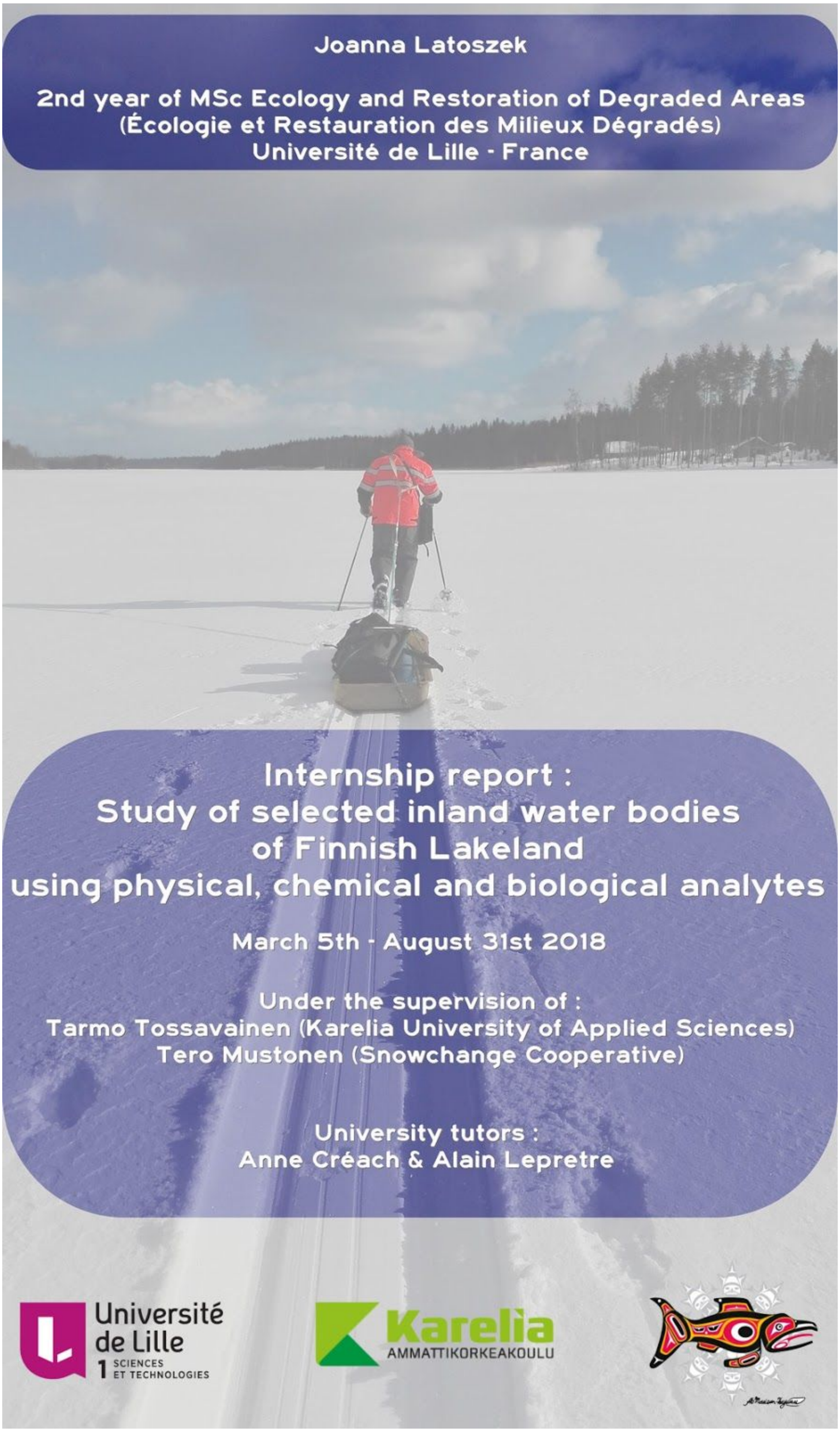

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Internship report : Study of selected inland water bodies of Finnish Lakeland using physical, chemical and biological analytes

March 5th - August 31st 2018

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You may turn Nature out of doors with violence, but She will still return.
Horace*, Epistles,* I. 10. 24

I - Introduction

When discussing environmental protection and sustainability, the Nordic countries - Norway, Sweden, Finland, Denmark and Iceland - are usually evoked as the experts in these fields and considered an example to follow. This is most notably illustrated by the Environmental Performance Index (EPI), which has been developed by Yale University in collaboration with Columbia University and takes into account different aspects of the environmental health and the ecosystem vitality (Yale, 2018a). First published in 2002, it has been consistently ranking the Nordic countries on the top of its list (Yale, 2018b).

1) Overview of Finland

Finland, nicknamed "the land of a thousand lakes", is internationally renowned for its vast forests, which cover 75% of the territory, and - as the title would suggest - its countless lakes (Metsäyhdistys, 2014). Since there is no set definition of a lake, it is extremely difficult to estimate the total number of them. If we would define a lake as a water body equal or larger than 500 m^2, then the estimated number of water bodies contained within Finland's border considered as such varies between 168,000 (Statistics Finland, 2018a) and 188,000 (IUCN, nd), depending on the source. In many cases, the lakes are connected between each other to the degree where long-distance navigation is possible.

It is also worth noting, that around 34% of forestry land consist of peatlands, which also are an important resource of their own. Such a high prevalence of peatlands is due to favourable environmental conditions : cool temperatures, characteristic of the subarctic climate - which dominates the country - lead to low evapotranspiration, which in turn helps create water-logged areas, and as a consequence - the affected areas experience a significant decrease of oxygen levels (Joosten & Clarke, 2002 ; Joosten, 2015). Moreover, only the hardiest vegetation can grow in the boreal areas. This includes the conifers, which strongly acidify the surrounding areas, when the organic acids contained in the discarded needles are released into the environment (Millar, 1974 ; Hornung, 1985 ; Augusto, 1998).

Both of these factors - high acidity and anoxia due to constant inundation - lead to the organic matter's slow and partial decay, which transforms into peat.

Because of the strong dependence on the natural resources (lakes, forests, agriculture) over the course of history, the Finns have maintained an equally strong connection to the surrounding environment. This nation-wide appreciation for Nature is reflected by the popularity of outdoor activities in Finland - be it fishing, hunting, berry/mushroom picking, or canoeing, among others (Tyrväinen, 2001 ; Vepsäläinen, 2010). It is also reflected by the interest in summer houses which evolved exponentially during the XXth century, going from around a 1,000 free-time residences at the turn of the century to roughly 500,000 today (Statistics Finland, 2007 ; Statistics Finland, 2018b). As illustrated by the maps below (**Fig.1**), a large part of them is located near water bodies, either at the maritime coast, or at lake shores.

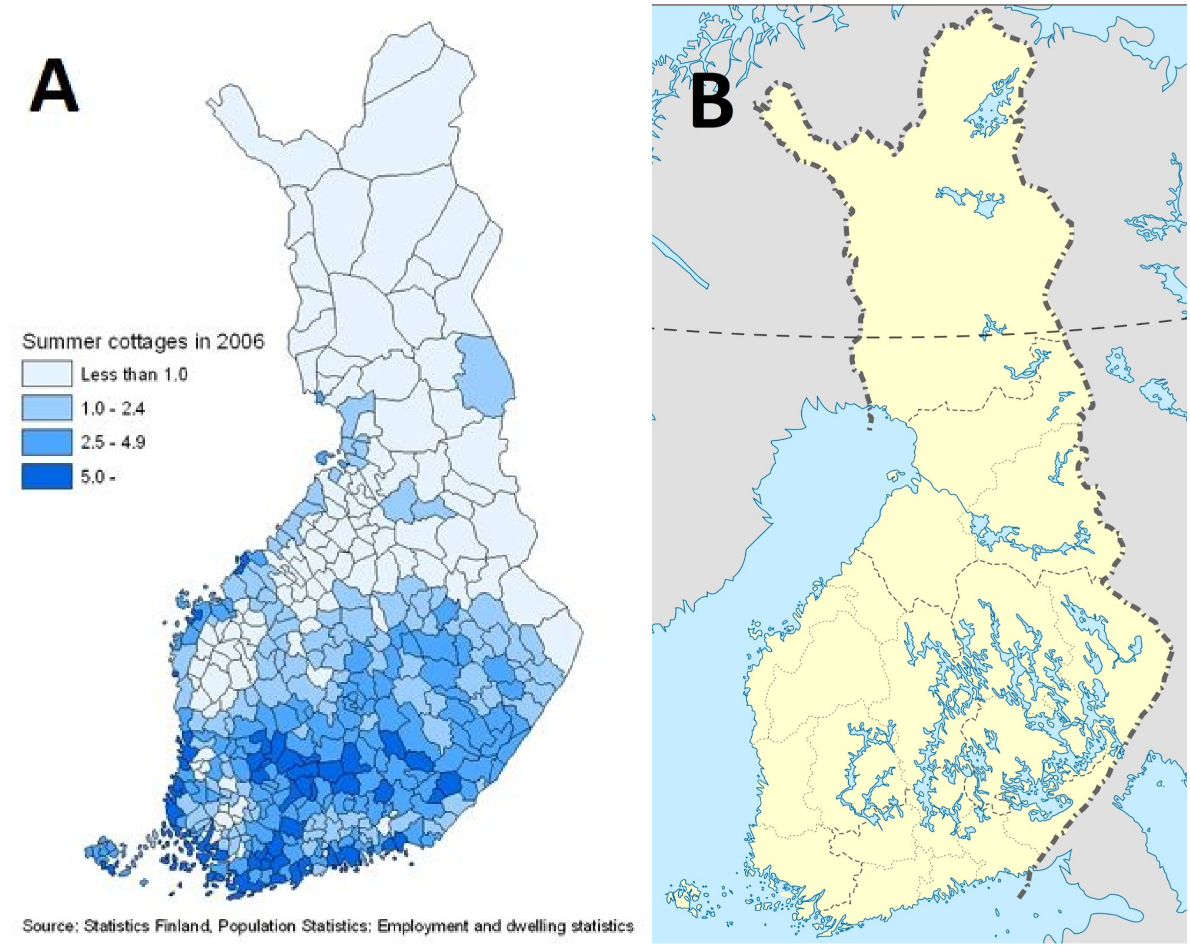

Fig.1 :
(a) (left) : Number of summer cottages per square kilometre by municipality
(b) (right) : The dense lake network, mostly in the Central and Eastern Finland.

