Seasonal variation between transects concerning vegetation growth and species richness

First year monitoring of permanent transects placed within the Bothnian Bay

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Summary

Monitoring programs have been carried out within the Baltic Sea for decades to evaluate the progress being made towards a good environmental status. Seven permanent transect were placed within the Bothnian Bay in the summer of 2015 as a Metsähallitus project; the present thesis is made for them. The transects were placed in three different geographical areas so that they could cover both the North-South-axis of the Bothnian Bay and the outer archipelago-inner archipelago-axis.

The main focus of this paper is seasonal variation between those seven permanent monitoring transects. The coverage percentage and bottom substrate of each species were monitored, this thesis does not focus on these but on the species and their seasonal variation. The method used for gathering data was SCUBA diving.

Each transect has been monitored three times except for one that was monitored four times. From the result obtained it was clear that there was a seasonal variation, the species composition and the amount of species were found to vary according to progressing growing season, according to the bottom substrate and also due to north-south –location of each transect.

Language: English Key words: Transect, seasonal variation, macrophytes, vegetation.

1 Introduction

"The constant changes in the nature and in our living environment can be understood and predicted by monitoring the state of the environment" (Ahlroth 2013)

This thesis will present a Metsähallitus project carried out during the summer of 2015. The project consisted of installing seven transects and monitoring them for the first time. This paper reviews the results of first year of monitoring and provides a brief description of why the different transects were installed and how they were placed. The purpose of the monitoring transect project was to build and place seven permanent transects within the Bothnian Bay. The location of each transect was decided through expert recommendations of marine biologist Essi Keskinen, whose decision was based on data collected from previous dives done in different areas of the Bothnian Bay, this in order to have background data of the areas. The seven transects were located in three different geographical areas so that they would cover both the North-South-axis of the Bay of Bothnia and the outer archipelago-inner archipelago-axis.

Since there is no prior water macrophyte monitoring transects north of the Quark area (Vaasa), Metsähallitus decided to start monitoring the Bothnian Bay for four reasons. First, there are no previous permanent monitoring transects within the Bothnian Bay, even though previously some places within the Bothnian Bay were dived but they were not permanently monitored. Second, all of the Finnish coast should be monitored, not just the South coast. Third, a salt pulse was received from the Danish straits during the winter storms of 2014 and the progress of the salt pulse should be monitored. Fourth, the Species and the Habitat Directives, the Water Framework Directive and the Marine Strategy Framework Directive compel Finland to monitor and to report regularly to the EU about the changes in the threatened species and habitats and about the ecological quality of the Baltic Sea.

Metsähallitus plays a central role in this matter because it manages most Natura 2000 Network conservation areas and because it manages the state owned land and sea areas (Metsähallitus 2015).

As mentioned earlier, this project took place in the summer, during 2015; the building phase of transect started in early June. Later on when the building phase was finished, the diving/monitoring phase took place. After putting down all transects, they were monitored three times during the 2015 summer in different months in order to find out the seasonal variation during the first year of monitoring. The dives were done in the beginning of June, in the middle/end of July and at the end of August of 2015. In the future, the transects should be monitored each year, starting with diving the transects once a year in early June in order to find out which species are annual and which are perennial. The second dive should be done in August or early September during the best growing season in order to document the seasonal variation.

1.1 Objectives of the study

The main objective of this thesis is to find out if there was a seasonal variation between the seven transects placed in the Bothnian Bay, regarding vegetation growth and species richness. Another objective, is to document the first year monitoring of the seven transects. In addition to this, and perhaps in a more personal way, another objective was to learn more about the type of research being done in the Baltic Sea to fulfill the EU recommendations to reach the goal of a good environmental state of the Baltic Sea.

2 Background

> *"Macrophytes are an important element of the aquatic ecosystem. Wide changes in the abundance of individual species and community composition provide valuable data on how and why an ecosystem might be changing. Macrophytes are also becoming progressively valued as means of indirectly monitoring water quality as, for instance, eutrophication can produce a progressive change in species composition and a loss of species diversity"* (The UK Environmental Change Network Protocols for Standard Measurements at Freshwater Sites).

Thus, it is important and valuable to monitor macrophytes other than bladderwrack since all macrophytes provide important ecosystem services. Macrophytes can also be good indicators of water quality which is one of the hot-topics within the badly eutrophicated Baltic Sea.

2.1 The Baltic Sea

The Baltic Sea is a relatively shallow inland sea in north-east Europe. It is bordered by the coastlines of Denmark, Estonia, Finland, Sweden, Germany, Latvia, Lithuania, Poland and Russia. It has a catchment area of 1 650 000 km^2, more than four times the area of the sea itself (see Appendix A for a better view of the Baltic Sea catchment area). Almost 80 million people live within the catchment area (Walday & Kroglund, 2002). Moreover, the Baltic Sea is one of the largest bodies of brackish water on the planet and one of the most polluted inland seas in the world. The water is a mixture of salt water from the North East Atlantic and fresh water from the catchment area of rivers and watercourses, it also sustains a unique brackish water flora and fauna. The Baltic Sea is very vulnerable due to the amount of people living in the catchment area, the high volume of ship traffic and the fact that the water does not change very often (The Baltic Sea Environment and Ecology, 2014). The exchange of water and inputs of salt water into the Baltic Sea are determined by the inflows of dense water dynamics through the Danish straits. Suchlike inflows are important to the brackish water ecosystem of the Baltic Sea because they are responsible for maintaining proper salinity and oxygenating the deep water (Gustafsson & Omstedt, 2009).

2.2 The Bothnian Bay

The Bothnian Bay is located in the northernmost region of the Baltic Sea. It has an average depth of only 40 meters, its deepest point reaching more than 100 meters on the Swedish coast (Bothnian Bay LIFE project, 2001-2005). The northern parts of the Bothnian Bay have gravel and rocky islands and sand banks while the southern shores are rockier and bedrock is exposed in many places. The Bothnian Bay is frozen on average 170 to 190 days a year. There are many freshwater rivers running into the Bothnian Bay, keeping the salinity low at approximately 3.5 psu (OCEANA 2013). The Bothnian Bay is in a relatively healthy ecological state, as it is not suffering from eutrophication as much as the Gulf of Finland and still has good oxygen levels even in deeper areas, unlike most of the Baltic Sea, where anoxic bottoms are common due to eutrophication (HELCOM, 2010).

2.3 Monitoring the Baltic Sea

Monitoring has been carried out within the Baltic Sea for decades to evaluate the progress being made towards a good environmental status. According to the Marine Strategy Framework Directive, the Baltic Sea should be in a good ecological condition by the year 2020. The same goal for HELCOM (HELCOM Baltic Sea Action Plan) is year 2021. Detailed information exists on the geological, physical, chemical and hydro-dynamical properties of the Baltic Sea system due to monitoring programs (Voipio 1981; Mälkki & Tamsalu, 1985). There are many different organizations doing the monitoring.

Metsähallitus is one of them, it manages the state owned land and water properties (Metsähallitus, 2015), another organization doing monitoring is the Finnish Environment Institute "SYKE", which co-ordinates the activities related to biodiversity monitoring stated by the Ministry of Environment. The monitoring data gathered by SYKE is used to assess the current state of the species and their living environments, their protection needs, and the ideal and sustainable use of their ecosystems as well as to develop methods for protection, management and restoration of biodiversity (SYKE, 2015). These, among other agencies are doing monitoring in the Baltic Sea region, all of them focusing on different things but aiming for the protection and conservation of the Baltic Sea.

2.4 Habitat Directive

The Habitat Directive is one more of the different EU directives involved in environmental conservation and protection, this directive focuses on habitat conservation. It was adopted as a response to the biodiversity decline crisis experienced 20 years ago. Its purpose is, as described in the European Commission website, to guarantee the conservation of an extensive range of rare, threatened or endemic animals and plants species (European Commission, 2016).

During the past 20 years a lot of progress has been achieved due to this Directive and the hard work of every Member State involved in the conservation of such habitats (Potočnik, 2012) The Habitat Directive requires Member States to delegate areas for protection in order to assure a positive conservation status. Monitoring of conservation status is a responsibility rising from Article 11 of the Habitats Directive for all habitats, according to Article 17 of the directive this monitoring has to be reported to the Commission every six years (European Commission, 2016).

The EU Habitat Directive has a list of 69 habitats in Finland that need to be preserved and protected as part of the Natura 2000 Network. From these 69, four small water body types are covered by the Water Act (Ymparisto, 2013).

2.5 Natura 2000

Natura 2000 is a network of specially protected sites that contains rare and threatened species as well as rare natural habitat types of European value and importance that need to be maintained and protected. Natura 2000 is one of the largest coordinated networks concerning protected areas in the world. The objective of this network is to guarantee the long-term preservation of Europe's most important threatened species and habitats being listed under both the Birds Directive and the Habitats Directive (European Commission, Natura 2000, 2016).

2.6 Marine strategy framework directive

The Marine Strategy Framework Directive aims to achieve an effective protection of the marine environment of Europe. In order to reach this achievement, EU Member States must develop a strategy for its marine waters conservation and protection (European Commission, 2016). The Marine Strategy Framework Directive provides requirements for countries to take the necessary measures to achieve or maintain Good Environmental Status (GES) by 2020 (BALSAM, 2015).

The Member States have established monitoring programs to keep an eye on the status of their marine waters based on the indicator list of elements set out in Annex III as well as Annex V. Such monitoring programs should follow some principles, such as, being adequate, coordinated, adaptive and coherent. Monitoring should provide data which support suitable indicators in order to assess if good environmental status has been achieved or is maintained.

They should provide practical data, link with assessments and apply the precautionary principle (Report EUR 26499 En, 2014).

2.7 Water Framework Directive

The objective of the Water Framework Directive (WFD) is to establish a framework for the protection of transitional waters, inland surface waters, coastal waters and groundwater among EU states. Another objectives are to promote sustainable water use; prevent deterioration of aquatic ecosystems and ensuring the progressive reduction of pollution of water bodies of any type (Directive 2000/60/EC). WFD demands Member States to categorize all surface water bodies according to their ecological status by their physical-chemical and biological features. As far as physical-chemical features are concerned, the coastal waters of the Member States are divided into different water types according to salinity levels, temperature, etc. (Ruuskanen, 2014). After categorizing water bodies, Member States are to develop measurements in order to respond to those human pressures having a negative impact on water bodies. Monitoring is one important assessment system for the improvement of ecological conditions.

2.8 Marine protected areas

The purpose of marine protected areas is to safeguard valuable marine and coastal habitats in the Baltic Sea. Areas with a particular nature value are defined protected areas and human activities within those areas are managed in order to protect such habitats. Each area has its exclusive management plan. Today there are 174 HELCOM MPAs in the Baltic Sea which is a lot compared with 1994 when the first Baltic Sea Protected Areas (BSPAs) was established and 62 sites were nominated (HELCOM, 2003).

A number of underwater habitats types are endangered, the lack of knowledge as well as precise data of those habitat types make the allocation of various uses in a sustainable manner difficult. The Finnish Inventory Programme for the Underwater Marine Environment (VELMU) has been working on this situation. Work on mapping the diversity of the underwater marine environment has been done in order to identify hot-spots of functional and species diversity as well as sites where species needing particular protection occur (VELMU, 2013).

