



Internship report

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2nd year of MSc – “Gestion et Evolution de la Biodiversité”

Ecological study of the Linnunsuo wetland and of the Jukajoki river
(North Karelia, Finland) using biological and physio-chemical
indicators.



Antoine Scherer, 2017

Receiving organisations

Karelia University of Applied Sciences - Snowchange Cooperative

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1. Introduction

Finland, the “Land of a thousand lakes”, is a country with natural boreal ecosystems. With 188000 lakes, 179000 islands, more than 75 % of its total area covered with forests, and about a third originally covered with peatlands, this country presents unique habitats that shelter a specific and rich biodiversity (IUCN, n.d.).

Finnish people have a strong relationship with this surrounding nature, many outdoor activities (such as berry-picking, fishing and hunting) constituting traditions deeply ingrained in the Finnish culture (Yrjölä, 2002). Despite this ancestral connection, the exploitation of natural resources over the last centuries led to deep modifications of the landscapes, from traditional practices such as the slash-and-burn farming (Lehtonen & Huttunen, 1997) to the modern and more damaging industrial farming practices. The war reparations owed to the Soviet Union after the Second World War catalyzed the recent and fast industrialization of Finland, which has been the main driver of an overall degradation of ecosystems. In that way, more than 50 % of the total number of habitat types are now considered endangered (Raunio *et al.*, 2008), and about 10 % of the species were classified as threatened on the 2010 Red List of Finnish Species (Rassi *et al.*, 2010).

Among these endangered habitats, wetlands have been severely damaged in the last decades. Peatlands, in particular, are receding on a worldwide scale (Bain, n.d.), and it is estimated that Finland has lost more than 60 % of its formerly extensive mire* area, mostly because of a policy of massive drainage for afforestation since the 1950s (Joosten & Clarke, 2002). This damaging procedure aimed to evacuate the water surplus to allow a better tree growth, in order to enhance forestry profits. Nowadays, new drainage schemes are rare, but existing ditches are cleared periodically, which keeps dense and complex networks that are still affecting the hydrology of economic forests (Metsähallitus, 2015). When left abandoned, these ditches can fill naturally within a few decades, but restoration actions are often needed to allow these ecosystems to go back to their original waterlogged state (Biodiversity.fi, 2015).

Peatland ecosystems in Finland have also been impacted by the exploitation of peat*. Peat has been used for centuries as a source of energy, but its extraction turned into an industrial activity after the Second World War. The hand-cutting technique, used until then, was replaced by much more damaging techniques that necessitate to ditch and drain extensive areas, and to use heavy machines to mill, harrow and harvest the peat (Vitt & Bhatti, 2012).

Peat is mostly used for energy production in Finland, and its exploitation intensified from 1980 in reaction to the 1970s oil crisis, peat consumption reaching its highest level in 2007 (OSF, 2017). Since then, the trend has been reversed, partly because of the growing concern about the environmental consequences of peat use. The National Energy and Climate Strategy, in its 2013 update, aims to reduce by a third the use of peat for energy by 2025 in Finland, which is consistent with the Parliamentary Committee on Energy and Climate Issues' "Energy and Climate Roadmap 2050" objectives (PCECI, 2014). How laudable these efforts may be, initiatives such as the "Nordic Baltic Wetland Initiative" underline the fact that an active restoration of peatlands is necessary on a national scale to bring back these essential ecosystems (Barthelmes *et al.*, 2015). Indeed, the remaining areas left after their exploitation are usually kept drained and replaced by economic forests (Picken, 2006), which rules out the possibility of a natural comeback to their original state. Yet, peatlands are essential habitats that provide many ecosystem services, as outlined in the Millennium Ecosystem Assessment (2005) : they play a huge role in hydrological regimes and act like water reservoirs, they influence the local climate, and constitute some of the most effective carbon sinks of the planet. Their exploitation, in this sense, leads to the release of vast amounts of greenhouse gases, which is of major concern in the current context of global warming. Peatland ecosystems can also be considered as hotspots that shelter a specific biodiversity. Many species of flora and fauna that are adapted to these ecosystems are now endangered because of the habitat destruction associated with peat mining (Similä *et al.*, 2014).

In North Karelia, Eastern Finland (**Fig. 1**), people from the village of Selkie faced an ecological disaster caused by industrial peat extraction. In the 1980s, VAPO, a state-owned company, started exploiting a peatland complex located just a few kilometres from the village. In 2003, they got an official permit to mine an area called Linnunsuo. Before the arrival of the company, this former mire sheltered a rich biodiversity, and especially many bird species ("Linnunsuo" literally means "Bird marsh"). It has always been an important natural environment for local people, as it was used for traditional activities such as gathering and hunting. Linnunsuo is connected to the adjacent Jukajoki river, which is a fundamental watercourse for many local people who depend on it for recreational, subsistence, and even small-scale professional fishing. In July 2010, in a section located after the crossing with the ditch coming from Linnunsuo, fishermen were the first to observe dead fish floating in the river, as well as a deterioration of the water quality. They informed the village of Selkie, who alerted the environmental authorities. The local "Center for Economic Development, Transport and the Environment"

(ELY-keskus/CEDTE) analysed the discharges from the Linnunsuo peat extraction site, and concluded that they were extremely harmful (pH values of 2,7 - 3,4 were recorded, and the iron concentration reached 300 000 $\mu\text{g.L}^{-1}$ – such conditions are lethal to all aquatic organisms). Despite these findings and the protests from the village, VAPO was allowed to keep its permit, and promised that they would fix the problem. In June 2011, once again, the same subsistence fishermen witnessed a massive fish die-off in the Jukajoki river. This time, the village alerted both the CEDTE and the police. As a result of these complaints, VAPO was legally obliged to stop its peat extraction activity in Linnunsuo. Its permit was renewed in 2012, but the Regional State Administrative Agency (RAA) imposed the implementation of restoration measures.

VAPO decided to rewet of the area, as a mean of stopping the oxidation processes that led to the leakage of acidic waters, responsible for this ecological disaster (Mustonen, 2014).

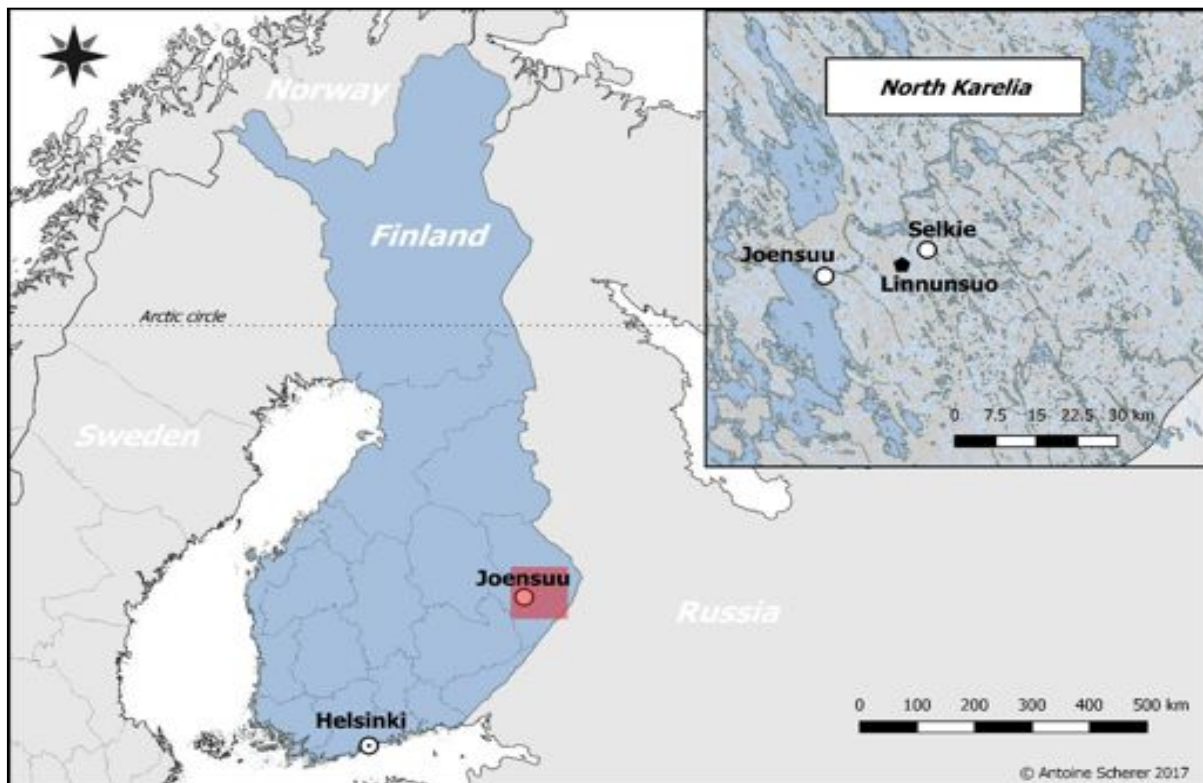


Fig. 1: Global location of the Linnunsuo wetland.

The restoration process was implemented in 2013. Linnunsuo is now a 120-ha wetland, whose main purpose is to prevent any further pollution of the Jukajoki river. Linnunsuo was purchased in May 2017 by Snowchange (located in Selkie) thanks to a loan from Rewilding Europe. An innovative collaborative management approach has been initiated in Linnunsuo, highlighting the importance of considering the views of all the local actors who have a

legitimate right to be involved in the project. The co-management council includes parties that, at first glance, seem to have opposite interests – such as the local birding association, the local hunting association, and even VAPO – but the focus is made on dialog, and agreements are reached for the common good. This new system aims to give back a local governance control to those who have been deprived from it when the State company appropriated the area. It also emphasizes that the local-traditional knowledge, despised by those in power until now, should be considered as equally relevant as the modern scientific knowledge (Mustonen, 2013): fishermen have been warning for years about the deterioration of the river state and about an imminent disaster, yet VAPO's monitoring protocol hasn't been able to prevent what happened.

Nowadays, the Linnunsuo wetland aims to protect the Jukajoki river from the acidic compounds and heavy metal released by the peat production by acting like a buffer area. It was initially just a step in the long-term restoration of the river watershed, but the area is showing an amazing resilience capacity. Indeed, while no one expected it, the area became, as soon as the first year, an important breeding, nesting and resting area for many different bird species, including rare species at regional and even national level. This consequence was not aimed by the restoration project, so new considerations are now appearing regarding its management. Birdwatchers consequently entered in the project as new actors of the co-management. The recent involvement of Rewilding Europe in the project also brings new opportunities for the future of the area, highlighting the importance of focusing on natural processes in this deeply human-influenced watershed. Rewilding, as a set of ecological practices and as a philosophy, could offer solutions to guide the restoration project and find back functioning ecosystems that could support traditional activities for local people and create viable nature-centred economic opportunities.

In this context, the present study aims to: (1) Assess the current ecological state of the Linnunsuo wetland using physio-chemical (water analyses) and biological (macrozoobenthos and birds) indicators ; (2) Evaluate the ecological health of the Jukajoki river, using fish as biological indicators ; (3) Suggest potential management measures for the wetland regarding these results and think about the future of the project ; (4) Produce a first synthetic document entirely written in English that could contribute to the international reach of the project.



Fig 2: Linnunsuo, March 2017.



Fig. 3: Same view, July 2017. Seasons shape landscapes in boreal regions, and nature management has to deal with long periods of snow and ice cover.

2. Presentation of the receiving organisms

This internship was done in collaboration with the Snowchange Cooperative and the Karelia University of Applied Sciences, and a frequent contact with Rewilding Europe was maintained.

Snowchange Cooperative:

The Snowchange Cooperative is an independent, non-profit organization based in North Karelia, Finland. The organism was officially founded in 2001, after a series of meetings with Saami people and communities in Canada that started in 1996.

Its main purposes are to document indigenous views on climate and ecology, and to link communities to help them face the ongoing environmental changes. Snowchange is devoted to keep alive the traditions and cultures of local and Indigenous communities. It started working in Northern regions, but is now collaborating with people from all around the world, including the Saami, Chukchi, Yukaghir, Inuit, Inuvialuit, Inupiaq, Gwitch'in, Icelandic, Tahltan, Maori, Indigenous Australians and many others.

The organisation has been led by Tero Mustonen since its inception, and the Snowchange International Steering Committee includes 25 people, 20 of them being recognized as leaders in their respective communities.

Snowchange is community-centred and aims to empower indigenous people by helping them conducting their own research, focusing on traditional knowledge*. In every project, Snowchange interviews local harvesters to gather traditional knowledge about their surrounding environment. Sometimes, these interviews are recorded, and they are then archived and made available to researchers and communities collaborating to the programmes. Every year, the cooperative holds conferences, where international participants can share their experiences. It also produces books, photo albums, organizes workshops about indigenous traditions, and recently collaborated with professional teams to produce movies about their ongoing projects.

Snowchange works with many governmental and scientific organisations, such as the Arctic Council, the Intergovernmental Panel on Climate Change (IPCC), the National Science Foundation (NSF), as well as universities and other partners around the globe. Snowchange is mainly funded by governmental and private sources, including the Saami Council, NSF, the Academy of Finland and the Finnish Ministry of the Environment.

Snowchange won several prestigious environmental and human rights awards, such as the World Wildlife Fund “Panda prize” in 2002 and the “National Energy Globe Award” in 2015. It is now considered as a major force in international climate and indigenous rights discussions worldwide.

Rewilding Europe:

Rewilding Europe was founded in 2011 and is based in the Netherlands. The foundation main aim is to rewild* at least 1 million hectares of land by 2022, by creating 10 wildlife and wilderness areas of international quality in Europe. Rewilding Europe has for the moment selected 8 areas, span in 10 countries, where they collaborate with local communities, NGOs and other stakeholders. Rewilding Europe aims to turn the Old Continent’s biggest challenges (such as land abandonment) into opportunities for both man and nature. It promotes the development of activities such as eco-tourism to create viable business models from wild nature that can benefit to local people.

The organisation has launched several programmes to reach its goals, such as the European Wildlife Bank, which has been created to support the reintroduction of native large herbivores in rewilding areas (and hence support natural grazing to keep open habitats), and the Rewilding Europe Capital (REC), to invest in rewilding activities and local businesses.

The innovative restoration project conducted by Snowchange in the Jukajoki basin (where this internship took place) integrated in November 2016 the European Rewilding Network (ERN), another Rewilding Europe initiative created to connect rewilding and restoration projects across Europe. In 2017, Snowchange benefited from a loan from Rewilding Europe to buy lands in the Jukajoki basin (this groundbreaking loan being the first provided by the REC to a member of the ERN), thus marking Rewilding Europe’s involvement in the project.

3. Materials and Methods

Presentation of the studied case

General context

The present study forms part of the ongoing Jukajoki restoration project, initiated by Snowchange in 2010 in response to the degradation of the ecological state of the river. This project aims to restore the entire Jukajoki watershed (part of the Vuoksi river basin), which represents an area of approximately 9000 ha located in North Karelia, in the Southern boreal zone of Finland. The project was described as “Best practice” in the 2014 annual report of the United Nations Environment Programme (UNEP), and led Snowchange to win the National Energy Globe Award in 2015. This innovative restoration project also generated a lot of media attention in the last few years.

The data of the present study were collected in the Linnunsuo wetland and in the Jukajoki Delta. A general map of the Jukajoki watershed and its surroundings can be found in **Fig. 4**, to give some context and help situating the mentioned locations relatively to each other.

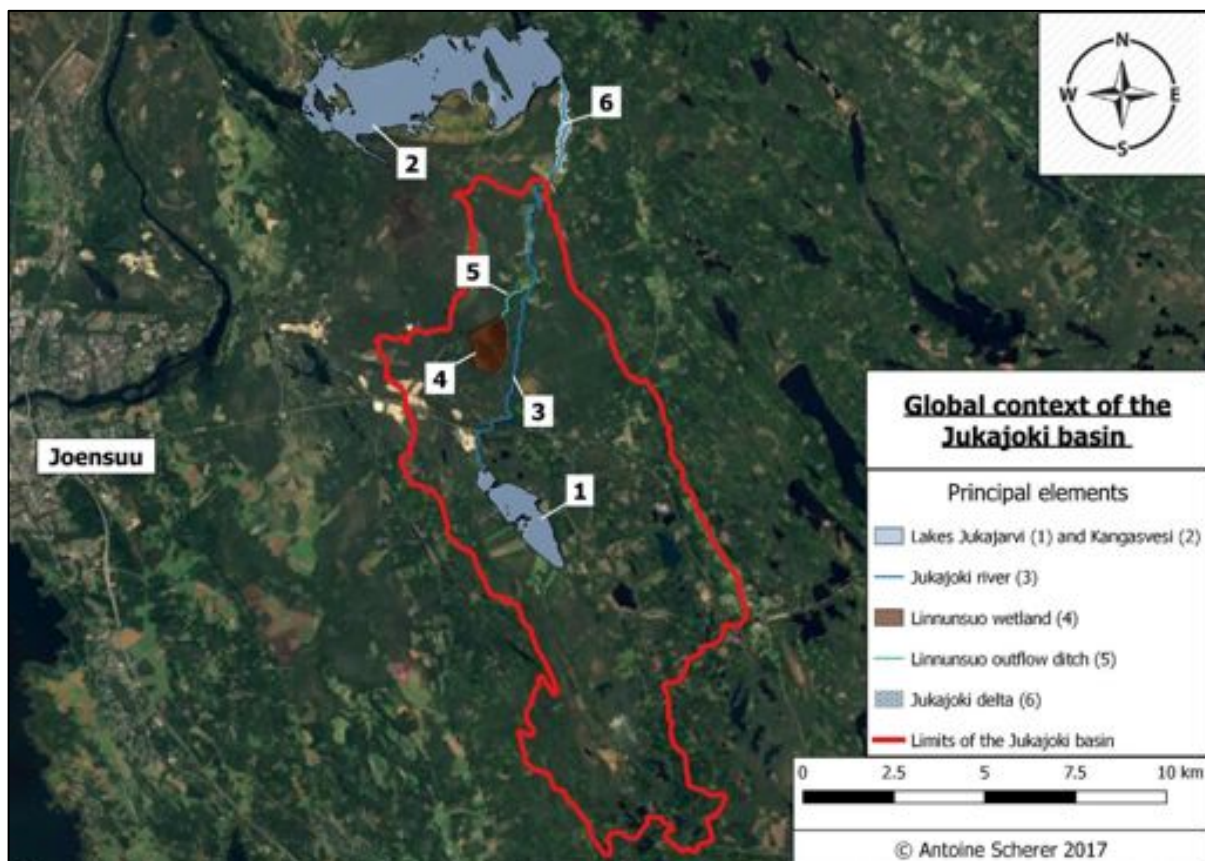


Fig. 4: Locations of the principal elements of the Jukajoki basin, including the study areas.

Carried studies

Water and benthic fauna sampling stations

For the sake of clarity along the study, the three pools have been numerated from 1 to 3, following the gravity flow into the area (**Fig. 5**). As a preliminary work, ten sampling stations (covering the entire wetland) were tested to determine which ones would be kept for the project. Given that the pools are very shallow, several stations presented a water depth so small that, during the winter, the ice reached the bottom. Such a phenomenon leads to the freezing of the sediment, which causes the death of most of the benthic fauna living there. Therefore, five stations, with the highest water level, were selected for the sampling effort: Linnunsuo 1, 3, 4, 7 and 9. During wintertime, it turned out that in the stations 7 and 9, the depth of the free water under the ice was considered too shallow ($< 0.50\text{m}$) to find any living organism in the sediment. Therefore, the work focused on the third pool for this period, with samplings from Linnunsuo 1, 3 and 4.

