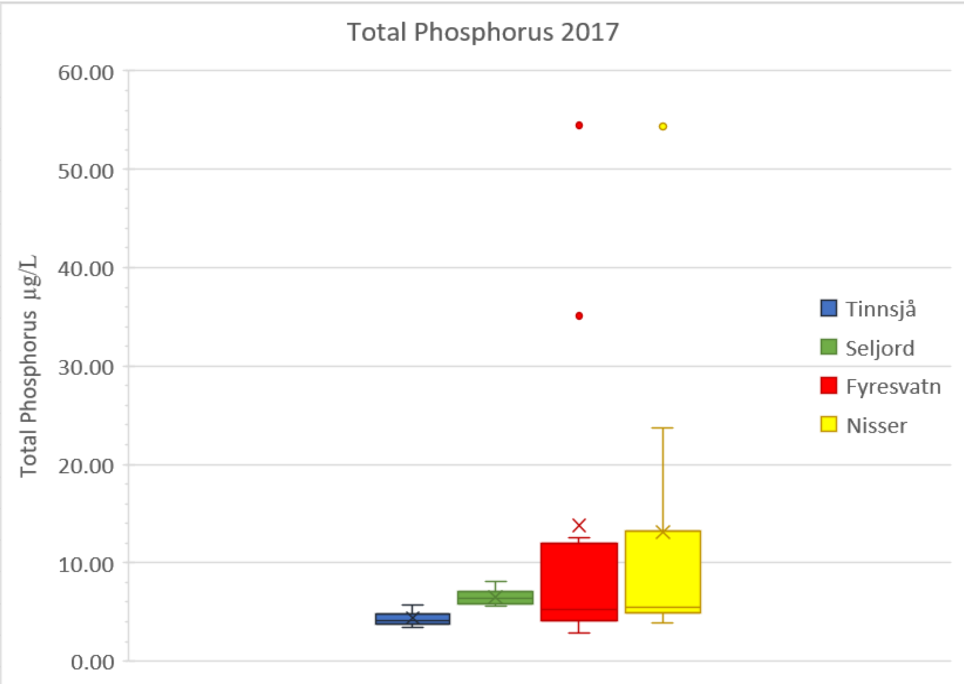


Figure 4- 8: Total Phosphorus 2017

Unit: µg/L	Tinnsjå	Seljord	Fyresvatn	Nisser
Minimum	3.40	5.59	2.81	3.93
Q1	3.73	5.79	4.07	4.91
Median	4.15	6.43	5.23	5.49
Q3	4.76	7.04	12.01	13.22
Maxium	5.71	8.05	54.50	54.35
Mean	4.37	6.49	13.79	13.09

Range	2.31	2.46	51.69	50.42

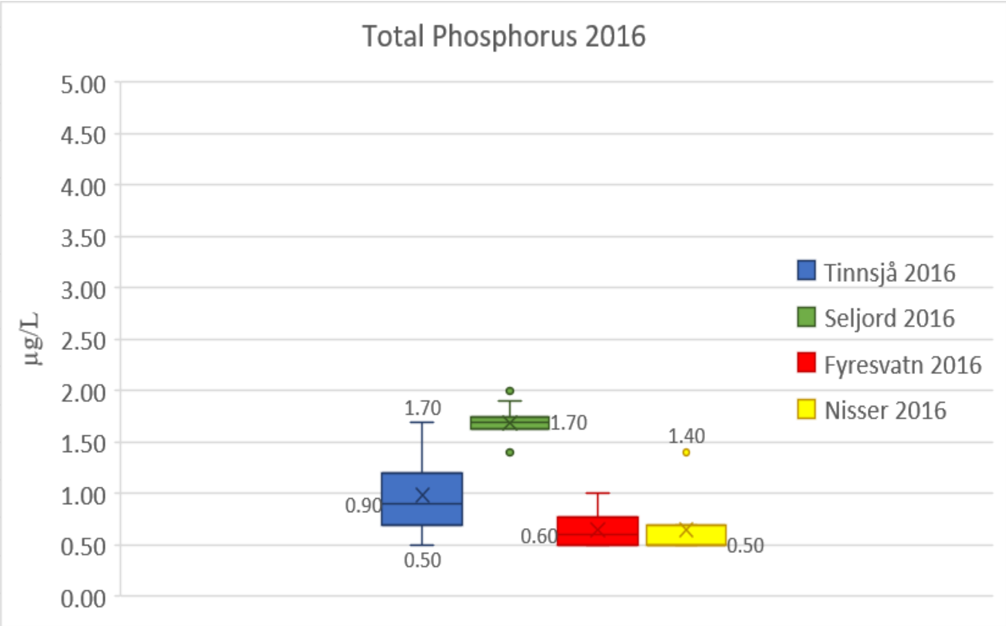


Figure 4- 9: Total Phosphorus 2016 (Measured by NMBI)

Unit: µg/L	Tinnsjå 2016	Seljord 2016	Fyresvatn 2016	Nisser 2016
Minimum	0.50	1.40	0.50	0.50
Q1	0.70	1.63	0.50	0.50
Median	0.90	1.70	0.60	0.50
Q2	1.20	1.75	0.78	0.70
Maximum	1.70	2.00	1.00	1.40
Mean	0.99	1.69	0.65	0.65
Average	1.20	0.60	0.50	0.90

We desired to get total phosphorus values under 5 microgram/L in order to meet "very good water quality" set up by NIVA. However, the values we measured in 2017 went to an opposite direction. Only Tinnsjå showed the average of total Phosphorus under 5 µg/L (4.37 µg/L /L) and the rest was higher than 5. Total Phosphorus of Seljord, Fyresvatn and Nisser was not only higher the limit value in term of mean (average) but also in term of median. That means the variation and dispersal of total phosphorus measured in 2017 was large. Fyresvatn and Nisser got 3 outliers which climbed up to approximately 60 µg/L - very bad threshold.

In contrast to our survey, NMBU lab published a different picture about total phosphorus status of those lakes. Data from 2016 was different at all 3 aspects: Mean, median/spread and outliers. Data 2016 definitely showed oligotrophic property in big and deep lakes in Telemark. The mean total phosphorus was well below 5 µg/L in all 4 lakes, there was no outliers that exceeded to bad threshold like 2017 datasheet.

This is the most challenged issue in this study. Extreme high concentration of total phosphorus was investigated in October 2017 together with the extreme points of total nitrogen. Natural events and contamination during sample handling might contribute to this.