Finland underwent a radical change within the XXth century, starting as an agrarian developing country, and currently enjoying its status as top performer in several socio-economic categories. The major shift occurred after World War II, when Finland had to hand over parts of its land, along with money and materials to Soviet Union as war reparations. This has forced the population to focus on developing the industries (energy production, machinery, chemicals, communications...), intensive agriculture and forestry (Hjerppe, 2008 ; Haapala, 2009). Following the 1970s energy crisis, an additional emphasis was put on the peat extraction in order to become more independent from external sources of fuel (International Peat Society, nd).

While the peat use has been growing steady, reaching its maximum in 2007, it has since declined due to environmental concerns raised by several organisations, such as the Parliamentary Committee on Energy and Climate Issues (PCECI, 2014 ; Similä *et al*, 2014a and 2014b). Additionally, the invaluable role of peatlands as carbon sinks, water reservoirs and home to many endangered fauna and flora species has lead to an increased interest in active peatland restoration projects (Barthelmes *et al*, 2015 ; Millenium Ecosystem Assessment, 2005).

2) Focus on Finnish Lakeland

As it is the case with most countries, Finland can be divided into major landscape - or topographic - regions. We can distinguish three major areas (Behrens and Lundqvist, nd) :

- Upland Finland : the northernmost part of the country, known for its low population density, low biodiversity and relatively high altitudes ;
- Coastal area : occupying south-west of the country, characterized by a large number of islands and archipelagos, but also by agricultural activities ;
- **Finnish Lakeland** : covering the central and eastern parts of the country, mostly known for the world-renowned forests and lakes.

Approximately 25% of the surface of the Finnish Lakeland (alternatively also known as Finnish Lake District) is occupied by lakes, which include some of the largest in the country and even Europe, such as Saimaa (1 377 km² for the main bassin, and 4 279 km² for the Greater Saimaa area), Päijänne (1083 km²) and Pielinen (894 km²) (Järviwiki, nda ; Järviwiki, ndb).

Administratively speaking, the Finnish Lakeland mostly covers the provinces of North Karelia, North and South Savonia, Central Finland (**Fig.2**) and sometimes includes the Pirkanmaa region, on the west.

Fig.2 : Finnish Lakeland and relation to the current administrative division of Finland

Because of its proximity to the Russian border, the area has experienced strong influences following the shift post-World War II. Most notably, the agriculture intensity has risen due to the accommodation of some of the 400,000 displaced people from the ceded lands, now known as Russian Karelia, out of which 223,000 were farmers (Asthana, 1996). However, it was also due to increasing use of fertilizers, pesticides and heavy machinery. Both of these factors have contributed a significant rise of pollution despite the ongoing decline of percentage of the Finnish population involved in agriculture, as illustrated below (**Fig.3**). One needs to keep in mind, that forestry remains another very important sector in Finnish Karelia, and a maximum of lands suitable for forest growth is heavily exploited in timber production (Saarinen, 2001).

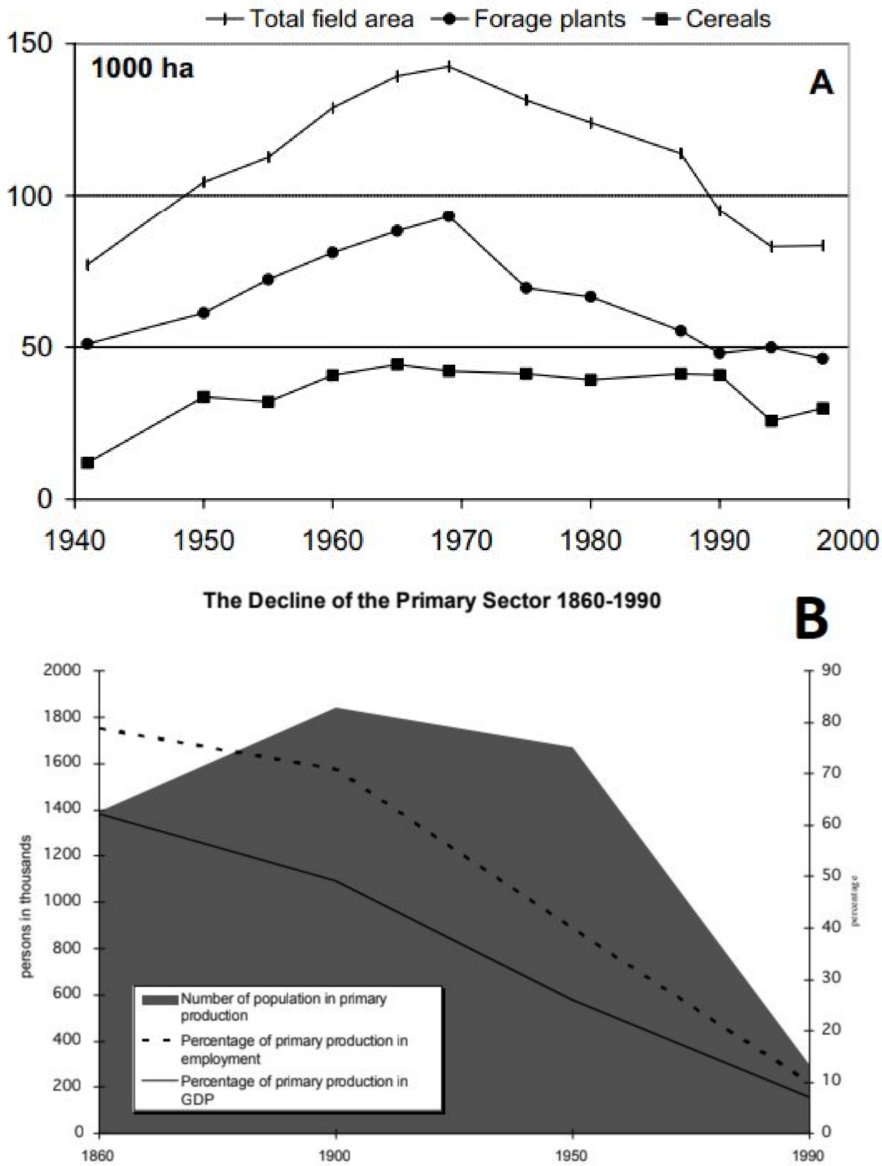

Fig.3 :
(a) (above) : The total field area and the area of fields with forage plants and cereals between 1940 and 1998 in North Karelia
(b) (below) : The decline of agriculture in Finland between 1860 and 1990

3) Goals and details of the study

i) Receiving institutions

The major part of the internship has been performed at the Karelia University of Applied Sciences (*Karelia-Ammattikorkeakoulu*). It has been established in 1992 in Joensuu, and up until 2013 operated under the name of North Karelia University of Applied Sciences (*Pohjois-Karjalan Ammattikorkeakoulu*). Karelia UAS is one of the Finnish institutions of higher education and applied research, hosting over 3,500 students and employing almost 300 staff members. Among different degree programs, the environmental domain is also well represented (forestry, environmental engineering, bioeconomy…). During this internship, Karelia UAS was the main driving force during the fieldworking trips, sampling, and water quality studies at different water bodies. It is also worth mentioning that Karelia UAS is involved in national and international networks, and actively cooperates with other local, regional and national companies, institutions and organisations.

One of such organisations, as well as the secondary partner for the time being of this internship is the Snowchange Cooperative. Created in 2000 and located in the Selkie village, (approximately 20 km east of Joensuu), its main goal is to cooperate with local and Indigenous communities. Starting with the local people (with Sámi tribe included), Snowchange has seen its network grow and currently works with Indigenous tribes in other parts of the world, such as Siberia (Chukchi, Yukaghir), North America (Inuit, Inuvialuit, Inupiaq, Gwitching, Tahltan), among others (Maori, Indigenous Australians etc). It is also actively establishing dialogue with other scientific organisations, political groups, universities, and has created important partnerships with Rewilding Europe and Gaia Foundation. The environmental efforts have been recognized at an international level, receiving the 2002 Panda Prize from WWF and attention from National Geographic. Thanks to Snowchange, it has been possible to contribute to their work during this internship on one of their most important rewilding projects : the Linnunsuo site.

ii) The projects

The internship's goal was to study the region's selected freshwater habitats (**Fig.4**), all of which are contained within the Vuoksi river basin, shared by Finland and Russia. It is worth mentioning that all the three locations have experienced the anthropic pressure at different degrees, and each one of them has a different kind of value. We have focused mainly on the physical, chemical and biological analytes in order to assess the water quality of these areas. Apart from performing *in situ* studies, the current results have been compared to past studies. This approach has allowed us not only to better understand the current values in the light of past and ongoing trends, but also helped us establishing the link between these values and the anthropic activities which had taken place in the past in these areas. At last, the new data allowed us to narrow down the most efficient restoration actions for these locations, if such actions are needed.

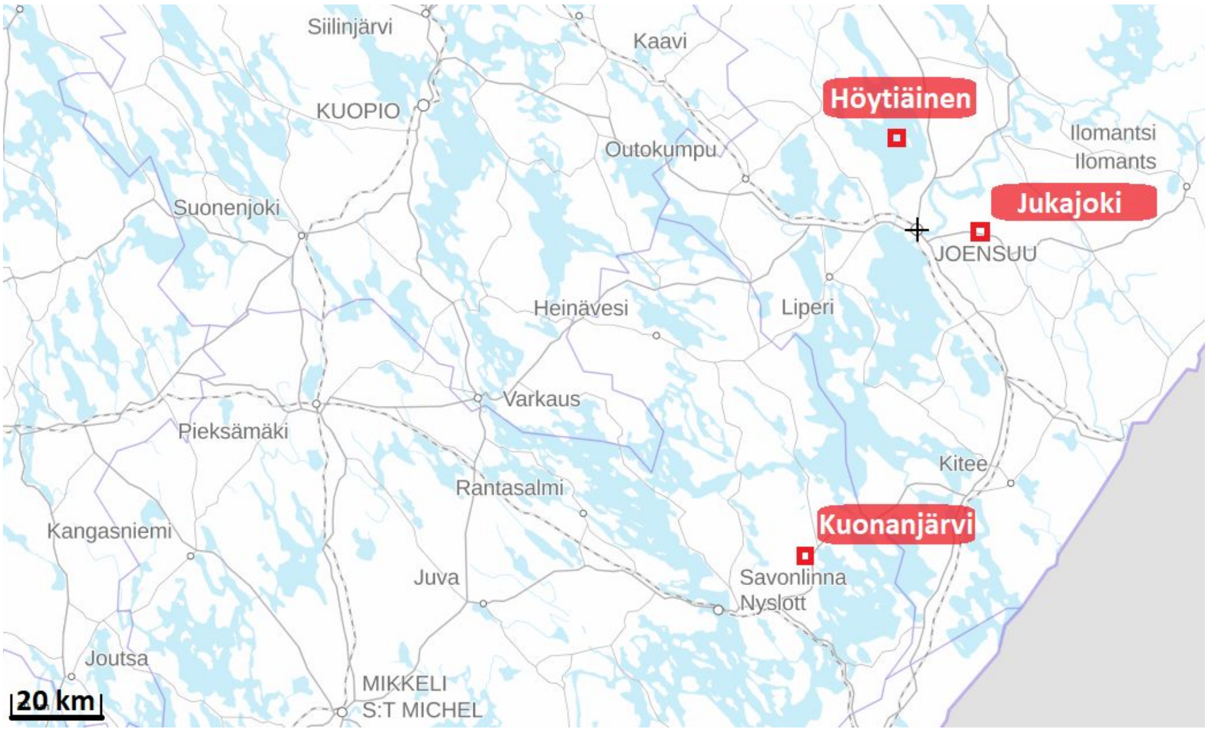

Fig.4 : Map depicting the three studied locations in relation to Joensuu (Maanmittauslaitos)