Concerning the section of water linking Linnunsuo to the Jukajoki river, the benthic fauna samples and the water samples were taken in different locations (**Fig. 5**). For the sake of clarity, this section of water is called “outflow” in the rest of the study. Four other sampling stations were located along the Jukajoki river (**Fig. 5**). They were set up so that the water samples taken there could give information about the impact of the water coming from Linnunsuo to the river. The cross with the outflow was located between “Myllyla” and “Ukonnurmi”. The sampling started in April 2017. One sampling station was located in the inflow coming from the forest into Linnunsuo. The presence of this ditch was found only in the end of April 2017. Hence, only one water sample was done in May 2017 on this ditch.

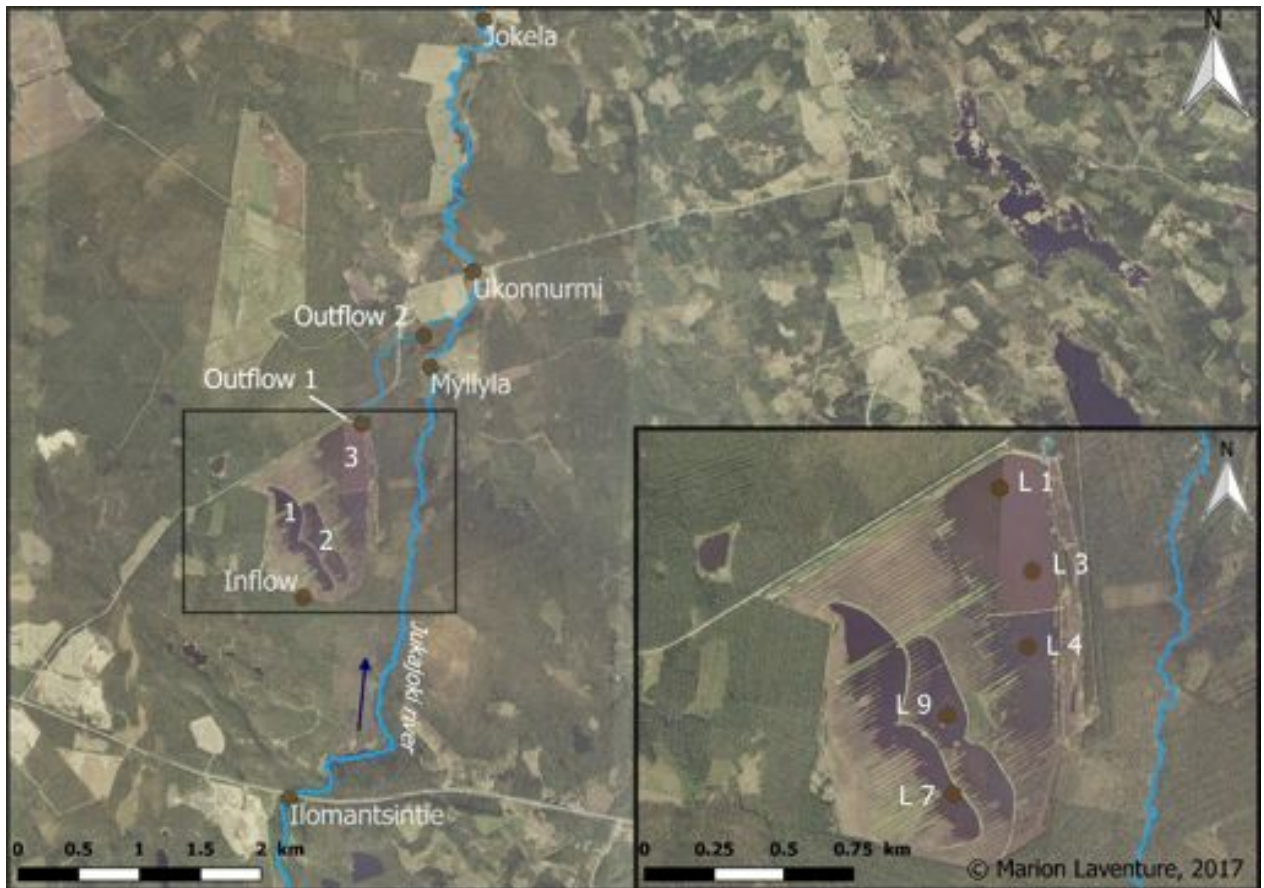


Fig. 5: Map of the study area with the different sampling stations (brown points) and the numeration of the pools (1,2,3). For the water samples, the following stations were used: L1, L9, L7, Outflow 1, the inflow, Ilomantsintie, Myllyla, Ukonnurmi and Jokela. For the benthic fauna samples, the following stations were used: L1, L3, L4, Outflow 2, Ilomantsintie, Myllyla, Ukonnurmi and Jokela.

Physio-chemical water analyses

Context and objectives:

The Linnunsuo wetland aims to stock back in the ground the different pollutants that were released from the soil during the exploitation. In that way, the area could become a suitable place for a more diverse number of species. It also has a role of buffer area for the Jukajoki river which suffered from the industrial activity. The water analyses from the wetland, the outflow and the river help to evaluate the efficiency of the wetland as a buffer area and might also help to understand the ecological state of the river. The results

Protocol:

The water samplings were harvested between November and April 2017. Each time, a first hole was done in the ice and the depth of the water was measured. This first measure enables to ensure the possibility to continue the sampling. Indeed, if the depth is lower than the length of the device, the sampling localization must be moved of a few meters. The water samplings were realised with a “Ruttner water sampler”. Two temporal periods were considered in this study: the winter (November to April) and the spring (May to June).

The conductivity ($\mu\text{S}/\text{cm}$) was measured using a “8200/8200 M” device. The measuring device was purchased in February and, therefore, there is no value of conductivity for January. This parameter was measured in complementarity with the pH to give information on the type of inorganic dissolved ions present in the water (Wenger, 1984 ; MacDonald *et al.*, 1994).

The pH was measured with a “Mettler Toledo” device. The pH is a major parameter that can have direct and indirect impacts on the water quality and aquatic organisms. For example, it can influence the concentration of metals in the water, such as iron and aluminium, by enhancing their dissolution and their toxicity (MacDonald *et al.*, 1994 ; Lee, 1985). The iron and aluminium concentrations ($\mu\text{g}/\text{l}$) were measured with the “Filter photometer photoLab® S12” and, respectively, the “Spectroquant Iron Test” and the “Spectroquant Aluminim Test” packages.

The dissolved oxygen concentration ($\mu\text{g}/\text{l}$) and the oxygen saturation (%) were measured in the three pools by the Savo-Karjalan Ympäristötutkimus Oy (“Environmental Research Company of Savo-Karjala”) laboratory in Joensuu. In April, a “8200/8200 M” device was purchased and the oxygen parameters were measured in the university laboratory.

The velocity of the water in the outflow was measured with a flow meter. Then, the discharge was calculated in order to have an estimation of the volume of water passing by Linnunsuo (**Fig. 6**).

Sediment samples were conducted with a “Russian core sampler” in the sampling station

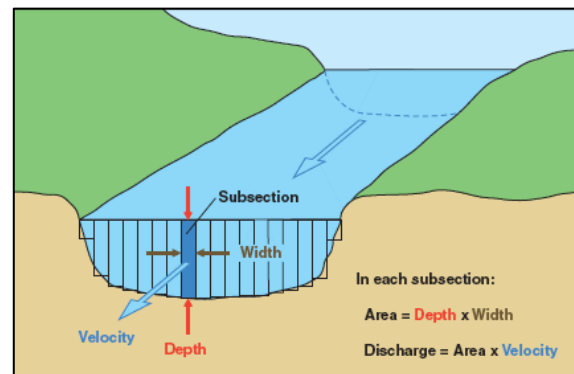


Fig. 6: Methodology applied to estimate the discharge in the outflow of the Linnunsuo wetland (water.usgs.gov).

L1, L7 and L9. The samples were used to highlight the presence of undecomposed organic matter on the bottom of the wetland. In February, three sediment samples were taken to be analysed by a laboratory located in Tampere (Kokemäenjoen vesistön vesiensuojeluyhdistys KVVY). The analyses focused on the concentration of different metals (iron, lead, mercury, aluminium, copper, zinc, chrome), as well as nitrogen and phosphorous concentrations. Two samples were collected from L7. The first sample was constituted of the first 10 cm layer of sediment and the other one was taken from 20 to 33 cm. The last sample was from L9 (11 to 15 cm).

Biological analyses

- Benthic fauna:

Context and objectives:

Benthic macrofauna is widely known and used as a biological indicator (Pearson & Rosenberg, 1978 ; Abbasi, 2002). Indeed, this type of organisms live on or within the substrate and depend on it, which implies that they stay in the same location during their entire life cycle. It is thanks to this sedentary way of living that the benthic macrofaunal can provide a lot of information about their surrounding environment by just monitoring them. As a matter of fact, the presence or absence of one species or another can already give reliable information on the quality of the water, for example. Furthermore, almost each taxon has its own range of sensitivity to the presence of pollutants. Thus, the survey of this group can help to identify the degree of pollution of the water bodies and to estimate their environmental state.

Protocol:

For the wetland area, macro-benthic fauna samples in Linnunsuo and in the outflow were realised at different times but the sampling effort was the same: 2 samples with 3 replicates per sampling station. An “Ekman sediment sampler” (**Fig. 7a**), with a sampling area of 302.76 m², was used to sample sediment from the pools. This device is adapted to soft-bottom sediments without high vegetation, as the one found in Linnunsuo. As for the water samplings, the depth of the water was first tested. Then, the ice was cut with a chainsaw and the blocks of ice were taken away.

The narrowness of the outflow prevented the use of the Ekman sampler. A kicking net or invertebrate net (**Fig. 7b**) was used instead. After the ice was broken, the net was immersed in the water for 3 minutes. In the same time, the sediment was disturbed in the aim of dispersing the benthic macrofauna organisms living on/in it. Then, the sediment was transferred from the net to a sampling box. The operation was done three times.

The book “Vesikirppu ja sudenkorento” (Olsen *et al.*, 1999) was used to identify the collected macroinvertebrates.



Fig. 7: A picture of an Ekman sediment sampler (eijkelkamp.com) on the left (a) and one of a kicking net (envcoglobal.com) on the right (b).

- **Birds:**

Context and objectives:

As soon as the year of its creation (2013), the Linnunsuo wetland turned out to be a very good environment for birds: over 120 bird species already visited Linnunsuo, and 20 of them nested there. By 2016, these numbers had increased, with 179 bird species recorded, including 27 nesting species. The wetland is now considered to be a staging area of major importance for many migratory birds, with the visit of rare species such as the Terek Sandpiper (*Xenus cinereus*) and the Tawny pipit (*Anthus campestris*). The bird monitoring also showed that this habitat is used to nest by protected breeding species such as the Northern Pintail (*Anas acuta*) (Kontkanen, 2016).

This part of the study aims to assess the ecological state of the Linnunsuo wetland, using breeding birds as indicator organisms. The monitoring of birds presents many benefits: birds are biologically and taxonomically well described; their observation doesn't necessitate the implementation of heavy protocols or the use of expensive tools, and their identification is relatively easy compared to other taxa. The presence or the absence of a given species can give insights about the state of a studied ecosystem (Brimont *et al.*, 2008). Birds are globally considered as good indicators of environmental changes (Gregory & van Strien, 2010; O'Connell *et al.*, 2000) and biodiversity (Blair, 1999; Mikusiński *et al.*, 2001), and they've been monitored in these purposes for many years in Finland (Koskimies, 1989; Biodiversity.fi, 2013 & 2014). They are also specifically used to assess the effectiveness of habitat restoration measures, especially in wetland ecosystems (Frederick *et al.*, 2009; Roché *et al.*, 2010). The monitoring of breeding birds, in particular, can give a lot of information about the habitat where they nest. Indeed, the bird diversity usually reaches its peak during the breeding season. During this period, most of the breeding species don't move far from their nest and exploit the available local resources to feed their brood. In this sense, they are then very sensitive to the quality of their surrounding environment and to disturbances (water level variations, food availability...). Consequently, their presence can be very informative about the studied area (Brimont *et al.*, 2008). By pursuing the bird monitoring that has been carried on since 2013, this study aims to detect potential population trends and the appearance/disappearance of breeding species. The interpretation of such data can be relevant to make decisions about the management of the wetland.

Protocol:

A combination of the "round-count" and "point-count" methods (Koskimies & Väisänen, 1991) was used to estimate the number of breeding pairs for each breeding species present there.

This strategy has been chosen for several reasons, including:

- The peculiar configuration of the Linnunsuo wetland, with its three pools separated by embankments and its patchy vegetation, which prevented the possibility of having an unobstructed view on the entire wetland from a single observation point. For an area of this size, one or two points are usually considered in the point-count method, while seven were considered here.

- The large range of bird taxa targeted: the study aimed to have an overview of all the birds breeding in the area, including taxa with very different sizes and behaviors, such as passerines and gulls for instance. If the point-count method has been proven to be as effective as the more time-consuming round-count method to census waterfowl populations in wetlands with a low vegetation cover (Pöysä & Nummi, 1992), the detection of less noticeable species necessitated to include in this study some aspects of the round-count method.

Seven observation points were considered in this study, and the same route was taken during all field sessions, always in the same direction. The observers stayed between 10 and 20 minutes on every point, depending on the number of birds and on their activity, and noted all bird pairs seen or heard. During the walk between the points, the individuals that were hiding and flew away because they were disturbed were counted, and the territorial songs heard on the walking route were also taken into account. The observation spots were set up to cover the entire wetland and to prevent as much as possible double counts. The trajectory and the observation spots are presented in **Fig. 8**. This protocol has been used since 2013 by Harri Kontkanen, an ornithologist who has been monitoring bird populations in Linnunsuo since its creation and who supervised the bird censuses in this study.

The bird monitoring started later than the previous years, on the 1st of May. The spring arrived late during the year of this study, and the Linnunsuo waters were totally freed from ice only in the beginning of May, resulting in a delay in the arrival of migrating birds. On average, two field sessions per week were realized. They took place early in the morning, starting between 5:00 and 8:00 am.

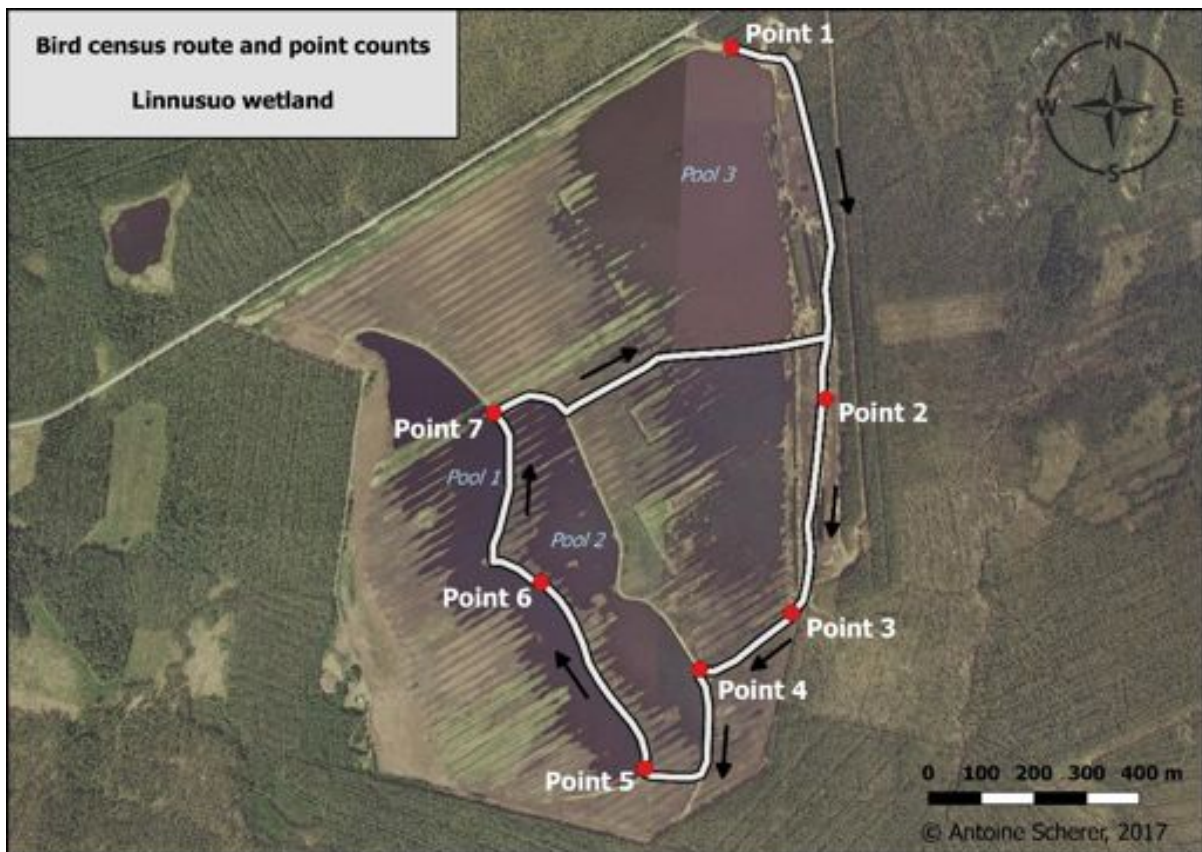


Fig. 8: Bird monitoring protocol: observation points and trajectory.

The first field visits were done to collect information about the arrival of migratory breeding species on the site. The goal was to determine, according to the bird observations and the climatic conditions, the time when the population census of breeding birds should be performed. Indeed, the census should coincide to the short period when the breeding individuals have settled on the area but the couples haven't split yet. Moreover, this time window must be identified so that non-breeding migrating birds do not bias the counts: there should be no transient flocks left, all the individuals of the considered species should be on the area to breed (Koskimies & Väisänen, 1991). These census periods are well described for the breeding birds of North Karelia, and an example can be seen in Table 1 (Kontkanen, 2009). Nevertheless, 2017 was a special year, with a very late and cold spring. It affected the bird migration, and these dates needed to be adjusted. The data collected during the entire study were compared to the data from other birdwatchers, and the number of pairs for 2017 was estimated *a posteriori*, for each breeding species, as the number of pairs present in Linnusuo during their specific adjusted census periods.