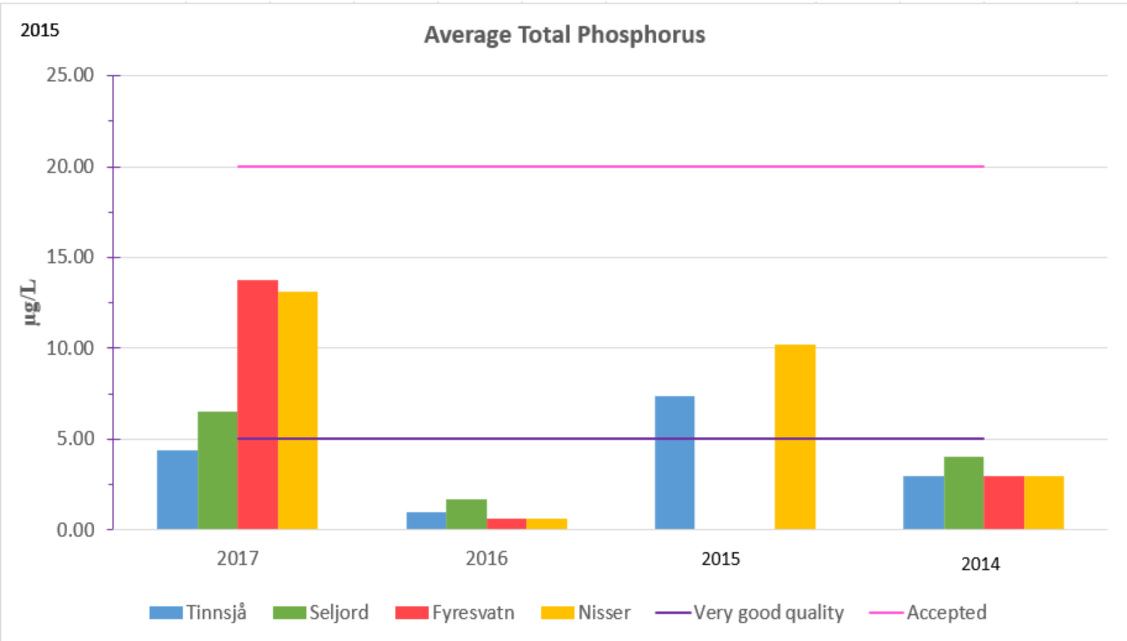


Figure 4- 10: Compare Total Phosphorus 2017 and 2016 and Other Years

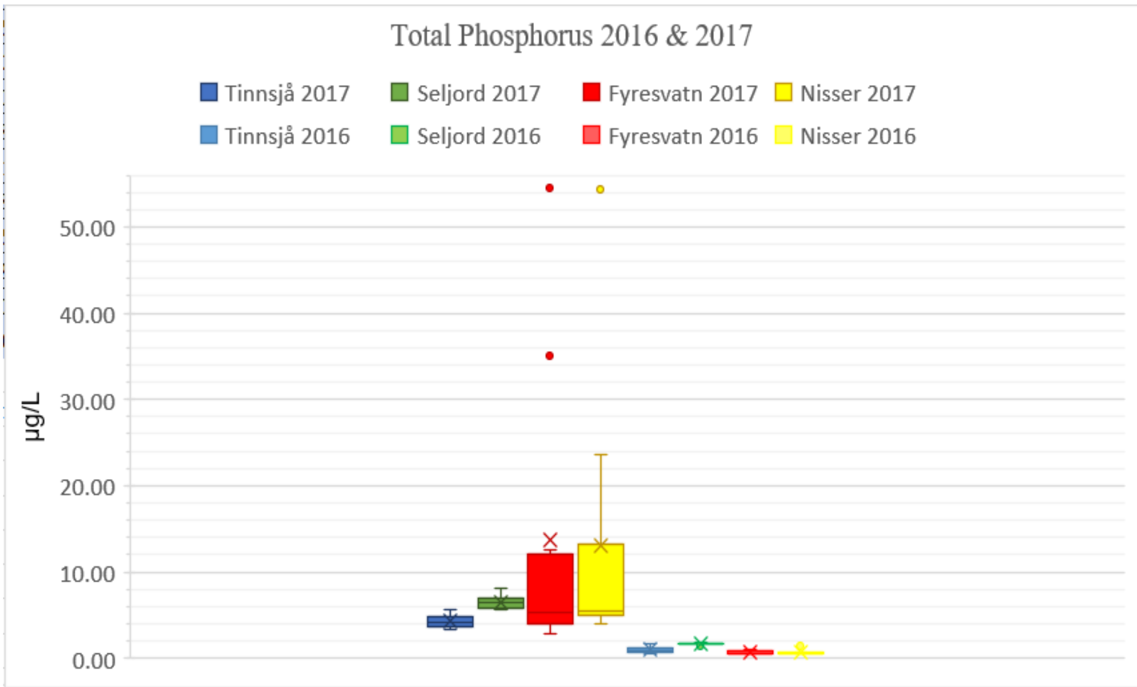


Figure 4- 11: Compare Mean, Median and Disperse of Total Phosphorus Between 2016 and 2017

In opposition to total phosphorus, concentration of Chlorophyll_a in 2017 looked stable and its distribution was narrow. Average Chl_a of 4 lakes was low, varied around 0.6 - 1 µg/L, far below threshold 2 microgram/L. The median was found very close to the mean. This is also the same trend described in the study at NMBU in 2016.

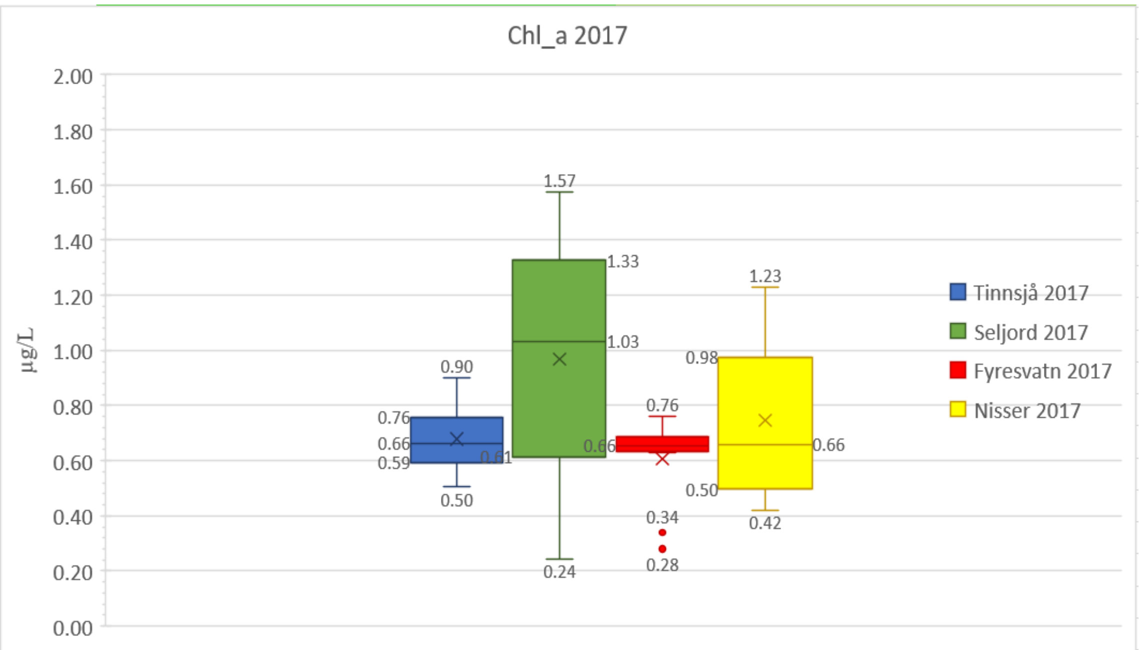


Figure 4- 12: Concentration of Chlorophyl_a 2017

Unit µg/L	Tinnsjå 2017	Seljord 2017	Fyresvatn 2017	Nisser 2017
Minimum	0.50	0.24	0.28	0.42
Q1	0.59	0.61	0.63	0.50
Median	0.66	1.03	0.66	0.66
Q2	0.76	1.33	0.69	0.98
Maximum	0.90	1.57	0.76	1.23
Mean	0.68	0.97	0.61	0.75
Range	0.39	1.33	0.48	0.81