⬦ *Lake Kuonanjärvi*

Lake Kuonanjärvi is located approximately 120 kilometers south from Joensuu, in South Savonia region, just north of the town of Kerimäki. As it has been mentioned previously, agriculture and forestry are two important activities, and they both took place in proximity to the lake. While it is not a large water body (with a surface of only 5.74 km² and 5.8 m of maximal depth (Järviwiki, ndc)), it does hold a tactical value. Lake Kuonanjärvi receives inflow from neighbouring lakes and the water then flows directly into the lake Puruvesi via Kuonanjoki stream. Puruvesi holds an important place among Finnish lakes for several reasons, such as being part of the Greater Saimaa lake network, its superior underwater visibility, being home to the highly endangered Saimaa Ringed Seal (*Pusa hispida saimensis,* Nordquist) (IUCN, nd), and being part of NATURA 2000 network (EEA, nd). By extension, studying the water quality of lake Kuonanjärvi would be useful for assessing the state of the lake network upstream and the risk of affecting Puruvesi area located downstream. The Finnish Environmental Institute (Suomen Ympäristökeskus, a.k.a. SYKE) has also noted the importance of this lake, and has been constantly monitoring Kuonanjärvi since 1966 thanks to three sampling stations.

⋄ *Lake Höytiäinen*

Lake Höytiäinen is the 15th largest lake in Finland, going up to 59 m deep (with average depth of 11.29 m), and occupying a total of 282.64 km² at the limits of Juuka, Kontiolahti and Polvijärvi municipalities, near Joensuu (Järviwiki, ndd). Despite this title, it used to be larger, until the unsuccessful drainage attempt in the mid-19th century. The works have begun in 1854, in order to uncover additional farm lands as well as to counteract the frequent flooding, by draining some of the lake Höytiäinen's waters to the lake Pyhäselkä nearby. However in August 1859 the water has corroded the construction foundations between the two water bodies and the area experienced uncontrolled outflow from Höytiäinen to Pyhäselkä, which resulted in 9.5 m drop of the water level, and uncovering of 170 km² of new lands (Saarnisto, 1968 ; Donner, 1995).

The main reasons for establishing constant monitoring in the 1961 by SYKE are the large catchment area (1 460 km²) and the high anthropic pressure. After all, three towns (Juuka, Kontiolahti, Polvijärvi) are located directly at the lake's shore, and Joensuu Airport is also located just south of the lake. It is worth mentioning that the sampling stations network created by SYKE is quite dense, with currently 243 registered sampling stations.

⋄ *Linnunsuo and Jukajoki-Jukajärvi area*

The studied area is located roughly 20 kilometres east from the city of Joensuu, at the border between the municipalities of Joensuu and Kontiolahti. The lake is the smallest water body studied during this internship (surface of 2.18 km², average depth of 3.77 m, with the deepest point at 17 m) (Järviwiki, nde).The water from lake Jukajärvi flows via the Jukajoki river into the peatlands located up north, allowing the area to be constantly waterlogged. The area is quite important for the local community for everyday living and recreational purposes, and has been known for its large biotic community, notably birds in the Linnunsuo site (with the name meaning "Bird marsh"). It is also an area monitored by SYKE, with a total of 83 registered sampling stations in the Jukajoki's catchment area.

This area has been exploited since the 1980s by the state-owned company, VAPO, for its peat. The Linnunsuo site has been included into the company's activity area in 2003. However, during summer 2010 the local community has observed the deterioration of water quality of river Jukajoki, accompanied by the fish die-off, following discharges originating from the company's activities. The community has informed the local Center for Economic Development, Transport and Environment (*ELY-keskus*), but despite very alarming water quality test results (pH ranging between 2.7 and 3.4, and iron levels reaching as high as 300,000 µg - both of these conditions being lethal to aquatic life), VAPO has not experienced any negative consequences and was able to continue the activities. When the situation repeated itself during the summer of the following year, the community has not only alerted the environmental authorities, but also the police, and the news has also been covered by media. This time, VAPO was forced to cease any activities in Linnunsuo, and - with the renewal of the activity permit in 2012 - implement restoration measures, by order of Regional State Administrative Agency. It has been ultimately decided that the most efficient way to counteract the very low pH would be to inundate the area. Not only it has stopped the oxidation processes linked to leakage of acidic waters, but it was also more economical and more long-term compared to other possible methods, such as liming (Mustonen, 2013a). Since the beginning of the restoration project in 2013, Linnunsuo became a 120 ha area that prevents any further pollution of Jukajoki. Moreover, thanks to the cooperation between Snowchange and Rewilding Europe it has been possible for the former to purchase the Linnunsuo site in May 2017. Since then, a collaborative management approach has been implemented, and all the parties related to the site can express themselves and establish a dialogue in order to attain a common goal. This approach also takes into account the local, traditional knowledge on the same level as the scientific knowledge (Mustonen, 2013b). These actions have resulted not only in improvement of water quality, but also in a return of a significant number of bird species, which has not been expected by experts working on the restoration project. As of now, as much as 185 bird species have been observed in Linnunsuo, whether as long-term residents, migrating and/or breeding.

II- Material & Method

1) Timeline

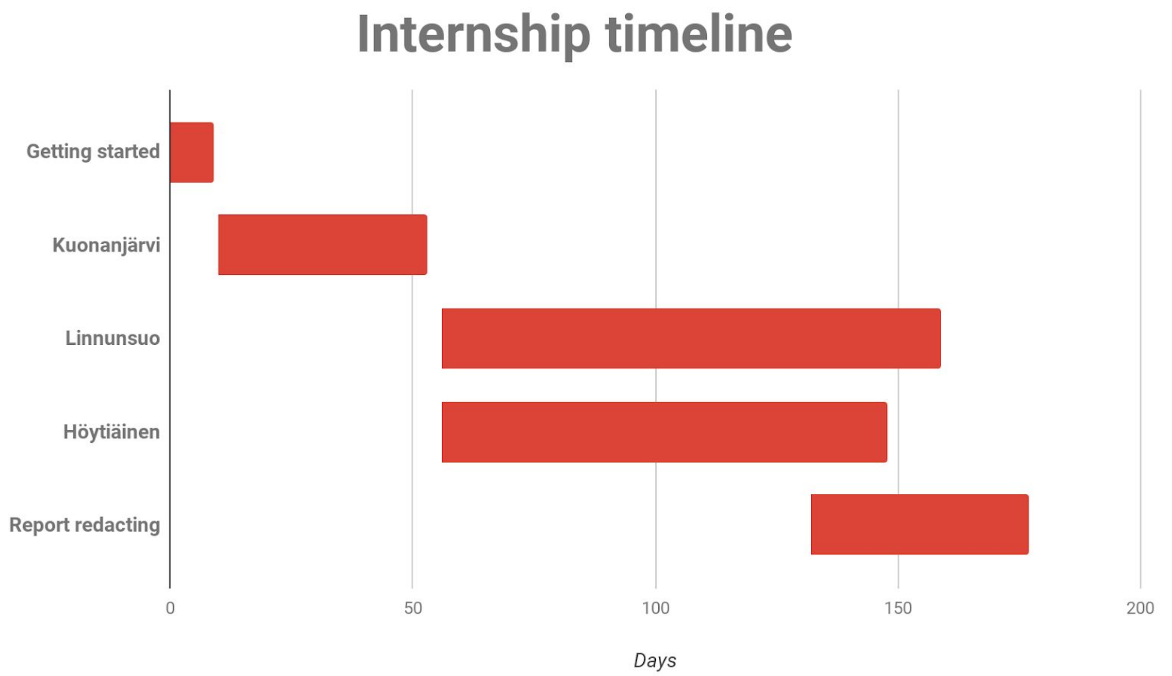

Fig.5 : Timeline representing the task division during the internship.

As it is to be expected, it was highly difficult to study the three water bodies simultaneously, or to start working on them without having a look at the general information regarding these water bodies (**Fig.5**).

After this preliminary period learning about the water bodies, type of impacts and the methodology used by Karelia UAS, the main focus during March and April was on field working trips to lake Kuonanjärvi. In total, 7 field working trips have been made, during which water, sediment and macrozoobenthos samples have been taken. The following months - May, June and July - have been mostly spent working on physico-chemical data concerning lake Höytiäinen, intertwined with bird watching sessions at Linnunsuo site. In total, 8 bird watching sessions have been made during this time between May 8th and August 11th. The lake Jukajärvi has also been visited, at the end of May.

Finally, from mid-July until the end of August, the time has been used for redaction of this final report.

2) Sampling procedures

During the winter time, any sampling efforts would be impossible without drilling through the ice cover isolating the water from the rest of the environment above. However, after winter, the locations could be directly sampled, but a boat would be needed to reach the given location.

The first thing checked would be the depth. Using the Limnos water sampler, it was possible to take few basic measurements right away, such as assessing the Secchi depth, or temperature at different depths. Depending on the depth, the number of measurements would vary, from one (very shallow waters), to three (1 m from surface, mid-depth and 1 m from the bottom) or more (for example every 5 meters).

Due to the unstable nature of redox potential of the sediment, the measurement would be performed *in situ*, a Redox combination electrode on a modified sediment sampler. Any other measurements, such as pH, nitrogen or phosphorus content would be performed in the lab, on water samples collected in plastic bottles and shielded from adverse conditions such as sunlight.

The sediment samples would be taken with a sediment sampler, prolonged with additional metal pipes to reach greater depths. The sediment sampling would stop when the layer of clay would be reached. The sediment samples would be described *in situ*, photographed and subsequently discarded. However, in few exceptional cases some samples have been preserved and sent to a specialty laboratory in Tampere. However, the results have not been made available during the elaboration of this report.

A similar, weighed tool would be used for sampling the top layer of the sediment in search for the macrozoobenthos. The sediment samples would go into sieve buckets, with the excess of sediment removed, and the specimens collected into plastic containers filled with water.