2.9 Line transects

Line transect is a method used for analyzing macrophytes and other types of aquatic plants as well as terrestrial and wetlands systems (Madsen, 2012 & Wersal, 2012). Using this method one can gather presence/absence data, cover percentage data, or implement quadrats alongside transects in order to collect density and abundance measurements (Titus, 1993). The line transect method involves less technology for its application as it can be established and sampled without the use of a computer or GPS technology, although GPS use is optional. This method has been adopted for many purposes, such as measuring the cover of target species or making set line intervals in which species presence is recorded (Madsen, 1999).

The length of the transect vary according to purpose of the study, both species presence and absence can be determined by snorkeling or SCUBA diving, this depending on the water depth, species of interest among other aspects. Using this method you draw a line out into the sea, perpendicular to the shoreline, inside the studied area of interest, the length as previously mentioned depends on the area to be studied and the objectives of the study. After this SCUBA diving or snorkeling is used to evaluate the area where the line transect has been set up. According to Monivesi Oy (2014) the monitoring is carried out along the line transect at one meter depth intervals. At each respective depth, a pause is executed and a measurement frame is performed. Nevertheless, in the present study ten meter depth intervals were used.

2.10 Seasonality

Marine and freshwater ecosystems are subject to great environmental variations, both daily as well as seasonally. Therefore, the life cycles of marine creatures show seasonal patterns in growth, reproduction and abundance (Gil, Ribes & Zabala, 2000). The annual cycle of the seasons is one of the most evident and most extraordinary cyclical processes in the littoral zone, the environmental conditions differ greatly from season to season, especially during winter where the intensity of sun light decreases (Hill, 2007).

It is significant that the seasonal variation in the amount of species corresponds closely to the environmental changes e.g. in weather, and to external factors in the ecosystem (Morrissey and Sumich 1960). Therefore, the change of season is one factor that affects the growth and coverage of species in an ecosystem.

2.11 Environmental factors contributing to seasonal variation

Variations in features of the marine environment produce different habitats and influence the types of organisms that will inhabit them. The accessibility of light, water depth, closeness to shore, and topographic complexity all affect marine habitat variation (Kingsford, 2014). Sun light penetration, turbidity, temperature, salinity and pH among other factors contribute greatly to marine biota growth as well. Seasonal cycles begin when light increases in the spring causing increased surface temperatures, which results in increased metabolism and therefore has an impact on the growth rates of organisms (Ecological Regulation -MarineBio.org. Marine Bio Conservation Society).

2.12 Biodiversity

> CBD (1992) defines biodiversity as "… biodiversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems".

Biodiversity also describes the total variety of life on earth at all its stages of biological organization, from genes to ecosystems, as well as the ecological and evolutionary processes that sustain it (Sterling, Chiles & Cullman, 2008).

The most used measure of biodiversity is species richness. However, according to Purvis & Hector (2000) measuring such a broad concept is actually difficult because biodiversity is a multidimensional concept that cannot be reduced to a single number. Biodiversity is very important for the productivity of all ecosystems, each species, no matter how minor, all have an important role to play. In other words, biodiversity is the basis of most ecosystems and we humans are very dependent of such services provided by ecosystems.

2.13 Species presented within this thesis

The results of this thesis will present a number of species belonging to different species groups. These groups are; vascular plants, bryophyte, charales, algae, blue-green algae, invertebrates and fish. The species classification in this paper was taken from the Metsähallitus data base and HELCOM HUB technical report, classification system, level six.

In the following paragraphs the main characteristic of vascular plants, bryophyte, charales and algae will be described.

2.13.1 Vascular plants

Vascular plants are about 80% of all plants on earth. These plants have special tissues in their stems in order to move water and nutrients up and down the plant itself, such characteristic allow the plant to grow to a much larger size. Vascular aquatic plants are found in relatively shallow areas in the littoral zone, they also occur in both salt water and fresh water habitats (Penfound, 1956). In Finland there are approximately 1200 indigenous species and archaeophytes (Pinkka, 2006).

2.13.2 Bryophytes

Bryophytes include, liverworts, hornworts and mosses, they have no vascular tissues in the midrib. Due to this characteristic they are usually small. There are about 23000 named species. Bryophytes in Finland comprise approximately 663 species of mosses and 227 species of liverworts (Pinkka, 2006).

Bryophytes can tolerate drier areas. Many of them are found within freshwater areas. Few species are found in brackish water. Since bryophytes are the second largest group in the world of plants they occur on every continent as well as in every habitable location (Glime, 2013).

2.13.3 Charales

The Charales (stoneworts) form a distinctive group within the Chlorophyta, they are often considered to be close relatives of land plants and embryophytes, offering progressive evolution towards cellular complexity within streptophyte green algae (Becker & Marin, 2009).

Charales live in fresh water habitats and few of them can be found in brackish waters. They vary in size, some can be small and others can be large, about a meter in length. Charales growth on soft bottoms, such as sand and mud (College Biology, 2015).

2.13.4 Algae

Algae are photosynthetic and aquatic plant organisms, they do not have true roots, steam, leaves nor vascular tissues. Algae can be found as microalgae and as macroalgae. The microalgae side include both cyanobacteria as well as green, brown and red algae. Algae are varied, they can be found approximately everywhere on this planet. Many ecosystems need algae in order to provide sources for aquatic food and support for fisheries in the ocean and sea (Hoek, Mann and Jahns, 1995).

2.14 Perennial and annual species

There are perennial and annual species; according to the Oxford dictionaries perennial plants are those that regrow every spring, they live year after year while annual plants are those that grow, bloom in one growing season and then die.

3 Material and methods

In the following section will be presented the experimental set up of the building phase of all seven transects and how these were placed in the respective locations. Moreover, the method which was used to collect data will be described as well as the parameters according to which the location of all transects was decided upon.

3.1 Location

Seven permanent monitoring transects were suggested to be established in the Bothnian Bay in the places shown in Figure 1 in Appendix B. The decision of where to establish the seven monitoring transects was done through expert recommendations. Moreover, as the places selected have been dived before, there was background data to be used. Transects were located in three different parts of the Bothnian Bay, the most Northern one in Perämeri National park (see Figure 2, Appendices B), the middle ones in the central North Bothnian Bay (Perämeren saaret Natura 2000 area, (see Figure 3, Appendix B) and the South ones in the Southern Bothnian Bay (Rahjan saaristo Natura 2000 area, (see Figure 4, Appendix B) in order to cover as much as possible of the Bothnian Bay.

In each area, a transect was placed in a sheltered zone and another in an exposed site in order to compare the two different exposures. Also, there is one hard deeper substrate transect and one shallower soft bottom substrate transect (silt, sand or mud) in each site and one extra transect in the Northernmost part of the Gulf of Bothnia. There is no previous monitoring within this area because most of the southern monitoring programs focus on Bladderwrack (*Fucus vesiculosus*) which does not grow in the north (Keskinen, pers. com. 2015). However, there are other kinds of macrophytes in the northern part that can be monitored.

Macrophytes are monitored because of different reasons, one of them is they are good indicators of water quality. As Ruuskanen (2014) expresses, the ecological status of a water type and body is decided by the Biological Quality Elements which are phytoplankton, zoobenthos and macrophytes.

It was decided to monitor both hard and soft substrates in order to get a better understanding of the different dynamics of the specific species on these types of substrates (algae and water moss on hard substrates, Charales and vascular plants on soft substrates) in the unique ecosystem of the Bothnian Bay. The transects were suggested to be monitored at first at least 2-3 times a year with the progressing growth season in order to get a better idea of the seasonal vegetation in each area. The seven transects were expected to be monitored each year, starting with diving all transects once in early June in order to find out which species are annual and which are perennial. The second dive should be done in August or early September during the best growing season to document the seasonal variation as suggested in annex 9 for the HELCOM COMBINE program.

3.2 Transects

Two or in one case three transects were located in each area. They would represent deep rocky shores with filamentous algae and water mosses and shallower sandy/soft bottoms with vascular plants and Charales. There was also a need to include outer and inner archipelago and sheltered and exposed marine nature. The suggested transects have been selected so that they are not very badly exposed to winds and so that one dive team can monitor all transects in one area in a one field day in good weather conditions (see Appendix B for a better view of the seven transects substrate characteristics).

3.3 Transect coordinates

The geographical position of each transect has been documented with a GPS device. In table 1 the different coordinates can be found. Each transect has three coordinate points, one in the start which means at zero centimeter; the second one in the middle of the transect, for those transects whose length is 100 meters the middle point was taken at 50 meter and for those whose length is 200 and 300 meters the middle point was taken at 100 and 150 meters respectively; the last point was taken at the end of transect 100, 200 or 300 meters.

The coordinate points were taken in this way in order to have an exact position of each transect and thus to find them easily for future monitoring.

Table 1. Coordinates of seven permanent monitoring transects.

Transect	Length (Meters)	ID	Latitude	Longitude
Selkä-Sarvi	200	Start	N65,615575	E024,196890
		100M	N65,616192	E024,198398
		End 200m	N65,616677	E024,200210
Pohjois-Kraseli	100	Start	N65,658525	E024,273811
		50M	N65,658381	E024,273422
		End 100m	N65,658328	E024,273094
Vähä huituri	100	Start	N65,710987	E024,262997
		50M	N65,711066	E024,263701
		End 100m	N65,710770	E024,262688
Kintasletto	300	Start	N65,140115	E025,058615
		150M	N65,138318	E025,058238
		End 300m	N65,137433	E025,058049
Hiuvet SE	100	Start	N65,130915	E25,141572
		50M	N65,130466	E25,141331
		End 100m	N65,130085	E25,141442
Anttikarvo	100	Start	N64,198194	E023,673780
		50M	N64,198109	E023,673851
		End 100m	N64,198056	E023,674199
Ryöpäs	100	Start	N64,217112	E023,639231
		50M	N64,217430	E023,638625
		End 100m	N64,217774	E023,637986

3.4 Experimental set up design

The transect method is one of the most used and recommended monitoring methods along the Baltic Sea countries (HELCOM COMBINE, 1999). Line transects are commonly established using a random sampling procedure (Plumptre & Reynolds 1994). During this project the Metsähallitus Marine Biology team has used measuring tape for setting up all transects. As mentioned earlier, there were seven transects with different lengths to be established. Five were 100m long; one was 200 m and one 300 m long.

The resources used for establishing transects were non-floating rope, measuring tape and cable ties. The measuring tape was attached to the rope with the cable ties. Concrete blocks were used to keep the transects at the bottom.

3.5 Establishing transects

The transects were established under water from a boat. The shore end was tied to a large concrete block and placed at the water line (mean water level 0 cm) and its coordinates recorded on a hand-held GPS device. All transects were laid down by backing with the boat and letting the transect fall to the bottom with smaller concrete blocks attached to it at every 10 meters. The transect was laid down as straight as possible at a 90 degree angle from the shoreline. A larger concrete block was attached to the other end and the end coordinates were recorded on a GPS. Photos were also taken from the starting place of the transect to better find the start when monitoring them.

3.6 Diving transects

The monitoring dives were carried out from June to August during the summer of 2015. The dives were done following the VELMU 2015 inventory manual. Each monitoring dive started by finding the GPS point of the transect.

Each SCUBA diver had his or her own task. The first diver’s task was to document the percentage of vegetation cover and the species and to give a description of the bottom substrate, divers should monitor two meters on both sides of the transect. The second diver’s task was to take samples and document the plant species using an underwater camera. The divers had sampling gear with them, mainly a writing board, sample bags, sample vials, forceps and an underwater camera. The depths at the beginning and end of the transect should be and were recorded.