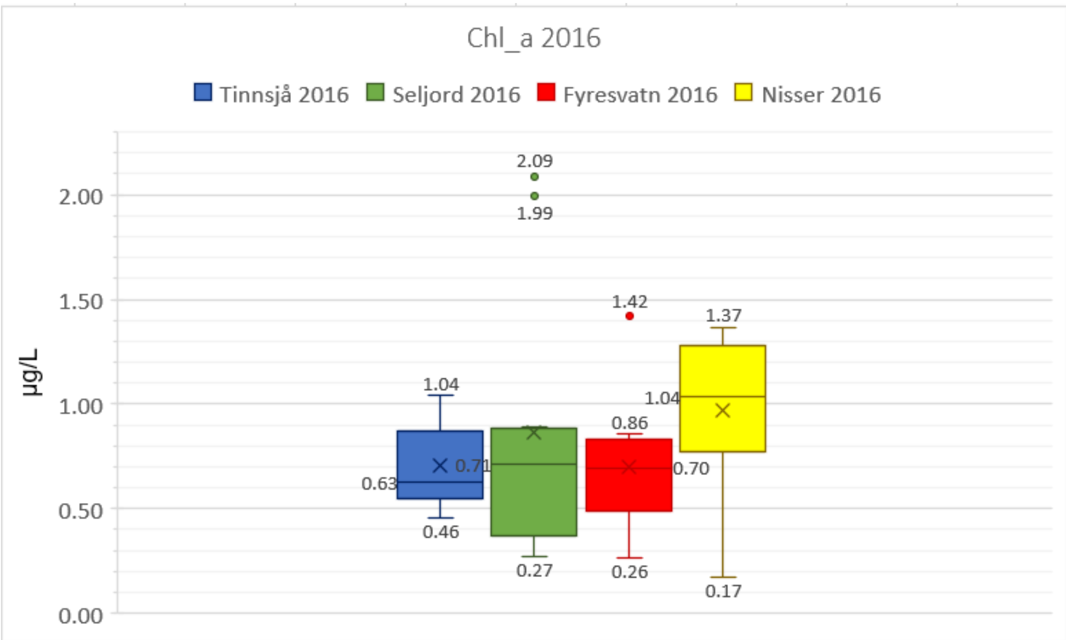


Figure 4- 13: Chlorophyll_a Concentration 2016

Unit µg/L	Tinnsjå 2016	Seljord 2016	Fyresvatn 2016	Nisser 2016
Minimum	0.46	0.27	0.26	0.17
Q1	0.55	0.37	0.49	0.77
Median	0.63	0.71	0.70	1.04

Q2	0.87	0.89	0.83	1.28
Maximum	1.04	2.09	1.42	1.37
Mean	0.70	0.87	0.70	0.97
Range	0.58	1.81	1.16	1.20

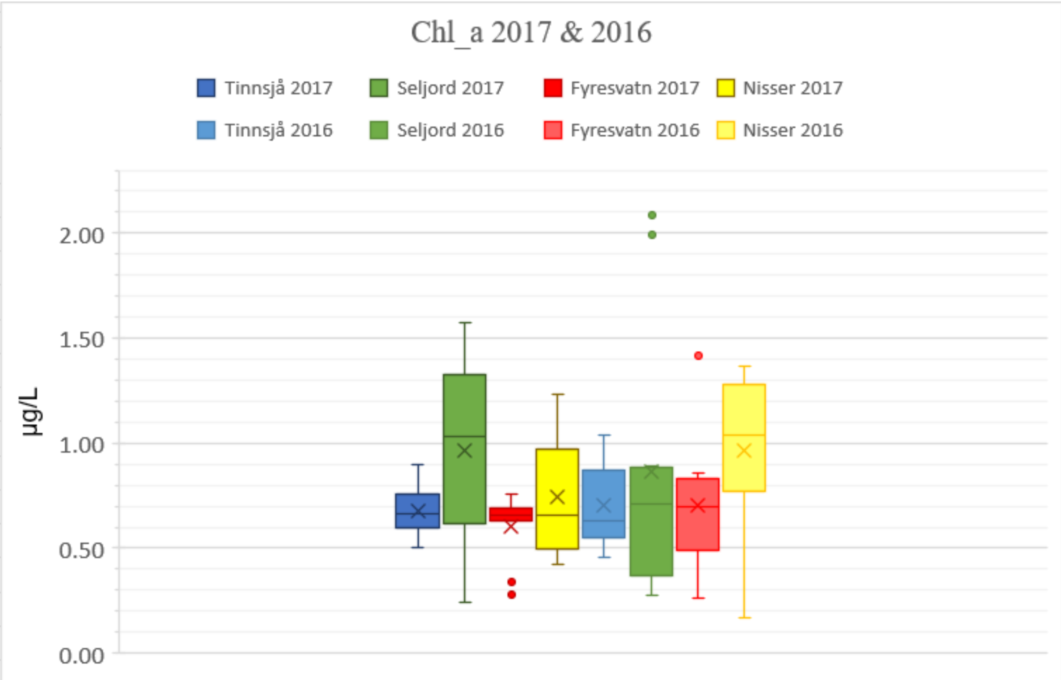


Figure 4- 14: Compare Chlorphyll_a Concentration Between 2017 and 2016

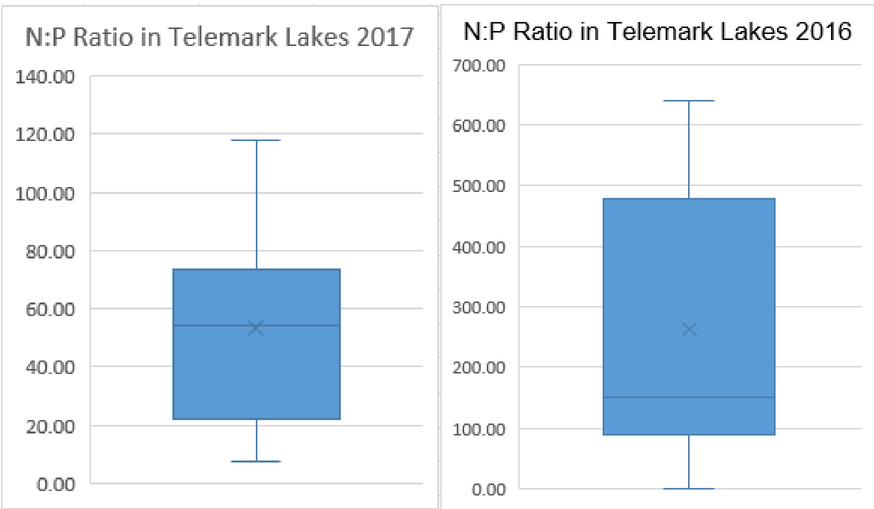


Figure 4- 15: N:P Ratio

As we had stated in page 11 and the study by Dillon & Rigler 1975, phosphorus will be the limiting factor for the growth of algae and eutrophication in deep and nutrient-poor lakes if N:P ratio exceeds 12. The figure above expresses the ratio of N:P in 4 studied lakes. This ratio well was much higher than 12. As amount of algae or algal biomass is often expressed by the concentration of Chl_a present, it is normally a strong positive correlation between Chlorophyll_a and total phosphorus (Rognerud, S., et al. 1979).