Table 1. Recommended periods for the census of bird breeding pairs in North Karelia (according to Kontkanen, 2009)

Species	Census period
<i>Podiceps cristatus</i>	15/05 - 25/05
<i>Podiceps griseigena</i>	20/05 – 31/05
<i>Podiceps auritus</i>	20/05 – 31/05
<i>Anas penelope</i>	18/05 – 02/06
<i>Anas crecca</i>	10/05 – 20/05
<i>Anas querquedula</i>	20/05 – 05/06
<i>Anas platyrhynchos</i>	25/04 – 10/05
<i>Anas clypeata</i>	15/05 – 31/05
<i>Anas acuta</i>	04/05 – 17/05
<i>Aythya ferina</i>	15/05 – 25/05
<i>Aythya fuligula</i>	25/05 – 05/06
<i>Bucephala clangula</i>	25/04 – 10/05
<i>Mergus albellus</i>	15/05 – 31/05
<i>Fulica atra</i>	15/05 – 31/05

- **Fish:**

Context and objectives

The Jukajoki used to be a clean and healthy river. According to the oral testimonies of local people, recorded by Snowchange, the fish harvests were very good until the 1950s. Large numbers of fish could then be sustainably taken from the river, and it was still common to harvest big individuals (such as 2-3 kg breams [*Abramis brama*]). Iconic species were still visiting the area, such as the Rainbow Trout (*Oncorhynchus mykiss*) and the Landlocked Atlantic Salmon (*Salmo salar sebago*), which were good indicators of the pristine state of the former river system. Nowadays, fishing is still an essential activity in the Jukajoki watershed for people from the villages of Selkie and Alavi (for recreational, cultural, subsistence-, and even small-scale professional purposes), but the situation is totally different. From the late 1940s, state-sponsored changes in land use in the watershed happened as part of the settlement programme established for Karelian refugees after Finland had to give territories to Russia in 1944. These practices had tremendous impacts on the ecological state of the river. Most of the surrounding mires were drained, economic forestry developed and ditches were dug and connected to the Jukajoki, and new farmlands were created by lowering the water level of the

adjacent lakes. These factors led to deep modifications of the physico-chemical profile of the river and of its water regime, causing a gradual deterioration of the fish populations, on both qualitative and quantitative levels: many species disappeared, and the population sizes started to decline (Mustonen, 2013). The implementation of the Kuurna hydroelectric power station in 1971 altered the water regime of the Jukajoki system even further, affecting the spawning of most of the species that were still present (Vesajoki & Pihlatie, 2011). The peat extraction in Linnunsuo gave the coup-de-grâce to the aquatic biocoenosis of the river, which was already much weakened, as illustrated by the two fish die-offs in 2010 and 2011 (Mustonen, 2014). Since the closure of the peat mining activity in Linnunsuo and the rewetting of the area, the situation is getting better in the river. The organic matter discharge has been stopped, as well as the input of toxic compounds. Other restoration actions in different places of the watershed had beneficial effects on the physico-chemical state of the river, but it will take time for the Jukajoki to overcome the remaining pollution and go back to a healthy ecosystem.

Freshwater fish are relatively easy to identify and they rely on many other aquatic organisms and environmental elements during their life to feed, shelter and spawn. They are sensitive to the physico-chemical parameters of their surrounding environment (with different ecological optimums and tolerance margins according to the species), and their mobility allow them to move, if they can, from pollutants and other stresses (EPA, n.d.). For these reasons, fish are used worldwide as environmental indicators. As many fish species are relatively long-lived, the mortality and the reproductive failure induced by environmental stresses can affect the structure of fish communities, making them long-term indicators of environmental degradation (Fausch *et al.*, 1990). They are also used as indicators of restoration success in freshwater systems (Growth, 2007; Hughes *et al.*, 2010).

In this context, the present study aims to assess the state of the fish assemblages for the Spring 2017, as an indicator of the general health of the Jukajoki river. The collected information, such as the presence/absence of indicator fish species or the population sizes, will be used to give insights about the restoration progress and the future management of the area, in a rewilding perspective. Collecting information about fish stocks is also a major concern because of their importance for local fishermen.

The fish populations have been monitored in the river delta since the inception of the Jukajoki Restoration Project, so this study follows the ongoing monitoring scheme. Two different protocols were used to monitor the fish populations in the Jukajoki river.

Protocols

Fyke trap:

The first fish trap was put on the 12/06/17. The principle of this “Fyke” trap (**Fig. 9**) is simple. The fish are led to the entrance of the cylindric section of the trap by the big rectangular nets (guiding nets). When they get there, their only option is to pass through a series of inner inverted funnels, which leads them to the tip of the main trap body. They can't escape from there, as the funnel apertures are too narrow for them to return in the opposite direction. The mesh sizes of the main trap body and the guiding nets are respectively 40-50 mm and 52 mm. The trap is tight to sticks anchored in the sediment, and is maintained in the water column by floating buoys.

This trap stayed for 3 weeks, and was visited regularly (for a total of 6 visits) to check if some fish were caught. On every session, the trapped fish were brought back to the shore, where the number of individuals of each species was recorded, and where their length and weight were measured.

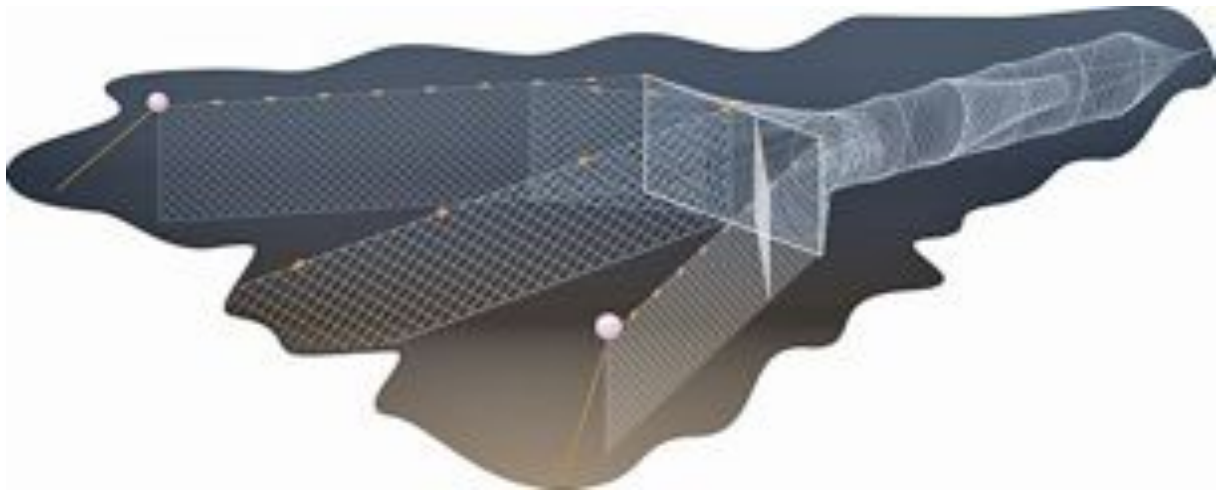


Fig. 9: Representation of a "Fyke" trap (www.kivikangas.fi).

This methodology has been used in the Jukajoki delta every year, in May-June, since 2012. It is not used in official monitoring programmes in Finland yet, but the fish monitoring in Jukajoki constitutes a good opportunity to test it and evaluate if it could be used in other projects of this kind as an official methodology. In this regard, the fish trap monitoring is

organised together with the Nordic Resource Management Project of NORDECO from Denmark. Even if it hasn't been done this year, the accumulation of organic matter on the net mesh is also usually noted in this protocol to assess the intensity of the organic loading from upstream visually.

The Fyke trap was put under the supervision of Tero Mustonen and checked with the help of Lauri Hämäläinen and Tommi Riikonen (Fig. 10, 11, 12 & 13).



Fig. 10: Tero is putting the Fyke trap.



Fig. 11: The Fyke trap is checked.



Fig. 12: The fish are brought to the shore.



Fig. 13: The fish are measured and weighted.

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Nordic net:

The second technique used in this study to monitor fish populations is the Nordic net. It consists of a 30 m x 1,5 m rectangular net made of 12 sections of different mesh sizes, as illustrated in **Fig. 14**. For each section, the mesh size is written below and expressed in millimetres.

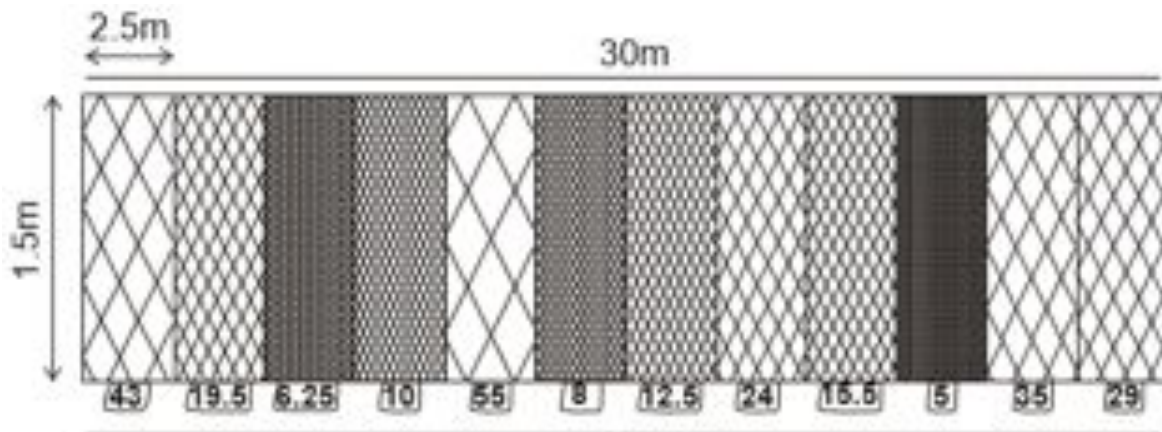


Fig. 14: Representation of the Nordic net used in this study (Olin *et al.*, 2014)

The net structure allows to target organisms of various sizes, in order to catch individuals from as many species and age classes as possible. This is recommended in many fish assemblages monitoring protocols, and is a *sine qua non* condition to collect representative data and perform a relevant bioassessment (Olin *et al.*, 2014). The fish caught in this net were gilled, which means that they were held by the mesh hooked behind the opercula.

Two nets were in the Jukajoki delta to optimize the catch, positioned approximately 100 metres from each other. They were placed in the area of the delta corresponding to the original river bed because it was the only place where the water level (3 to 4 m) was sufficient to put these nets vertically, the rest of the delta (which could be described as a floodplain) being particularly shallow (1 to 2 metres deep). The nets were tensed and anchored to the sediment with ropes attached to rocks, and maintained in the middle of the water column by floating buoys.

This net is used in several official fish monitoring programmes in Nordic countries. This protocol follows the instructions of the Nordic Resource Management Project (Olin *et al.*, 2014), to which fish data from the Jukajoki river have been sent in 2015 and 2016. This project is over, and the data are now sent to the Nordic Agency for Development and Ecology (NORDECO).

This protocol imposes to let the nets 14 to 16 hours in the water before taking them off. In this regard, they were put on the 27/06/17 at 7 pm, and taken off on the 28/06/17 at 9 am. The nets were then brought back to the shore and the fish from each mesh section were measured and weighted. Many environmental parameters were also recorded (water temperature, atmospheric conditions, ...), as recommended by the Nordic Resource Management protocol. An example of the data sheet used on the field for this study can be found in Appendix 1. Sixteen fish species, typical from boreal freshwater systems, are targeted in this protocol and are listed, in Finnish, in this Appendix (their translations can be found in the legend of the Appendix 1). Only one catch session was realized with this technique for this study, as the next ones will be realized in August 2017, after the end of this internship.

This net was put under the supervision of Tarmo Tossavainen, with the help of Lauri Hämäläinen and Tommi Riikonen (**Fig. 15 & 16**).



Fig. 15: Floating buoys marking the location of the Nordic nets.



Fig. 16: The net is carefully unfolded and the fish caught in each section are collected.

A map representing the locations of the Fyke trap and the Nordic nets in the Jukajoki delta can be found in **Fig. 17**.

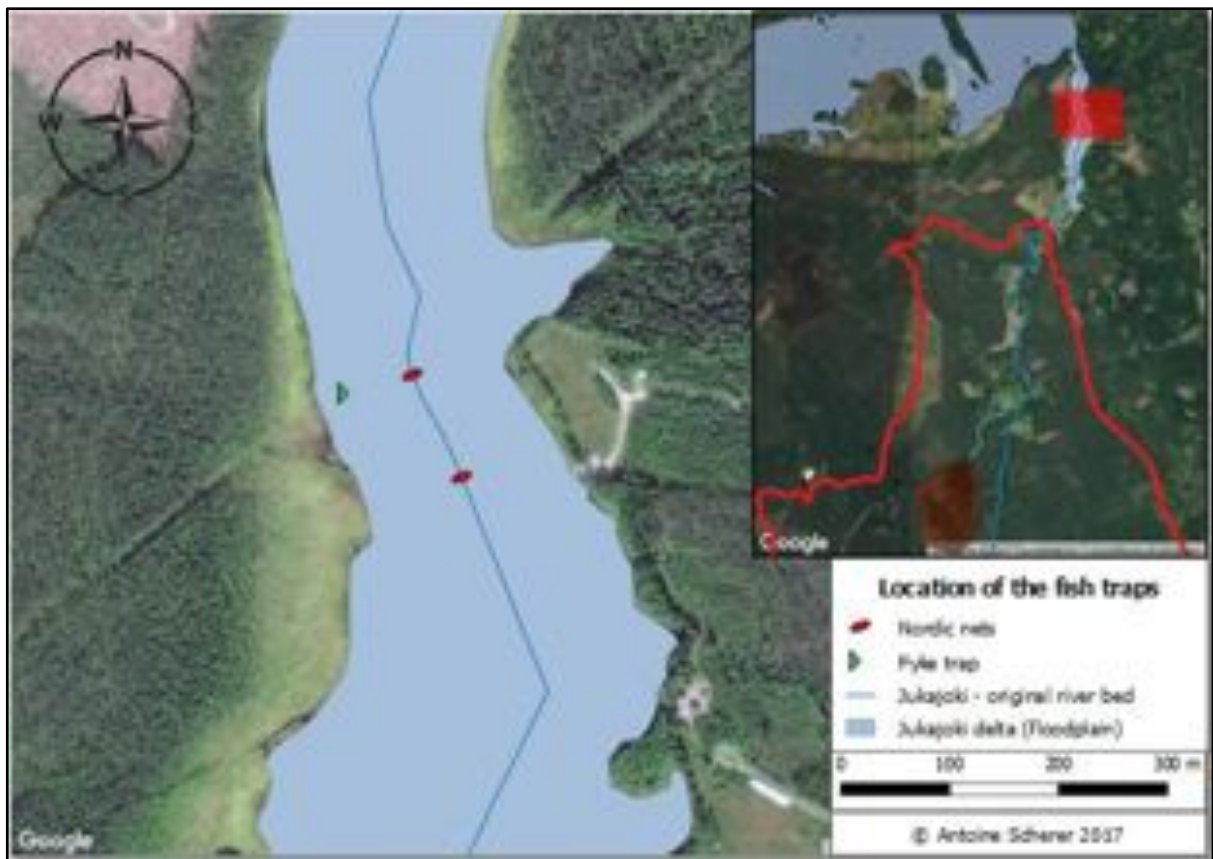


Fig. 17: Locations of the two fish monitoring protocols implemented in the Jukajoki delta.

4. Results

Abiotic characteristics

In wintertime, both the Linnunsuo wetland and the outflow had high iron and aluminium concentrations combined with a low pH (**Table. 2**). The dissolved oxygen in Linnunsuo didn't indicate any anoxia during the winter. For budget reasons, the outflow hasn't been tested for the oxygen-related parameters.

Table 2: Mean values of the different physio-chemical parameters measured in the Linnunsuo wetland (the three pools combined) and in the outflow for the winter.

	Linnunsuo	Outflow
[Fe]	3674 µg/l (± 755.73)	3700 µg/l (± 890.57)
[Al]	266 µg/l (± 120.36)	188 µg/l (± 36.30)
pH	3.96 (CV = 1.29%)	4.32 (CV = 1.31%)
[O ₂]	4.92 mg/l (± 2.84)	
O ₂ saturation	31% (± 23)	

At the scale of the pools, the first pool was significantly different from the other pools for two parameters. Its aluminium concentration was significantly higher than the others' (Kruskal Wallis, $p < 0.05$; $\mu = 610 \mu\text{g/l} \pm 153.84$). Also, the pH was significantly different between the first and the third pool only (Kruskal Wallis, $p < 0.05$), with the lowest pH found in the first pool ($\mu = 3.56$; CV = 0.52%).

In the Linnunsuo wetland, the conductivity was negatively correlated to the pH during the month of April (Appendix 2). The conductivity and pH mean values were, respectively, 148 µS/cm (± 29.3) and 4.23 (CV = 1.68%).

The iron concentration was significantly correlated to the residential time (Spearman, $p = 0.950$). The two parameters varied in the same way through time. For example, when the residential time increased, the iron concentration increased (**Fig. 18 A**). It is notable that in April, this relation changed. The residential time dropped to 46 days but the iron concentration barely changed (**Fig. 18 A**). The aluminium concentration was significantly correlated to the residential time (Spearman, $p = 0.410$), but its concentration decreased when the residential time increased (**Fig. 18 B**). This relation lasted until February, when the aluminium concentration increased despite a constant residential time. After this month, the two parameters decreased.