3) Water sample analysis

The water samples would be kept in a laboratory refrigerator until the time of analysis. Different analytes would be measured, such as pH (with a pH-meter), conductivity and phosphate, nitrate and ammonium levels with equipment of Karelia UAS laboratory. As for the macrozoobenthos, the majority of taxa has been determined to the family level, with some going down to the genus level.

4) Studied analytes

During the water quality analysis, several analytes have been taken into account. Depending on their type, they can be divided into three categories : physical, chemical and biological analytes. In the paragraphs below, their biological relevance is explained in order to give a better understanding as to why they were studied, along with the minimal, maximal and average values whenever available. For a quick reference regarding these values of the analytes in a well-functioning lake, you are welcome to consult the appendix 1, attached at the end of this internship report.

i) Physical analytes

◇ Temperature

The temperature varies with time and with depth of the water body. Usually, the thermal stratification of a lake is most evident during summer and winter, while in the spring and autumn the joint action of wind and changes of air temperature leads to homogenization of all the water layers. During our study, the Celsius scale (℃) has been used.

Temperature is a crucial variable, because it affects several other physical and chemical properties, such as conductivity, speed of chemical reactions, or solubility. It also influences the type of biota able to survive in a given location. Therefore, temperature is not studied on its own, but in relation to other analytes. Moreover, the majority of aquatic organisms is poikilothermic and heavily relies on the environmental temperature for survival (Brönmark, 2005).

◇ Turbidity and suspended solids

Another important variable for the biota is the availability of light. The light is essential for the photosynthetic organisms and directly affects the productivity of the lake. However, the amount of light can be affected by the amount of particles suspended in the water column. The amount of particles can be estimated by measuring the turbidity and/or the amount of suspended solids (Reid, 1998).

Turbidity refers to the general cloudiness and appearance of the fluid, and is measured in Formazin Turbidity Unit (FTU). An equivalent unit defined by ISO is the Formazin Nephelometric Unit (FNU). Values lower than 1 FNU indicate a very transparent sample, between 1 and 5 FNUs - moderately turbid sample, and samples are considered as turbid when the limit of **5 FNUs** is exceeded.

The suspended solids - aside from their effect on the appearance of the water - also studied for their potential to transport pollutants and pathogens on their surface (Schillinger, 1985). In all the studies the values are noted as mg/l. Values above **5 mg/l** have been considered critical in this study.

◇ Secchi depth and visibility

The Secchi depth is closely linked to the turbidity, visibility and phytoplankton density (Jeppesen, 2005). It is measured by lowering a Secchi disk in a water column until no longer visible. It is noted in meters (m). Productive photosynthesis can take place up to double of the Secchi depth, ie. if Secchi depth is equal to 1 meter, productive photosynthesis can take place up to 2 meters of depth.

Since Secchi depth is not always relevant on its own, we have defined visibility as following :

$$\underset{(\%)}{\text{Visibility}} = \frac{\text{Secchi depth}}{\text{Total depth}} \times 100$$

ii) Chemical analytes

◦ pH and alkalinity

The acidity (or basicity) of an aqueous solution is expressed on the pH scale. The pH affects the availability of the nutritional elements and heavy metals in the water. As a consequence, if the water is too acidic, there is a possibility of heavy metals precipitating on the fish gills, ultimately leading to asphyxia and mass deaths (Evans, 1987 ; Spry & Wiener, 1991). The fish kills can also be caused by a disturbance of normal ion and acid-base balance by the low environmental pH levels (Schofield, 1976). Other organisms can also be affected - mollusks and crustaceans, which possess shells with high calcium carbonate content are vulnerable to attack because of shell erosion at low pH levels (Glass, 2009). All Finland's species of fish can survive in waters with a pH between 5.5 and 9, while crayfish require a pH of at least 6. For reference, the national average of pH in fresh waters is approximately 6.9.

The capacity of water to resist changes in pH is called alkalinity. Measuring alkalinity enables to estimate the capacity of a waterbody to neutralize acidic inflow, such as from rainfall, wastewater or melted snow. A waterbody is considered acidified when the alkalinity is lower than **0.05** mmol/l.

◦ Conductivity

The conductivity refers to the capacity of water to conduct electricity, heat and sound, among others. It is proportional to the amount of dissolved salts in water. Apart from physicochemical properties, conductivity has a biological relevance. In fact, conductivity is related to the osmotic pressure exerted on the cell membranes. Moreover, low conductivity is often an indicator of a precipitation-dominated water bodies, which are at an increased risk of experiencing floods, downs and formation of anchor-ice. These phenomenons can further exacerbate the disturbances, and lead to damage and/or death of local biota. The organisms would then be forced to adapt to them, either by entering a dormant state, or by seeking refuge in less affected habitats (Dartmouth College, nd). An average Finnish lake possesses conductivity of 6,7 mS/m.

◇ *Dissolved oxygen and saturation*

Oxygen is an element which is essential for survival in all lifeforms. This is due not only to it being a key element in cellular respiration, but it is also present in the vast majority of organic molecules, inorganic compounds, as well as the major constituent of organisms : water. The oxygen levels are kept stable thanks to the balance between oxygen consumption and its renewal via photosynthesis.

The term "dissolved oxygen" refers to the absolute value of the oxygen contained in a given sample, expressed as mg/l, while "oxygen saturation" is a relative measure of the dissolved oxygen in proportion of the maximal possible oxygen concentration in that sample, expressed as %. The maximum possible amount of dissolved oxygen is directly linked to the temperature and pressure : in general, oxygen is more easily dissolved in cold waters. The oxygen values can be also influenced by other parameters, such as presence of photosynthetic organisms, decaying matter or nutrient pollution (Kramer, 1987).

Apart from directly causing death of aquatic organisms (such as fish kills), environmental hypoxia can also increase the concentration of anaerobic organisms, fueling further adverse events. Moreover, the low level of oxygen are also linked to releases of heavy metals from the sediments (Li, 2013). The situation is deemed critical if the concentration of oxygen drops below **5 mg/l**. Conversely, oxygen saturation is deemed optimal if it oscillates between **85 and 110%**.

◇ *Chemical oxygen demand*

Chemical Oxygen Demand (COD) is an analyte which enables to measure the quantity of oxygen consumed during chemical reactions (Kim, 2000). By extension, it is also possible to quantify the amount of organic compounds in a given sample, which includes pollutants, that can potentially be oxidized. COD should not be confused with BOD (Biochemical Oxygen Demand), which measures the amount of oxygen consumed by biological organisms while they break down organic matter. The Finnish lakes possess on average 10,1 mg/l O_2. The situation is considered critical, when the values exceed **15 mg/l O_2**.

◇ *Dissolved elements*

The water's ability to dissolve many substances is very well known and has been extensively studied (Greenwood, 1997). As it has been mentioned earlier, several parameters can affect the solubility capacities, as well as bioavailability, such as temperature or pH (Cusimano, 1986 ; Vicente-Martorell, 2009). Several elements have been studied by SYKE.

◦ Aluminium

Aluminium is a non-essential metal, known as the third most abundant element on the planet, making up to 8% of the Earth's surface. It can be mobilized and enter the water bodies via acidic precipitation from natural and industrial sources. In high concentrations aluminium can negatively impact the cell metabolism and lead to oxidative stress (Dolara, 2014).

◦ Calcium

On the contrary to aluminium, calcium belongs to the category of elements essential to life. It is also quite abundant, placing fifth among the most abundant elements on Earth's surface (Greenwood and Earnshaw, 2012), and widely used in building construction (contained in lime) (Miller, 1998) and metallurgy (Habashi, 2017), among others. The calcium ions (Ca^{2+}) play an important role in cell metabolism and signal transduction pathways in animals, including humans (Brini, 2013). Calcium is as well a main component of bones and invertebrates' exoskeletons (Greenaway, 1985). In plants, they are also implicated in the growth, development, and several cellular processes (Bush, 1995). The Finnish lakes contain on average 6 mg/L.

◦ Iron

Iron is another metal essential to life, being implicated in several biological processes, such as nitrogen fixation and oxygen transport (Moore, 2009 ; Hodis *et al*, 2016). It is also the fourth most common element on Earth's surface, and has been used in metallurgy and continues to be one of the most used metals in the industry (Morgan, 1980). However, excess levels of iron can lead to oxidative stress and iron-induced carcinogenesis (Toyokuni, 1996 ; Livingstone, 2003). On average, the iron concentration in Finnish lakes is equal to 262 µg/L.

◦ Magnesium

Another commonly found element - magnesium - has found its usefulness in heavy machinery components, but also electronic devices, among others. Due to its high solubility, it is often found in fresh and sea waters (Avedesian, 1999). Magnesium also belongs to the group of essential elements, being present in chlorophyll, activating enzyme systems and energy metabolism processes, to name a few. In general, excess magnesium levels are efficiently excreted via renal system (Anonymous, 2006). However, along with calcium magnesium is closely linked to pH and alkalinity, and excess magnesium levels may reflect the occurrence of such events as acidic precipitations (Haines, 1981).

⋄ Manganese

While manganese might not be as abundant or widely used in the industry as the elements described above, it holds an important biological role. It is used as a cofactor, or a building block of polypeptides, and is vital in photosynthesis, where it enables the oxidation of water into dioxygen (Law *et al*, 1998). The global ecotoxicity of manganese is relatively not well known - most of the tests have been done using manganese in ionic forms, but colloids, or nanoparticles have not been tested (Howe *et al*, 2004). In Finnish lakes, the average concentration of manganese is 30 µg/L, while values above 100 µg/L are considered alarming.

iii) Biological analytes

⋄ Nitrogen and its forms

Nitrogen is a key element in protein and nucleic acids synthesis, as well as organic chemicals, such as adenosine triphosphate, which provides energy in cellular processes. The nitrogen compounds which contribute to growth - directly or not - are collectively defined as reactive nitrogen. The term includes - among others - ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-) (Galloway, 2002). Those three elements are common components of fertilizers.

In case where reactive nitrogen levels have been exceeded, the plants and algae experience an excessive growth. After they die, there is an intense bacterial degradation of their biomass, which can lead to oxygen depletion by excessive oxygen consumption - such an event is called eutrophication. Several adverse phenomena are linked to eutrophication, such as toxicity, decreased biodiversity and water quality, as well as modification of local biota, among others (Andersen, 2006).

An average Finnish lake contains 500 µg/l of total nitrogen, 23 µg/l of ammonium, 92 µg/l of nitrate and 1 µg/l of nitrite. A concentration of total nitrogen exceeding 600 µg/l is considered as alarming.