The dives were mostly done in pairs. However, there were exceptions in which groups of three or a single diver was doing the monitoring. When there was only one diver doing the monitoring, he or she was attached to a rope connected to the boat where somebody was looking after the diver’s movement and security. While the divers were diving there was always a safety person on the boat looking after the divers, this in order to guarantee the divers’ safety.

All transects were monitored three times during the summer, except the Selkä-Sarvi Maasarvi transect, which was monitored in September for a fourth time.

4 Results

Each species' coverage percentage and bottom substrate coverage percentages were also monitored, but this thesis will not concentrate on them. To keep the work within reasonable limits only the species and their seasonal variation will be explained.

4.1 Results of each monitoring transect

In the following pages the findings of the three times the seven transects were monitored will be presented. The result will be shown individually per transect, presenting the species found in the different months.

4.1.1 Vähä-huituri 100 Meters

This transect had most recorded species during the July monitoring, mostly water mosses and vascular plants. 8 different types of water mosses and vascular plants were found in July. The June and the August monitoring had similar percentages for the species, although some of the species were different. Different species occurring each month can be seen in Table 2. It is noteworthy that Vähä-huituri has a rocky/hard bottom, although in the end of the transect at the deeper part (~80-100meter) soft bottom can be found.

Table 2: Species found during the three times of monitoring in the Vähä-huituri transect.

Vähä-Huituri 100 m

Species group	Species	June	July	August
Vascular plants	*Myriophyllum verticillatum*	x	x	
	Myriophyllum sibiricum			x
	Myriophyllum sp		x	
Bryophyta	*Fissidens fontanus (Octodiceras fontanum)*	x	x	x
	Fontinalis antipyretica	x	x	x
	Fontinalis hypnoides			x
	Platyhypnidium riparioides	x	x	x
Charales	*Chara aspera*		x	
	Chara globularis			x
	Chara/Nitella	x		
Algae	*Ulothrix sp*	x	x	
	Filamentous unidentified algae <5 cm	x	x	x
	Batrachospermum sp	x	x	
	Aegagrophila linnaei (Cladophora aegagrophila)		x	
	Rhizocolonimum sp			x
	Filamentous epiphytic algae		x	
Blue-green algae	*Rivularia sp*		x	
Invertebrates	*Anodonta anatina*	x	x	
	Other invertebrates		x	
	Ephydatia fluviatilis	x		
	Polyps	x	x	x
Fish	*Perca fluviatilis*	x		

4.1.2 Pohjois-Krasseli 100 Meters

The Pohjois-Krasseli transect is located in a rocky/hard bottom in an exposed area. The number of species found in this transect did not vary so much during the three monitoring dives. The species found were almost the same during the three dives, but the coverage percentage of each species varied much. The species found during the first month (June) were small patches and in July there were big and healthy meadows of vascular plants and water mosses. The ones found in August were the same as in July meaning no change had occurred later in the season.

Three species of water mosses were found but no vascular plants at all. Two species of benthic animals were found and algae was present during July and August, however in different amounts. See table 3 for more details of species names.

Table 3: Species found during the three times of monitoring in the Pohjois-Krasseli transect.

Pohjois-Kraaseli 100 m

Species group	Species	June	July	August
Bryophyta	*Fissidens fontanus (Octodiceras fontanum)*	x	x	x
	Fontinalis antipyretica	x	x	x
	Platyhypnidium riparioides	x	x	x
Algae	Filamentous unidentified algae <5 cm	x	x	x
	Aegagrophila linnaei (Cladophora aegagrophila)		x	x
	Batrachospermum sp		x	
Blue-green algae	Bluegreen algal layer		x	
Invertebrates	Polyps	x	x	x
	Ephydatia fluviatilis	x	x	x
Fish	*Potamoschistus sp*			x
	Pisces sp			x
	Gymnocephalus cernuus	x		

4.1.3 Selkä-Sarvi 200 Meters

The Selkä-Särvi transect has a mixture of sand/silt and soft bottom and it is located in a sheltered area between Selkä-Sarvi and Maasarvi islands. During the first dive in June a low number of species of any kind were found. As shown in the table 4 the amount of species varied according to time of year. In June the amount of species was lower than those on August and September. In July the amount of vascular plants and water mosses was higher than in other months, 11 species of vascular plants and water mosses were found in total.

Table 4: Species found during the four times of monitoring in the Selkä-Sarvi transect.

Selkä-Sarvesta Maasarveen 200 m

Species group	Species	June	July	August	September
Vascular plants	Vascular plant (unidentified)	x			
	Callitriche hermaphroditica		x	x	x
	Eleocharis acicularis	x	x	x	x
	Elatine sp		x		
	Elatine hydropiper			x	x
	Isoëtes sp		x	x	
	Isoëtes echinospora				x
	Potamogeton berchtoldii		x		
	Potamogeton filiformis		x		
	Potamogeton gramineus		x	x	x
	Potamogeton perfoliatus		x	x	x
	Potamogeton pusillus		x	x	x
	Subularia aquatica			x	x
	Zannichellia sp		x		
	Zannichellia palustris			x	x
Charales	*Chara aspera*		x	x	x
	Nitella sp.		x	x	x
Algae	*Hildenbrandia sp*	x			
	Filamentous unidentified algae <5 cm	x	x		x
	Filamentous unidentified algae >5 cm	x	x		x
	Filamentous epiphytic algae		x		x
	Aegagrophila linnaei (Cladophora aegagrophila)			x	
	Vaucheria sp			x	
	Unattached plant material		x	x	
Blue-green algae	Bluegreen algal layer	x		x	x
Invertebrates	*Anodonta anatina*	x	x	x	x

	Other invertebrates	x		x	
	Ephydatia fluviatilis		x	x	
Fish	*Potamoschistus* sp				x

4.1.4 Kintasletto 300 Meters

As observed in table 5, monthly variations occurred in the Kintasletto transect, although not very strong. During the monitoring in July the amount of vascular plants and water mosses was more abundant than in the other months, as was the presence of benthic animals and blue green algae. In August the number of species decreased, but not drastically. Benthic animals other than polyps were not present during this month.

In numbers July had 11 species belonging to the vascular plants and water mosses category, June had 4 and August 7. Algae was only present during July as well as blue green algae. The number of benthic animals was 5 for July while for June and August 1 or 2. This transect is situated in a rocky/hard bottom at the beginning but the end of the transect is in a muddy area.

Table 5: Species found during the three times of monitoring in the Kintasletto transect.

Kintasletto 300 m

Species group	Species	June	July	August
Vascular plants	*Potamogeton gramineus*			x
	Potamogeton gramineus x perfoliatus	x	x	
	Potamogeton perfoliatus		x	x
	Stuckenia pectinata (Potamogeton pectinatus)	x	x	x
	Myriophyllum alterniflorum		x	
	Myriophyllum sibiricum	x		x
	Myriophyllum spicatum		x	
Charales	*Chara aspera*		x	x
	Chara globularis			x
	Chara/Nitella		x	

Bryophyta	*Fissidens fontanus (Octodiceras fontanum)*		x	x
	Fontinalis antipyretica	x	x	x
	Platyhypnidium riparioides		x	x
Algae	Filamentous unidentified algae <5 cm	x	x	x
	Aegagrophila linnaei (Cladophora aegagrophila)		x	
Blue-green algae and bacteria	*Rivularia sp*		x	
	Beggiatoa sp		x	
Invertebrates	*Anodonta anatina*	x	x	
	Other invertebrates		x	
	Lymnea sp		x	
	Mysidae sp		x	
	Polyps	x	x	x

4.1.5 Hiuvet SE 100 Meters

The amount of species present in the Hiuvet transect varied depending of the month. In June a varied ecosystem in which vascular plants, water mosses, algae, filamentous algae, benthic animal and filamentous epiphytic algae were all present was observed. However, not in large number or size, they were all rather small. Table 6 presents the Hiuvet transect species for each monitoring time.

In July, 12 species of water mosses and vascular plants were found. Also two species of benthic animals and two fish species were found in July. In August some of the same species were still found in addition to three new species of macrophytes. At this point the amount of benthic animals was reduced but a fish was observed. However, August did not have as many species as July.

The Hiuvet transect is mostly sandy or muddy with some stones especially in the beginning.

Table 6: Species found during the three times of monitoring in the Hiuvet SE transect.

Hiuvet 100 m

Species group	Species	June	July	August
Vascular plants	*Callitriche hermaphroditica*			x
	Eleocharis acicularis	x	x	
	Eleocharis uniglumis	x	x	
	Elatine hydropiper			
	Phragmites australis	x	x	x
	Isoëtes echinospora			
	Poa sp			x
	Potamogeton sp	x		
	Potamogeton filiformis	x	x	x
	Potamogeton gramineus x perfoliatus		x	
	Stuckenia pectinata (Potamogeton pectinatus)		x	x
	Potamogeton perfoliatus	x	x	x
	Potamogeton pusillus		x	x
	Tolypella nidifica	x	x	x
Charales	*Chara aspera*	x	x	x
	Chara/Nitella	x	x	
	Nitella opaca		x	
	Nitella sp			x
Algae	*Cladophora glomerata*	x		
	Filamentous unidentified algae <5 cm	x		
	Filamentous unidentified algae >5 cm			
	Filamentous epiphytic algae	x	x	
	Unattached plant material	x	x	
Invertebrates	*Mysidae*	x	x	
	Other invertebrates	x		
	Ephydatia fluviatilis		x	
	Polyps	x	x	x
Fish	*Gymnocephalus cernuus*		x	
	Zoarces viviparus		x	
	Pisces sp			x

4.1.6 Ryöpäs 100Meters

The Ryöpäs transect is situated on a rocky/hard bottom. The percentage of species coverage did not vary much throughout the monitoring months. Of all the transects, Ryöpäs has the fewest species with no vascular plants and only one species of water moss during one monitoring time. Mostly only blue green algae and benthic animals were found. Although in July in other transects most species were found, there were only two species of vascular plants and a low number other species in the Ryöpäs transect, see table 7.

Table 7: Species found during the three times of monitoring in the Ryöpäs transect.

Ryöpäs 100 m

Species group	Species	June	July	August
Bryophyta	*Fissidens fontanus (Octodiceras fontanum)*			x
Algae	*Cladophora glomerata*	x		
	Hildenbrandia rubra	x		x
	Filamentous unidentified algae <5 cm		x	x
	Ceramium tenuicorne			x
Blue-green algae	Bluegreen algal layer			
	Rivularia sp		x	x
	Ophrydium colony			x
Invertebrates	Polyps	x	x	
	Spongilla lacustris			x
	Ephydatia fluviatilis	x	x	x
	Saduria entomon	x		
Fish	*Perca fluviatilis*	x		

4.1.7 Anttikarvo 100 Meters

The amount of species varied according to months. July and August were the months with more species. June had a small number of species compared with the following months of monitoring. The amount of vascular plants and waters mosses was 7 species in June. July and August have almost the same amount of species and the same species. In table 8 species on this transect can be found. The bottom of this transect is mainly sand/silt and soft bottom and the transect is very sheltered.

Table 8: Species found during the three times of monitoring in the Anttikarvo transect.