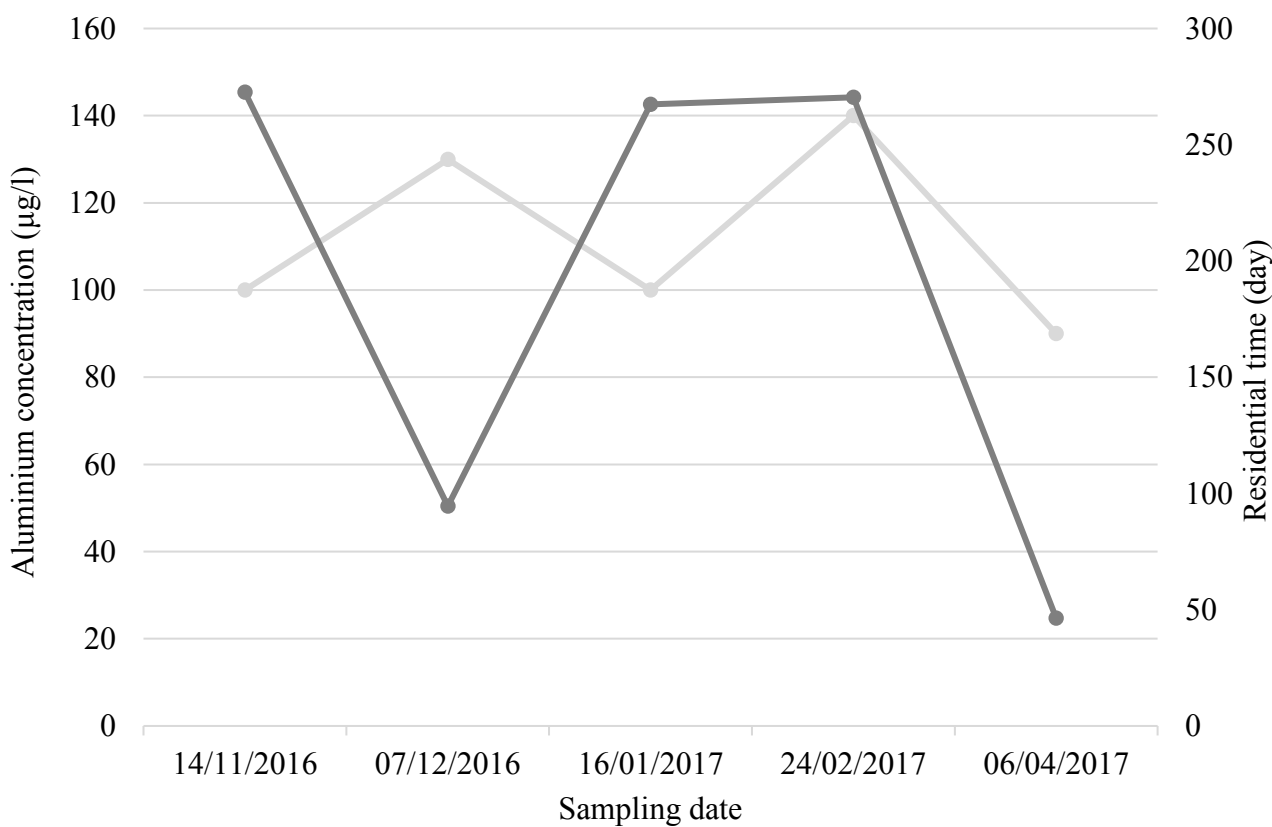
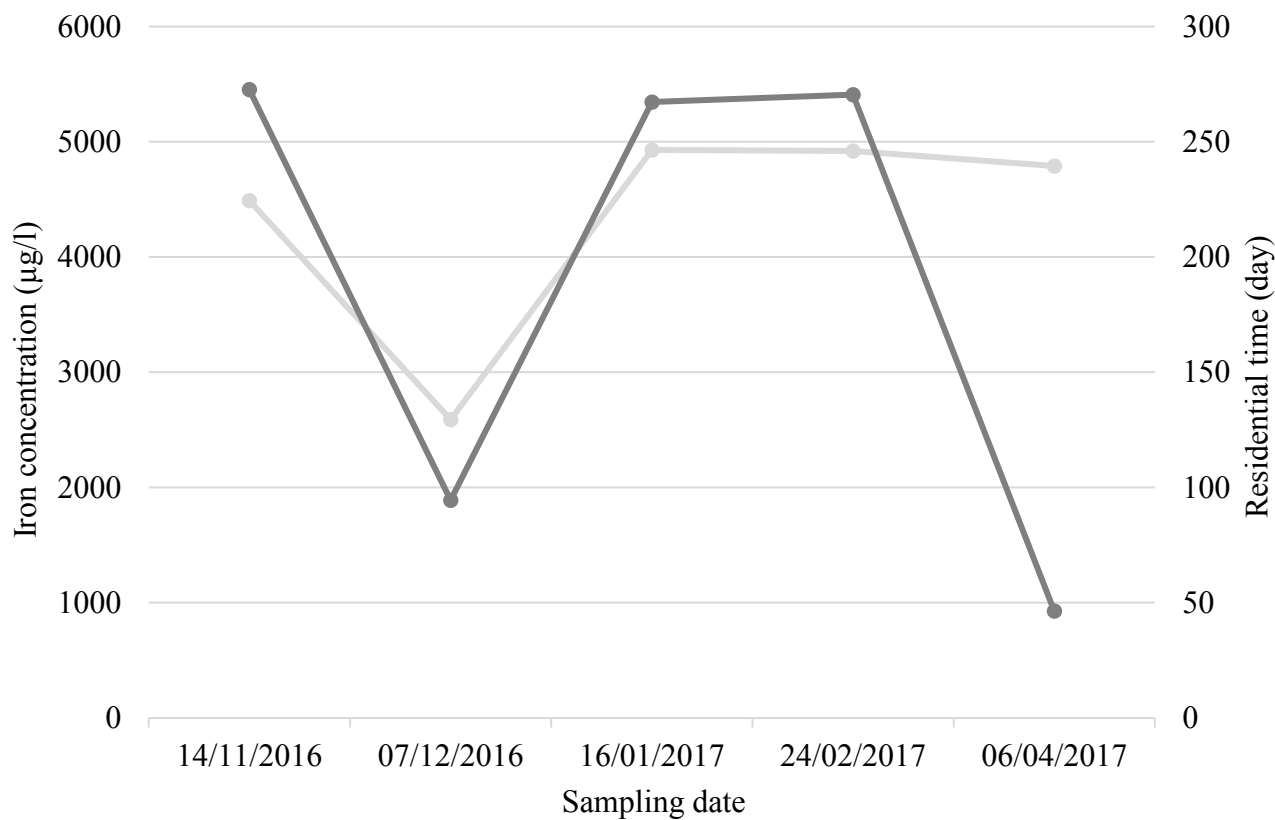


Fig. 18: Metal concentration ($\mu\text{g/l}$) variations (light grey) depending the residential time (day ; dark grey) in the third pool. The observed metals are iron (A) and aluminium (B).

In the Jukajoki river, the correlation between the same two parameters was positively correlated in April (Appendix 2). For the entire river, the conductivity and pH mean values were, respectively, 65 $\mu\text{S}/\text{cm}$ (± 2.4) and 5.43 $\mu\text{S}/\text{cm}$ ($\text{CV} = 0.04\%$). In springtime in the Jukajoki river, the iron concentration decreased between the two first sampling stations from 1777 $\mu\text{g}/\text{l}$ to 1593 $\mu\text{g}/\text{l}$. After the cross with the ditch coming from Linnunsuo, the concentration increased to 1740 $\mu\text{g}/\text{l}$ (**Fig. 19 A**). Globally, the iron concentration did not vary significantly along the river. The aluminium concentration increased linearly ($[\text{Al}] = 14.33 * (\text{sampling station}) + 58.33$; $R^2 = 0.79$) from upstream to downstream and ranged from 67 $\mu\text{g}/\text{l}$ to 133 $\mu\text{g}/\text{l}$, with the maximum values obtained in Ukonnurmi (**Fig. 19 B**). It is notable that between the two last stations, the concentration decreased. The pH values decreased linearly ($[\text{pH}] = -0.0764 (\text{sampling station}) + 5.635$; $R^2 = 0.83$) from 5.59 to 5.37 from upstream to downstream (**Fig. 19 C**).

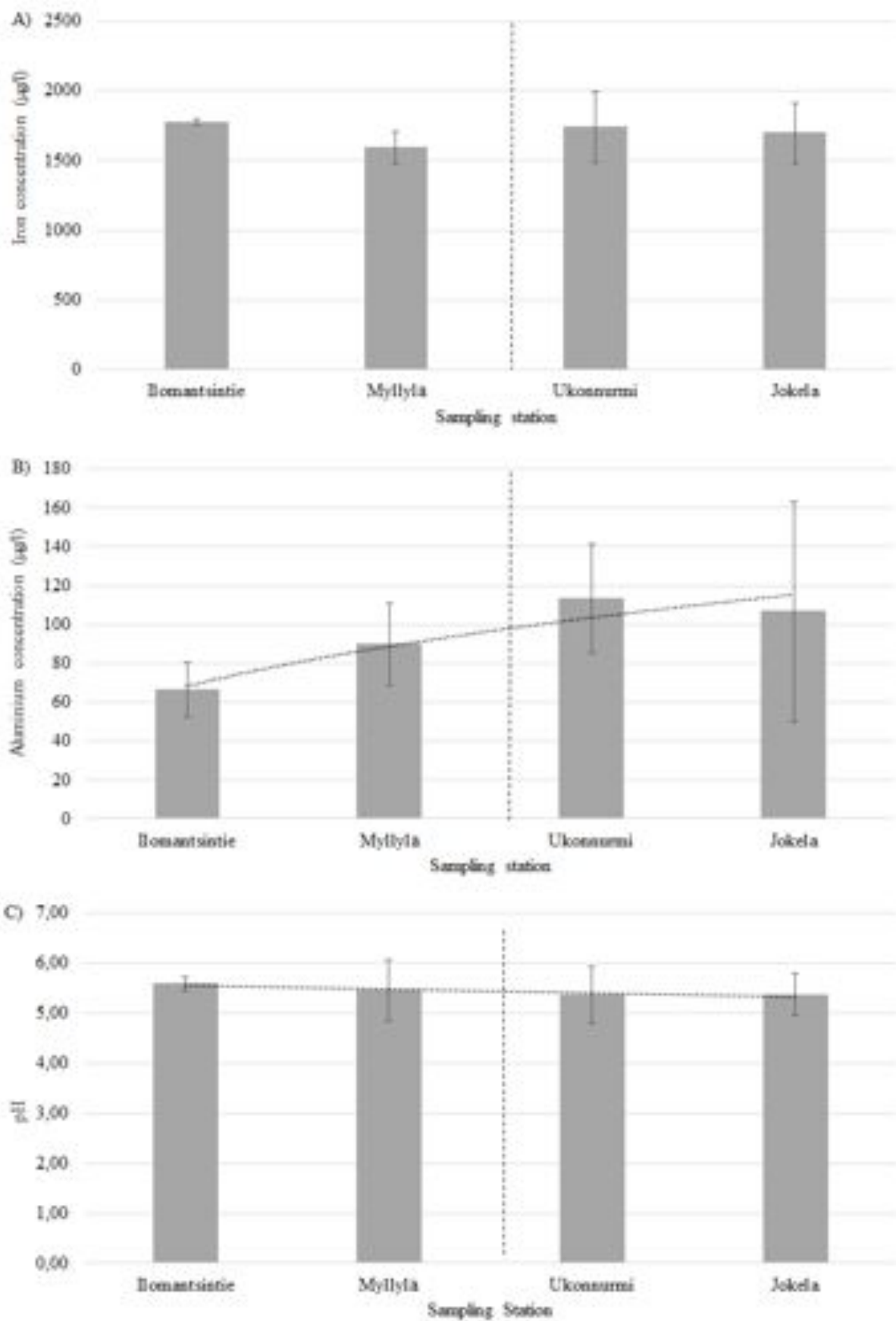


Fig. 19: Evolution of the weighted mean concentrations of iron (A), aluminium (B) and the pH (C) along the Jukajoki river, from upstream (Ilomantsintie) to downstream (Jokela). The dotted black line represents the crossing between the ditch from Linnunsuo and the river Jukajoki.

In April, the inflow had high metal concentrations, with 5280 µg/l of iron and 1040 µg/l of aluminium, and a low pH of 3.76.

The sediment samples taken on L1 and L7 revealed the presence of a thick layer (sometimes more than 40 cm) of black mud in the bottom of each pool. The sample from the sampling station L7 was mainly constituted of organic matter (OM = 77% total dry weight). The analysis realised on this sediment samples indicated the presence of aluminium and iron in the first ten centimetres of soil and in 20 - 33 cm sediment layer. The iron concentrations in the upper and deeper layers were, respectively, 4100 mg/kg and 6200 mg/kg. The aluminium concentration decreased with the depth of the sampled layer, reducing from 2.1 g/kg to 1.4 g/kg. The sample taken in L9 revealed the presence of a high concentration of mineral matter (OM = 2% total dry weight). The iron and aluminium concentrations were respectively 1000 mg/kg and 510 mg/kg.

Biotic characteristics

Benthic macrozoobenthos results

During wintertime, 4 taxa were recorded in the third pool: Chironomus sp., Chaoborus sp, Megaloptera and Corixa sp (**Fig. 20**). A low diversity was found and one taxa was dominating (**Table 3**). Indeed, among the total individuals collected, 97.2% belonged to Chironomidae. Each of the other present taxa represented less than 2% of the total individuals collected.

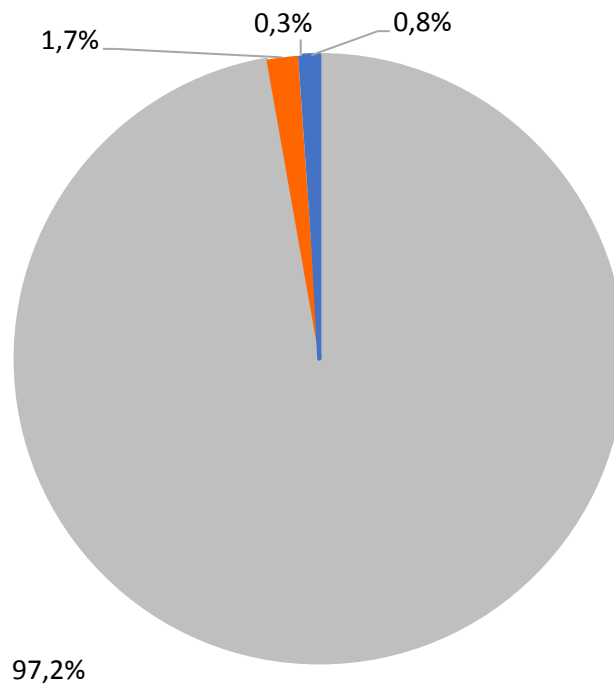


Fig. 20: Distribution of the percentage of the total individuals found in Linnunsuo depending on their taxa. Four taxa were found: Chironomidae (grey), Chaoborus sp (orange), Megaloptera (yellow), Corixa sp (blue).

In February, 10 taxa were recorded in the outflow: Chironomus sp, Chaoborus sp, Dicranota sp, Ephemeroptera, Plecoptera, Trichoptera, Oligochaete, Ceratopogonidae, Megaloptera and Asellus aquaticus (**Fig. 21**). The diversity was also low, with a moderate dominance of the Chironomidae (**Table 3**), which represented 56.7% of the total amount of collected individuals. The second dominant taxon was Plecoptera, with 28.6% of the total amount of collected individuals. All the other taxa represented 5% or less of the total amount.

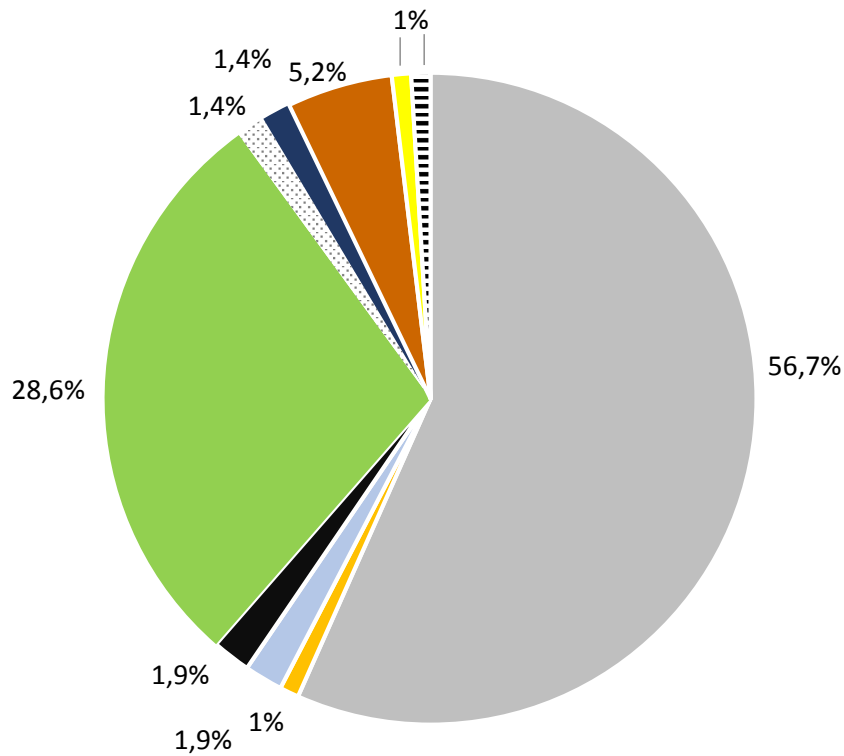


Fig. 21: Distribution of the percentage of the total individuals found in the outflow of Linnunsuo depending on their taxa. Ten taxa were found: Chironomidae (grey), Plecoptera (green), Ceratopogonidae (brown), Dicranota sp (light blue), Ephemeroptera (black), Trichoptera (black dotes), Oligochaeta (dark blue), Chaoburus sp (orange), Megaloptera (yellow), Asellus aquaticus (black lines).

In the third pool as in the outflow, Chironomus sp was the only taxon that was found in all samples and through the entire winter period.

Table 3: Diversity indices for the pool 3 (January and April) and for the outflow (February).

	Shannon (H')	Simpson (1-D)	Evenness (J')
Pool 3	0.2402	0.1073	0.4239
Outflow	1.24	0.5931	0.3454

Birds

The number of breeding pairs of each breeding species in Linnunsuo for 2017 can be found in Table 4, next to the data from previous years (Kontkanen, 2016).

One more species has been added to the list of breeding species in 2017: the Common Redshank (*Tringa totanus*), raising the number of breeding species recorded in the wetland since its creation in 2013 up to 29. Among them, 26 species have demonstrated breeding behaviours and formed pairs in 2017.

Table 4. Bird monitoring results - breeding pairs data

Species			Number of breeding pairs				
Scientific name	Finnish name	English name	2013	2014	2015	2016	2017
<i>Acrocephalus schoenobaenus</i>	Ruokokerttunen	Sedge Warbler	0	0	1	12	5
<i>Actitis hypoleucos</i>	Rantasipi	Common Sandpiper	2	2	2	1	1
<i>Alauda arvensis</i>	Kiuru	Eurasian Skylark	2	2	1	1	2
<i>Anas acuta</i>	Jouhisorsa	Northern Pintail	1	5	4	6	5
<i>Anas clypeata</i>	Lapasorsa	Northern Shoveler	0	3	2	3	3
<i>Anas crecca</i>	Tavi	Eurasian Teal	16	30	35	26	30
<i>Anas penelope</i>	Haapana	Eurasian Wigeon	7	4	7	6	7
<i>Anas platyrhynchos</i>	Sinisorsa	Mallard	4	5	10	5	10
<i>Anas querquedula</i>	Heinätavi	Garganey	1	1	1	1	1
<i>Anthus pratensis</i>	Niittykirvinen	Meadow Pipit	3	2	2	10	4
<i>Aythya fuligula</i>	Tukkasotka	Tufted Duck	3	4	10	10	5
<i>Bucephala clangula</i>	Telkkä	Common Goldeneye	8	12	25	20	29
<i>Charadrius dubius</i>	Pikkutylli	Little Ringed Plover	3	4	3	5	2
<i>Emberiza schoeniclus</i>	Pajusirkku	Common Reed Bunting	0	2	?	?	3
<i>Gallinago gallinago</i>	Taivaanvuohi	Common Snipe	2	2	3	2	3
<i>Hydrocoloeus minutus</i>	Pikkulokki	Little Gull	10	25	50	15	0
<i>Larus argentatus</i>	Harmaalokki	European Herring Gull	0	1	1	1	0
<i>Larus canus</i>	Kalalokki	Mew Gull	2	3	1	5	7
<i>Larus ridibundus</i>	Naurulokki	Black-headed Gull	35	10	350	400	70
<i>Motacilla alba</i>	Västäräkki	White Wagtail	?	?	?	?	3
<i>Motacilla flava</i>	Keltävästäräkki	Yellow Wagtail	1	3	1	2	2
<i>Porzana porzana</i>	Luhtahuitti	Spotted Crake	0	0	0	1	0
<i>Saxicola rubetra</i>	Pensastasku	Whinchat	0	2	1	1	3
<i>Sterna hirundo</i>	Kalatiira	Common Tern	2	3	1	2	1
<i>Tringa glareola</i>	Liro	Wood Sandpiper	2	2	3	2	2
<i>Tringa nebularia</i>	Valkoviklo	Common Greenshank	3	3	2	3	2
<i>Vanellus vanellus</i>	Töyhtöhyppä	Northern Lapwing	3	6	5	5	4
<i>Mergellus albellus</i>	Uivelo	Smew	0	0	0	0	1
<i>Tringa totanus</i>	Punajalkaviklo	Common Redshank	0	0	0	0	1

Between 2013 and 2016, the number of breeding species increased from 19 to 26 (Appendix 3). This year, 24 breeding species were recorded on the Linnunsuo wetland, but the breeding status was uncertain for 2 species (*Porzana porzana* and *Hydrocoloeus minutus*). Among these species, the Black-headed gull (*Chroicocephalus ridibundus*) was the most abundant with 70 breeding pairs, followed by the Eurasian Teal (*Anas crecca*) and the Common goldeneye (*Bucephala clangula*) with respectively 30 and 29 breeding pairs. All the other species had 10 or less breeding pairs. These 3 species were also the more present the previous years. The Little gull (*H. minutus*) is usually among the most abundant but, this year, the number of breeding pairs for this species couldn't be accurately estimated due to a late migration. For the first time, a couple of Smew (*Mergellus albellus*) and two couples of Yellow wagtail (*Motacilla flava*) were considered as breeding on the site.