⋄ Phosphorus and its forms

Similarly to nitrogen, phosphorus is a compound essential for life, being equally present in nucleic acids and adenosine triphosphate, but also is a main building block of the phospholipids. It is also present in fertilizers, as well as pesticides. The phosphorus is mostly used by organisms under the form of phosphate (PO_4^{3-}).

Just like in the case of nitrogen, excessive amounts of phosphorus can lead to eutrophication and algal blooms, which can cause the collapse of the local ecosystem (Andersen, 2006).

The average value of total phosphorus in Finnish lakes oscillates around 23 µg/l, while the average amount of phosphates is equal to 4 µg/l. Further monitoring is necessary, when a concentration of total phosphorus exceeds **35 µg/l**.

◦ The limiting nutrient

The limiting nutrient is defined as the essential nutrient, ie. nitrogen or phosphorus, which is relatively scarce in a given environment, and once used up, further growth cannot take place. In freshwater ecosystems, phosphorus is the scarcer nutrient (Behar, 1997). The limiting nutrient is determined by the following formula:

$$LN = \frac{Ntot / Ptot}{\dfrac{(NH_4^+ + NO_2^- + NO_3^-)}{PO_4^{3-}}}$$

When LN < 1, then it means that the limiting nutrient is phosphorus, and conversely - if the value exceeds 1 - the nitrogen is the limiting nutrient. In rare cases where LN is equal to 1, the limiting nutrient cannot be determined.

◦ Chlorophyll a

Chlorophyll a is a specific form of chlorophyll used in oxygenic photosynthesis. As a consequence, the quantity of chlorophyll enables to assess the quantity of algae in a given water body, and by extension - whether or not there is an ongoing algal or cyanobacterial bloom (Boyer, 2009). Such events are more likely to occur in eutrophic lakes (Lindholm, 1989). The values are considered critical if they exceed **7 µg/l**. The Finnish national average amounts to 6,3 µg/l in the lakes.

◦ Bioindicators

◦ Birds

As mentioned earlier, as much as 185 species of birds have been observed at the Linnunsuo site. Such a high diversity may be useful to assess the state of Linnunsuo and surrounding areas. Additional advantages linked to use of birds as bioindicators are ease of observation, vast amount of studies on birds, and increased public interest and care compared to other animal groups such as invertebrates (Furness, 1993 ; Becker, 2003).

◦ Invertebrates

Given their direct and constant contact with the environment, invertebrate populations can vary greatly in case of a disturbance, from a quantitative (*how many specimens ?*) and qualitative (*which species are present ?*) points of view. This characteristic has rendered invertebrates as reliable bioindicators of environmental stress, both in terrestrial and aquatic ecosystems (Paoletti and Bressan, 1996 ; Hodkinson and Jackson, 2005).

5) Statistics and cartography

i) Stations and data

⋄ Kuonanjärvi

During the 7 field working trips, 13 out of 15 sampling stations (3 SYKE stations : Kuonanjärvi 003, 030 and 090 ; 12 stations created by UAS Karelia : Kuona 1 to Kuona 12) have been visited at least once between March 15th and April 18th, 2018 (**Fig.6**). Moreover, two additional field working trips from the end of February 2018 have been included to bulk up the available data on the present state of lake Kuonanjärvi (see Appendix 2).

Since the surface of the lake has been isolated from the surrounding environment by a 40-50cm ice cover, the present data has been studied altogether, as if the samplings were all done simultaneously.

For the study of historical trends, the data for the 3 existing SYKE stations has been obtained from the SYKE OpenData database. While the earliest studies date back to 1960s, the focus was put on the 1980-2017 period, as it is only since the 1980s that all three stations have been studied during each decade. Linear regression analysis has been performed on data.

⋄ Höytiäinen

The work on lake Höytiäinen has been done exclusively using the data contained by the SYKE OpenData database. Originally, a total of 2620 studies performed at 243 stations has been counted (**Fig.7**). However, it has been decided to focus on the 2000-2018 period and the most recent changes. This has brought the amount of data to 40% of its original volume, with 1470 studies at 123 stations. Additional cut-downs had to be done, when a given station was studied only once and/or a given analyte was very rarely studied. For an example of raw data obtained from SYKE OpenData database, please consult appendix 3. For selected stations, linear regression analysis has also been performed to assess the trends over time.

⋄ Jukajoki area

The hydrological assessment of the Jukajoki area has been made using the data from the 6 most relevant (most studied) SYKE stations. In total, 256 studies have been gathered, all done between 1968 and 2016. However

During birdwatching sessions, no particular protocol has been used.

Unfortunately, due to time and resource limits, an ongoing water quality assessment was not possible during the internship.

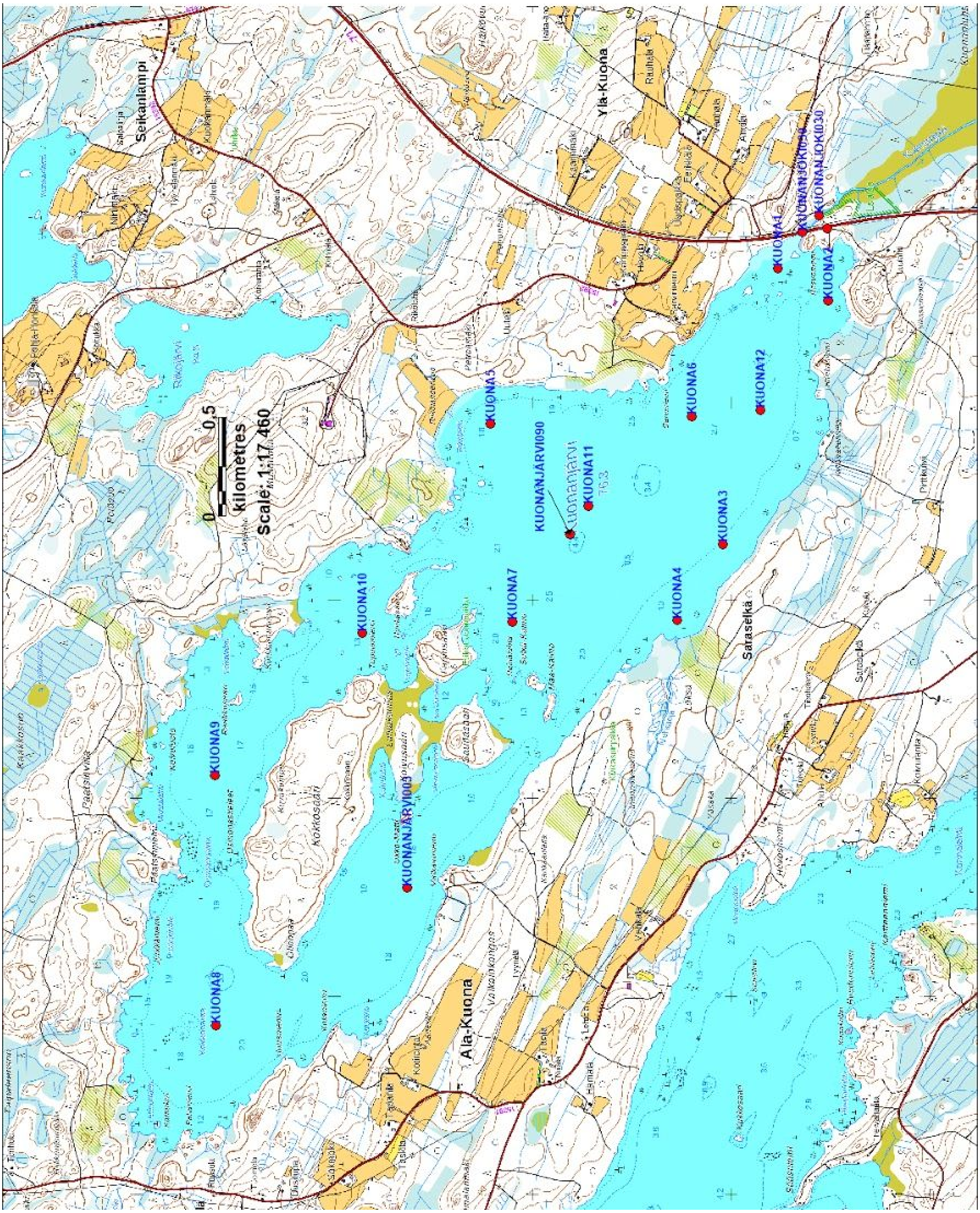

Fig.6 : Map of lake Kuonanjärvi, along with the sampling stations.