Anttikarvo 100 m

Species group	Species	June	July	August
	Callitriche hermaphroditica		x	x
	Eleocharis acicularis		x	x
	Elatine hydropiper			x
	Myriophyllum sibiricum	x	x	
	Myriophyllum verticillatum			x
	Najas marina			x
	Poa sp		x	
	Potamogeton sp		x	
Vascular plants	*Potamogeton berchtoldii*	x		
	Potamogeton filiformis		x	x
	Potamogeton friesii		x	
	Stuckenia pectinata (Potamogeton pectinatus)	x	x	x
	Potamogeton perfoliatus	x	x	x
	Potamogeton pusillus		x	x
	Sparganium sp		x	
	Tolypella nidifica	x	x	x
	Zannichellia palustris			x
	Chara aspera	x	x	x
Charales	*Chara/Nitella*		x	
	Nitella sp.	x		x
Bryophyta	*Bryophyta* sp			x
	Drepanocladus aduncus	x		
	Filamentous unidentified algae <5 cm			x
Algae	Filamentous unidentified algae >5 cm	x		
	Aegagrophila linnaei (Cladophora aegagrophila)			
	Vaucheria sp			x
Blue-green algae	*Rivularia sp*			x

Invertebrates	Other invertebrates		x	x
	Ephydatia fluviatilis	x	x	x
	Polyps	x	x	x

4.2 Variation in number of species

In the previous tables species being present within each transect were presented. In figure 8, the variation in number of species can be observed more clearly. It is clear that June was a month with less number of species compared with July, a month in which a higher number of species were found, except for the Ryöpäs line transect where less species were found. August on the other hand was different. During this month, most transects looked similar, meaning the number of species stayed with as many as, or with a lower number than in July. However, the Anttikarvo line transect gave different results, during August the number of species increased, surpassing July.

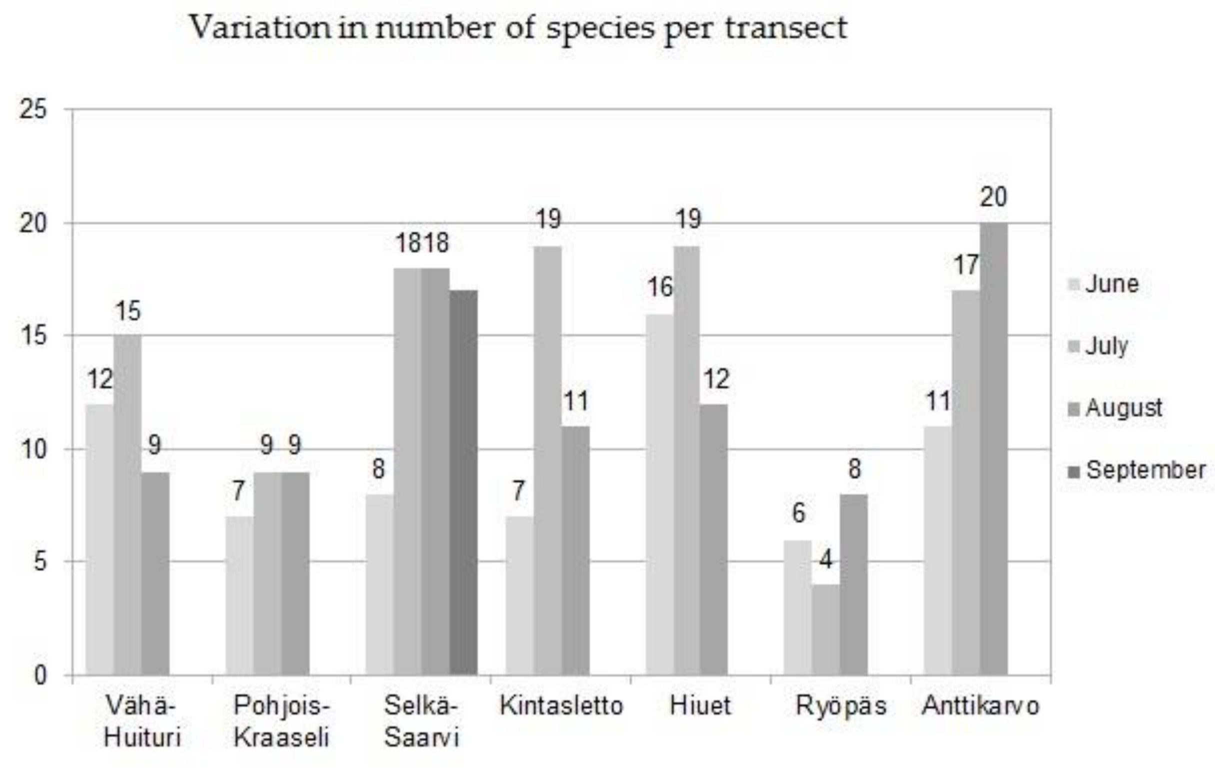

Figure 5. Variation in number of species per transect.

5 Discussion

The species composition and the species richness were found to vary according to progressing growth season, according to the bottom substrate and also due to north-south –location of the transect.

The findings from all seven transects indicate that, as was expected, there was a strong seasonal variation both in the coverage percentage and in the number of species. Each transect differs from one to another regarding the species, species richness and coverage of species. Despite the differences in the number of species, the seasonal variation has occurred in a similar way in all seven transects from north to south.

The amount and type of species found differed due to transect location and characteristics of location as well as the environmental factors and the bottom substrate. Some transects were located in a sheltered area while others in an exposed one, the bottom and depth were different in all transects contributing to differences between the species. Transects with rocky/hard bottoms (at least in the beginning) are Vähä-Huituri, Pohjois-Kraaseli, Kintasletto and Ryöpäs. The other transects are mainly sand/silt and soft bottoms. Nevertheless, there were some rocks almost on all transects and some soft bottom at deeper parts.

One important finding in this study was the two regionally threatened species of water moss on many of the northern transects (*Fissidens fontanus* and *Platyhypnidium riparioides*). By monitoring these transects in the future, these threatened species can be monitored.

5.1 Seasonal variation within transects

Even though each transect has its own type and number of species and different location characteristics, the variation between the monitoring months has occurred in a similar way, starting with June having a low number and species coverage percentage to August with a high species number and coverage in most of the transects. The flow between monitoring months has brought new species and let the ones left from June to grow bigger. This variation has a natural source and will be discussed in the next paragraph.

5.2 Environmental factors contributing to seasonal variation

The underwater growing season in Finland normally starts in mid-May and lasts until the end of September. This monitoring project started in the beginning of June. This early growth season could be seen in the amount of species, which was lower than during the following months. However, not all depends on the water temperature. Growth also depends on the type of vegetation on the transects. Water mosses are perennial and they overwinter. This explains why these species were found already in the beginning of the monitoring. However, if water mosses are not found, it can be because they have been scraped away by the ice during winter. Annual species like most vascular plants (*Potamogeton* species etc.) do not overwinter so they disappear at the end of the season and grow again in the spring. The vascular plants found in June within the different transects were still small and in small quantities, while in July they were bigger in size and coverage.

5.3 Differences between south and north transects

There were no major differences in seasonal variation between transects from the north and those from the south. As already discussed, the seasonal variation has occurred in a similar way for all transects. Nevertheless, one difference could be seen in the type of species growing in the different areas. Transects located in the south, Ryöpäs and Anttikarvo, have a lower number of bryophyte species compared with for instance Vähä-Huituri, which is located in the northern part of the Bothnian Bay and had three species during June, July and four species in August.

The differences are somehow surprising. However, it is important to remember the bottom substrate of these transects. Vähä-Huituri has a rocky bottom, Anttikarvo has a soft bottom and Ryöpäs has a rocky/exposed bottom. Usually water mosses can be found in all sorts of substrates but especially in rocky ones (Glime, 2007). Most of the bryophytes found within this project were found attached to rocks, like those on Vähä-Huituri transect. The only water moss found in the south transects was *Fissidens fontanus* (*Octodiceras fontanum*) and it was found in August at the last monitoring time in the Ryöpäs transect. Anttikarvo had two Bryophyta species but neither were real water mosses. Anttikarvo bottom substrate (silt and soft bottom) were not optimal for water mosses.

Also, North Bothnian Bay has usually much more species of water mosses compared to the South Bothnian Bay. *Fontinalis* species are again more common in the Quark area. Why they do not grow optimally in the South Bothnian Bay is still a mystery (Keskinen E. pers. com. 2016).

Salinity also plays an important role here. Some of the macrophytes found can tolerate salinity but not at a high level. Each species has its own salinity preference. A duck mussel *Anodonta anatina* was only found in the north transects because it is a fresh water species. *Najas marina* is a more saline water species and it is found at its distribution's northern limit at Anttikarvo transect due to the amount of salt.

5.4 Variation between divers and dives

Experienced divers can find and identify the species more easily than inexperienced divers. This is an important factor in monitoring. The results can be reliable if divers have experience and more importantly if they know the species. Usually a scientific diver who has done this job for a long time knows the species best, therefore the dive may take less time and the results of the monitoring can be trusted. In this project, divers were professionals and have previously been doing these kinds of jobs, which let us rely on their work. Moreover, Essi Keskinen, a professional diver and marine biologist, has identified the species the other divers could not identify at the time of the dive. Thus, data presented in this paper is reliable due to the reasons already exposed. Having said this, it is not guaranteed that all divers could find all species. Some species are very small and might be hiding under filamentous algae and go unnoticed.

However, even if the diver is experienced, there is one extra factor that may alter the results. Not all people have the same estimation range, which means all divers can make a different estimation of plant coverage, which may then alter the data, although not in a significant way.

Also, the water turbidity and color can change between the monitoring times so that sometimes the visibility is very bad and a smaller area might be inspected. A diver should monitor two meters on both sides of the transect but in case of very low visibility it is not advisable to venture far from the transect in order not to lose it and get lost. This might alter some results.

5.5 Recommendation for the future

Due to the importance monitoring programs have for increasing the knowledge on the underwater ecosystem of the Baltic Sea and therefore helping to improve the Baltic Sea / The Bothnian Bay state I consider that the monitoring of the seven transects should be done each year, preferably. If doing so is not possible, then at least every 2nd year. In many of the northern transects two regionally threatened species were found (*Fissidens fontanus* and *Platyhypnidium riparioides*), being this a notable reason to do the monitoring each year in order to check on the changes of such species.

The monitoring should be complemented with photo-quadrat techniques, this in order to provide a more precise picture of temporal changes. Moreover, the personnel conducting the monitoring should have experience of aquatic plant identification in order to give more reliability to the project. This will have a positive effect on the diving time required per transect.

Regarding estimations between divers, it would be good for the project if two divers did the monitoring and individually documented the plants seen and the coverage of those, to this way see if the data has any similarities, and thus guarantee that data is reliable for future uses.