According to the diversity indices, the diversity among the breeding species is mainly stable through the last four years. For the last two years, the Black-headed gull was the species with the more breeding pairs, with more than 300 couples. This year, it seems that the number of species was slightly lower than the last two years, but the number of breeding pairs seemed to be more equally distributed among species (**Table 5**).

Table 5: Diversity indices values for the breeding species in the Linnunsuo wetland from 2013 to 2017.

	Shannon (H')	Simpson (1-D)	Evenness (J')
2013	2.376	0.8501	0.5661
2014	2.622	0.8887	0.5983
2015	1.37	0.5296	0.1711
2016	1.284	0.4511	0.1505
2017	2.267	0.8202	0.4197

Among all the breeding species, 4 vulnerable species were recorded: Wigeon (*Anas penelope*), Common reed bunting (*Emberiza schoeniclus*), Black-headed gull (*C. ridibundus*), Common snipe (*Gallinago gallinago*). Also, 2 endangered species at the national level were recorded: the Northern pintail (*Anas acuta*) and the Tufted duck (*Aythya fuligula*). Among these species, 2 are vulnerable at the European level (*A. acuta* and *A. penelope*). Two species found

in the 1st Appendix of the European Directive on “Birds” (*H. minutus* and *Tringa glareola*) were also observed.

Since 2013, the same functional groups were found in Linnunsuo (**Fig. 22**). However, the number of breeding pairs decreased for the Gulls. Indeed, during the census period, a colony of black-headed gulls, which usually is the more abundant gull species, failed twice to settle in the wetland. Indeed, 70 couples were counted in the beginning of May, then a crash down to about 10 pairs was observed. Later in the month, the colony reached 14 pairs but decreased to 1 couple in the middle of June. Nevertheless, the number of 70 breeding pairs was retained as it matches with the usual breeding period for this species. The number of dabbling ducks, diving ducks and passerines tended to increase since 2013. For the waders, the number of individuals was stable ($\mu = 16.8 \pm 2.2$). The study couldn't assess the number of breeding individuals for the rails.

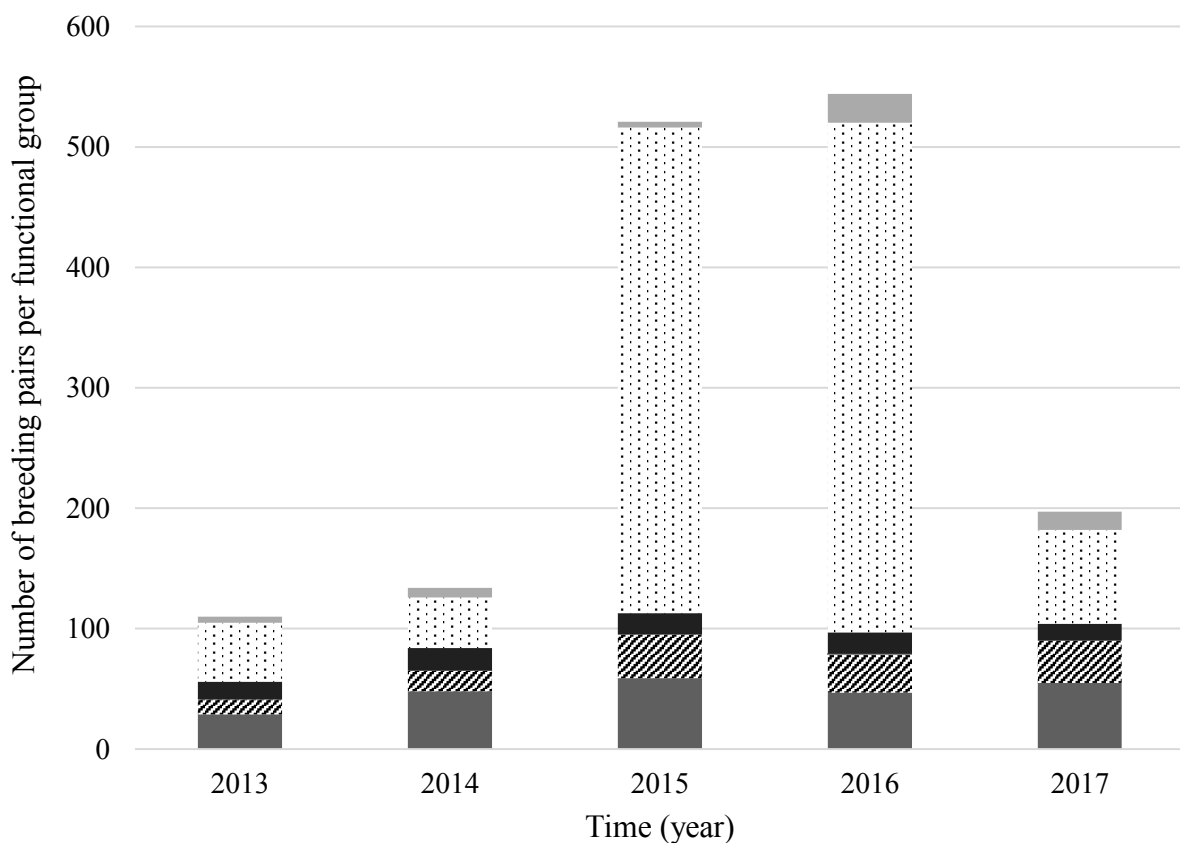


Fig. 22: Number of breeding pairs per functional group since the creation of the Linnunsuo wetland. Five functional groups are presented: dabbling ducks (dark grey), diving ducks (black stripes), gulls (black dots), passerines (light grey).

Concerning the reproductive success, a few notable results can be mentioned :

- No Black-headed Gull chick was born this year in Linnunsuo,
- 15 broods of Eurasian Teal were observed (for 30 couples),
- 1 brood of 2 Northern Pintail ducklings was recorded,
- 1 brood of 2 Tufted Duck ducklings was recorded,
- About 10 broods of Goldeneyes were counted,
- About 3 broods of Mallards were seen in the wetland,
- 1 brood of 2 Common Redshank chicks was observed.

N.B: The exceptional cold spring during the study delayed the birds breeding season, so the exact number of chicks and ducklings couldn't be determined in time before the end of this study for some species.

Fish

- **Fyke trap:**

On completion of the 6 sessions, a total of 55 individuals (all species) were found in the trap, which represents an average of 9,2 individuals per catch. A total of 33,56 kg of fish were caught, representing an average of 5,593 kg per catch. The fish had a mean length of 40,4 cm, and weighted in average 610 g. Two species were found during this fish monitoring campaign: among the 55 individuals, 50 were Common breams (*Abramis brama*) and 5 were Ides (*Leuciscus idus*). Common breams were found 10 times more often in the trap than Ides.

A total of 29,808 kg of Common breams was found in the trap, representing an average of 4,968 kg of this species per catch. The mean individual weight of Common breams was 599,145 g, and their mean individual length was 40,02 cm. Commons breams were found in every catch.

A total of 3,748 kg of Ides was found in the trap, representing an average of 0,625 kg per catch. The mean individual weight of Ides was 750 g, and their mean individual length was 39,9 cm. Ides were only found during the first and the fourth sessions.

More detailed information can be found in the following tables:

Table 6: Synthetic table for the 6 sessions, all species.

All fish						
Session	1 (15/06/17)	2 (19/06/17)	3 (22/06/17)	4 (27/06/17)	5 (30/06/17)	6 (03/07/17)
Number of individuals	16	6	6	11	9	7
Weight of the catch (kg)	10,379	2,918	3,905	5,553	5,687	5,114
Mean individual weight (g)	648,69	486,33	650,83	504,82	631,89	730,57
Mean individual length (cm)	40,31	35,17	42,33	37,27	41,67	43,5

Table 7: Synthetic table for the 6 sessions, Common bream (*Abramis brama*)

Common bream (<i>Abramis brama</i>)						
Session	1 (15/06/17)	2 (19/06/17)	3 (22/06/17)	4 (27/06/17)	5 (30/06/17)	6 (03/07/17)
Number of individuals	12	6	6	10	9	7
Weight of the catch (kg)	7,389	2,918	3,905	4,795	5,687	5,114
Mean individual weight (g)	615,75	486,33	650,83	479,5	631,89	730,57
Mean individual length (cm)	40,458	35,17	42,33	37	41,67	43,5

Table 8: Synthetic table for the 6 sessions, Ide (*Leuciscus idus*)

Ide (<i>Leuciscus idus</i>)						
Session	1 (15/06/17)	2 (19/06/17)	3 (22/06/17)	4 (27/06/17)	5 (30/06/17)	6 (03/07/17)
Number of individuals	4	0	0	1	0	0
Weight of the catch (kg)	2,99	0	0	0,758	0	0
Mean individual weight (g)	747,5	0	0	758	0	0
Mean individual length (cm)	39,875	0	0	40	0	0

The details of all individuals caught with the Fyke trap protocol (raw data) can be found in Appendix 4.

- **Nordic net:**

Only one of the two Nordic nets put in the Jukajoki Delta caught some fish. Five fish were found, from 2 different species: three Common Breams and two Common Roaches (*Rutilus rutilus*).

One Common Bream was found in the section of the net with a 29 mm mesh size, and all the other fish were found in the 15,5 mm section. The total weight of the catch was 305 g. The average fish was 61 g and measured 16,9 cm.

The average Common Bream caught with the Nordic net weighted 85,33 g and measured 18,83 cm.

The average Common Roach caught with the Nordic net weighted 24,5 g and measured 14 cm.

More details can be found in **Table 9**.

Table 9: Fish data collected with the Nordic net.

Nordic net - 27/06/17 (19h00) : 28/06/17 (09h00) - (+13°C, cloudy)				
	Individual	Mesh section of the net	Length (cm)	Weight (g)
1	Common Bream (<i>Abramis brama</i>)	15,5 mm	14	26
2	Common Bream (<i>Abramis brama</i>)	15,5 mm	15	28
3	Common Roach (<i>Rutilus rutilus</i>)	15,5 mm	15,5	30
4	Common Roach (<i>Rutilus rutilus</i>)	15,5 mm	12,5	19
5	Common Bream (<i>Abramis brama</i>)	29 mm	27,5	202

5. Discussion

Ecological statement

Abiotic characteristics

- **Observations:**

The Linnunsuo wetland, as the outflow, presented a highly acidic water with high metal concentrations. For example, the iron concentrations in the water of these areas were all at least 3 times higher than the concentration usually found in the streams and ponds of North Karelia (c.a. 1000 µg/l), and the concentration in the sediment in Linnunsuo was 66 times to 100 times higher than the standard concentration value (c. a. 62 mg/kg ; Pajunen, 2004). When the ice started to melt, iron precipitates could be seen with the naked eye on the ice (**Fig. 23**), which tends to confirm high concentrations of iron (Fe(OH)₃) in the water (Dodds & Whiles, 2010). Due to a pH lower than 4 in Linnunsuo, the aluminium might be present under its most toxic form: Al³⁺ (Brown & Sadler, 1989 ; Last *et al.*, 2002 ; Waters & Webster-Brown, 2013). Moreover, the pH and conductivity values, added to the relation found between these two parameters, suggest a strong presence of sulphate in the wetland (Grande *et al.*, 2010). These characteristics are typically found in water bodies affected by acid mine drainage (Joosten & Clarke, 2002 ; Holden *et al.*, 2004 ; Valente & Leal Gomes, 2009 ; Downing, 2014).



Fig. 23: Signs of the presence of metal pollution in the Linnunsuo wetland. On the left side, iron precipitates on the melting ice of the third pool (April 2017). On the right side, a ditch between the second and the third pool with the typical brown-orange colour of acid mining drainage ditches (May 2017).

As iron and aluminium are present in the upper layer of the sediment, this ecosystem compartment can represent a source of metal pollution during flood events, which erodes the sediment (Ciszewski & Grygar, 2016). This phenomenon could explain the results obtained for the month of April, when the iron concentration remained the same while the residential time decreased (**Fig. 18 A**).

The spring discharge is caused by the ice melting, which has also been associated to increases in metal concentrations in the water (Gaillardet *et al.*, 2005 ; Seto & Akagi, 2005). Warmer temperatures were recorded in the end of March – beginning of April, which tend to confirm this hypothesis (AccuWeather, 2017). During the previous months, the iron seemed to leave the pool with the water (c. a. when the residential time was low). When the residential time increased, it is likely that the iron concentration increased due to the moderate hypoxia conditions, which enhanced the release of iron (Moses & Herman, 1991 ; Kadlec & Wallace, 2008 ; Kauppila *et al.*, 2016 ; Saari *et al.*, 2017). The aluminium behaviour is mainly influenced by the pH and the Dissolved Organic Carbon (DOC) (Brown & Sadler, 1989 ; Cory *et al.*,

2006). Hence, with the diminution of the residential time, the DOC might have increased in result of the erosion of the sediment, enhancing the aluminium dissolution (Cory *et al.*, 2006).

The Jukajoki river had high metal concentrations, with an iron concentration above the one usually found in streams of North Karelia. Its pH exceeded the optimal pH value defined by the EPA (1986) to reach a good water quality ($6.5 < \text{pH} < 9$), but was higher than the ones in Linnunsuo and the outflow. The impact of the water quality on fishes will be evaluated in a further study that is going to be conducted this year on the fish populations of the river. According to the results in the Figure 6, an impact of the water from Linnunsuo seemed to be detected. As a matter of fact, there are only two ditches crossing the river between the two sampling stations Myllyla and Ukonnurmi. One comes from the east side of the river and carries water from the forest. According to analyses conducted this year, this ditch isn't a significant source of pollution for the river (Tossavainen, 2017). The second ditch comes from the west side of the river and is the outflow from the Linnunsuo wetland. Therefore, increases in metal concentrations observed between these two sampling stations are likely to be caused by the input of water from the outflow. Despite this impact, the results for the conductivity and the pH indicate a lower inorganic dissolved ions concentration than in Linnunsuo. These two parameters also suggest that the sulphates from Linnunsuo don't have a wide influence on the river and that there is a stronger presence of cations (Ca^{2+} , Na^+ , Mg^{2+} ...) in the Jukajoki river than in Linnunsuo. According to a study realised by two Finnish students on the river (Hämäläinen & Hiltunen, 2017), the impact that Linnunsuo used to have on the river when the exploitation was conducted is still visible. Indeed, a thick layer of undecomposed organic matter mainly dominated by Chironomidae is present on the river bottom and these sediment conditions are visible after the cross between the Jukajoki river and the outflow. Therefore, it seems that the river is still suffering from the impact of the past mining activity even if, nowadays, the influence of Linnunsuo seems to have decreased. Indeed, according to Tarmo Tossavainen, who has been conducting sampling campaigns on the catchment since 2013, the river water quality has been improving since the end of the peat exploitation. Studies are still actively conducted in the catchment to find and understand the different sources of pollution to the Jukajoki river.

- **Management implications:**

On the short-term perspective, some management measures are recommended to improve the water quality. One of them is to reduce as much as possible the pollution brought by the inflow into the first pool. According to the results, this inflow is mainly bringing significant amounts of iron and acidic water in the wetland. Redirecting this ditch into the forest water network wouldn't be a relevant solution, as its water would end up in the Jukajoki river without passing the buffer area constituted by the Linnunsuo wetland. In the aim of improving the water quality, limestone sand could be spread on the bottom of



Fig. 24: Areas where liming techniques have been implemented within the European continent (Henrikson & Brodin, 1995).

the inflow. Because of the narrowness and the shallowness of the inflow, the limestone should be applied as sand in order to have the best effectiveness as possible (Schmidt & Sharpe, 2002). This method is already used in various European countries (**Fig. 24**) to enhance the sedimentation of metals, decrease their toxicity and increase the pH (Hindar & Rosseland, 1988 ; Henrikson *et al.*, 1995).

The limestone erodes and releases dissolved calcium carbonate (CaCO_3) into the water, which reduces the solubility of metal and thus, increase their sedimentation (Olem, 1990). Calcium carbonate is also responsible for reducing the toxicity of metals and particularly of the aluminium (Henrikson *et al.*, 1995 ; Cravotta & Trahan, 1999). Before setting up this management measure, further studies should be conducted on the inflow to determine its hydrologic and physico-chemical characteristics. Indeed, the amount and the type of limestone that should be used and the location where the limestone will be put depend on these characteristics. According to Schmidt & Sharpe (2002), this method presents the advantage of being simple, quite inexpensive, and it doesn't require any important maintenance. On the other

hand, its success can't be guaranteed and its effectiveness might decrease with time. Furthermore, the problem with the sand liming is that it doesn't stop the organic matter from the forest to end up in the wetland. Indeed, the water of the inflow carries vegetal detritus from the forest and, as the shoreline is constituted of bare sediment, it can add organic matter. All the possibilities and decisions about the inflow have to be discussed with the owner of the land where the inflow passes by. Now that the inflow has been discovered and its impact have been assessed, its monitoring should be included in the evaluation of the wetland. Indeed, it has a great influence on the physiochemical parameters of the first pool. Therefore, it could influence the effectiveness of the sedimentation in this pool by favouring the acidity of the water.

In the beginning of the outflow, the presence of a muddy sediment with a high concentration of organic matter has been observed. This substrate represents a source of organic and metal pollutions for the water of the Jukajoki river. A dredging work could be conducted to clean the outflow from this mud. This way, the transfer of pollutants to the river could be slowed down. The access to this zone by caterpillar excavator is easy, as it is located very near to the main road and the pathway going to Linnunsuo.

The section requiring to be cleaned should be isolated from Linnunsuo and from the rest of the outflow, to avoid the spread of the mud and its pollutants into the downstream. First, the input of water coming from the wetland should be blocked, and then the side going to the river. Care should be given that the sediment stays wet enough, otherwise there will be a risk that oxidation reactions take place. If the sediment completely dries out, then the risk would be even greater, as the contaminated dust could be spread with the wind and pollute other surrounding places.

To this measure, limestone gravel could be added directly in a bulk in the outflow. The aims of this liming technique would be to improve the protection of the river from the Linnunsuo water and store the pollutants in the outflow. Indeed, not only it would have the same purpose than in the inflow (increase the pH and settle the metals in the bottom) but it would also allow the sedimentation of the organic matter and humic acids. The latter are known to act like chelators, which means they can prevent the precipitation of metals like iron by maintaining them in solution (Dodds & Whiles, 2010). The installation acts as an obstacle. It doesn't prevent the water from flowing, but it slows the flow down, which leads to the sedimentation of compounds in the bottom (Schmidt & Sharpe, 2002). The limestone should

be located far enough from the river to provide a buffer area where the metals could precipitate. If such an area isn't provided, the metals could settle in the Jukajoki river. Also, there would be a risk of creating a mixing zone between the limed water from the outflow and the more acidic water from the river. This mixing zone is the place of different reactions involving various species of aluminium, which create a toxic zone for fish (Rosseland *et al.*, 1992 ; Larsen & Hesthagen, 1995). Indeed, the aluminium forms in presence will obstruct the gills of the fish, which deprives them of oxygen (Baker & Schofield, 1982).