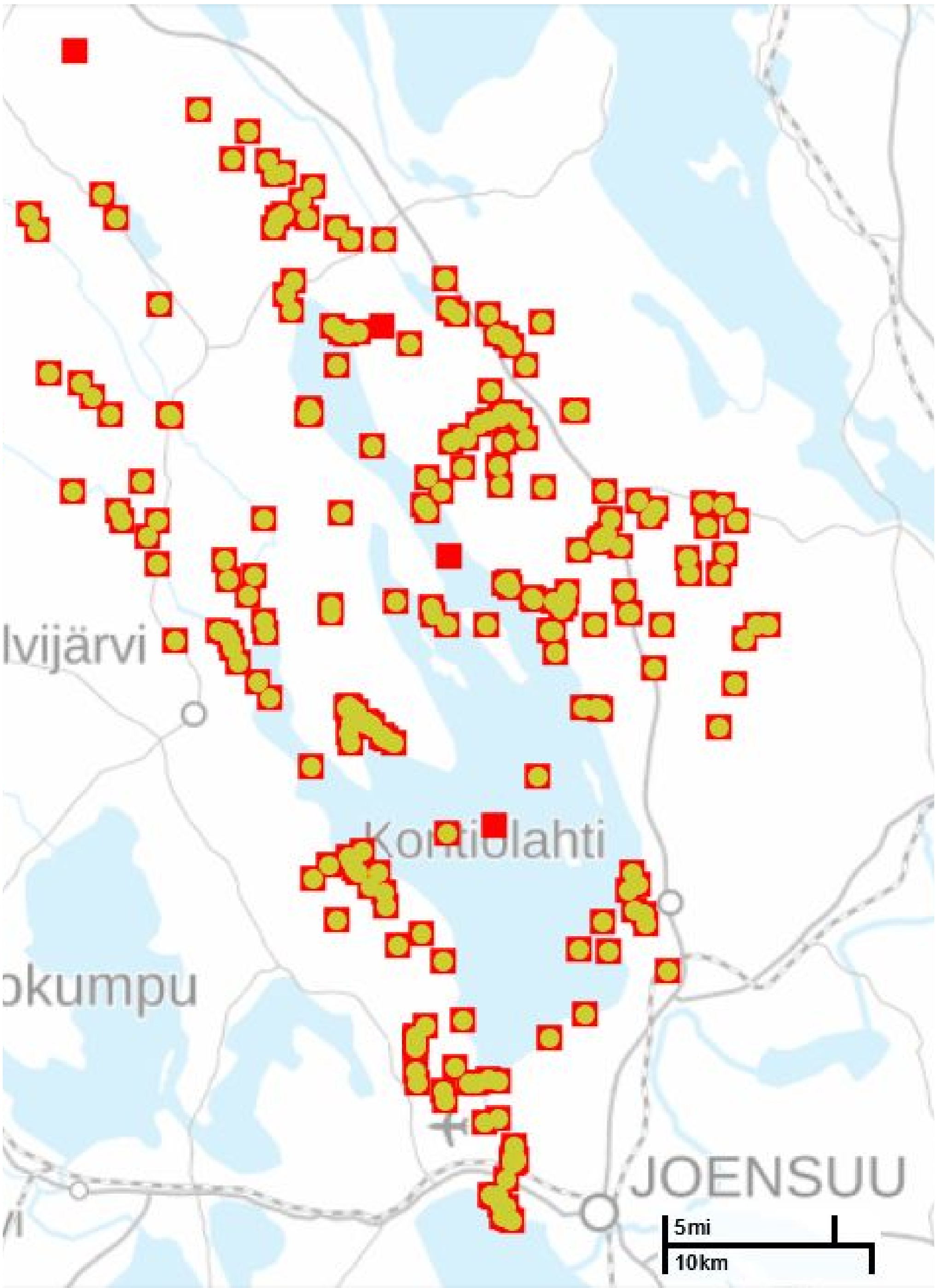

Fig.7 : map of the dense SYKE sampling station network contained within lake Höytiäinen's catchment area (marked with green circles in red squares)

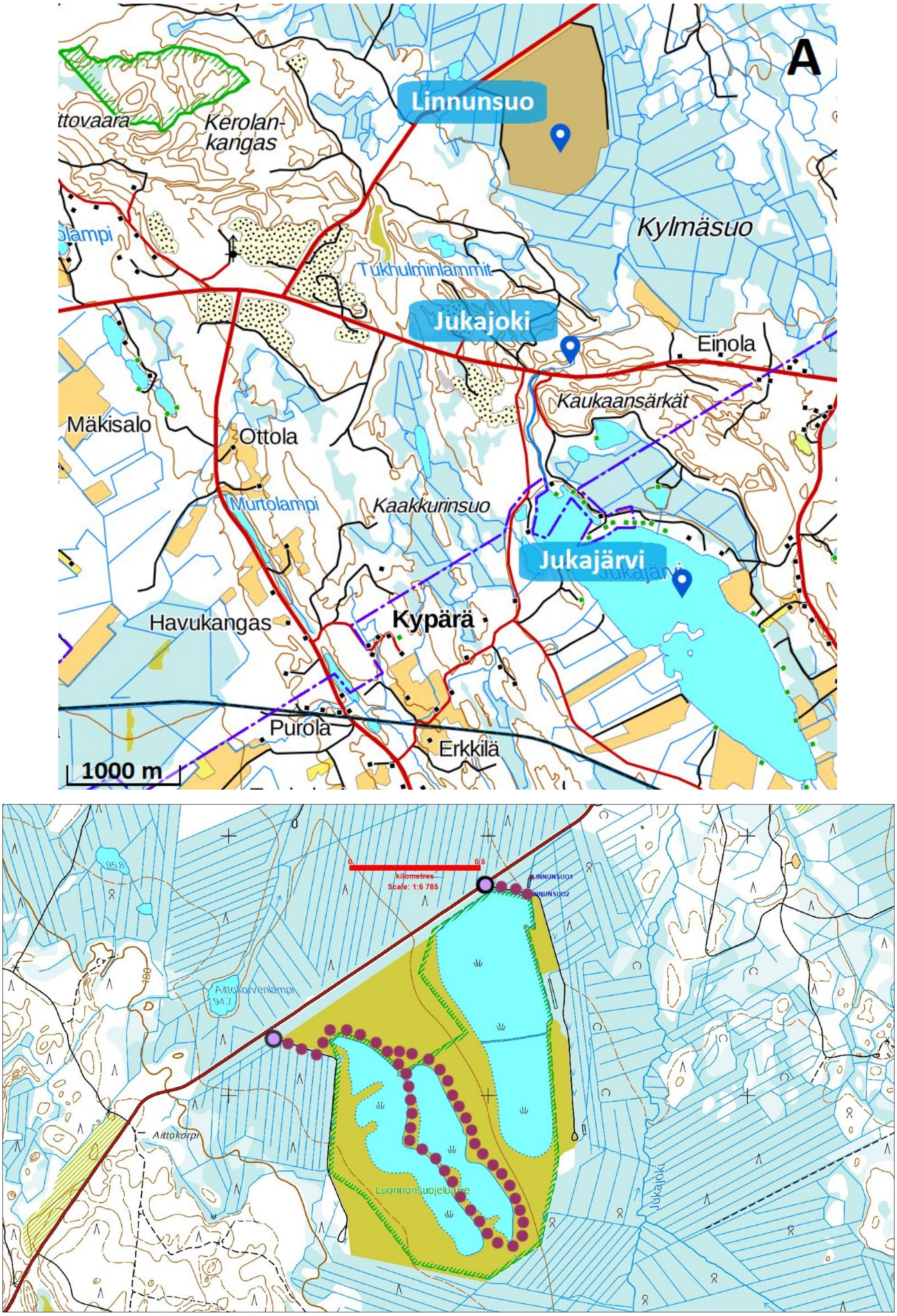

Fig.8 :
(a) map of Jukajoki area
(b) map of Linnunsuo site, with routes marked

ii) Software

All statistical work has been performed using Microsoft Excel and R software.

Maps have been elaborated with the help of software available when obtaining data from SYKE OpenData database, as well as with National Land Survey of Finland website, with optional modifications done with personal freeware graphic editor software.

III - Results

1) Lake Kuonanjärvi

Table 1 : Long-term trends (based on studies performed between 1980 and 2017)

Analyte	Station	Trendline coefficient (y)	R^2	Trend	Remarks
Turbidity	003	0,323x + 1,03	0,237	↗↗	-
	030	0,195x + 1,79	0,323	↗↗	-
	090	0,0305x + 3,42	0,026	↗	little data
Visibility	003	-0,725x +51	0,063	↘	-
	090	-0,837x + 50,9	0,076	↘	little data
Temperature	003	$-9,07.10^{-3}x + 11,7$	0	→	-
	030	0,0616x + 6,04	0,027	↗	-
	090	-0,262x + 20,7	0,096	↘	little data
pH	003	$9,9.10^{-3} + 6,55$	0,134	↗	-
	030	-0,0152x + 6,91	0,026	↘	-
	090	$-2,7.10^{-3} + 6,76$	0,006	↘	little data
Alkalinity	00	$6,6.10^{-4} + 0,127$	0,153	↗	-
	030	$2,11.10^{-3}x + 0,13$	0,172	↗	-
	090	$6,36.10^{-4}x + 0,142$	0,235	↘	little data
Conductivity	003	$-6,58.10^{-3}x + 5,22$	0,026	↘	-
	030	$8,83.10^{-3} + 5,79$	0,009	↗	-

	090	$-6,41.10^{-3}x + 5,9$	0,012	↘	little data
Oxygen, dissolved	003	-0,0416x + 11,7	0,147	↘	-
	030	-0,079x + 9,95	0,095	↘	-
	090	0,0488x + 8,38	0,057	↗	little data
Oxygen saturation	003	-0,0785x + 91	0,006	↘	-
	030	-0,506x +78,8	0,067	↘	-
	090	0,151x + 78,3	0,006	↗	little data

Table 2 : Analytes taken into account during present-day water quality assessment

Analyte	**Number of stations concerned**	**Out of norm ?**
Temperature	13/13	-
pH	11/13	no
Conductivity	11/13	-
Phosphate	11/13	no
Nitrate	11/13	relatively high
Ammonium	11/13	relatively high
Organic matter sediment	11/13	NW-SE gradient
Redox	8/13	-
Macrozoobenthos	8/13	eutrophic species assemblages

2) <u>Lake Höytiäinen</u>

For practical reasons (very limited time), the main focus has been put on the outflow, since the outflowing water would be representative of the lake and the total of inflow.

After getting acquainted with the data, only one station has been checked regularly and long-term by SYKE. The trends are listed below.

Table 3 : Trends observed at the outflowing station (Höytiäisen kanava 1) 2008-2018

Analyte	**Trendline coefficient (y)**	**R^2**	**Trend**	**Remarks**
Turbidity	-0,0361x + 2,12	0,084	↘	never above threshold

Suspended solids	$-0{,}0421x + 2{,}15$	0,068	↘	never above threshold
Alkalinity	$-2{,}38.10^{-4}x + 0{,}233$	0,006	→	never below threshold
pH	$-1{,}37.10^{-3}x + 7{,}03$	0,006	→	never below threshold
Ptot	$-9{,}01.10^{-3}x + 4{,}91$	0,003	→	never above threshold
Ntot	$-1{,}59x + 367$	0,158	↘	never above threshold
N/P ratio	$9{,}14.10^{-3}x + 0{,}775$	0,018	↗	variable
Oxygen	$1{,}78.10^{-3}x + 11{,}4$	0	→	never below threshold
COD	$0{,}0252x + 6{,}9$	0,048	→	never above threshold
Manganese	$0{,}449x + 12{,}2$	0,043	↗	includes period without studies
Iron	$-12{,}8x + 589$	0,064	↘	generally below threshold

⋄ *Other water bodies*

While other water bodies are not directly connected to lake Höytiäinen and therefore did not present as much interest, one has been chosen for study : Iso-Polvijärvi. Located just south of the lake, it is in proximity to the Joensuu-Liperi Airport, and therefore there is an increased chance of receiving a greater amount of pollutants. One must keep in mind though, that there weren't many studies done at the station.

Table 4 : Trends observed at Iso-Polvijärvi between 2004 and 2015

Analyte	**Trendline coefficient (y)**	**R^2**	**Trend**	**Remarks**
Turbidity	$4{,}24.10^{-5}x + 1{,}33$	0,17	↗	never above threshold
Alkalinity	$1{,}7.10^{-6}x + 1{,}73.10^{-3}$	0,493	↗	never below threshold
pH	$0{,}055x + 6{,}41$	0,392	↗	never below threshold
Ptot	$1{,}46.10^{-4}x + 2{,}73$	0,083	↗	never above threshold

Ntot	6,33x + 184	0,97	↗	never above threshold
N/P ratio	-0,0139x + 587	0,768	↘	variable
Oxygen	$-2{,}83.10^{-5}x + 11{,}9$	0,002	dow/stn	never below threshold
COD	$-2{,}64.10^{-4}x + 13{,}2$	0,703	↘	never above threshold

3) Jukajärvi area

As mentioned earlier, little could be done in regards to water quality assessment. In the table below the raw data from Linnunsuo site has been presented.