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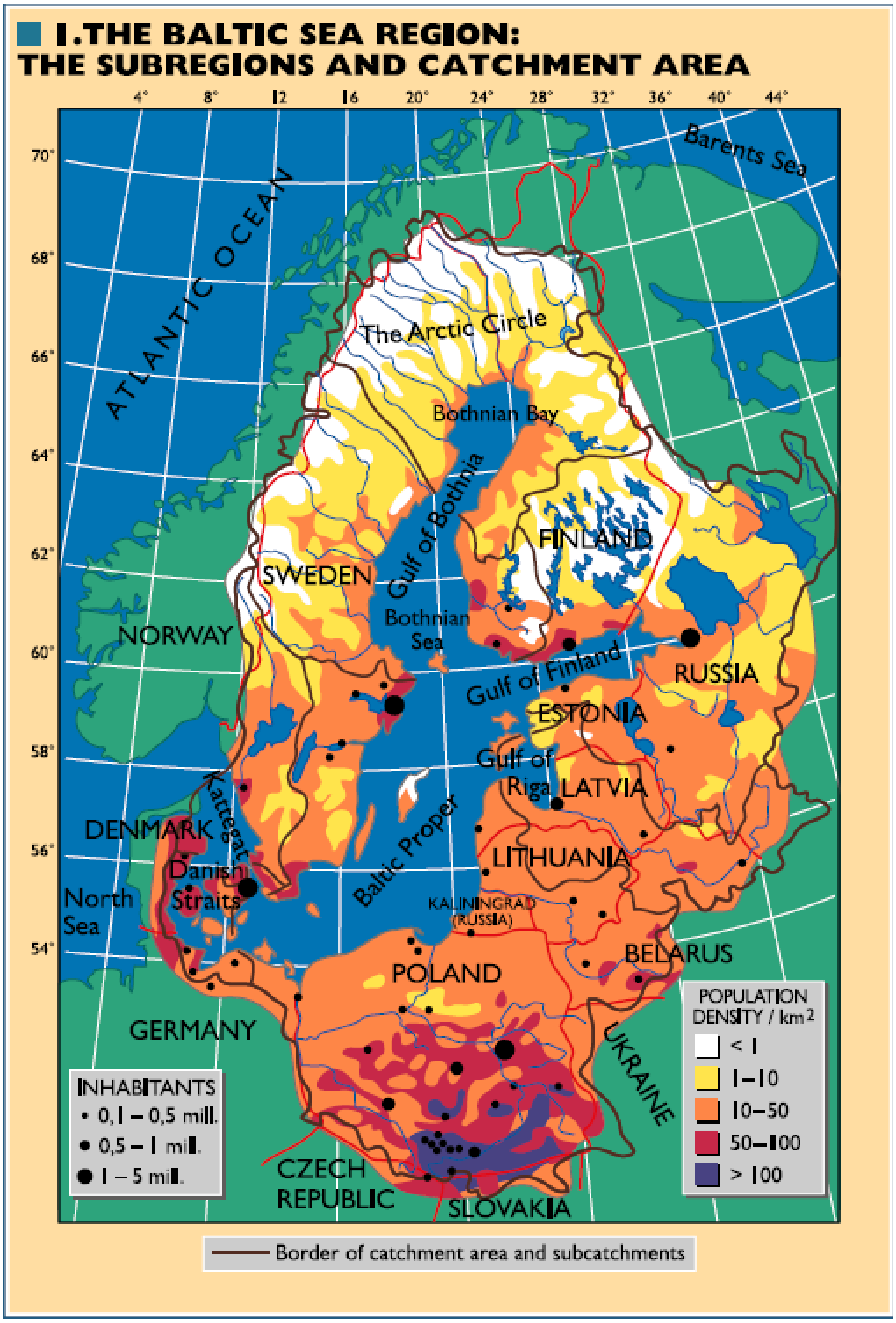
Appendix A

Baltic Sea catchment area (Source HELCOM)



Appendix B

Figure 1. *Bothnian Bay from Kokkola to Tornio with the established permanent monitoring transects. MPA stands for HELCOM Marine Protected Area (Natura 2000 site or a national park).*

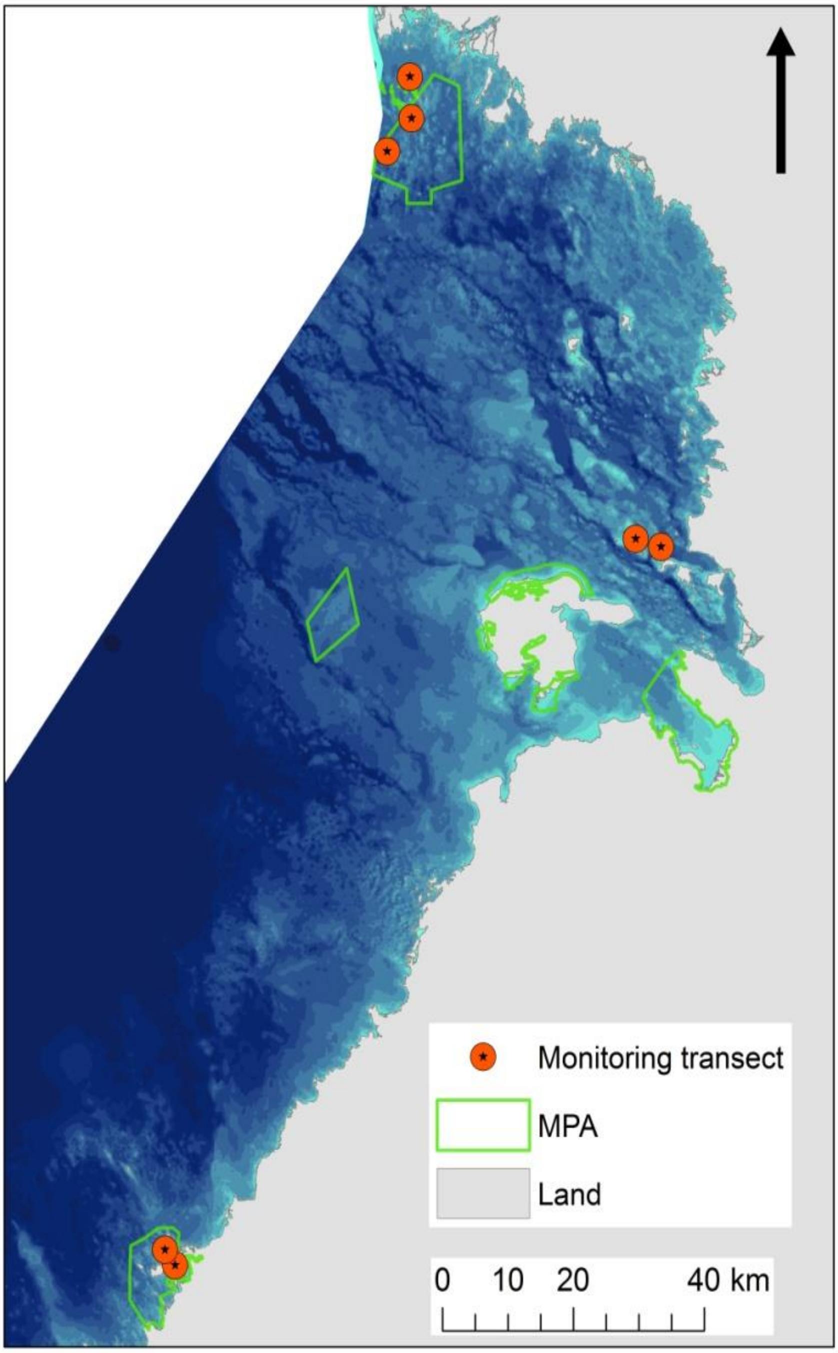


Figure 2. *Perämeri National Park with the established permanent monitoring transects. Vähä-Huituri 100 meters long, Pohjois-Krasseli 100 meters and Selkä-Sarvesta Maasarven 200 meters. MPA stands for HELCOM Marine Protected Area (Natura 2000 site and a national park).*

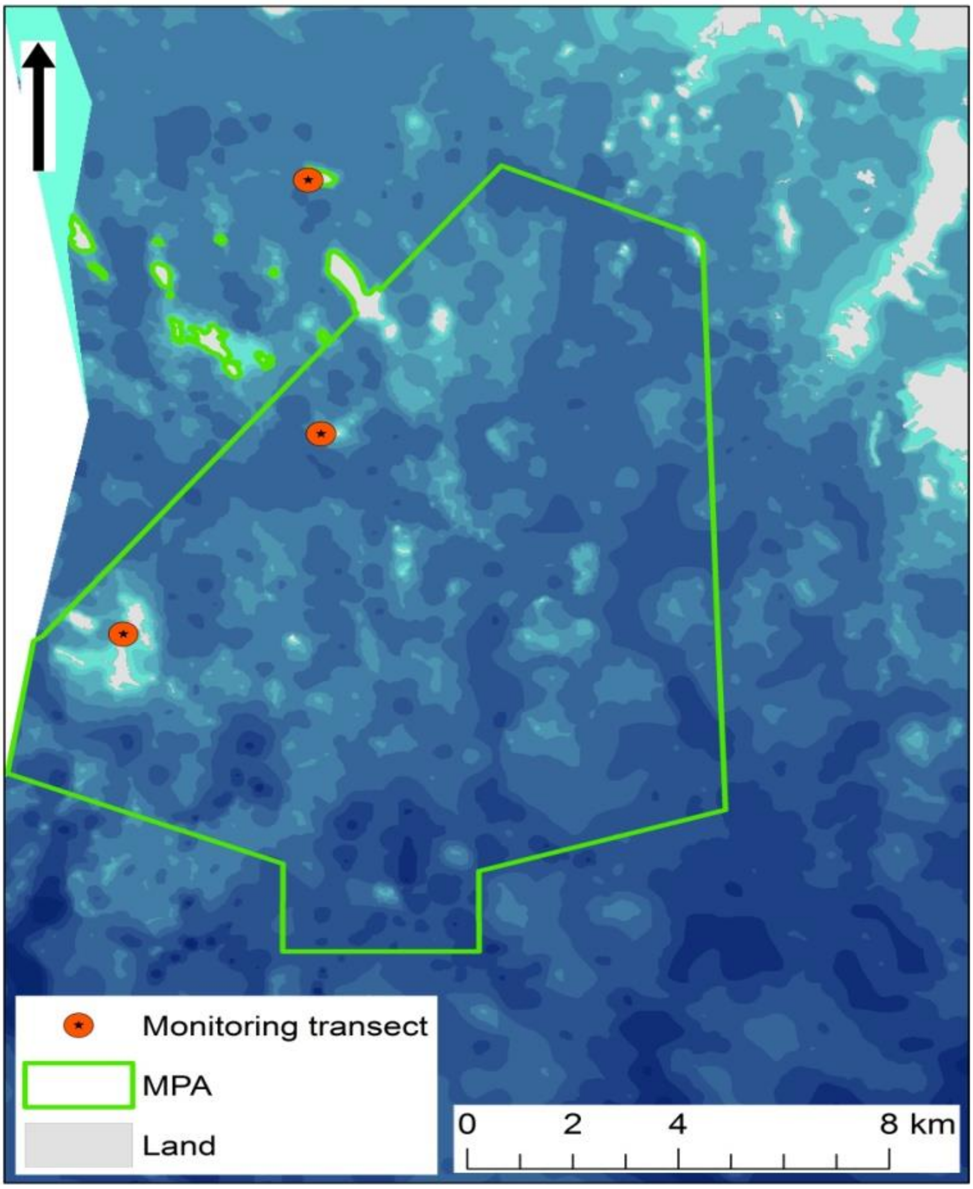


Figure 3. *Oulu established monitoring transects which are Kintasletto 300 meters long and Hiuet SE 100 meters. MPA stands for HELCOM Marine Protected Area (Natura 2000 site).*