In order to cope with high concentration of total phosphorus as well as large uncertainties if we just use measured total phosphorus to estimate fish farming production, this total P concentration was calculated indirectly based on Chlorophyll_a concentration. Leader of the fish farming project - Prof. Espen Lydersen had collected original data of 10 lakes in Telemark, data was cited from the study of Rognerud et al. (1979). Then, he theoretically assumed that the function between average concentration of Chlorophyll_a and Total Phosphorus for 10 deep and big lakes in Telemark which assumed by the research of Rognerud et al. 1979:

[Tot-P] = 2.47*[Chl_a] + 2.51 ($r^2 = 0.95$) linear function (Equation 1)

[Tot-P] = 5.09*[Chl_a]$^{0.54}$ ($r^2 = 0.89$) exponential function (Equation 2)

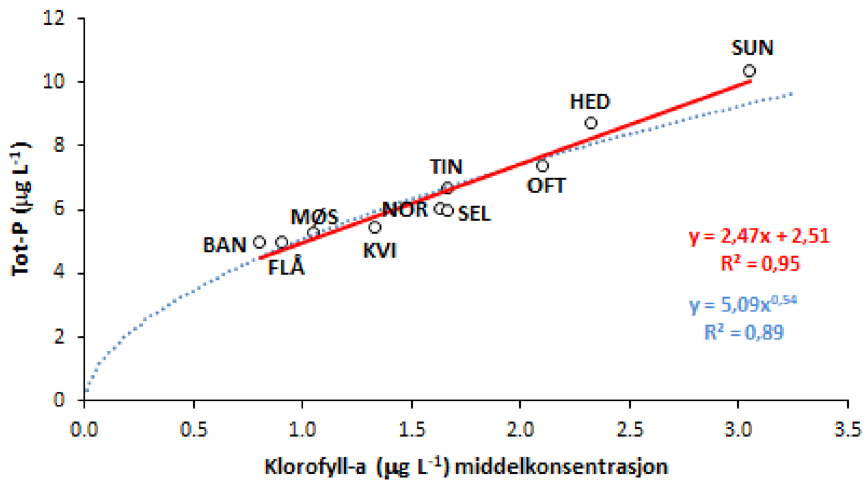


Figure 4- 16: Relation Between Concentration of Chl_a and Total P. The Lakes Are: SUN - Sundkilen, HED - Heddalsvatn, OFT - Oftenvatn, TIN - Tinnsjå, SEL - Seljord, NOR - Norsjø, KVI - Kviteseidvatn, MØS - Møsvatn, FLÅ - Flåvatn, BAN – Bandak

Source: Espen Lydersen, 2017

Therefore, the equation developed by Prof, Espend Lydersen plays as a key and kink in this study. High concentration of total phosphorus measured in 2017 made a real difficulty. We expected to get low phosphorus concentration as NMBU found in 2015 with pretty good values of Chl_a and other parameters but it did not go very well with determination of low phosphorus water sample. So total phosphorus was calculated indirectly and the phosphorus storage as well as potential fish production are based on this indirectly calculated total phosphorus.

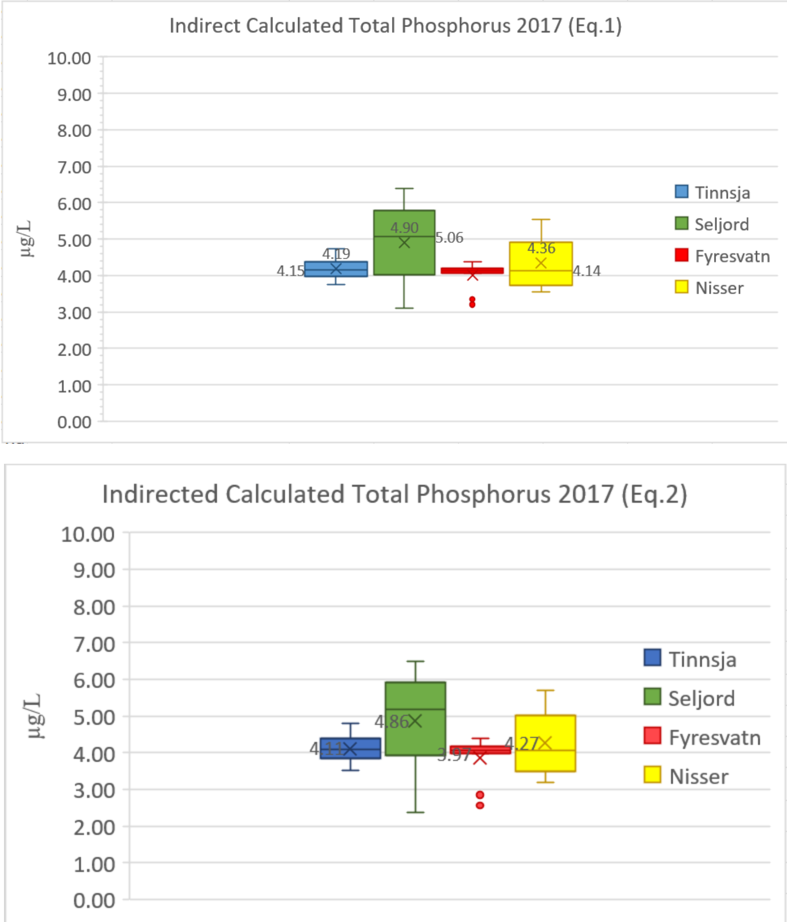


Figure 4- 17: Indirect Calculated Total Phosphorus 2017

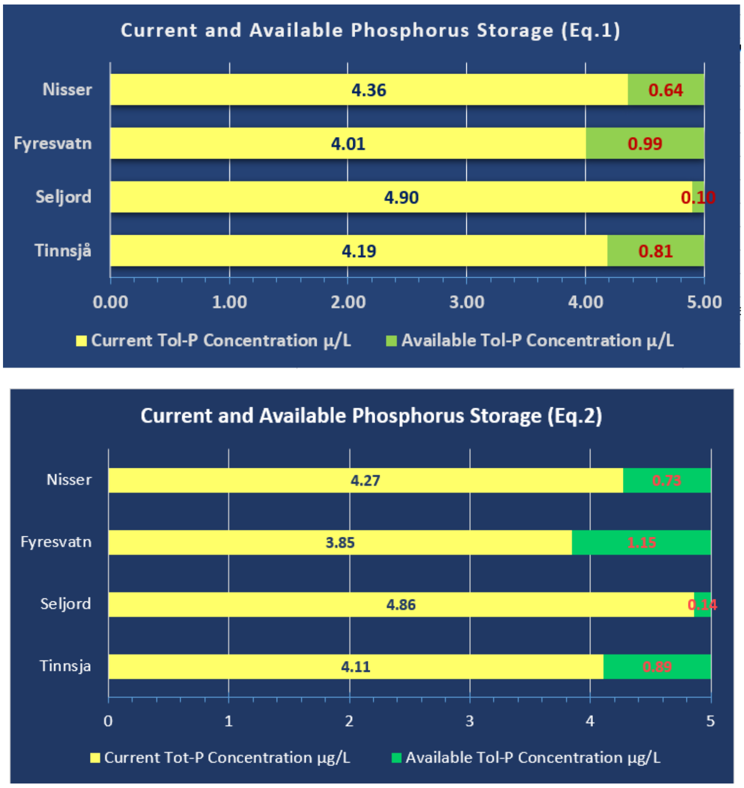
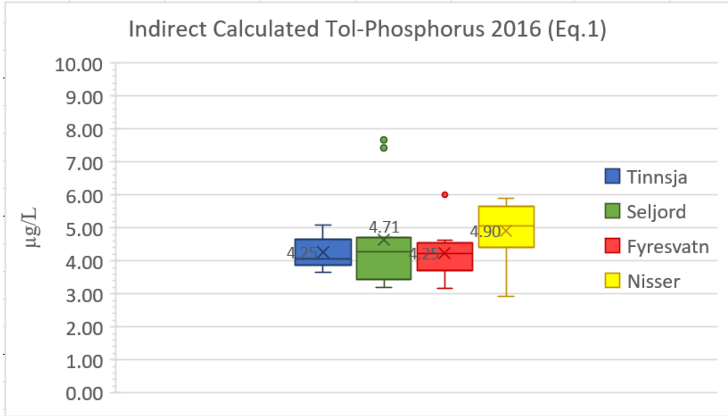