Another purpose of this management measure would be the creation of micro-habitats, by adding heterogeneity to the ecosystem. As a matter of fact, studies have proved that the benthic fauna diversity changes after the implementation of limestone. Indeed, Degerman *et al.* (1995) concluded that Chironomidae and *Chaoborus* will be disadvantaged, as they are acidophilic, while Trichoptera, *A. aquaticus*, Molluscs and Ephemeroptera will be advantaged after a liming operation. However, it is not possible to predict accurately the changes that will happen on the long-term to the benthic fauna, including the taxa mentioned above (Bradley & Ormerod, 2002). This liming method is not expensive and simple but some maintenance would be needed. Indeed, the interstice between gravels will tend to get clogged by the organic matter and the iron hydroxides (Schmidt & Sharpe, 2002). For this summer, management measures have already been adopted. Currently, the beginning of the outflow isn't effective anymore as metal concentrations as high as the ones in the wetland were found. The beginning of the outflow will be modified to implement a small pond. This installation should enhance the sedimentation by slowing down the flow. The aim will also be to set up a more natural-looking area and improve the heterogeneity in the outflow. Indeed, for the moment, this part is constituted of a metallic pipe and the remain of the obstacle from the old sedimentation installation implemented in the 1980's (**Fig. 25**).



Fig. 25: Beginning section of the outflow at the end of the Linnunsuo wetland. The two pictures on the top show the side where the water comes from Linnunsuo (visible on the right side picture). The one on the left shows the exit after the metallic pipe. The old sedimentation structure is visible after the ice on the second plan.

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Biotic characteristics

Benthic macrozoobenthos

- Observations:

In Linnunsuo as in the outflow, low species richness (as defined by Spellerberg & Fedor, 2003) and low diversity indices values were found concerning the benthic fauna. These results confirmed a poor ecological quality of the water in the wetland. However, the outflow seemed to have a better water quality where the benthic fauna samples were taken than where the water samples were taken. Indeed, Ephemeroptera, Plecoptera and Trichoptera, which represented 32% of the total number of individuals collected, are sensitive groups toward water pollution and it is very unlikely that they could have survived in a water like the one sampled in the beginning of the outflow (Abbasi, 2002). Two main reasons might explain this result: the presence of a rocky bottom in the outflow, which is known to shelter a higher diversity than muddy substrates (Hussain & Pandit, 2012) and the water input from a brook that joins the outflow between the two sampling stations. Indeed, according to recent analyses (Tossavainen, 2017), this brook brings in the outflow a water of higher quality than the one found in the outflow. In the two waters bodies, *Chironomus sp* widely dominated the benthic fauna diversity. The Chironomidae family is known to gather species that are very tolerant to acidity and metal pollution. For instance, studies have shown that *Chironomus plumosus* can survive in acidic waters of mine lakes with a pH down to 2,3 (Harp & Campbell, 1967). The survival of *C. riparius* in ponds with a pH of 2,8 has also been proven (Havas & Hutchinson, 1982). This family includes species that are very tolerant to hypoxic or even anoxic conditions (Cranston *et al.*, 1995). This benthic taxon is also used to qualify water quality as poor in different water quality indices (IBGN, BMWP ; Abbasi, 2002). In Linnunsuo, this pollution-tolerant taxon seems to be filling all the niches that are vacant due to the harsh physico-chemical conditions of the water. Despite the fact that the dominance of this group of opportunistic colonizers induces a very low taxonomic diversity of macrozoobenthos (**Table 2**), these organisms actually play a huge role in the wetland. Indeed, big densities of Chironomidae larvae can lead to changes in the physico-chemical conditions of eutrophic waters, by filtrating the water and mineralizing the organic matter deposited in the bottom, acting as primary consumers (McLachlan, 1977). They also play an important role in the bioturbation process, by building their tubes at the sediment-water interface, and by carrying significant amounts of compounds

such as ammonium, phosphates and oxygen from the sediment (Svensson, 1997 ; Fukuhara & Sakamoto 1987). Their most interesting role in the perspective of this study is the fact that they are one of the major supports for animal communities in freshwater systems (Coffman & Ferrington Jr., 1984). Indeed, they represent a major food source for many wetland birds, such as duck species (Gardarsson *et al.*, 2008 ; Eriksson, 1978 ; Maher & Carpenter 1984), waders (Székely & Bamberger, 1992 ; Goss-Custard *et al.*, 1977), gulls, terns and swallows (Tester, 1995). For dabbling ducks, the benthic fauna is more a complement of their diet but they also need it (Weller, 1999). Chironomidae organisms can be consumed at different stages of their life cycle by these bird groups. The large numbers of Chironomidae found in Linnunsuo have certainly been one of the main drivers for the comeback of such a great diversity of birds. In northern marshes, this food availability has been proven to be a factor influencing the habitat selection by wetland birds (Weller, 1999).

Birds monitoring

- Observations:

One of the most important observations that arises from the 2017 bird census is the crash of the Black-headed gull (*Larus ridibundus*) population in Linnunsuo. The number of breeding pairs for this species constantly increased from year to year since 2013, reaching a peak of 400 couples in 2016 (**Table 6**). Hundreds of individuals were spotted in early May during this study, but disappeared shortly after from the wetland. The Spring 2017 has been one of the coldest ever recorded in Finland (Yle, 2017). In early May, some areas of the wetland were still iced, and freezing temperatures were frequent. It is likely that the Black-headed gull colony considered the conditions as inadequate to start breeding there and flew to the West coast or to the South, where temperatures were milder. Some of them came back in the region and tried a second time to breed in Linnunsuo between the 11/05 and the 19/05. They settled in the wetland, so



Fig. 26: Wolverine tracks in Linnunsuo (May 2017 ; Antoine Scherer, 2017 ©).

the individuals observed during this period were considered as breeding there, and the pairs were counted as such (70 pairs). However, after the 19/05, only 10 couples were still in the area, and no Black-headed gull chick was seen in the wetland. This means that, among the 70 breeding pairs counted, it is highly probable none of them actually succeeded breeding this year. The weather was still colder than normal in late May and in June, and it could be one of the factors explaining why the breeding of this species failed. Cold waves are known to impact negatively Black-headed gull clutches (Indykiewicz, 2015), and it is possible that some individuals didn't even lay eggs in the wetland because the environmental signals were unfavourable.

Moreover, the predation pressure seems high in Linnunsuo. During the bird monitoring sessions, Red foxes (*Vulpes Vulpes*) were seen looking for bird nests and feeding on them several times. Fox tracks were spotted on almost every field visit, and Raccoon dog (*Nyctereutes procyonoides*) and Wolverine (*Gulo gulo*) tracks could be seen frequently (Fig. 26). The Raccoon dog and the American mink (*Neovison vison*), whose presence has also been proven in the area, are both invasive species in Finland that are considered as major threats for the nests of water birds (Väänänen *et al.*, 2007; Nordström *et al.*, 2002). One Eurasian otter (*Lutra lutra*) has also been seen foraging in the pool 3 of the wetland in July, and many birds of prey, such as the Marsh Harrier (*Circus aeruginosus*), were seen hunting in Linnunsuo during the bird monitorings.

Black-headed gulls usually nest in colonies, and are able to synchronize their breeding periods (Patterson, 1965). Individuals in these big groups can also display a large range of aggressive and fleeing behaviours. This whole strategy has been proven to be effective to protect their clutches and broods by keeping predators at bay (Kruuk, 1964). Even if other factors may have impacted the Black-headed gull population dynamics this spring, it seems that the harsh conditions of the cold spring have weakened the “colony”, making it more vulnerable to predation (the size of the group that stayed on the wetland was certainly too small to defend itself). *Larus ridibundus* is classified as “Vulnerable” in the 2015 Red List of Finnish Birds (Tiainen *et al.*, 2016), and is therefore protected in Finland. One of the main drivers for its decline being habitat loss, the protection of this species constitutes in itself a good argument to justify conservation actions in the Linnunsuo wetland. However, it is important to temper the results for this species: an irregular productivity is frequent with Black-headed gulls, and their long breeding lifespan allow individuals to have many broods in their lifetime. In this sense, bad breeding years like this one are not a threat to the populations, as long as they're occasional

(Flegg & Cox, 1975). What is more concerning with the absence of the Black-headed Gull colony is the influence this species can have on the reproductive success of other aquatic birds in the wetland. A recent study by Väänänen *et al.* (2016), conducted in Finland, showed that many duck species nest within or close to gull colonies (especially Black-headed gulls), where they can benefit from the gulls' protection against predators during the breeding season. *Larus ridibundus* is now considered as a keystone species* in ecosystems similar to the Linnunsuo wetland (Leito *et al.*, 2016).

The Tufted Duck (*Aythya fuligula*) and the Northern Pintail (*Anas acuta*) are both described as “Endangered” in the 2015 Red List of Finnish Birds (Tiainen *et al.*, 2016) and are therefore protected on a national scale. In the recent years, their populations have decreased in Finland, especially in eutrophic wetlands like Linnunsuo (Lehikoinen *et al.*, 2016; Pöysä *et al.*, 2013); in this sense, they both represent conservation targets in the wetland. These two duck species are known to benefit from the protection of gull colonies (Väänänen, 2000; Väänänen *et al.*, 2016). Only five couples of Tufted Ducks were present this year, while ten were recorded in 2015 and 2016 (Table 6). Only one couple succeeded breeding, and the brood was small (two ducklings). Usually, two Tufted Duck broods can be found in Linnunsuo every year (Kontkanen, 2016). The number of Northern Pintail pairs is quite stable, but only one brood of two ducklings was found this year, while three broods of four ducklings are usually seen in Linnunsuo in summertime (Kontkanen, 2016). Even if the cold weather may have directly impacted the breeding of these protected species and the survival of their ducklings, it is likely that the absence of the gull colony had an influence on their reproductive success. For instance, at least five Northern Pintail ducklings from the same brood were initially seen in the wetland, but only two seemed to have survived at the end of this study, the others having potentially been eaten by predators. Dabbling ducks are usually more vulnerable to foxes than diving ducks (Sargeant *et al.*, 1984) and Northern Pintails, in particular, suffer more from nest predation because they nest earlier than most other ducks (NWF, n. d.; Kontkanen, 2009).

The Little gull (*Hydrocoloeus minutus*), which is often found in heterospecific colonies with Black-headed gulls and Terns (Väänänen *et al.*, 2016) has also certainly suffered from the cold weather and / or the absence of the Black-headed gull colony: since the creation of the wetland, it is the first year this species doesn't breed there (Table 6). The Little gull has only a “LC” status in Finland, but it is included in the first annex of the European Bird Directive (BirdLife International, 2015) and is therefore a conservation priority on the European level.

It is interesting to note that the duck species that don't need the gulls' protection as much as those previously described managed to breed this year but also had a lower reproductive success than in previous years. The Goldeneye (*Bucephala clangula*), who nests in tree cavities in the surrounding forest, sheltered from land predators (Väänänen *et al.*, 2016), had about ten broods this year, for 29 couples. The brood sizes couldn't be accurately estimated before the end of this study, but they were clearly lower than usual (Kontkanen, 2016). In the same way, the Mallard (*Anas platyrhynchos*) and the Eurasian Teal (*Anas crecca*) also had fewer and smaller broods than usual (Kontkanen, 2016). Once again, it is impossible to conclude on which factor influenced the most the reproductive success of these ducks this year. Even if they don't need the gull's protection to nest, the absence of the colony may have impacted the mortality rate of their ducklings, who are exposed to predation when they come to the wetland to feed. Nevertheless, the management decisions should focus on the controllable factors incriminated in Linnunsuo, namely predation pressure.

- **Management implications:**

With the presence of protected bird species, a new responsibility arose in Linnunsuo. Such a spectacular wildlife comeback was not expected so quickly in the wetland, which was designed in the sole purpose of stopping the oxidation processes responsible for the pollution of the river. For this reason, clear management objectives in Linnunsuo still need to be determined. In the meantime, whatever these objectives turn out to be, conservation actions should be implemented as soon as possible to protect the endangered bird species of the wetland, their presence bringing ethical and legal considerations.

The results of this study clearly show the importance of *Larus ridibundus* as a keystone species in Linnunsuo, and we suggest the implementation of management actions taking this observation into account. Despite what the high avian species diversity suggests, the Linnunsuo ecosystem is still fragile and can be deeply impacted by harsh environmental conditions or by the disappearance of a single species. On the short term, a pertinent objective could lie in optimizing the Black-headed gulls' chances to form a successful breeding colony every year. By achieving this, the management actions could favour other nesting bird species both indirectly (by ensuring the natural protection of the gulls against predators during the breeding season) and directly (if they're conceived in a way that could benefit as many species as

possible). This kind of approach is consistent with rewilding, because it focuses on ecological interactions instead of considering species individually, and it aims to strengthen the ecosystem by making it more resilient. Rewilding focuses on natural processes and aims to intervene as little as possible in the considered areas, but active restoration or reintroduction measures are sometimes necessary (Allen *et al.*, 2017). Given the intensity of environmental destruction caused by human economic activities in Linnunsuo and in the rest of the Jukajoki basin, guiding the recovery of the ecosystems through measured actions seems necessary with this project, and could even be considered as a moral obligation.

One of the major issues nesting birds are facing in Linnunsuo is the lack of safe places to nest. The vegetation is getting denser every year and now provides good nesting habitats where birds can hide, but the nests are still easily reachable by predators. A few small islands and isolated reed spots allow some waterfowl nests to be out of range of land mammals, but it clearly doesn't represent an area large enough to have an impact on the population level. Considering this, an effective management action could be to build new islands in the wetland. By keeping most of the land carnivores at bay, this measure could benefit to many bird species in Linnunsuo. The density and the surface of the new islands should be thought to support the large numbers of birds nesting in Linnunsuo every year, and notably the Black-headed gull colony: for instance, several small islands are more valuable to a bird colony than a big one (RSPB, n.d.). In the best scenario, the islands could benefit to the protected waterfowl and wader species both directly, by offering them a safe nesting area, and indirectly, by allowing the sustainability of the Black-headed gull colony and hence an additional protection from predators. The reduction of the predation pressure on nesting birds in Linnunsuo could be particularly helpful for them during the years when harsh weather conditions alone are already jeopardising their reproductive success. The implementation of artificial islands in wetlands is known to provide effective feeding, resting and nesting places for many groups of aquatic birds, from waders to ducks (Burgess & Hirons, 1992; RSPB, n.d.).

Different materials can be used to build deposit islands, heaped peat being a common option. Bare peat is available in large quantities on the sides of the wetland, but its use should be subject to preliminary reflections because of the high concentrations of metals and acids it contains. Concrete frames filled with sand on their top are also used to build artificial islands. In a rewilding context, even if the overall area is man-made, the management measures implemented should aim to favour naturalness on both functional and aesthetical levels, if the

options allow it. An example of this aspect is the removal of the concrete pipe of the outflow ditch in Linnunsuo in August 2017 in order to reshape it in a more natural-looking way (Tero Mustonen, pers. comm., 2017). In addition to the artificial aspect, the permanent nature of the concrete frame option should also be considered, as the long-term objectives in Linnunsuo are not clearly defined yet.

A good intermediary option could lie in the use of limestone gravel to build the core of the islands. Besides being a cheap material, the implementation of limestone can improve the quality of acidic waters: by releasing dissolved calcium carbonates (CaCO_3) in the water, it can increase its pH and reduce the solubility of metals, facilitating their sedimentation (Olem, 1990). The use of limestone can lead to a reduction of the toxicity of metals, especially aluminium, and is a method commonly used in Nordic countries to restore water bodies (Henrikson *et al.*, 1995; Hindar & Rosseland, 1988). The Linnunsuo waters are still acidic and contain high iron and aluminium concentrations (Laventure, 2017), so this measure could be beneficial for both the biodiversity of the wetland and its physico-chemical state. However, in order to be effective, the limestone has to be in direct contact with the water, which raises questions about the stability of the gravel piles. Moreover, the special local chemical conditions induced by the nature of the substrate on limestone islands could be challenging regarding the revegetation of their surface. It could be necessary to put polythene bags held by rocks on the top of the islands to flatten them and maintain them, but other options should be considered, as the use synthetic materials should be a last resort. A top layer of substrate could then be put, the nature of which would depend on the vegetation expected on the islands.

An active revegetation involving the transplantation of herbaceous plants is recommended in order to quickly provide suitable nesting habitats for water birds. In a rewilding context, special consideration must be given to ensure that only native plant species are integrated in the revegetation scheme (Allen *et al.*, 2017). As many bird groups are targeted, the revegetation pattern should include islands with a dense and low vegetation (which could benefit to many duck species such as the protected Northern Pintail), as well as more sparsely vegetated islands, which could provide good habitats for Terns and waders (Svensson, 2009) such as the Common Redshank, a new species on the list of breeding birds in the wetland whose protection should be promoted due to its “Vulnerable” status on both national and european scales (Tiainen *et al.*, 2016; BirdLife International, 2015). Artificial islands require a regular maintenance: the development of the vegetation may necessitate occasional reshaping

operations, and eventual deep-rooted woody plants should be removed because they could damage the smallest islands.

Another possibility could be to isolate some areas by excavating the peat around them, creating ditches deep enough to be impassable for land predators and leaving remnant islands that could constitute safe feeding and nesting zones. Even if this option is one of the cheapest ones, it presents a major problem: the digging activities could disrupt the sediment and re-suspend particles. Also, the issue of the future of the extracted peat remains, as it can't be spread out anywhere because of its toxicity.

Floating artificial islands could represent an interesting alternative to deposit islands in Linnunsuo. A floating island consists in a revegetated floating platform made of substrate wrapped in geotextile and covered with a biofilm, anchored to the sediment with heavy rocks tight to strings. This technique has been widely used in Asia to restore polluted water bodies, and the scientific literature now underlines its efficiency to provide safe habitats for many organisms (invertebrates amphibians, birds), to protect the shoreline from erosion and to improve water quality (Nakamura & Mueller, 2008). Indeed, the plants selected to revegetate floating islands can mitigate the effects of eutrophication by taking up dissolved nutrients. Their dense floating root system shelters the microorganisms of the biofilm (algae, bacteria and fungi), which also contribute to absorbing nutrients. The mycorrhizae living in symbiosis with the plants can even sequester heavy metals and bind them to their cells (Hwang & LePage, 2011).

In Linnunsuo, this method could therefore have a twofold benefit by offering good resting, feeding and nesting habitats to waterfowl species and by reducing the effects of the excessive organic matter loading and of the high metal concentrations, these problems being otherwise difficult to deal with.

Compared to the previous ones, this option has the advantage of being non-permanent: the islands can be moved or even removed if new management decisions require it, which is appreciable given that long-term objectives in Linnunsuo are not defined yet. Moreover, this technique allows a total control on the vegetation pattern of the islands, and their maintenance is easy. On an aesthetical level, these islands can now mimic natural ones perfectly, making them valuable landscape features.

The problem with this method is its cost: the prices vary according to the companies, but a 27 m² island will in average cost about 10 000 euros (Eigmina-Chemali, 2013). Moreover, in order to be effective on the scale of Linnunsuo (on both biodiversity and phytoremediation aspects), large surfaces of such floating islands should be implemented, which could represent considerable expenses. However, this option should be considered, as this kind of islands can be hand-made and partnerships could be found to help funding this project, as illustrated by a recent initiative to save the Common Scoter (*Melanitta nigra*) in the UK (RSPB, 2017). Besides constituting new nesting areas, the revegetation associated with all these measures could enhance the food availability for the primarily herbivorous duck species of the wetland (such as the Northern Pintail), which could even attract new species in the area.

In addition to or instead of the implementation of islands, another management possibility lies in an active regulation of the land predator populations. This proposition brings ethical considerations and should therefore be supported by evidence showing that the predation pressure is too high and that such a measure is necessary to the health of the ecosystem.