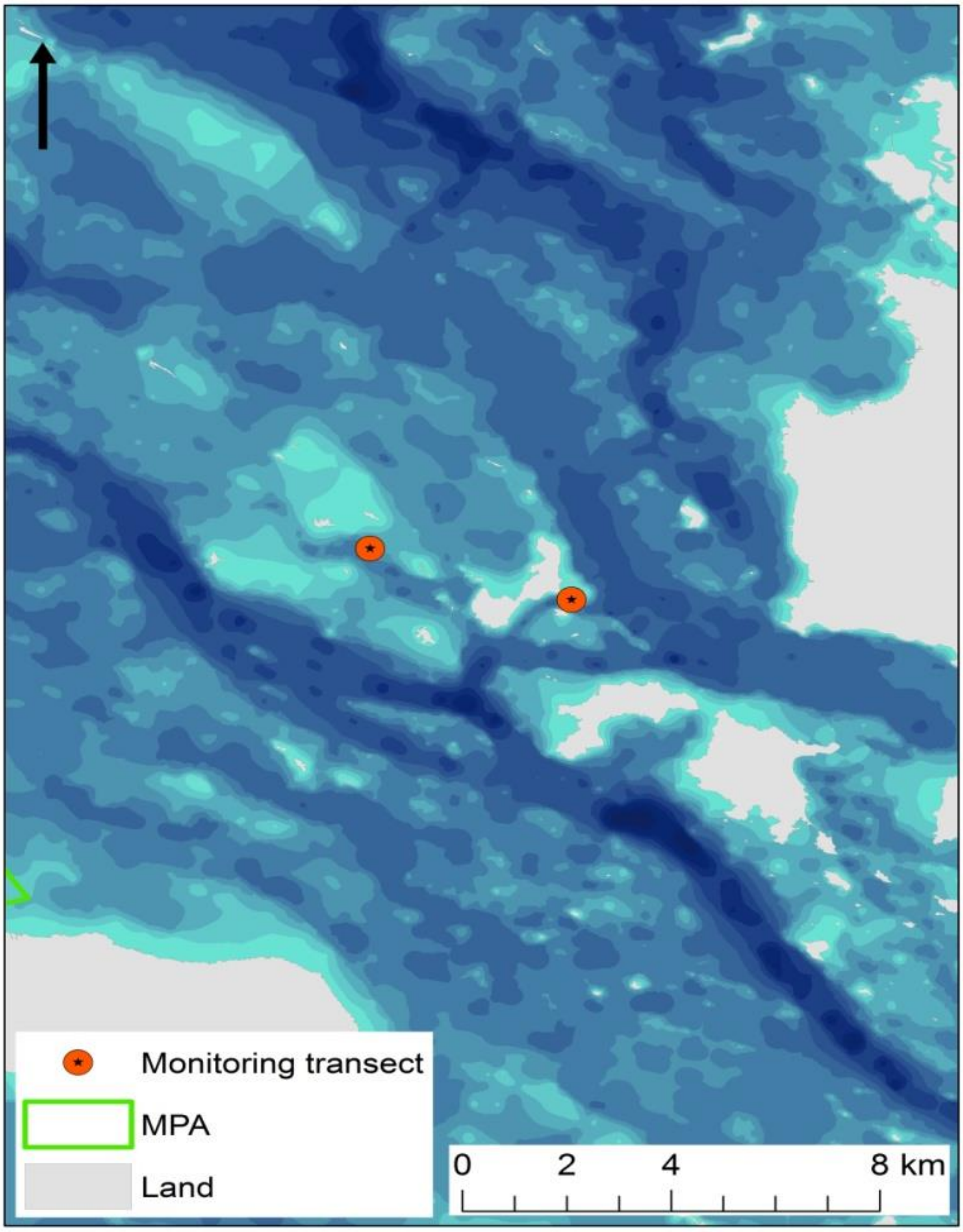
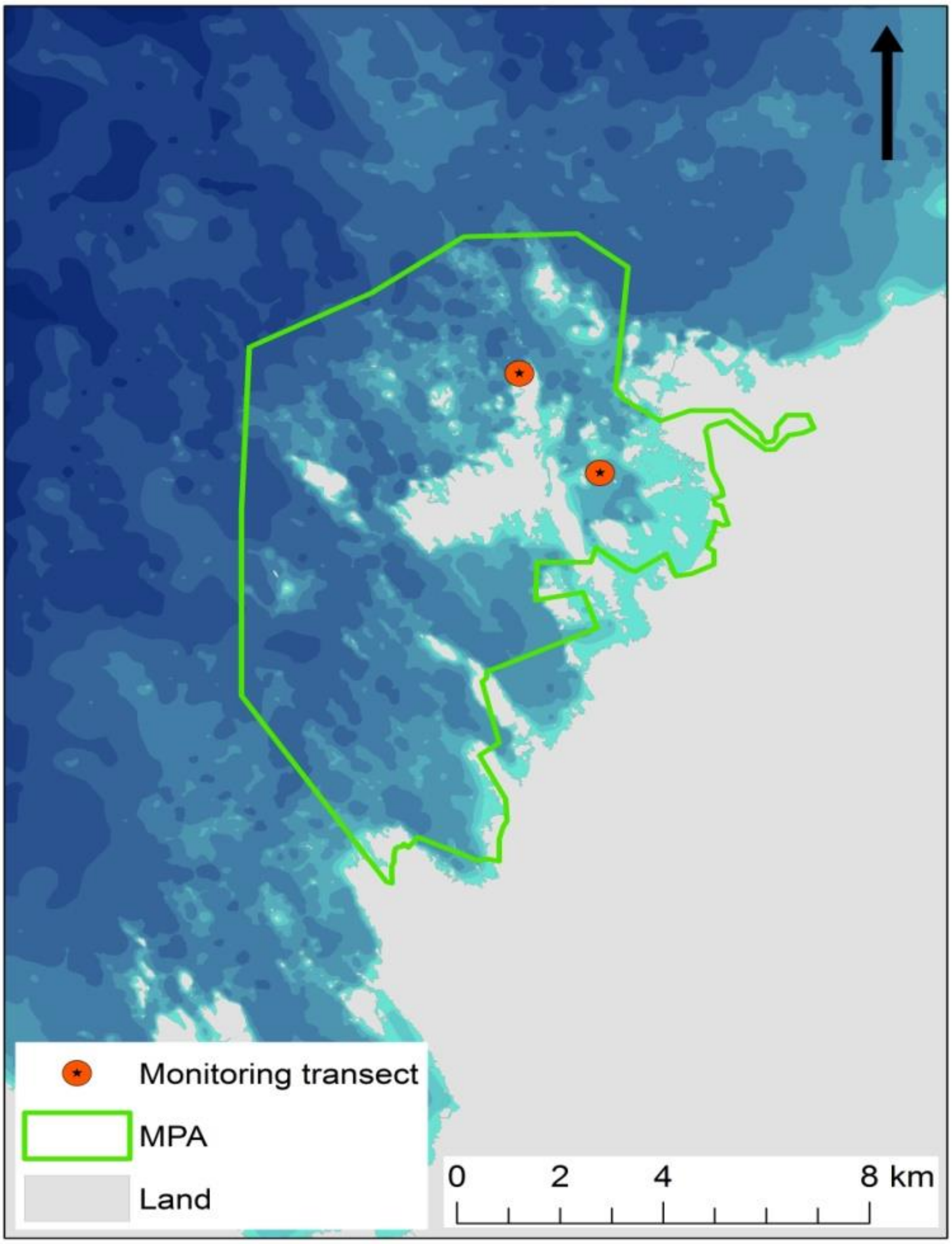


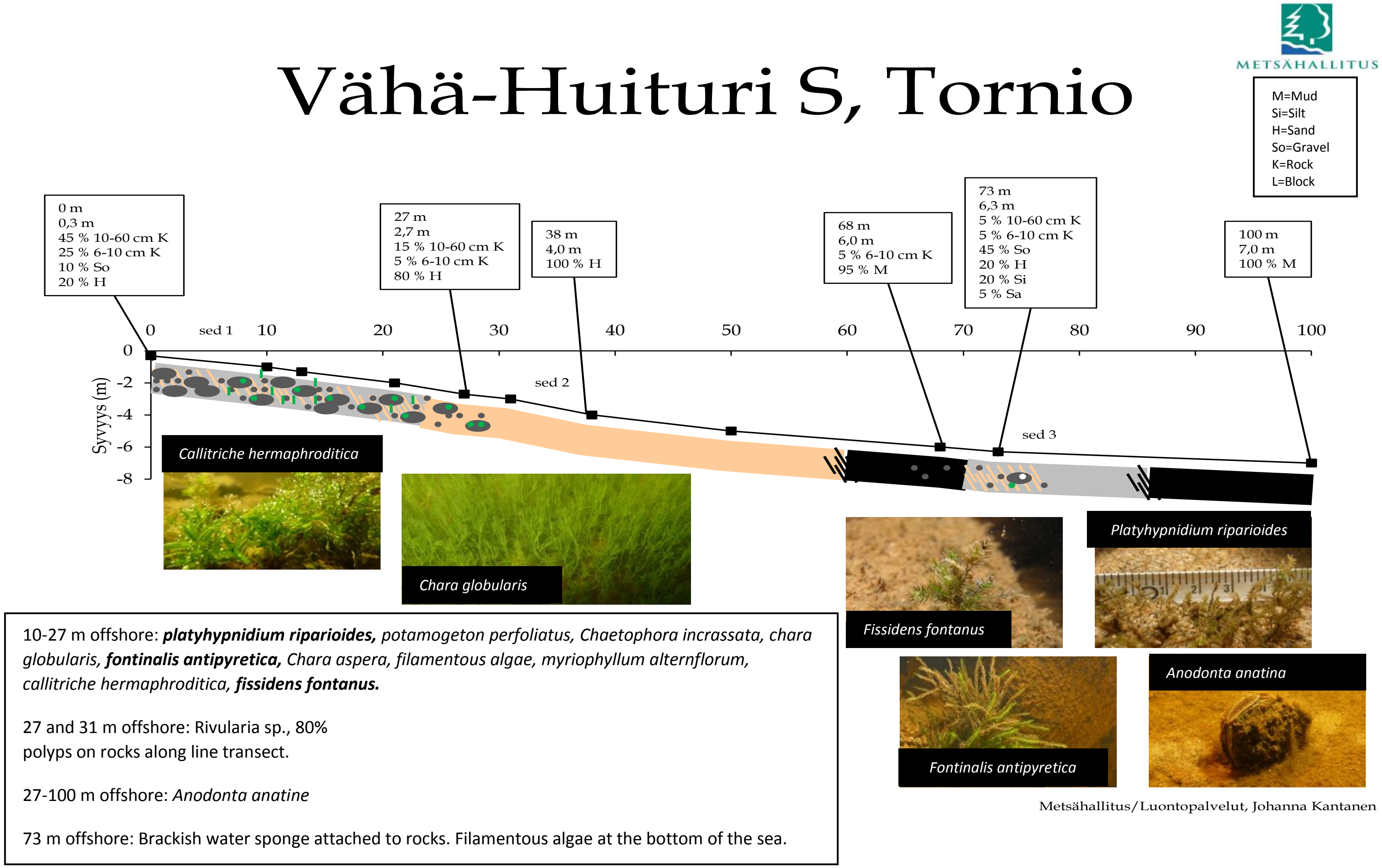
Figure 4. *Rahja archipelago established monitoring transects. Ryöpäs 100 meters and Anttikarvo 100 meters long. MPA stands for HELCOM Marine Protected Area (Natura 2000 site).*