Figure 4- 18: Current Concentration of Total Phosphorus and Available Phosphorus for Fish Farming According to Equation 1 and 2, 2017

Figure 4- 19: Phosphorus Storage 2017, Based on Indirect Calculated Total Phosphorus and Limit Threshold 5 µg/L



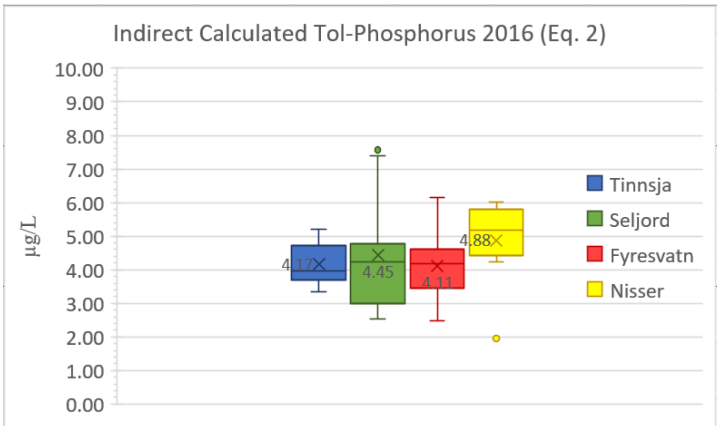
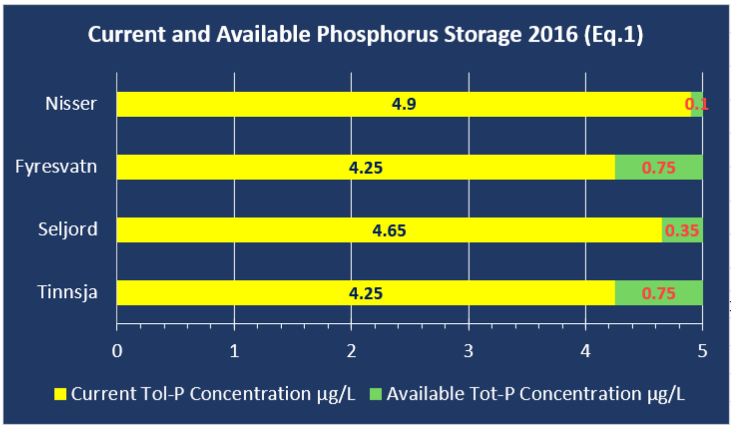


Figure 4- 20: Indirect Calculated Total Phosphorus 2017 and 2016



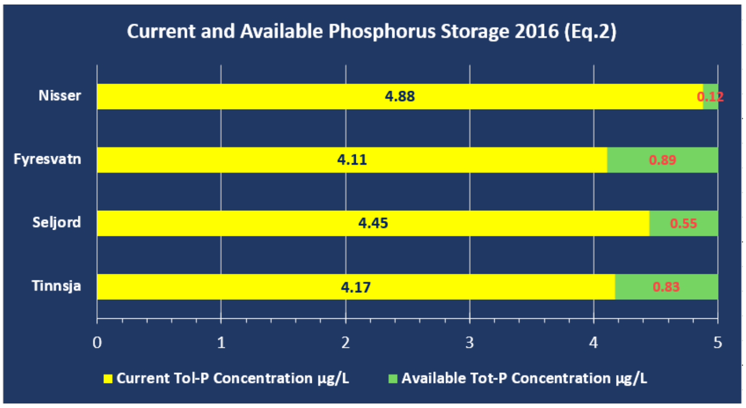


Figure 4- 21: Current Concentration of Total Phosphorus and Available Phosphorus for Fish Farming According to Equation 1 and 2, 2016

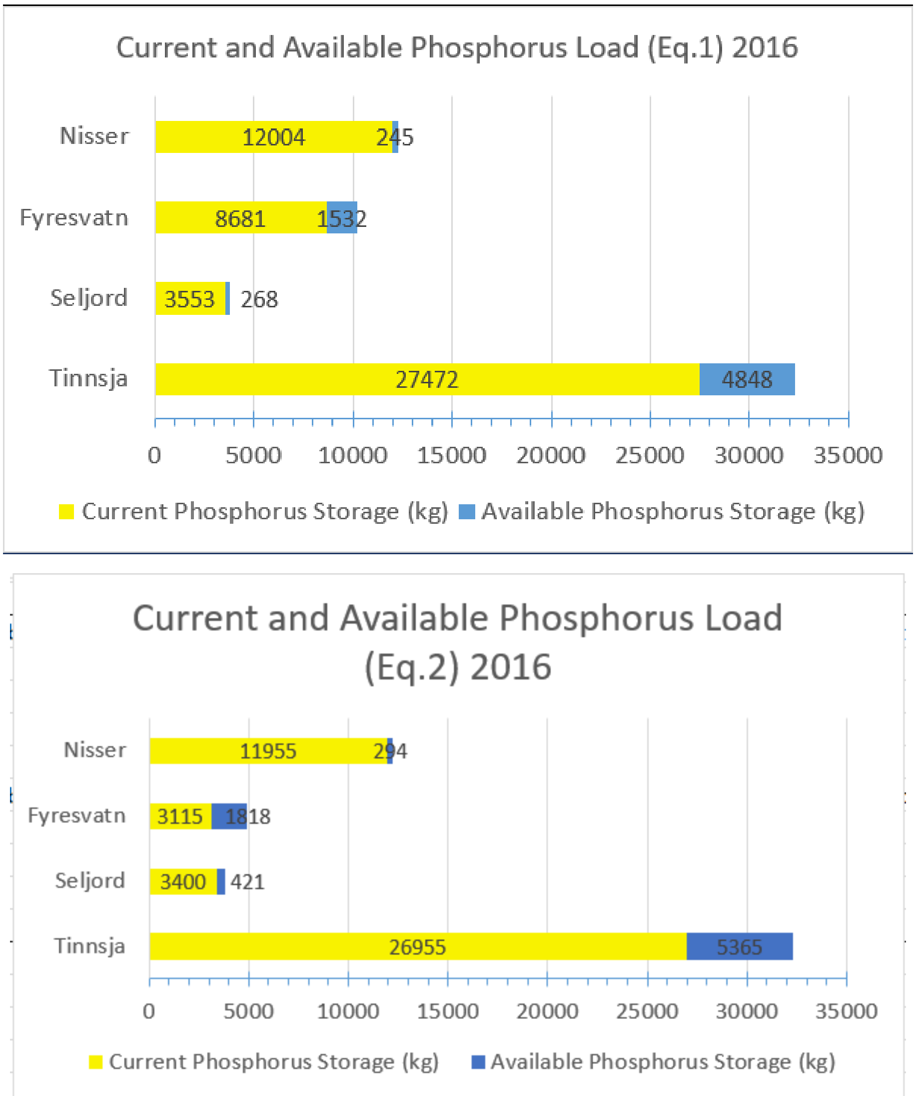
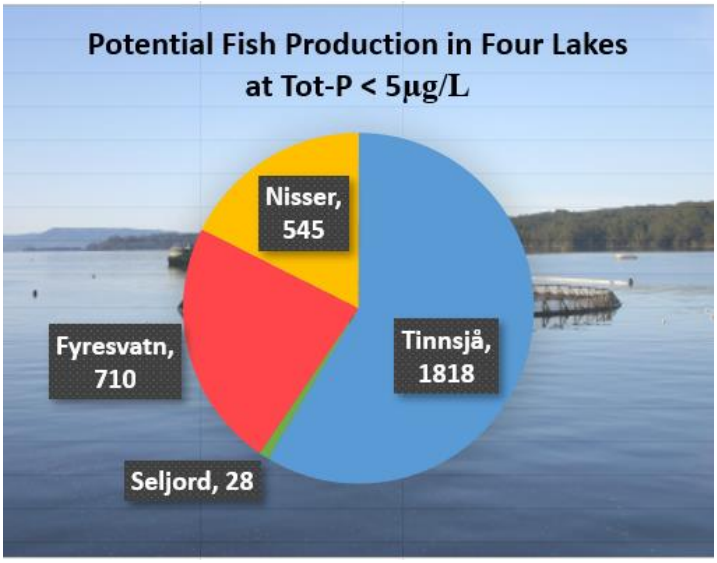