All land predators are not concerned. The situation of the American Mink and the Raccoon Dog, two non-native introduced species in Finland, could raise delicate questions. Indeed, if the rewilding process emphasizes the importance of native predators in rewilded areas, it also gives priority to the proper functioning of ecosystem interactions. In this regard, theoretically, what should be done in a rewilding perspective if non-native species now fill ecological niches left vacant in a damaged ecosystem ? Should the stability of the food web prevail over the native status of the considered species ? These problematics should be considered before implementing any culling operations in the young and still fragile ecosystem Linnunsuo is. In our case, the American mink and the Raccoon dog are both considered as major threats for Finnish biodiversity because they impact disproportionately water bird and amphibian populations and compete with native small carnivores such as the European mink (*Mustela lutreola*). They are both targeted by Finland's National Strategy on Invasive Alien Species and their culling is highly recommended by the government (MMM, 2012). Many studies in Finland showed that this measure has beneficial effects on the local biodiversity and on the ecosystem structure (Väänänen *et al.*, 2007; Nordström *et al.*, 2002). In this regard, a dialog should be initiated with the local hunters (who are part of the co-management council) to start a regular culling campaign targeting these two mammals. The trapping methodology used should be thought not to be harmful to other animals. A human regulation of the Red fox populations has

also been mentioned by local birdwatchers as a mean to reduce the predation pressure in Linnunsuo. However, as the Red fox is a native species and has an essential mesopredator role in the food web in Finland, this option should be carefully weighted (Trewby *et al.*, 2008). A regulation of Fox populations is sometimes necessary, especially when the top-down natural regulation is disrupted because of a decline of top predator populations (Elmhagen *et al.*, 2010), but the effectiveness of this measure has also been questioned in recent years (Baker & Harris, 2006). Nevertheless, a culling campaign targeting the Red Fox in Linnunsuo and its surroundings should rely on solid data and should be considered only if the measures mentioned earlier (implementation of islands and culling of the small invasive predators) are not enough to protect water bird populations.



Fig. 27: Birdwatchers on the Linnunsuo wetland (June 2017, Marion Laventure 2017 ©)

Fish – Jukajoki Delta :

Both fish monitoring protocols revealed a very low fish diversity in the Jukajoki delta. Only three species were found during the entire study: the Common Bream, the Ide and the Common

Roach, the Common Bream dominating largely the catches. All these species are native to Finland and are part of the Cyprinidae family, a taxa known to include many species with a wide environmental tolerance. The density of Cyprinidae group individuals and the number of tolerant* species are two factors commonly used in fish-based biological indices in boreal watercourses, where they contribute to indicating a poor ecological status of the water. Among the three fish species found in the Jukajoki, *Abramis brama* and *Rutilus rutilus* are considered as tolerant (Vehanen *et al.*, 2010). The presence or absence of species intolerant to habitat perturbations, in the same way, can be very informative (Karr, 1981).

Increases of the proportion of tolerant species in river systems are usually highly correlated with the intensity of human-induced environmental changes (Morgan & Cuschman, 2005; Stainbrook *et al.*, 2006). In disturbed streams, the relative abundance of trophic and habitat generalists (such as the Common Bream) usually increases (Scott & Hall, 1997). This was shown by Vehanen *et al.* (2010) in Finnish rivers, where the proportion of the Cyprinidae family increased with the level of disturbance, as the proportion of sensitive species decreased. An increase of the proportion of Cyprinids is particularly associated with increasing eutrophication (Persson *et al.*, 1991).

These observations are consistent with the physico-chemical and benthic fauna studies conducted in the Jukajoki river in 2017. The exploitation of the Linnunsuo wetland, among other factors, led to an acidification of the river and a pollution by metals, as well as a large discharge of organic matter. As a result, the bottom of the downstream section of the river is in some places covered with a thick layer of undecomposed organic matter mud, and the benthic fauna is largely dominated by the Chironomidae family (Hämäläinen & Hiltunen, 2017), which constitutes a major food source for the Common Bream (Kakareko, 2002).

No indicator fish species was seen this year, contrary to previous years (Tero Mustonen, pers. comm., 2017). In 2013 and 2014, Zanders (*Sander lucioperca*) were occasionally caught in the trap. Eggs and larvae of this species are sensitive to low dissolved oxygen concentrations, and can therefore die if they are put in contact with a muddy substrate (Poulet, 2004). The Rainbow trout (*Oncorhynchus mykiss*) was caught for the first time since the beginning of the fish monitoring in 2015. Even if it's not native in Finland, this species is a very important indicator species because it does not tolerate acidity at all and also has strict spawning requirements (Hunter, 1991). The abundance of salmonids such as the Rainbow trout is a factor contributing to revealing waters with a good ecological status in fish-based indices in boreal ecosystems (Vehanen *et al.*, 2010).

On a quantitative aspect, the size of the catches in this study were small compared to previous years. Since 2012, the fish catches from the Fyke trap weighted in average 10-20 kg, but less than 6 kg of fish were caught in average per catch this year. The mean individual size of the fish caught during this study is also lower than the trend since 2012 (Tero Mustonen, pers. comm., 2017).

All these results could significantly suggest a poor ecological condition in the river, but they need to be tempered given the special environmental conditions that occurred during the study. The very cold spring is likely to have disturbed the spawning of many species and therefore affected their population sizes by inducing small spawning sizes and/or causing a high mortality in early life stages (Kamler, 1992). In 2016, the conditions were also extreme : very high temperatures in early May triggered the spawning of the Common Bream too early, which affected its population size (Tero Mustonen, pers. comm., 2017).

If it can't prove in which proportion the weather conditions and the remaining pollution of the river (besides many other potential factors that could have affected them) acted on the fish abundance, diversity and size, this study underlines how the notion of ecological resilience* is important in damaged ecosystems.

The ecological disaster that occurred in the Jukajoki clearly affected the resilience capacity of its ecosystems, making them more vulnerable to stochastic environmental events, as illustrated by the low fish diversity, abundance and sizes in 2017. As fish play a central role in the function of their ecosystems, fluctuations in fish communities can impact many other organisms and affect the ecosystem services they provide (Dudgeon *et al.*, 2006; Holmlund & Hammer, 1999). Specialist species such as the predatory Northern Pike (*Esox Lucius*), who is present in good quality streams with suitable spawning areas in North Karelia and have significant impacts on the fish community composition (He & Kitchell, 1990), were absent of the fish monitoring of this study, while only a few generalist species such as the Common Bream were present. This highlights how the industrial practices in the watershed have led to less diverse fish communities, hence affecting the ecological resilience, which is positively correlated to an ecosystem's species richness (Downing & Leibold, 2010).

Among the actions that could be planned in a rewilding perspective, the reintroduction of fish species could allow the comeback of diverse and functional communities, which could then strengthen the overall ecosystem. However, such a measure can't be applied for now, considering the amount of environmental and anthropic pressures that still exist in the area.

First of all, the physico-chemical parameters of the Jukajoki waters are still not good enough most of the year to allow some key fish species to durably thrive in the delta (Hämäläinen & Hiltunen, 2017). The restoration actions undertaken in the watershed (such as the creation of the Linnunsuo wetland, the implementation of limestone and the creation of sedimentation areas) are starting to show encouraging results on the pH and the metal concentrations in the delta. The organic matter discharge and the leakage of polluted water from Linnunsuo were significantly reduced with the shutdown of the peat extraction in Linnunsuo and the rewetting of the area (Tero Mustonen, pers. comm., 2017), but it will take time for the river to regain a functional absorption capacity* and be able to assimilate and settle the pollutants through natural biogeochemical processes, thus allowing a potential comeback of intolerant fish species. Moreover, the thick layer of undecomposed organic matter accumulated on the bottom of the river and the low aquatic vegetation cover make the largest part of the delta unsuitable for the spawning of most of the fish species that used to lay there when the sediment was composed of sand, gravel and rocks (Rosenau & Angelo, 2000; Birtwell, 1999). However, it seems that not much can be done about this in terms of management: the only effective solution to evacuate the mud, on the short term, would be to dredge the area with adapted machines. The costs of such a vast operation would be very high, and the issue of the future of the huge amounts of excavated mud would appear because of its toxicity.

Above this and despite all the potential improvements that could appear in the river, the hydraulic installations located downstream from the Jukajoki (Kuurna power station) would still constitute obstacles to the movement of the fish, including iconic species such as the Landlocked Atlantic Salmon (*Salmo salar sebago*), whose migration is compromised by the dam (Vesajoki & Pihlatie, 2011; Mustonen, 2013).

The wildlife comeback in Linnunsuo happened so quickly after the rewetting of the area that no long-term management objectives have been defined yet. As mentioned above, the presence of protected species brings conservation responsibilities that need to be considered when thinking of the future of the wetland. Given the site's attractiveness for birdwatchers, a view was expressed in favour of the development of a birdwatching activity in Linnunsuo. Rewilding aims to develop viable economic activities supporting nature in rewilded areas, in a way that benefits to local people. In this sense, such an initiative in the wetland could be a good opportunity to emphasize the governance of the local co-management actors in a way that could sustain the future management of the area. Some practical examples of successful transformations of cutaway peatlands into wetlands dedicated to bird conservation and

birdwatching appeared in the recent years. In Ireland, one of the main peat energy companies, Bord Na Móna, is changing its business model from peat extraction to the creation of wetlands on their cutaway peatlands (Bord Na Móna, 2016), creating recreational areas of high conservation and patrimonial values, such as the Lough Boora wetland.

Developing a birdwatching activity in Linnunsuo implies to invest in some installations and in active management measures, which would come in addition to the ones mentioned earlier to protect water birds. The implementation of floating islands could be particularly adapted to this scenario: they could be put in the pool 3, which is the biggest and the closest to the parking place. Given that there is an unobstructed view on this pool from the North side path, the floating islands could be disposed in such a way that many bird species could be seen from the path, decreasing the risk of disturbance from birdwatchers.

A birdwatching tower would be an essential asset, but the implementation of such an installation represents a high cost, estimated at about 50 000 €. Moreover, in this land use scenario, an active management would be required to keep the wetland suitable for birdwatching. Among other measures, the vegetation colonizing the embankments should be controlled to keep open paths, trees should be cut to keep an unobstructed view on the pools and prevent the shoreline to erode, and some dead vegetal material should be removed periodically to prevent the pools from filling. To make birdwatching a viable activity in Linnunsuo, these imperatives would represent expenses that should be compensated by incomes. A whole strategy should be developed, but it seems unlikely, as of now, that such an economic model could be built in Linnunsuo.

Long term perspectives

On the long-term perspective, the management plan can take two main directions that rely on the vegetal succession. Indeed, the co-management actors will have to decide if the implemented management measures should guide this ecological process or if they should oppose it. Here, we will explore the different scenarios, the way to reach them, and their consequences.

Rewilding

This scenario would take place in a rewilding philosophy. The idea is to help the recovery of the vegetal succession and accompany it if needed. Even if the goal is to avoid human intervention as much as possible, management measures can be considered to improve the physico-chemical conditions of the area in the present case. This approach lies on the principles of naturalness and ecological functionality. In that way, the aim isn't necessarily to go back to the initial state of the area, but to reach the climax ecosystem that is attainable under the current environmental conditions. This process corresponds to the hysteresis effect which occurs when the ecosystem shift from a climax state to another because of major perturbations (Gillingham & Johnson, 2016). In the present study case, because the topography has been modified during the rewetting process, the hydrological conditions have changed too and thus, it is more likely that the new settling vegetation will be different than the initial one if no management measures are implemented (Vasander *et al.*, 2003). Regarding on the surrounding environment and the vegetation that is already found in Linnunsuo, it is very likely that the vegetal succession will lead to a swamp forest.

On a philosophical perspective, this scenario is in accord with the values carried by the Rewilding Europe organisation. It could also allow the return of traditional activities like hunting, berry picking, hiking. However, the bird communities would change and their diversity might decrease. Nevertheless, a forest formed with a rewilding strategy would be more diverse than the usual managed forests in Finland. Indeed, the Finnish forests are drained and most of the time contain just a few tree species, with the combination *Betula pubescens* - *Pinus sylvestris* - *Picea apies* being the most common. Some forests are even monospecific (only birch trees or conifers). In the future Linnunsuo forest, as no selection would be done towards the growing trees and the dead trees could stay on the forest floor, the biodiversity would be higher than in the current forest. Indeed, for example, dead trees shelter saproxylic species, which are among the most threatened species in Europe, high diversity of fungi and also add organic matter to the soil which might enhanced the diversity of soil organisms (Ódor *et al.*, 2006 ; Stokland *et al.*, 2012).

A wetland in Linnunsuo

According to the Millennium Ecosystem Assessment (2015), wetlands are disappearing due to anthropic pressures and already more than 50% of them around the world have been converted for human activities. However, this ecosystem provides many essential ecosystemic services such as water supply, water purification, climate regulation, recreational activities, and they also are key habitat for various type of organism. Thus, another future for Linnunsuo would be to keep it as a wetland. This project would require the determination of accurate objectives and active management measures. One possibility would be to maintain it as a wetland suitable for birds. A study conducted by Lehtikoinen *et al.* (2017), highlights the fact that the restoration and maintain of wetlands in Finland have a significant positive impact on bird populations, including red-listed species and species with special conservation concerns according to the EU. In the present case, the management strategy would require controlling the vegetal succession by, among other measures, cutting trees and shrubs, limiting the spread of the common reeds, surveying the sedimentation process to avoid a complete siltation. In that aim, annual cuttings and grubbing-up should be set up. These measures could help maintaining a heterogenous vegetation and avoid the spread of the ligneous, which aren't used nor suitable for the bird species currently found in Linnunsuo. Management measures could also be implemented to enhance the nesting process of birds. For example, hunting scenes by a Red fox were observed within the gull colony during the field sessions. In response to this pression, small islands could be built on the third pool to create new nesting places and increase the protection of the clutch form predators (birds of prey, foxes and wolverines). This implementation could be done under the form of floating island. In regard to the present results, moving the wetland's sediment in order to create island might not be the wiser idea as it could re-suspend toxic elements. A floating island is composed of a platform lashed to the soil to immobilize it. The platform is made of substrate wrapped in geotextile and covered with a biofilm. This type of structure is already used in different country such as Japan, England or Germany (Nakamura & Mueller, 2012). The third pool is the deepest and the biggest and thus, the more adapted for this implementation. This kind of island could be suitable for the Black-headed gulls and thus could favour the breeding of the species benefiting from its presence. As a matter of fact, the "Endangered" and "Vulnerable" species recorded during this study are part of them. Therefore, this measure would also help various species and functional groups, such as dabbling ducks who would gain new foraging areas.

This scenario of maintaining the area would be conformed with the European Directives on “Birds” (79/409/EEC), which prescribes the protection and the maintenance of wild bird populations and of their habitats. Indeed, as Linnunsuo shelters breeding species that belong to the 1st Appendix of this European Directive, such as *Sterna hirundo*, *Tringa glareola*, *Hydrocoloeus minutus* among others, it is recommended to maintain the area as it is now. The Linnunsuo wetland is also an important area for migrating birds, which use it to rest and feed before going to the North to breed. Through the years, *Podiceps sp*, *Mergus sp*, *Calidris sp* and *Tringla sp*, among others, were seen exploiting the area during their migration. This scenario is less in accord with the rewilding philosophy, as an active management would be involved.

However, one can reflect upon the consistency of such a land use with the theoretical foundations of rewilding. Rewilding can be defined as a process aiming to restore dynamic and self-sustaining ecosystems (Allen *et al.*, 2017). In this regard, how pertinent would it be to maintain an habitat by actively opposing to the natural dynamics of the ecological succession ?

Recover a peatland

In the Linnunsuo case, this scenario would take place in a distant future and would consist in helping the recovery of a functioning peatland ecosystem. Indeed, to achieve this scenario the mosses responsible for the formation of peat should first come back and then the peat has to be formed, which can take millions of years. The idea of such a scenario came up after the discovery of *Sphagnum sp* along the shore line of the third pool. The individuals were found during a first experimental survey realised in May 2017. This survey wasn't done on the entire wetland, only the monitored areas are present on the **Fig. 28**. Different species were suspected to be present but a more complete study with an appropriate material would be needed to confirm this hypothesis. Their presence might indicate two things: that the environmental conditions required for their establishment can be found in Linnunsuo and that the soil of Linnunsuo is still furnished with propagules.

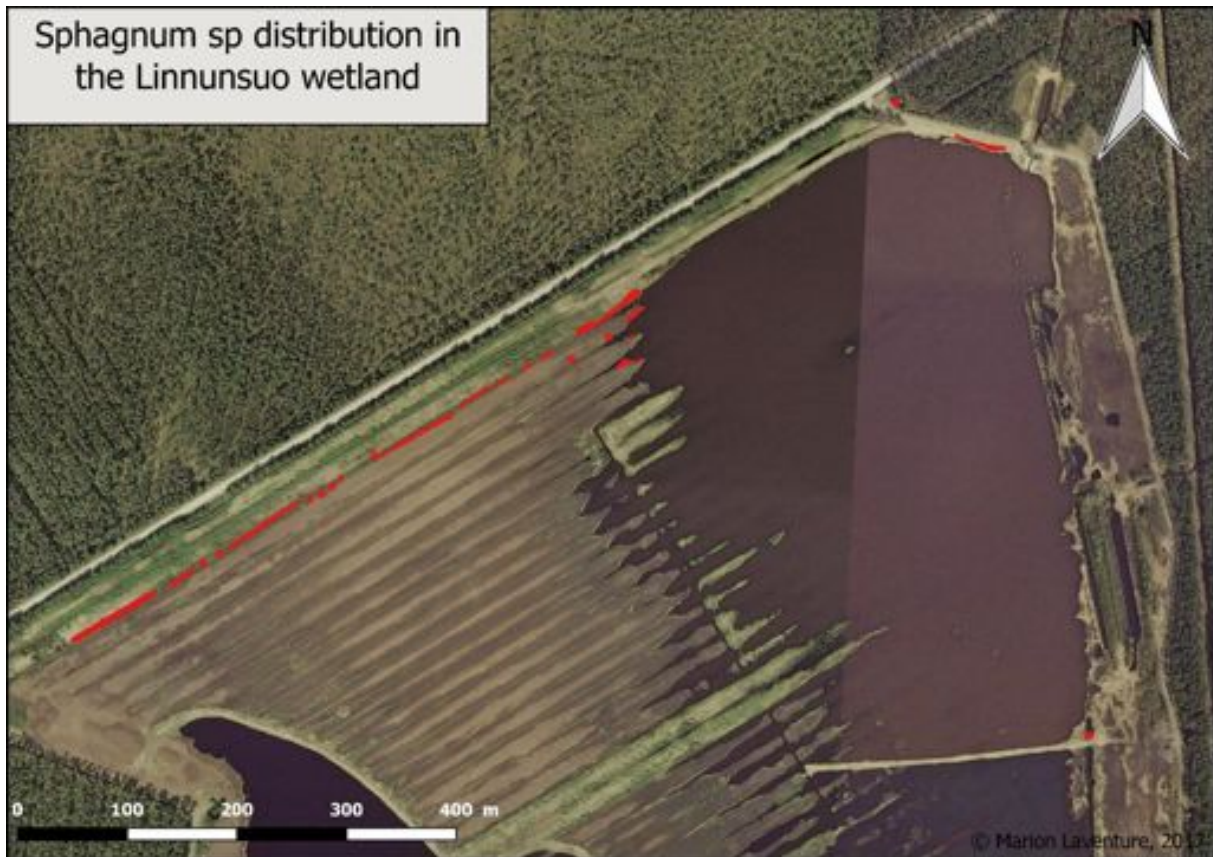


Fig. 28: Distribution of the *Sphagnum sp* (red) in the Linnunsuo wetland.