Appendix C

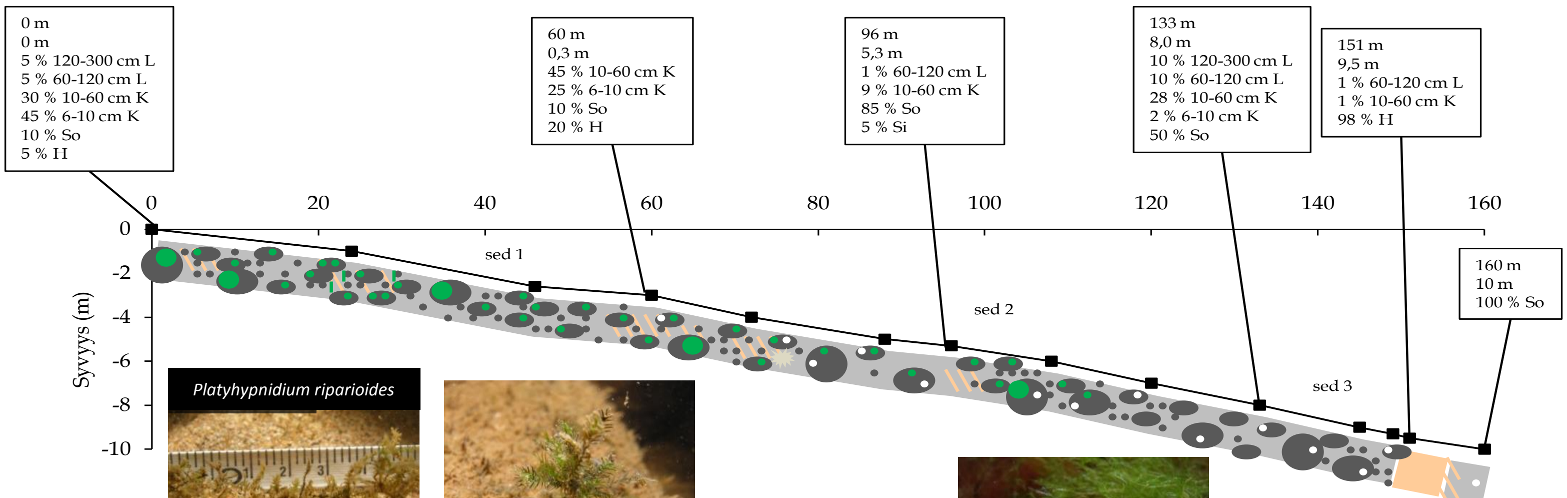
Substrate characteristics of the seven transects placed in the Bothnian Bay.

Vähä-Huituri S, Tornio, 100 meters line transect.



Pohjois- Kraaseli NW, Tornio, 100 meters line transect.

Pohjois-Kraaseli NW, Tornio



Metsähallitus/Luontopalvelut, Johanna Kantanen

0-88 m offshore: ***platyhypnidium riparioides***, *potamogeton gramineus, fontinalis antipyretica, fontinalis sp.,* ***filamentous algae***, *myriophyllum alterniflorum,* ***fissidens fontanus, cladophora glomerata.***

96-108 m offshore: ***platyhypnidium riparioides,*** *fontinalis sp.,* ***cladophora aegagropila, octodiceras fontanum.***

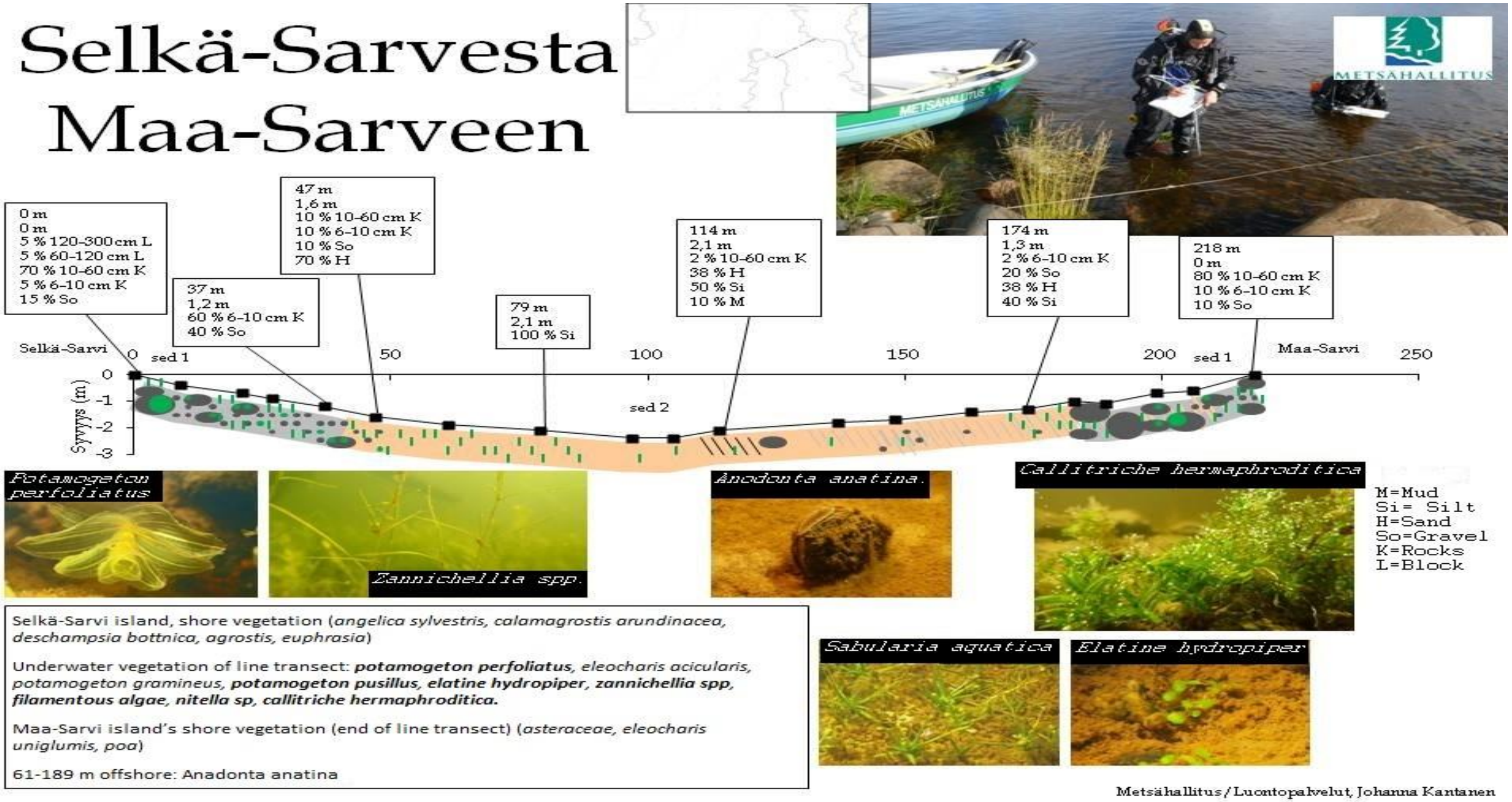
60-151 m offshore: Brackish water sponge attached to rocks

88-151 m offshore: Polyps

72 m offshore: *Isopoda*

88 m offshore: *Anodonta anatine.*

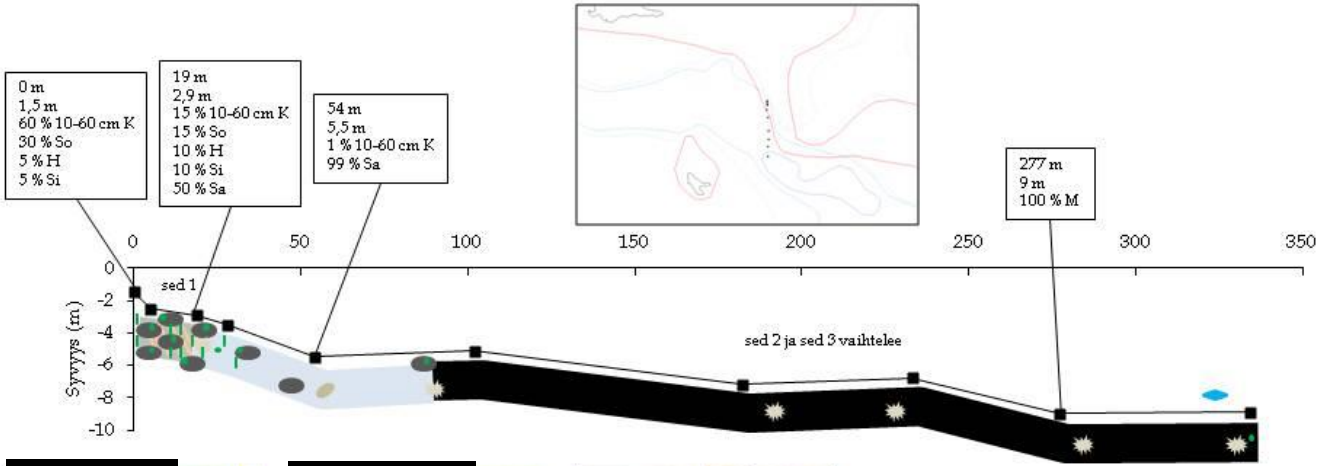
Selkä-Sarvesta Maa-Sarveen, 200 meters line transect.

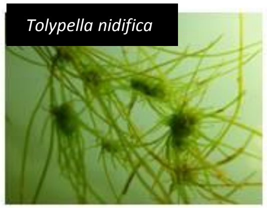


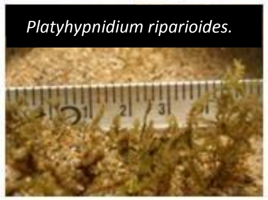
Kintasletto S, Oulu, 300 meters line transect.

METSÄHALLITUS

Kintasletto S, Oulu







M=Mud
Si=Silt
H=Sand
So=Gravel
K=Rock
L=Block

At the beginning (0-28m offshore): ***platyhypnidium riparioides,*** *potamogeton pectinatus, potamogeton gramineus, fontinalis antipyretica,* ***tolypella nidifica,*** *chara,* ***aegagropila linnaei, filamentous algae,*** *fissidens fontanus, cladophora glomerata, myriophyllum.*

54m offshore: *Anodonta anatine*

Isopoda was almost found throughout the entire line transect. At the end of the line a fish was seen.