Figure 4- 22: Phosphorus Storage 2016, Based on Indirect Calculated Total Phosphorus and Limit Threshold 5 µg/L

If we assume that there is maximum 40% of current phosphorus storage is bioavailable (Braaten, B., et al. 1992). We get more 40% of available phosphorus load and here is final estimated environmentally friendly fish production of 4 lakes in Telemark



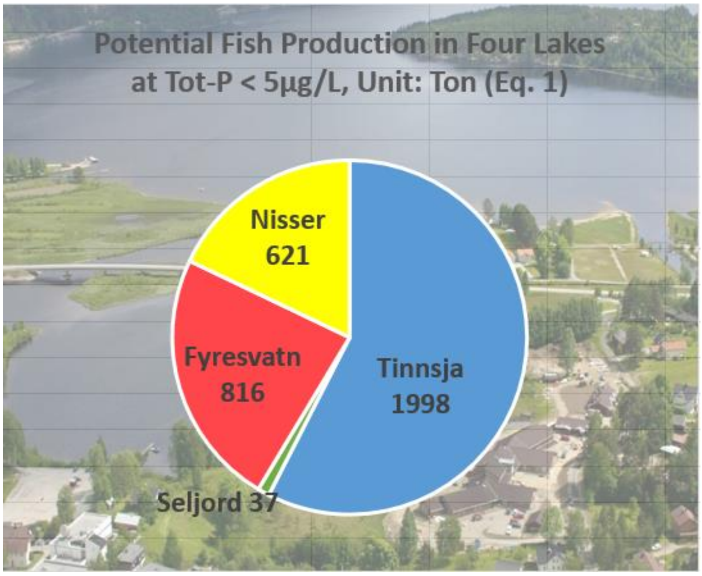


Figure 4- 23: Potential Fish Production, Based on Survey 2017

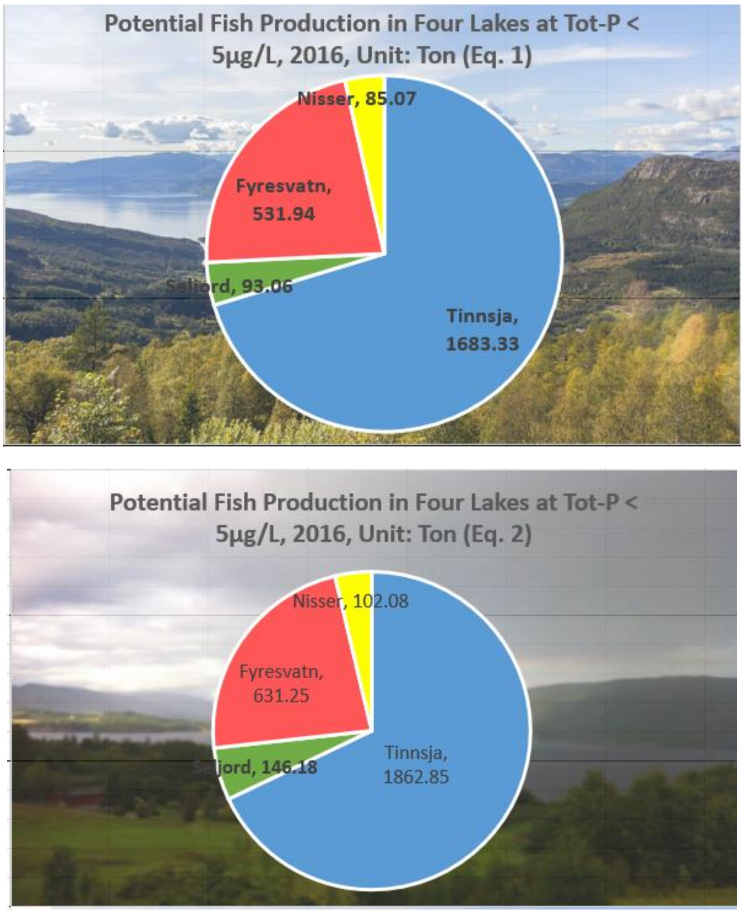


Figure 4- 24: Potential Fish Production, Based on Survey 2016

Total phosphorus concentration was indirectly calculated by 2 equations which similarly describe the relation between total phosphorus and concentration of Chl_a. Additionally, datasheet from 2016 was also used to estimate in order to get a broader comparison of final results and uncertainty of the estimation.

Equation 2 gives a slightly lower concentration of total phosphorus and thus results in a smaller current phosphorus storage and higher potential production. As NIVA decreased the threshold for very good quality of total phosphorus to only 5 µg/L, the potential production also reduced sharply. We assumed that only 40% of phosphorus in water is available for biological activities. Hence, the potential production was multiplied by 2.5 times.

Moreover, difference in total phosphorus concentration between 2 surveys makes difficulties. Concentration of Chlorophyll_a seemed to make sense when we estimated fish farming production at the final step. For 2017, total phosphorus concentration exceeded the limit value while it was very low in 2016 and that casts doubt on big uncertainty in this study.

However, the potential production still varies. Tinnsjå has highest potential production (1683 tons to approximately 2000 tons). On the other hand, Seljord is not a promising for place for large scaled fish farming due to its pretty high nutrient content (total organic carbon, total nitrogen, total phosphorus and Chlorophyll_a). Both surveys in 2016 and 2017 delivered a small potential production that there was lower available environmental load for less than 150 tons fish.

Data from 2016 and 2017 indicated a relative stable concentration of nutrients in Fyresvatn as we can see the potential production of Fyresvatn was fluctuated around 532 – 816 tons. In contrast, Nisser got different values for production between 2 years. This is caused by difference in Chlorophyll_a. As is shown by figure 24, Chlorophyll_a of Nisser in 2017 decreased compared to the survey in 2016 and that led to a large gap between 2 estimated potential production. This is probably caused by natural events such as dry period.

Because of the fact that new threshold for very good natural water quality is only 5 µg/L, we can tolerate and assume that the potential fish farm production of these lake is approximately 1900 tons for Tinnsja and 800 tons for Fyresvatn whereas Seljord does not have large capacity for fish farming. The water quality may vary from very good to good. About Nisser, data from 2 surveys shows differences and causes difficulty as well as uncertainty to conclude a final answer for fish farming potential.