Table 5 : Water quality at the outflow in Linnunsuo, April 30th 2018					
Station	**Temperature**	**pH**	**Fe**	**Al**	**Mn**
1	6,1	5,48	5120	50	719
2	5,5	5,69	5020	50	1671

Table 6 : List of bird species observed in Linnunsuo from May to August 2018					
Latin name	**Name**	**Status**	**No of obs.**	**Abundance**	**Sight/Sound**
Alauda arvensis	Skylark	LC	1/8	+	sound
Anas crecca	Teal	LC	7/8	+++	sight
Anas platyrhynchos	Mallard	LC	6/8	++	sight
Anthus pratensis	Meadow pipit	NT	3/8	+	sound
Apus apus	Swift	LC/VU	5/8	++	sight
Aythya fuligula	Tufted duck	LC/EN	3/8	++	sight
Bucephala clangula	Goldeneye	LC	7/8	+++	sight
Buteo buteo	Common buzzard	LC	2/8	+	sight
Charadrius dubius	Little ringed plover	LC/NT	5/8	++	sight
Circus aeruginosus	Marsh harrier	LC	1/8	+	sight
Clangula	Long-tailed duck	NT/VU	2/8	+	sight

hyemalis					
Coturnix coturnix	Quail	LC/VU	1/8	+	sound
Cuculus canorus	Cuckoo	LC	7/8	+	sound
Cygnus cygnus	Whooper swan	LC	6/8	+	sight
Delichon urbicum	House martin	LC/EN	6/8	++	sight
Emberiza citrinella	Yellowhammer	LC	3/8	+	sight, sound
Falco subbuteo	Hobby	LC	1/8	+	sight
Fringilla coelebs	Chaffinch	LC	2/8	++	sight
Gallinago gallinago	Snipe	LC/VU	3/8	+	sound
Grus grus	Crane	-	1/8	+	sight
Haliaeetus albicilla	White-tailed eagle	LC/VU	1/8	+	sight
Hirundo rustica	Barn swallow	LC/NT	6/8	++	sight
Hydrocoloeus minutus	Little gull	LC	7/8	++	sight
Larus canus	Common gull	LC	7/8	++	sight
Larus ridibundus	Black-headed gull	LC/VU	7/8	++	sight
Mergus albellus	Smew	LC	1/8	+	sight
Motacilla flava	Yellow wagtail	LC/NT	5/8	++	sight
Philomachus pugnax	Ruff	LC	3/8	++	sight
Phylloscopus trochilus	Willow warbler	LC	6/8	++	sound
Pluvialis apricaria	Golden plover	LC	4/8	++	sight
Sylvia communis	Whitethroat	LC	3/8	++	sound
Tringa erythropus	Spotted redshank	LC/NT	5/8	++	sight
Tringa glareola	Wood sandpiper	LC/NT	6/8	+++	sight
Tringa ochropus	Green sandpiper	LC	4/8	++	sight
Vanellus vanellus	Lapwing	LC/NT	6/8	++	sight

IV - Discussion & Perspectives

1) Kuonanjärvi

While doing preliminary observations of changes that have been recorded by SYKE at lake Kuonanjärvi, we can observe that the degradation has taken place between the 1980s and 2017, with increase of turbidity (nowadays the values exceed the threshold of 5 FNU), along with loss of visibility, as well as decrease in oxygen (both dissolved and saturation). However, the pH was not deviating too far from the national average, and alkalinity was satisfying.

Currently, nitrogen levels (mainly ammonium and nitrate) are relatively high. This might indicate eutrophication. It is rendered more plausible by the macrozoobenthos assemblages which indicate eutrophic environment : *Chaoborus, Chironomidae, Oligochaeta*, among others. Turbidity or oxygen levels - which have been the "analytes of interest" - could not be checked. However, a gradient for sediment could be established, along the north west to south east axis.

Since no information was available regarding any restoration projects conducted in Kuonanjärvi, one may assume that no such projects have been conducted in there. This belief is strengthened by rather well marked long-term trends. Variations on a shorter term scale might be attributed to weather changes and different seasons.

2) Höytiäinen

All the analytes taken into account seem to respect the thresholds established by environmental authorities.

As it is the case with the lake Kuonanjärvi, no information was available regarding any recent restoration projects conducted in the lake Höytiäinen area. This is also strengthened by well-marked long-term trends, with minor variations on a short scale due to possible weather changes or simply stochasticity.

3) Jukajoki area

Little statistical work could be done regarding the current situation due to largely unavailable data.

As it has been mentioned earlier, the Jukajoki area - with strong emphasis on Linnunsuo site - has been monitored by SYKE, and restoration efforts have been ongoing in the recent years. It seems that these efforts have been successful in increasing the pH (from 27-3,4 to roughly 5,5), but it is still an acidic, peatland environment. The high levels of iron and manganese are most likely due to the previous industrial activities, and their mobility linked to low pH levels.

4) Conclusions

The selected inland water bodies are all characterized by different anthropic pressures, be it proximity to several cities or intense industrial activity. The need to conduct water quality assessments is even more important, given the fact that these water bodies are embedded in a lake network. This topographical structure might cause a cascade effect - the more connections a given lake has with other water bodies, the more it is at risk of accumulating pollutants.

The first water body studied - lake Kuonanjärvi - seems to suffer from an increase of turbidity and decrease of oxygen levels. The two might be linked, with increasing turbidity affecting the amount of light capable of penetrating the water column, and as a consequence - less vegetation could develop and continue producing the oxygen via photosynthesis. An additional observation concerns the current relatively high nitrate and ammonium levels, as well as heterogeneous organic matter layer thickness (thicker in the northern half, almost non-existent in the southern part), with the maximum thickness being recorded at Kuona8, (360cm), in front of the inflow from Päähinen, north-west from the lake. It would indicate Päähinen as source (direct or intermediate) of nutrient pollution. On a positive note, pH levels are quite homogenous (all being close to 6,06), and given the long-term trends of alkalinity analyzed, the lake is quite resistant to acidic inflow.

The waters leaving lake Höytiäinen are in a very good state despite several towns located on the shore of this lake : clear appearance, suitable pH and alkalinity levels, as well as acceptable nutrient and oxygen levels, allowing the aquatic lifeforms to survive. Low COD also indicates that little amount of compounds is being oxidized.

Surprisingly, similar observations can be made regarding the Iso-Polvijärvi water body, located in the Höytiäinen catchment area, despite heavy road and air traffic in the proximity. Several hypotheses can be made in order to explain it, ranging from good filtration characteristics of surrounding soil, little inflow, or dominating wind currents moving the acidic precipitations away from Iso-Polvijärvi.

As it was mentioned previously, due to time restrictions the outflowing waters were considered as representative of the lake. However, further statistical analysis would be interesting for several reasons : determining whether or not there is an actual source of pollution upstream (that is undetected due to the dilution in the lake), or for instance, whether any pollutants just have a tendency to sink and form the sediment, leaving the waters appearing as of good quality (Verta, 1989).

In a similar fashion, little could be done at Linnunsuo site, for various reasons. However, a vast array of bird species has been observed, representing all feeding patterns (predator, omnivore, herbivore), living patterns (resident, migratory, breeding) etc. Some of these species are quite rare, which is the case of White-tailed Eagle (3 recorded couples) or Quail (rare in North Karelia). One must keep in mind that most of the bird population has been dominated by few species, such as Teals, Sandpipers and Lapwings.

5) Possible future actions

Depending on the nature of the disturbance, different strategies can be used. It would be obviously preferable to eliminate the source of said disturbance, but it is often impossible. Whenever possible, strategies can be used to alleviate the disturbances already occurring.
Besides the already-known sources of pollution, such as agriculture, forestry and industrial activities, it would be interesting to quantify in the future the environmental impact of tourism, especially due to high number of summer villas (Hiltunen, 2016).

In case of Kuonanjärvi, the turbidity levels are the main issue, along with possible nutrient pollution, coming from Päähinen. Two methods could be proposed : one would require introduction of aquatic macrophytes in order to reduce available nitrogen as well as the resuspension of particles. The other one would consist in introducing filter feeders, such as *Daphnia*, *Eurycercus* or *Simocephalus* (Scheffer, 1999). Either way, research should be made on the state of Päähinen and optionally other connected water bodies upstream.

It would seem that lake Höytiäinen is in a very good state and requires little restoration efforts. However, further regular monitoring is recommended due to several urban areas located at its shore.

Finally, visits to Linnunsuo site have shown that the water quality has improved. However, it might be important to include some kind of metal stabilization method in order to decrease the heavy metal levels in water. Also, other bioindicators could be used (see paragraph below).

6) Personal constructive criticism

There are some aspects that need to be mentioned in order to understand better the work that has been done.

First of all, it is necessary to mention that the focus was made on the present-day data. Moreover, water quality assessments are done using more the "threshold" approach than "statistic significance" approach. In other words, while statistical approach might be useful to get a more precise idea about the long term trends that have been going on in the last decades, the present-day water quality is assessed by comparing the analyte values to the thresholds established by environmental authorities.

While efforts were made to ensure a most complete approach, some aspects could not have been studied at all, or the study was not as satisfactory due to small amount of data. For example, total organic and inorganic carbon (TOC and TIC, respectively) could not have been taken into account at all due to very insufficient data. However, those analytes could be very interesting given the fact that the presence of peatlands has been previously positively correlated to TOC concentrations in lakes (Kortelainen, 1993 ; Arvola, 2004).

A similar remark could be made about bioindicators. First of all, it should be noted that the use of birds as the sole bioindicator has its limits. We can mention the lack of gathering of biological material that could bring additional data, such as feathers or egg shells; no knowledge on whether or not the migratory birds have been affected by their stay at Linnunsuo or another site on their route (Burger, 2004) ; potential interspecific differences in sensitivity to the environmental disturbances have not been taken into account (Fernández, 2005) ; difficulty estimating the number of birds ; as well as lack of an official bird watching protocol followed, similar to - for example - French citizen project STOC (*Suivi Temporel des Oiseaux Communs*), which defines size of area, and time and number of observations, as well as possesses guidelines regarding data interpretation (MTES, 2018).

On the other hand, other potentially useful taxa, such as plants, diatoms, invertebrates, fish or amphibians and reptiles have not been studied more closely.