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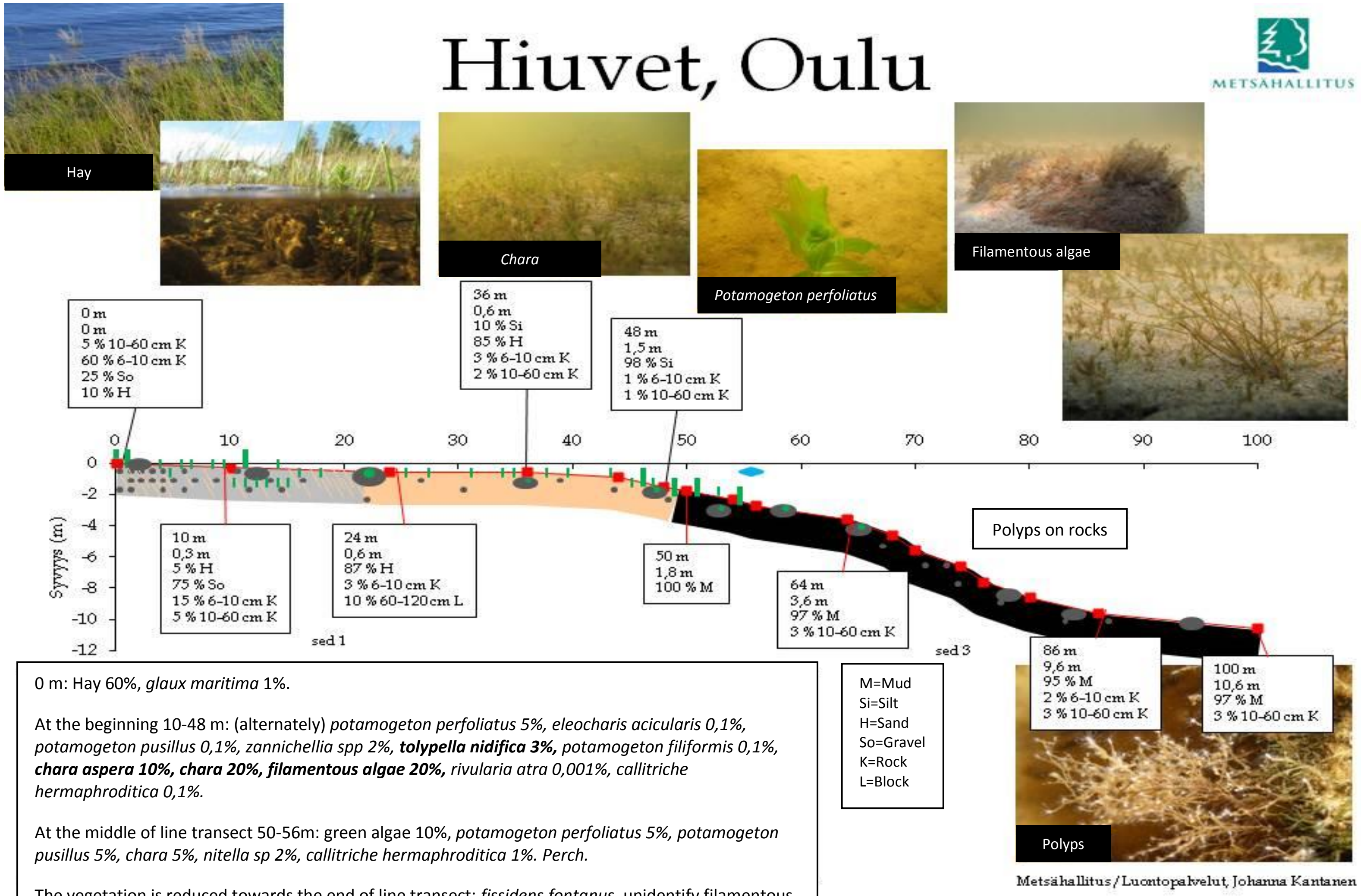
Hiuvet, Oulu, 100 meters line transect



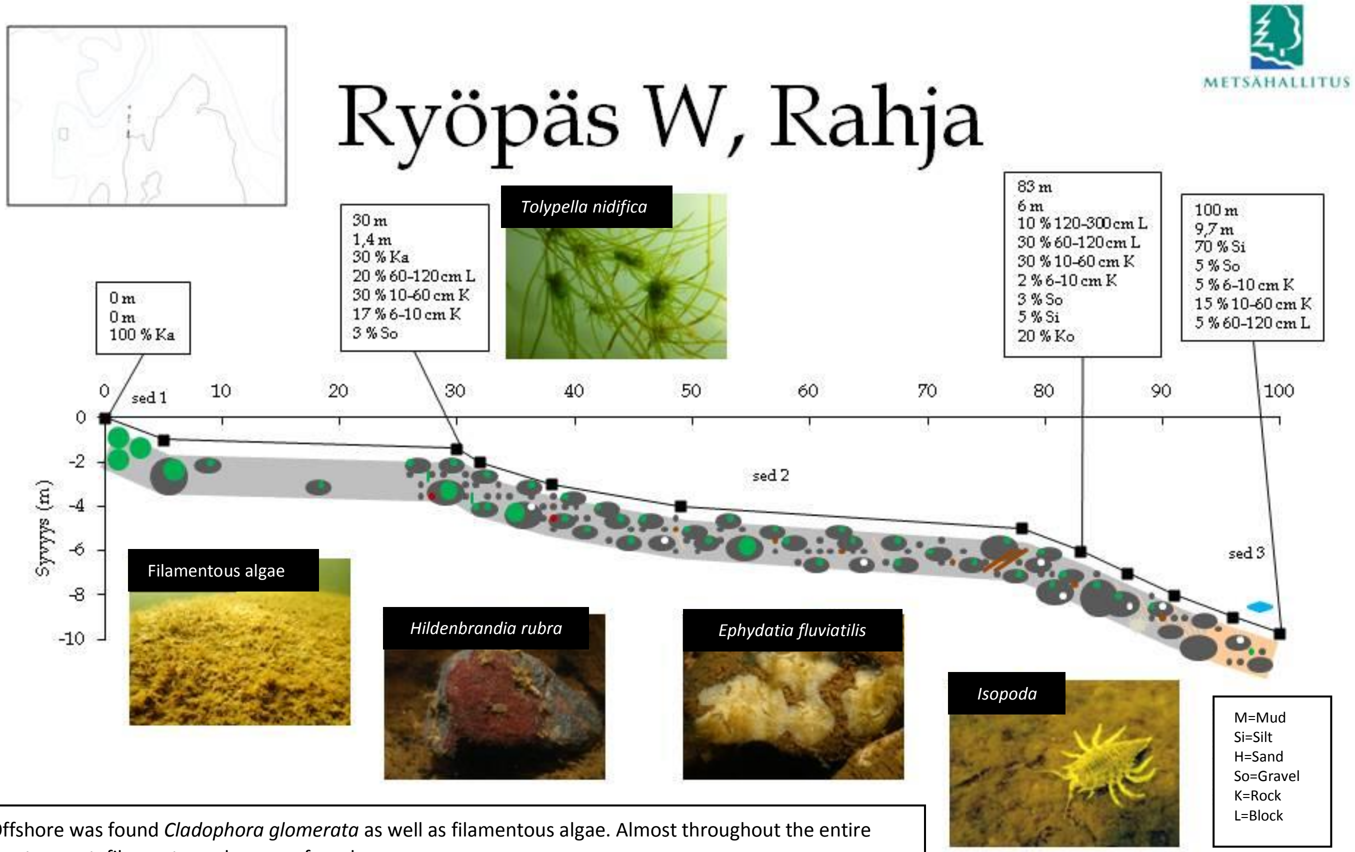
0 m: Hay 60%, *glaux maritima* 1%.

At the beginning 10-48 m: (alternately) *potamogeton perfoliatus 5%, eleocharis acicularis 0,1%, potamogeton pusillus 0,1%, zannichellia spp 2%,* ***tolypella nidifica 3%,*** *potamogeton filiformis 0,1%,* ***chara aspera 10%, chara 20%, filamentous algae 20%,*** *rivularia atra 0,001%, callitriche hermaphroditica 0,1%.*

At the middle of line transect 50-56m: green algae 10%, *potamogeton perfoliatus 5%, potamogeton pusillus 5%, chara 5%, nitella sp 2%, callitriche hermaphroditica 1%. Perch.*

The vegetation is reduced towards the end of line transect: *fissidens fontanus,* unidentify filamentous algae and polyps grows randomly on rocks.

Ryöpäs W, Rahja, 100 meters line transect.



Offshore was found *Cladophora glomerata* as well as filamentous algae. Almost throughout the entire line transect, filamentous algae was found.

30-32m offshore: *Tolypella nidifica and Chara.*

At the end of line transect a couple of *Isopoda* and fish were seen.

Ephydatia fluviatilis and polyps were attached to rocks.

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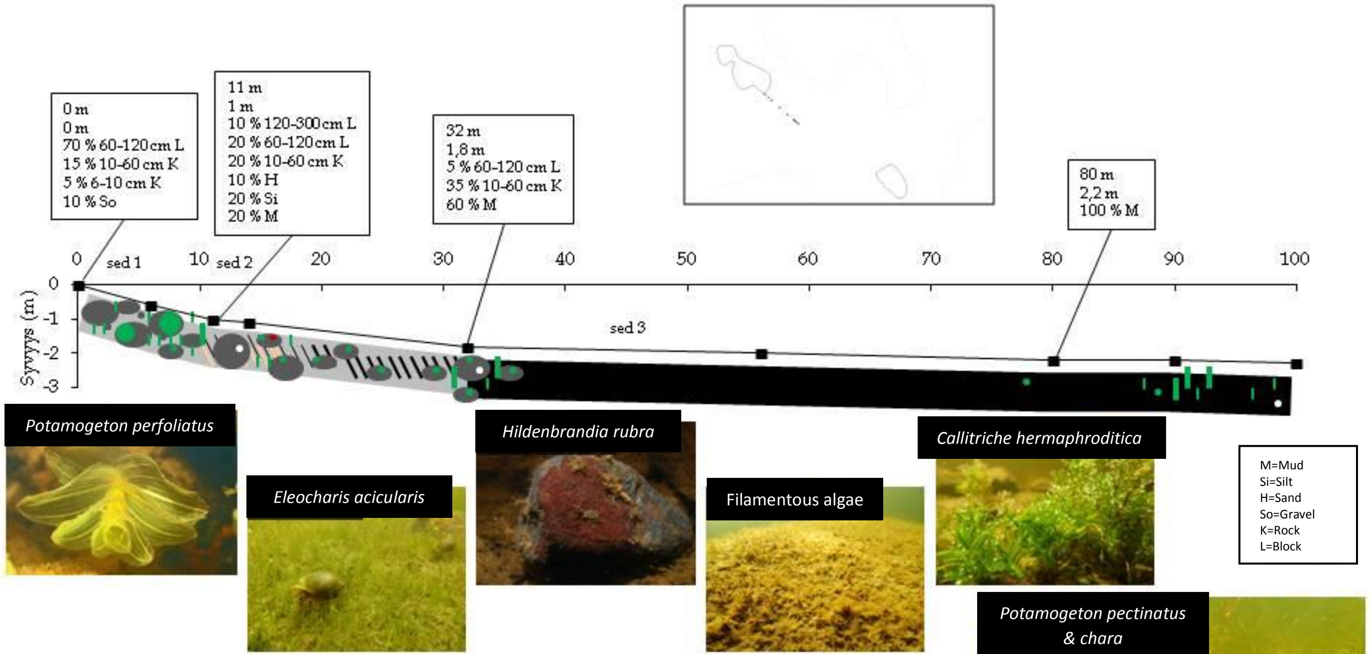
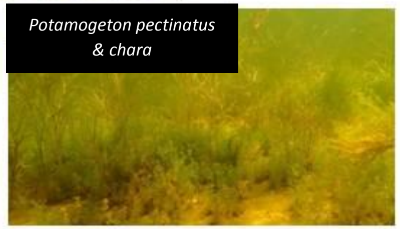
Anttikarvo NW, Rahja, 100 meters line transect.

Anttikarvo NW, Rahja





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Shore vegetation, filamentous algae.

0-32m offshore: *Potamogeton perfoliatus, Eleocharis acicularis, Potamogeton filiformis, Chara, Hildenbrendia rubra,* filamentous algae, *Rivularia atra, Callitriche hermaphroditica, Gastropoda.*

At the end of line transects (90-100m): *Potamogeton pectinatus, Chara, and* filamentous algae.

On rocks *Ephydatia fluviatilis and* polyps were found. Drifting filamentous algae at the bottom.