5. CONCLUSION

5.1 Water Quality and Potential of Fish Farming in 4 Lakes

These lakes was categorized as oligotrophic lakes due to low concentration of nutrients and turbidity and high transparency.

Many of parameters reached very good condition. Tinnsja has best water quality according to requirements of NIVA. Fyresvatn and Nisser had pretty low pH but the values were not out of the limit threshold. Total phosphorus and nitrogen were also relatively high in those lakes. In Seljord, we found high concentration of total nitrogen which was categorized as "bad".

Table 5- 1: Water Quality of Tinnsja, Seljord, Fyresvatn and Nisser, 2017

Water Quality 2017	Tinnsja	Seljord	Fyresvatn	Nisser
Total Nitrogen µg/L	390.52	657.05	350.05	339.59
Total Phosphorus µg/L	4.37	6.49	13.79	13.09
Chlorophyll_a µg/L	0.68	0.97	0.61	0.75
Transparency meter	-9	-4.5	-6.5	-6.2
TOC mg/L	2.02	4.52	3.50	3.33
pH	6.53	6.6	5.83	5.94
Turbudity NTU	0.38	0.58	0.56	0.53
Very Good	Good	Moderate	Bad	Very Bad

Because of very low concentration of both phosphorus and chlorophl_a, Tinnsja has highest fish farming production which can tolerate approximately 1900 tons per year. Fyresvatn is also a good lake for fish farming with the potential production is predicted to get approximately 800 tons per year. Iceland is leading farmed Artic charr with more than 3200 tons produced in 2013, according to Runarsson, G. (2013). Fyresvatn and Tinnsja have potential to make up 80% of Iceland's farmed Arctic charr produced in 2013.

Higher nutrient values make Seljord have least fish farming production. Although data in 2017 displayed a good potential production for fish farming in Nisser, it is not very certainly to leave a comment on Nisser owing to fluctuation of total phosphorus and chlorrophyl_a in 2016 and 2017.

5.2 Technical Issues and Uncertainties of The Study

"All science has uncertainty" (Baruch Fischhoff and Alex L. Davis, 2014). The unit of potential production of fish farming is ton per year. The uncertainty is really large. Hence, "estimate" and "approximately" are better word to describe the potential production of fish farming. Here are factors that contribute to the uncertainties in this study:

- Systematic Error: Associated with faulty equipment, measuring tools produce consistent errors and it repeated with the same error every time water parameters were measured.
- Random Error: Occurred because our inability to take the same measurement in exactly the same way. For instance, reading water temperature on thermometer.
- The equation used to estimate phosphorus storage P_{in} = 1.59 * [P] * $e^{\wedge(0.067*Tw)}$*Q has large uncertainty because of the fact that T_w's and Q's unit is year and km^3. A tiny change in T_w or Q will obviously causes a huge fluctuation of the result.
- Natural events: We got several outliers in measuring total nitrogen, total phosphorus. Some of them had very unusual high values. Natural events such as heavy rain in autumn which increased nutrient components into the lake by runoff could be responsible for that. In addition, the gap between total phosphorus of Nisser between 2016 and 2017 resulted in a variation in fish farming production.
- Besides, there is a challenge to measure water having very low phosphorus content. Contamination had happened somewhere during water taking procedure, for example from contaminated plastic bottle.

Finally, some important points are summed up after this study:

- ✓ Technique to measure low nutrient content in water plays a crucial role in this study.
- ✓ Moreover, estimating which bases only on total phosphorus also gives large uncertainties. That's why empirical formula is important as well
- ✓ Statistic test had neither been mentioned nor applied in this study. This is a short coming of this study. Hence, comments on difference between 2 datasheets could not go further than visual comparison. "Significant difference" could not be

declared. Statistics test such as comparing two means is given as recommendation for other studies.

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ANNEXES

Annex 1: Datasheet 2017

						NS-ISO 7888	NS-EN ISO 7027	NS 4754	NS 4766	NS 4720	NS-EN 1484		NS-EN 4743
Lake name	Station	Sample date	Analysis date	Sight depth	Chl-a filt. vol	Conductivity	Turbidity	Alkalinity	Chl-a	pH	TOC	Tot-P (HSN)	Tot-N (HSN)
				m	mL	mS cm^{-1}	NTU	mmol L^{-1}	mg L^{-1}		mg L^{-1}	µg L^{-1}	µg L^{-1}
Tinnsjø	North	6/13/2017	6/13/2017	4.5	2800	13.0	0.53	114	0.90	6.74	2.10	4.2	234
Tinnsjø	South	6/13/2017	6/13/2017	5.0	2940	12.7	0.42	105	0.64	6.59	2.64	3.6	318
Seljord	South	6/13/2017	6/13/2017	4.0	1820	19.6	0.77	129	1.35	6.70	4.19	7.1	1543
Seljord	North	6/13/2017	6/13/2017	3.5	2770	19.6	0.67	132	0.24	6.59	4.37	6.2	898
Tinnsjø	North	7/5/2017	7/6/2017	10.0	3500	12.7	0.40	112	0.55	6.19	1.60	4.1	227
Tinnsjø	South	7/5/2017	7/6/2017	11.0	2700	12.8	0.30	110	0.65	6.42	1.83	3.6	560
Seljord	South	7/5/2017	7/6/2017	5.0	3500	19.7	0.64	130	0.53	6.36	4.28	5.6	407
Seljord	North	7/5/2017	7/6/2017	4.3	2730	19.6	0.60	129	0.59	6.50	4.29	5.7	472
Tinnsjø	North	8/10/2017	8/10/2017	11.5	3500	12.6	0.32	106	0.58	5.70	1.69	4.1	183
Tinnsjø	South	8/10/2017	8/10/2017	12.0	5300	12.5	0.27	100	0.50	6.40	1.74	3.4	352
Seljord	South	8/10/2017	8/10/2017	5.5	3500	19.3	0.41	122	1.38	6.50	4.25	5.9	382
Seljord	North	8/10/2017	8/10/2017	4.5	3000	19.3	0.48	125	1.10	6.60	4.39	6.8	362

Tinnsjø	North	9/7/2017	9/7/2017	9	3500	12.9	0.30	116	0.82	6.87	1.73	4.8	236
Tinnsjø	South	9/7/2017	9/7/2017	10	4700	13.2	0.28	111	0.78	6.95	1.94	4.7	1136
Seljord	South	9/7/2017	9/7/2017	5	3500	19.8	0.37	134	0.68	6.62	4.33	5.8	643
Seljord	North	9/7/2017	9/7/2017	5	2000	19.5	0.62	136	1.57	6.77	4.41	6.6	433
Tinnsjø	North	10/17/2017	10/17/2017	8	4000	13.2	0.47	111	0.68	6.75	2.33	5.7	269
Tinnsjø	South	10/17/2017	10/17/2017	9	4500	12.9	0.51	107	0.68	6.73	2.58	5.5	
Seljord	South	10/17/2017	10/17/2017	4	3000	18.9	0.54	127	0.97	6.62	5.20	7.2	843
Seljord	North	10/17/2017	10/17/2017	3.5	1820	18.4	0.71	124	1.27	6.69	5.49	8.0	586
Fyresvatn	North	6/12/2017	6/27/2017	5	1640	11.6	1.06	55.6	0.69	5.83	3.70	5.5	281
Fyresvatn	South	6/12/2017	6/27/2017	7	1700	10.9	0.52	51.3	0.73	5.74	3.56	4.0	306
Nisser	North	6/12/2017	6/27/2017	4.5	1400	11.1	0.70	54.1	1.15	5.98	3.82	4.9	256
Nisser	South	6/12/2017	6/27/2017	6.5	2000	10.9	0.64	48.7	0.64	5.74	3.00	5.6	263
Fyresvatn	North	7/11/2017	8/11/2017	6	2200	12.4	0.49	73	0.66	5.90	3.03	12.6	268
Fyresvatn	South	7/11/2017	8/11/2017	7.5	2420	11.1	0.39	54	0.63	5.70	3.12	10.3	260
Nisser	North	7/11/2017	8/11/2017	7.5	2600	11.5	0.55	61	0.66	5.80	3.73	4.6	259
Nisser	South	7/11/2017	8/11/2017	7.5	2620	11.8	0.28	55	0.66	5.70	3.34	5.0	287
Fyresvatn	North	8/17/2017	8/18/2017	6	2220	10.3	0.54	58	0.68	6.06	3.32	5.0	360
Fyresvatn	South	8/17/2017	8/18/2017	8	3500	10.3	0.45	54	0.64	6.05	2.68	3.9	331
Nisser	North	8/17/2017	8/18/2017	6	1850	10.3	0.53	60	1.03	6.20	2.83	5.4	359