Monitoring for *Sphagnum sp* should be done every year to see if this recovery keeps going by itself. According to Tuittila *et al.* (2003), the recovery of the moss might not be linear and is very sensitive to period of flood and drought. Thus, the environmental conditions from a year to another should be taken into account to explain the evolution of the *Sphagnum* carpet in Linnunsuo. If the hydrological conditions allow it, it could be possible to import *Sphagnum sp* from other area to help its spread.

About the technic, according to Boudreau and Rochefort (1999), the diaspores should be collected manually rather than mechanically to insure the most successful establishment. It is not possible to accurately predict how long it would take for the mosses to settle but the final aim would be to recover a sphagnum moss carpet.

This scenario would result in a habitat with a lower biodiversity than the one currently present. However, it would be in line with nowadays concerns about peatland but the restoration and preservation of peatlands are currently nurtured by diverse European and international texts, such as the Millennium Ecosystem Assessment (2005) or the European Habitats Directive

(92/43/EC). Indeed, peatlands are home to a very specific biodiversity and supply major ecosystemic services. The destruction of such habitat represents a huge loss on a global scale as much as on the regional scale. In Finland, mires can be the place of cultural and recreational activities like hunting, hiking, picking berries... They are also an important part of the Finnish landscape. On the national level, Finland only exploits 2% of the total mire surface of the country. However, the ecological and socio-economic impacts resulting from the exploitation are often irreparable (Heikkilä *et al.*, 2012). In order to encourage restoration project, Natura 2000 can provide funds via the LIFE project network (Similä *et al.*, 2014).

6. Conclusion

The Jukajoki restoration project is a symbol of major importance that crystallizes some of the biggest issues of our century:

- The biodiversity crisis: in the current biological mass extinction context, the need to restore and protect habitats sheltering endangered species, such as Linnunsuo, has never been stronger (Ceballos *et al.*, 2017),
- Climate change: the restoration and protection of peatlands, which constitute some of the most effective carbon sinks on the planets, could contribute to reducing greenhouse gases concentrations in the atmosphere and slow global warming (IPS, 2008; Joosten, 2015),
- Social issues and the loss of traditions: the victory against the State company is a striking event that can give hope to other local communities around the globe struggling with the same kind of land appropriation and ecological degradation issues. The implementation of a co-management gives back governance to the local people, who will take decisions in the aim of retrieving ecosystems supporting ancestral activities through a combined use of expert and traditional knowledges.

Because they can address all these issues, the principles of rewilding could guide the Jukajoki Project to achieve long-term restoration objectives, and could be helpful in the management of the Linnunsuo wetland. However, in order to be effective in North Karelia, rewilding will have to adapt to the specificities of the region. The cultural background imposes to have a different mindset to approach nature management in Finland, and especially in its Eastern regions. In some villages, the cultural shifts happened quite recently, and hunting and gathering, which were the base of the local societies, still have an important influence on people's identities. The notion of "wilderness" in Finland is therefore different from the one we have in Western Europe, so a constant dialog will have to be maintained to make sure that the actions undertaken respect the link local people have with their surrounding environment and allow them to perpetuate their culture. The introduction of rewilding in Finland could be beneficial to both local communities, whose deeply impacted ecosystems could be restored using this innovative discipline, and to rewilding itself, which could enrich from a new way to apprehend nature management. By strengthening the health of wild nature in Eastern Finland, rewilding could help strengthening local communities.

The management actions currently launched in the Jukajoki watershed (such as the implementation of limestone and the digging of pools) should be pursued and the biological and physico-chemical monitorings on the river as well, as the future managements decisions about the river depend on their results. In the same way, the monitoring schemes in the Linnunsuo wetland should be pursued, and a special attention should be paid to follow the wildlife populations. The Linnunsuo wetland success story already constitutes an inspiration that could help other restoration projects to turn damaged cutaway peatlands into biodiverse and functioning ecosystems, but further studies should be performed to make Linnunsuo an exportable model. If the long-term objective is defined as achieving a peat-accumulating bog ecosystem, a vegetation monitoring scheme, in particular, should be quickly set up. The colonization of the area by plants should be followed in order to make sure that the natural processes are going in a way that is consistent with such objectives. A vegetation monitoring could detect the presence of invasive species before they spread out, and it could also focus on the development of typical bog plants such as *Sphagnum sp* (**Fig. 28**) and its associated companion species (such as *Eriophorum vaginatum* and *Polytichum sp*), bringing valuable information to potential similar restoration projects about the natural succession from a cutaway peatland to a functional bog.

The Jukajoki Project and the future of Linnunsuo deserve an international attention and could constitute the starting point of new way of taking care of Nature.

7. Glossary

Absorption capacity: Absorption capacity is understood as a pollution load introduced into river water that will not cause permanent and irreversible changes in the aquatic ecosystem and will not cause a change of classification of water quality at the river profile (Wilk *et al.*, 2017).

Cutaway peatland: Land area that is left after the major portion of the original peat deposit has been removed by industrial means. There is no economically useful peat left. The peat layer that is left can be of varying depths, from 1 m or more to nothing left over mineral subsoil. Some countries set standards for minimum depths of peat to be left overlying the subsoil, such as 50 cm (Leupold, 2004).

Ecological resilience: Among the numerous definitions of this notion, two can be retained: “Ecological resilience is the amount of disturbance that an ecosystem could withstand without changing self-organized processes and structures” and “Ecological resilience is the return time to a stable state following a perturbation” (Gunderson, 2000).

Keystone species: Species whose loss is likely to have serious effects on the continued existence of other species and hence on the long-term persistence of the community (Leito *et al.*, 2016).

Mire: A mire is a peatland where peat is currently being formed (Joosten & Clarke, 2002).

Ombrotrophic: Describes a mire that is only supplied with nutrients from the atmosphere (Joosten & Clarke, 2002).

Peat: Peat is sedentarily accumulated material consisting of at least 30% (dry mass) of dead organic material (Joosten & Clarke, 2002).

Peatland: A peatland is a type of wetland, with or without vegetation, with a naturally accumulated peat layer at the surface (Joosten & Clarke, 2002).

Rewilding (official working definition): Rewilding ensures natural processes and wild species to play a much prominent role in land- and seascapes, meaning that after initial support, nature is allowed to take more care of itself. Rewilding helps landscapes become wilder, whilst also providing opportunities for modern society to reconnect with such wilder places for the benefit of all life (Schepers & Bosman, 2015).

Tolerant species: A species is qualified as tolerant when it's capable of inhabiting a wide range of environments (Vehanen *et al.*, 2010)

Traditional knowledge: Associated in our case to the “local ecological knowledge”, refers to “those individuals that are living and habiting sites of change and who have capacities for ecosystem observations and interpretations” (Mustonen, 2013).

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9. Appendix

Appendix 1: Example of the data sheet used on the field for the Nordic Resource Management protocol.

NRT:n viikkokortti 21/2014
 Opetus- ja tutkimuskeskus, kasvatustieteiden osasto

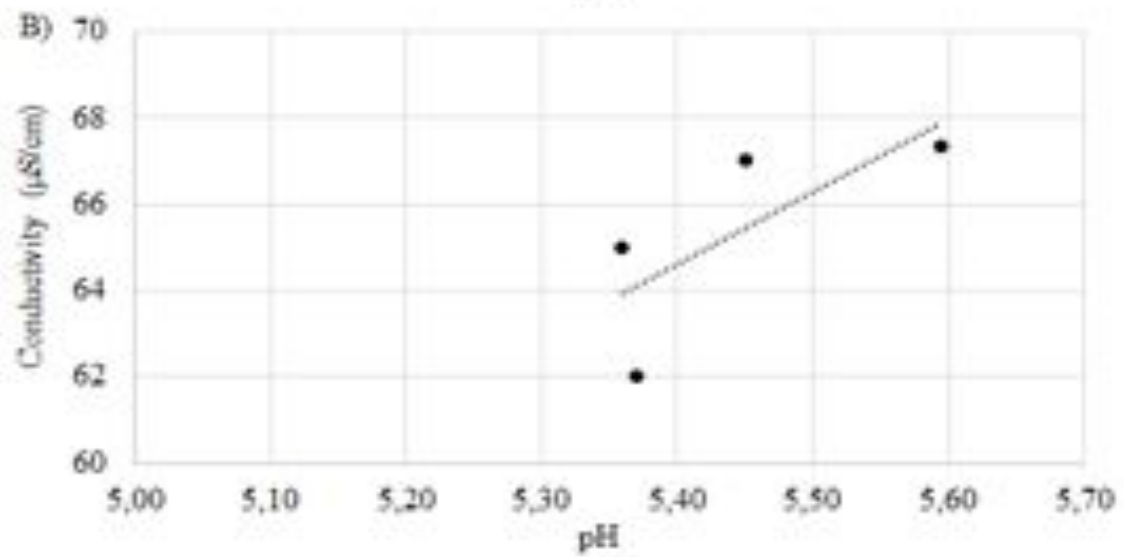
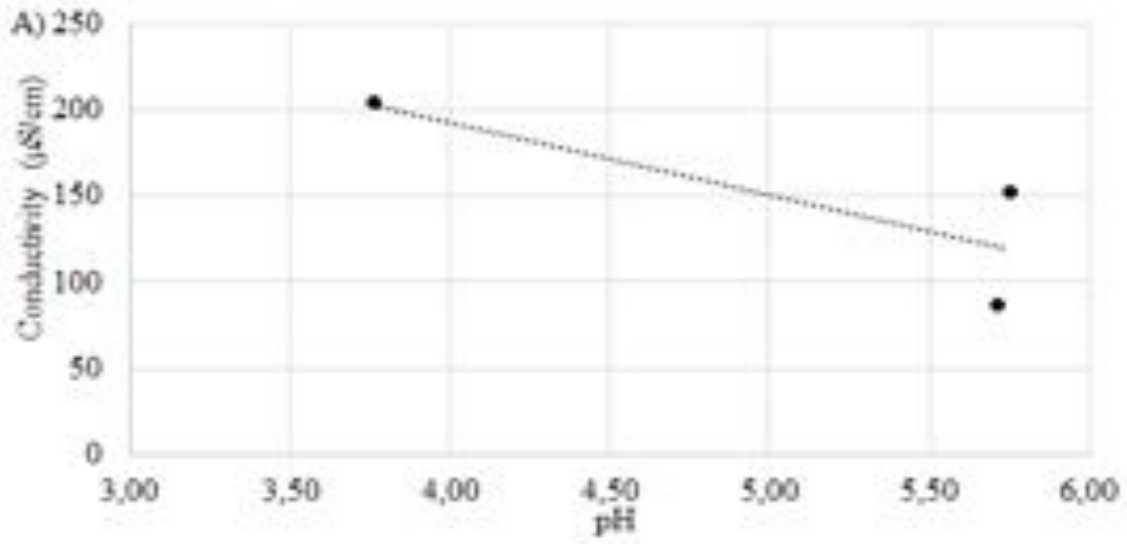
Lite 1. Maastolomakkeet

NORDIC-YLIHAKKATAUVAVERKKOPÖYTÄKIRJA

Ilmiö: _____ Keskustelijat: _____
 Havaintopaikka: _____ Vyyryydenlaatu: _____ Päättäjien lämpötila: _____
 Pää: _____ Vyyryydenlaatu (päättäjien): _____ Näkövyyry: _____
 Pyyntöala (ala-tila): _____ Vyyryydenlaatu: _____ Mitta: _____
 Sää (ilmapöly, tuuli, pilvitys): _____

olosuhteet	laji	oksa	kuha	lähde	kuoli	kuusi	malha	tilka	maha	tärki	ruokka	puu	tilaus	ruokka	seura	ruokka	ruokka
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f	f																
6.25	laji																
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oksa	f																

Appendix 2: Relation between the conductivity ($\mu\text{S}/\text{cm}$) and the pH in Linnunsuo (A) and the Jukajoki river (B).



Appendix 3: Breeding species and their number of breeding pairs from 2013 to 2017 in the Linnunsuo wetland. The “?” means that territorial sons were heard but the number of couple couldn’t be assessed. When the number of breeding pairs is written in *italic*, it means that the evaluated number of couple might change (increase or decrease). The total number of breeding species is indicated in the last line of the table.

Scientific name	Finnish name	English name	2013	2014	2015	2016	2017
<i>Anas penelope</i>	Haapana	Eurasian Wigeon	7	4	7	6	7
<i>Anas crecca</i>	Tavi	Eurasian Teal	16	30	35	26	30
<i>Anas platyrhynchos</i>	Sinisorsa	Mallard	4	5	10	5	10
<i>Anas acuta</i>	Jouhisorsa	Northern Pintail	1	5	4	6	5
<i>Anas querquedula</i>	Heinätaavi	Garganey	1	1	1	1	0
<i>Anas clypeata</i>	Lapasorsa	Northern Shoveler	0	3	2	3	3
<i>Aythya fuligula</i>	Tukkasotka	Tufted Duck	3	4	10	10	5
<i>Bucephala clangula</i>	Telkkä	Common Goldeneye	8	12	25	20	29
<i>Porzana porzana</i>	Luhtahuitti	Spotted Crake	0	0	0	1	?
<i>Vanellus vanellus</i>	Töyhtöhyppä	Northern Lapwing	3	6	5	5	4
<i>Charadrius dubius</i>	Pikkutylli	Little Ringed Plover	3	4	3	5	2
<i>Actitis hypoleuca</i>	Rantasipi	Common Sandpiper	2	2	2	1	1
<i>Tringa nebularia</i>	Valkoviklo	Common Greenshank	3	3	2	3	2
<i>Tringa glareola</i>	Liro	Wood Sandpiper	2	2	3	2	2
<i>Gallinago gallinago</i>	Taivaanvuohi	Common Snipe	2	2	3	2	3
<i>Sterna hirundo</i>	Kalatiira	Common Tern	2	3	1	2	1
<i>Hydrocoloeus minutus</i>	Pikkulokki	Little Gull	10	25	50	15	?
<i>Larus ridibundus</i>	Naurulokki	Black-headed Gull	35	10	350	400	70
<i>Larus canus</i>	Kalalokki	Mew Gull	2	3	1	5	7
<i>Larus argentatus</i>	Harmaalokki	European Herring Gull	0	1	1	1	0
<i>Alauda arvensis</i>	Kiuru	Eurasian Skylark	2	2	1	1	2
<i>Anthus pratensis</i>	Niittykirvinen	Meadow Pipit	3	2	2	10	4
<i>Saxicola rubetra</i>	Pensastasku	Whinchat	0	2	1	1	2
<i>Acrocephalus schoenobaenus</i>	Ruokokerttunen	Sedge Warbler	0	0	1	12	3
<i>Emberiza schoeniclus</i>	Pajusirkku	Common Reed Bunting	0	2	?	?	2
<i>Motacilla alba</i>	Västaräkki	White Wagtail	0	?	?	?	2
<i>Mergellus albellus</i>	Uivelo	Smew	0	0	0	0	1
<i>Motacilla flava</i>	Keltavästaräkki	Yellow Wagtail	0	0	0	0	2
Number of breeding species	-	-	19	24	25	26	25

Appendix 4: Raw data of all individuals caught with the Fyke trap protocol.

Session 1 - 15/06/17 - 19h30 (+18°C, sunny)			
	Individual	Length (cm)	Weight (g)
1	Ide (<i>Leuciscus idus</i>)	42	828
2	Ide (<i>Leuciscus idus</i>)	43,5	988
3	Ide (<i>Leuciscus idus</i>)	38	605
4	Ide (<i>Leuciscus idus</i>)	36	569
5	Common Bream (<i>Abramis brama</i>)	45	837
6	Common Bream (<i>Abramis brama</i>)	38,5	481
7	Common Bream (<i>Abramis brama</i>)	42	553
8	Common Bream (<i>Abramis brama</i>)	34	650
9	Common Bream (<i>Abramis brama</i>)	40	533
10	Common Bream (<i>Abramis brama</i>)	46	783
11	Common Bream (<i>Abramis brama</i>)	36	434
12	Common Bream (<i>Abramis brama</i>)	39	524
13	Common Bream (<i>Abramis brama</i>)	39	536
14	Common Bream (<i>Abramis brama</i>)	43	690
15	Common Bream (<i>Abramis brama</i>)	42	650
16	Common Bream (<i>Abramis brama</i>)	41	718
	Average	40,31	648,69
	Total	645	10379

Session 2 - 19/06/17 - 09h00 (+14°C, windy)			
	Individual	Length (cm)	Weight (g)
1	Common Bream (<i>Abramis brama</i>)	43	801
2	Common Bream (<i>Abramis brama</i>)	41	632
3	Common Bream (<i>Abramis brama</i>)	42	698
4	Common Bream (<i>Abramis brama</i>)	32	430
5	Common Bream (<i>Abramis brama</i>)	29	233
6	Common Bream (<i>Abramis brama</i>)	24	124
	Average	35,17	486,33
	Total	211	2918

Session 3 - 22/06/17 - 09h00 (+9°C, cloudy and windy)			
	Individual	Length (cm)	Weight (g)
1	Common Bream (<i>Abramis brama</i>)	49	903
2	Common Bream (<i>Abramis brama</i>)	43	693
3	Common Bream (<i>Abramis brama</i>)	41,5	620
4	Common Bream (<i>Abramis brama</i>)	44	738
5	Common Bream (<i>Abramis brama</i>)	37,5	406
6	Common Bream (<i>Abramis brama</i>)	39	545
	Average	42,33	650,83
	Total	254	3905

Session 4 - 27/06/17 - 20h00 (+15°C, sunny)			
	Individual	Length (cm)	Weight (g)
1	Ide (<i>Leuciscus idus</i>)	40	758
2	Common Bream (<i>Abramis brama</i>)	43	669
3	Common Bream (<i>Abramis brama</i>)	37	450
4	Common Bream (<i>Abramis brama</i>)	47	920
5	Common Bream (<i>Abramis brama</i>)	30	272
6	Common Bream (<i>Abramis brama</i>)	40,5	564
7	Common Bream (<i>Abramis brama</i>)	30	226
8	Common Bream (<i>Abramis brama</i>)	35	382
9	Common Bream (<i>Abramis brama</i>)	42	710
10	Common Bream (<i>Abramis brama</i>)	39,5	494
11	Common Bream (<i>Abramis brama</i>)	26	108
	Average	37,27	504,82
	Total	410	5553

Session 5 - 30/06/17 - 08h30 (+15°C, sunny, water : +11°C)			
	Individual	Length (cm)	Weight (g)
1	Common Bream (<i>Abramis brama</i>)	41	617
2	Common Bream (<i>Abramis brama</i>)	41,5	706
3	Common Bream (<i>Abramis brama</i>)	41,5	617
4	Common Bream (<i>Abramis brama</i>)	49,5	917
5	Common Bream (<i>Abramis brama</i>)	38	486
6	Common Bream (<i>Abramis brama</i>)	42	657
7	Common Bream (<i>Abramis brama</i>)	41	525
8	Common Bream (<i>Abramis brama</i>)	41	623
9	Common Bream (<i>Abramis brama</i>)	39,5	539
	Average	41,67	631,89
	Total	375	5687

Session 6 - 03/07/17 - 18h30 (+23°C, sunny)			
	Individual	Length (cm)	Weight (g)
1	Common Bream (<i>Abramis brama</i>)	33	338
2	Common Bream (<i>Abramis brama</i>)	41,5	603
3	Common Bream (<i>Abramis brama</i>)	42	624
4	Common Bream (<i>Abramis brama</i>)	47	829
5	Common Bream (<i>Abramis brama</i>)	48	994
6	Common Bream (<i>Abramis brama</i>)	52	1167
7	Common Bream (<i>Abramis brama</i>)	41	559
	Average	43,50	730,57
	Total	304,5	5114