The plants - being immobile - are easy to observe and constantly under the influence of the surrounding environment. One needs to keep in mind though, that obtaining the specimens would require additional efforts, especially the aquatic species. Additionally, most plants concerned are all vascular plants. Mosses and lichens cold have even greater potential as bioindicators, but the resources are not as easily available, compared to vascular plants. More research would be necessary to establish the most relevant species.

Another category of organisms - diatoms - has not been studied at all during the internship, regardless of the location. This comes in as quite surprising, since they are so commonly used as water quality indicators and have already been established as a reliable way to estimate total phosphorus concentration in Finnish lakes (Miettinen, 2003). The lack of data could be linked to several reasons, such as need for additional equipment, sample preparation, and use being limited to lotic environments (Lobo *et al,* 2016).

While invertebrates have been taken into account *per se*, the studies have been limited to macrozoobenthos. However, other taxa could be just as reliable bioindicators in wetland areas, such as odonates. This order could be a very useful indicator at Linnunsuo site, given their dependence on water for reproduction, large numbers observed *in situ*, and previous successful studies of lake restoration (D'Amico et al, 2004). Another potentially useful invertebrate taxon in case of wetland areas could be water mites (Więcek, 2013).

Fish assemblages can also be used as reliable bioindicators (Chovanec *et al,* 2003), however the fish population study has been performed only once, in a separate project, and the amount of data was too low to present it in this report.

Finally, since the presence of amphibians has been noticed on the Linnunsuo site (sounds heard), the amphibian abundance and species assemblage could also serve as bioindicators (Saber, 2017). Their sensitivity is due to their permeable skin, which makes exposure to pollutants easier compared to other taxa, as well as their semi-aquatic lifestyle (Wagner & Brühl, 2017).

Another factor that has made the statistical analysis a bit more challenging was the fact that the stations were not all created and or at least checked simultaneously, or with the same frequency. It should go without saying that comparison of a station A with 15 studies and a station B with only 3 studies - even if done during the same time period - could be flawed. The same remark could be said about the frequency of studies of different analytes (some being checked at each study of a given station, and others being measured every fifth study), or studies of different water layers.

Speaking of challenging statistical analysis, it should be kept in mind that the amount of data regarding lake Höytiäinen to process was extremely large and barely manageable for one unassisted person, with just some occasional general feedback. This has led to considerable cuts in amount of data that could actually be processed. Full-extent analysis regarding the inflow and the lake itself were considered, but the amount of available time was inversely proportional to amount of data needed to be processed.

In a similar fashion, one needs to keep in mind a factor that affected the potential amount of data that could be gathered during fieldworking trips is the personal dependence on other parties logistically. Without any alternative ways to get oneself to a given location, it was impossible to make independent expeditions and obtain additional data on the current state of the said location.

All in all, during the internship several methods of assessing water quality have been used, but unfortunately they have not been used all together (and to the full extent) at each water body. Instead, there has been definitely some amount of data lost due to only using physico-chemical analytes, or only bioindicators.

In conclusion, diagnostic and restoration projects would benefit greatly from :

1) greater care in performing the samplings at the greatest amount of stations in the shortest amount of time,

2) respecting the same protocol at each sampling (checking the same depths and analytes each time),

3) elaborating a protocol for analytes that might need it (such as for birdwatching),

4) taking into account several types of bioindicators, and

5) getting a larger team involved for data analysis.

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Image sources

⋄ Cover photo : own work

⋄ Figure 1 :

- a : https://www.stat.fi/tup/suomi90/kesakuu_en.html
- b : http://mapsof.net/finland/finland-locator-map

⋄ Figure 2 : https://commons.wikimedia.org/wiki/File:Finnish_Lakeland_travel_map.png

⋄ Figure 3 :

- a : excerpt from Saarinen *et al*. (2001)
- b : excerpt from Haapala (2009)

⋄ Figure 4 : own modifications, original map from National Land Survey of Finland's MapSite (https://asiointi.maanmittauslaitos.fi/karttapaikka/)

⋄ Figure 5 : own work

⋄ Figure 6 : original map from National Land Survey of Finland's MapSite, modifications by Tarmo Tossavainen (received before the start of fieldworking trips)

⋄ Figure 7 : rendered with SYKE OpenData database (https://wwwp2.ymparisto.fi/Vesla/SiteListInMap.aspx)

⋄ Figure 8 :

- a : original map from National Land Survey of Finland's MapSite
- b : shared by Tarmo Tossavainen before visiting the site, own modifications

<u>Appendix 1</u> : Table resuming the information about water quality analytes' national average, as well as their minimum and maximum values for a well-functioning lake

Analyte	Minimum	National average	Maximum
Physical analytes			
Temperature (℃)	n/a	n/a	n/a
Turbidity (FNU)	n/a	n/a	5
Suspended solids (mg/l)	n/a	n/a	5
Secchi depth (m)	n/a	n/a	n/a
Visibility (%)	n/a	n/a	n/a
Chemical analytes			
pH	5,5	6,9	n/a
Alkalinity (mmol/L)	0,05	n/a	n/a
Conductivity (mS/m)	n/a	6,7	n/a
Oxygen dissolved (mg/L)	5	n/a	n/a
Oxygen saturation (%)	n/a	n/a	n/a
COD (mg/L)	n/a	10,1	15
Aluminium	n/a	n/a	n/a
Calcium (µg/L)	n/a	6	n/a
Iron (µg/L)	n/a	262	1000
Magnesium	n/a	n/a	n/a
Manganese (µg/L)	n/a	30	100
Biological analytes			
Ntot (µg/L)	n/a	500	600
Ammonium (µg/L)	n/a	23	n/a
Nitrite (µg/L)	n/a	1	n/a
Nitrate (µg/L)	n/a	92	n/a
Ptot (µg/L)	n/a	23	35
Phosphate (µg/L)	n/a	4	n/a
Chlorophyll a (µg/L)	n/a	6,3	7

Appendix 2 : Table depicting the frequency of Kuonanjärvi stations samplings

Date	Kuona 1	Kuona 2	Kuona 3	Kuona 4	Kuona 5	Kuona 6	Kuona 7	Kuona 8	Kuona 9	Kuona 10	Kuona 11	Kuona 12	Kuonanjärvi 003	Kuonanjärvi 030	Kuonanjärvi 090
23/02/2018	-	YES	-	-	-	YES	-	-	-	-	-	-	-	-	-
28/02/2018	YES	-	YES	-	-	-	YES	-	-	-	-	-	-	-	-
15/03/2018	-	-	YES	YES	-	YES	-	-	-	-	YES	-	-	-	-
26/03/2018	-	-	-	-	-	-	-	YES	-	-	-	-	YES	-	-
03/04/2018	-	-	-	-	-	-	-	YES	-	-	-	-	-	-	-
06/04/2018	-	YES	-	-	-	YES	-	-	-	-	-	YES	-	-	-
10/04/2018	-	-	-	-	-	-	-	-	-	-	-	-	YES	-	-
13/04/2018	YES	YES	YES	-	-	-	YES	-	-	-	-	-	-	-	-
18/04/2018	-	-	-	-	-	-	-	YES	YES	YES	-	-	-	YES	-

Appendix 3 : Example of raw data, obtained from SYKE OpenData database

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Site name	Site ID number	Site coord ETRS east	Site coord ETRS north	Site depth (m)	Sampling time	Sample depth	Determination code	Analyte (in English)	Flag	Original value	Unit	Result
2	Aisusjoki 10	23880	619525	6988054	0,4	08/06/2006 09:30			Total depth		1	m	1
3	Aisusjoki 10	23880	619525	6988054	0,4	08/06/2006 09:30	0,5		Alkalinity			mmol/l	0,108
4	Aisusjoki 10	23880	619525	6988054	0,4	08/06/2006 09:30	0,5		Aluminium			µg/l	200
5	Aisusjoki 10	23880	619525	6988054	0,4	08/06/2006 09:30	0,5		Chemical oxygen demand			mg/l	21
6	Aisusjoki 10	23880	619525	6988054	0,4	08/06/2006 09:30	0,5		Colour number			mg/l Pt	150
7	Aisusjoki 10	23880	619525	6988054	0,4	08/06/2006 09:30	0,5		Dissolved oxygen			mg/l	10
8	Aisusjoki 10	23880	619525	6988054	0,4	08/06/2006 09:30	0,5		Iron, digestion			µg/l	900
9	Aisusjoki 10	23880	619525	6988054	0,4	08/06/2006 09:30	0,5	MN;D11;SP	Manganese		31	µg/l	31
10	Aisusjoki 10	23880	619525	6988054	0,4	08/06/2006 09:30	0,5		Nitrite nitrate as nitrogen, unfiltered			µg/l	2
11	Aisusjoki 10	23880	619525	6988054	0,4	08/06/2006 09:30	0,5		Oxygen saturation			kyll.%	88
12	Aisusjoki 10	23880	619525	6988054	0,4	08/06/2006 09:30	0,5		pH				6,65
13	Aisusjoki 10	23880	619525	6988054	0,4	08/06/2006 09:30	0,5		Phosphate as phosphorous, unfiltered			µg/l	2
14	Aisusjoki 10	23880	619525	6988054	0,4	08/06/2006 09:30	0,5		Temperature			°C	9,9
15	Aisusjoki 10	23880	619525	6988054	0,4	08/06/2006 09:30	0,5		Total nitrogen, unfiltered			µg/l	390
16	Aisusjoki 10	23880	619525	6988054	0,4	08/06/2006 09:30	0,5		Total phosphorous, unfiltered			µg/l	11
17	Aisusjoki 10	23880	619525	6988054	0,4	08/06/2006 09:30	0,5		Turbidity			FNU	1,4
18	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00			Secchi depth		1	m	1
19	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00			Total depth		1	m	1
20	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00	0,2		Alkalinity			mmol/l	0,048
21	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00	0,2		Aluminium			µg/l	330
22	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00	0,2	CA;;PLO	Calcium		3,3	mg/l	3,3
23	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00	0,2		Chemical oxygen demand			mg/l	35
24	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00	0,2		Colour number			mg/l Pt	260
25	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00	0,2		Dissolved oxygen			mg/l	11,1
26	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00	0,2		Iron, digestion			µg/l	1300
27	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00	0,2	MG;;PLO	Magnesium		0,7	mg/l	0,7
28	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00	0,2	MN;D11;SP	Manganese		52	µg/l	52
29	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00	0,2		Nitrite nitrate as nitrogen, unfiltered			µg/l	74
30	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00	0,2		Oxygen saturation			kyll.%	83
31	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00	0,2		pH				5,72
32	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00	0,2		Phosphate as phosphorous, unfiltered			µg/l	8
33	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00	0,2		Temperature			°C	3,3
34	Aisusjoki 10	23880	619525	6988054	0,4	13/11/2008 09:00	0,2		Total nitrogen, unfiltered			µg/l	680