Nisser	South	8/17/2017	8/18/2017	6	2670	10.6	0.46	56	0.81	6.20	2.70	3.9	395
Fyresvatn	North	9/19/2017	9/20/2017	6	2300	10.5	0.63	53	0.76	5.71	3.90	35.1	740
Fyresvatn	South	9/19/2017	9/20/2017	6.9	3000	10.3	0.48	51	0.65	5.62	3.08	2.8	243
Nisser	North	9/19/2017	9/20/2017	6.4	1100	11.0	0.50	62	1.23	5.88	3.41	8.8	336
Nisser	South	9/19/2017	9/20/2017	7	4500	10.6	0.51	53	0.42	5.94	3.21	14.7	333
Fyresvatn	North	10/25/2017	10/26/2017	5.5	2750	11.3	0.62	59	0.34	5.91	3.77	54.5	410
Fyresvatn	South	10/25/2017	10/26/2017	7	4000	10.6	0.44	51	0.28	5.79	3.41	4.2	302
Nisser	North	10/25/2017	10/26/2017	5	2810	12.2	0.51	64	0.42	5.91	4.02	23.7	439
Nisser	South	10/25/2017	10/26/2017	6.5	3500	10.6	0.46	53	0.45	6.04	3.23	54.3	469

Annex 2: Datasheet 2016

		Siktedyp	Turb.	pH	Alk.	TOC	Tot-P	**Tot-N**	**Chl-a**
Lokalitet	Prøvedato	m	NTU		mmol L^{-1}	mg L^{-1}	mg L^{-1}	**mg L^{-1}**	**mg L^{-1}**
Fyresvatn, Nord	6/16/2016	7.0	0.50	5.26	26	2.27	1.00	250.22	0.47
Fyresvatn, Nord	7/12/2016	7.0	0.21	5.99	22	2.31	0.70	379.65	0.26
Fyresvatn, Nord	8/17/2016	6.5	0.21	5.90	25	2.35	0.50	246.66	0.78
Fyresvatn, Nord	9/16/2016	7.5	0.19	6.03	24	2.38	**0.50**	320.11	0.85
Fyresvatn, Nord	10/13/2016	6.5	0.20	6.02	21	2.40	0.80	295.97	0.54
Fyresvatn, Sør	6/16/2016	7.0	0.55	6.00	34	2.20	**0.50**	299.44	0.86
Fyresvatn, Sør	7/12/2016	7.0	0.27	5.96	27	2.24	**0.50**	294.22	0.45

Fyresvatn, Sør	8/17/2016	8.5	0.19	6.03	24	2.26	0.50	246.29	0.71
Fyresvatn, Sør	9/16/2016	7.0	0.53	6.00	29	2.30	0.70	336.64	1.42
Fyresvatn, Sør	10/13/2016	6.0	0.22	5.93	27	2.35	0.80	342.57	0.69
Nisser, Nord	6/16/2016	6.0	0.23	6.09	24	2.40	**0.50**	306.14	0.76
Nisser, Nord	7/12/2016	8.0	0.20	6.09	38	2.30	**0.50**	271.90	0.96
Nisser, Nord	8/17/2016	7.0	0.19	6.14	30	2.41	1.40	240.17	1.32
Nisser, Nord	9/16/2016	7.0	0.22	6.14	33	2.36	**0.50**	200.81	1.11
Nisser, Nord	10/13/2016	8.0	0.20	6.17	26	2.40	0.50	195.65	0.71
Nisser, Sør	6/16/2016	7.0	0.21	6.02	31	2.22	0.70	259.01	0.80
Nisser, Sør	7/12/2016	8.5	0.20	6.04	34	2.15	**0.50**	236.13	0.17
Nisser, Sør	8/17/2016	8.0	0.22	6.09	23	2.31	0.70	243.01	1.14
Nisser, Sør	9/16/2016	7.0	0.20	6.05	33	2.28	0.50	249.12	1.33
Nisser, Sør	10/13/2016	7.0	0.24	5.90	22	2.38	0.70	274.74	1.37
Seljord, Nord	6/22/2016	5.3	0.22	6.64	73	3.25	1.70	196.15	0.69
Seljord, Nord	7/28/2016	5.3	0.19	6.52	75	3.68		175.65	0.44
Seljord, Nord	8/29/2016	4.0	0.20	6.52	75	4.03	1.70	189.43	0.27
Seljord, Nord	9/29/2016	5.5	0.16	6.59	79	3.91	1.90	167.79	0.89
Seljord, Nord	11/3/2016	7.0	0.20	6.59	77	3.91		164.44	0.35
Seljord, Sør	6/22/2016	5.0	0.17	6.82	73	3.37	1.70	209.24	0.35

Seljord, Sør	7/28/2016	5.6	0.18	6.62	72	3.37	1.70	183.85	2.09
Seljord Sør	8/29/2016	4.5	0.20	6.62	69	3.71	1.40	186.60	0.88
Seljord Sør	9/29/2016	5.5	0.18	6.66	76	3.73	1.40	173.85	1.99
Seljord, Sør	11/3/2016	7.0	0.20	6.70	78	3.77	2.00	118.24	0.73
Tinnsjå, Nord	6/21/2016		0.15	6.64	62	1.28	1.40	118.10	1.04
Tinnsjå, Nord	7/28/2016	12.0	0.20	6.61	58	1.38	0.70	63.75	0.54
Tinnsjå, Nord	8/29/2016	9.5	0.18	6.50	60	1.49	0.70	68.43	0.64
Tinnsjå, Nord	9/30/2016	8.0	0.14	6.69	59	1.41	1.00	64.13	0.93
Tinnsjå, Nord	10/25/2016	12.5	0.19	6.69	59	1.38		70.66	0.87
Tinnsjå, Sør	6/21/2016		0.15	6.66	60	1.39	0.90	89.65	0.51
Tinnsjå, Sør	7/28/2016	11.0	0.19	6.56	52	1.45		78.09	0.86
Tinnsjå, Sør	8/29/2016	9.0	0.17	6.61	55	1.48		68.93	0.61
Tinnsjå, Sør	9/30/2016	14.0	0.20	6.59	56	1.39	0.50	60.29	0.46
Tinnsjå, Sør	10/25/2016	12.5	0.20	6.69	57	1.41	1.70	34.34	0.57