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An overview of different water quality monitoring methods

Comparison between ''Mobile'' and ''fixed station'' water quality monitoring methods.

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Abstract

It is critical to periodically monitor various sources of water, such as oceans, rivers, surface water, and ports, which is necessary for both persons and businesses who utilize it. Furthermore, it aids in the analysis of trends and keeping up to date in order to develop plans and strategies to enhance water quality and check that it meets the needed level. The purpose of this thesis is to investigate the applicability and utility of various water quality monitoring methods, such as manual, fixed, and mobile approaches, for assessing water quality in a fragmented, topographically complicated (archipelago) setting. We are particularly interested in comparing mobile-based and fixed-station monitoring methods.

The specific research questions we aim to answer are: How do the methods differ and for what purposes are they useful? How is the mobile monitoring method perceived by students in the sustainable coastal management study program?

To address the research question, multiple data types, such as open-source data and raw data, may be compared and interpolated into maps using ArcGIS Pro. Similarly, an opinion poll (questionnaire) assisted in gathering firsthand data to summaries how the procedures are evaluated by peers. According on a review of existing information and facts from many viewpoints, we conclude that; any methodologies are not alternatives, but rather complement one other according on the objective, landscape, and other significant variables of the study. More efficiently, the mobile monitoring approach can serve as a bridge between the two fixed stations that collect data for enhanced comprehension.

Language: English
Key Words: Fixed station, Mobile-based, Remote sensing, Water quality monitoring method

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1 Introduction

Water in oceans, lakes, rivers, glaciers, groundwater, rain, and snow is a vital resource covering 71% of Earth's land surface. It plays a vital role in living organisms and is increasingly studied for quality. To live a healthy and prosperous life, it is crucial to examine water quality to ensure the well-being of all living organisms (Toyin, 2019). Freshwater is one of the finite natural resources, crucial for agriculture, industry, and means of existence for humans and all living things (Toyin, 2019). On the other hand, human activities are the cause of negative impact on all environmental factors including the source of water. Human activities such as socio-economic factors, urbanization, industrialization, and agriculture are the major activities that immensely impact the source of water. In these circumstances, it is essential to safeguard the quality of water for the existence of humans and all living organisms. As well, we could say good quality water sources help to balance the entire ecosystem (Abbaspour, 2011). Hence, keeping track of the quality of water requires monitoring and acting in favor of it. According to the International Organization for Standardization (ISO), water monitoring is defined as ‘‘the programmed process of sampling, measurement and subsequent recording or signaling, or both, of various water characteristics, often to assess conformity to specified objectives’’ (Bartramand Ballance, 1996, WHO).

Traditionally water quality has been monitored by collecting water samples and shipping them to laboratories for analysis, which is highly expensive, time-consuming, and uses excessive human resources (Bogdon et al., 2023). The conventional method will not offer real-time data and the result may vary because of inaccuracy or mismatch of data entry. Modern water quality monitoring systems are portable and particularly helpful for extracting data on various variables instantly such as oxygen, pH, turbidity, conductivity, water level detection, atmospheric temperature and humidity, and continuous and real-time data (Bogdon et al., 2023).

Water quality is determined by its chemical, physical, and biological properties, and even minor changes can harm water-dependent species. Monitoring water characteristics like conductivity, pH, salinity, temperature, dissolved oxygen, and turbidity is crucial for maintaining its quality (Li & Liu, 2018). Water Quality Monitoring involves monitoring freshwater sources like rivers, streams, lakes, ponds, springs, reservoirs, groundwaters, cave water, floodplains, wells, and wetlands to ensure safe drinking and other human and animal activities (Adu-Manu et. al, 2017). Water Quality Monitoring systems regularly test water for safe chemical concentrations, with WHO establishing different targets to ensure safe levels of certain chemicals in water, and to raise alarms if they fall outside these limits (WHO, 2011). In the 2000s, water quality monitoring relied on manual methods for collecting and analyzing water samples. The research focused on network design, variables for measuring water quality, sampling locations, and sample frequencies. Objectives, strategies, and techniques were identified for water analysis. Researchers emphasized the need for fixed sampling stations for convenient access and consistency in sample collection (Sanders, 1983; WHO, 2011; Strobl and Robillard, 2008).

In general, the way we acquire information regarding concern about the condition of the streams, lakes, bays, inlets and coast is recognized as water quality monitoring. In other words, the monitoring of water answers whether the mentioned source of the water is safe enough to swim and play, or useable for drinking purposes or not (EPA, 2023).

1.1 History of water quality monitoring in Finland

The Finnish Environmental Institute (SYKE) is the official agency for water monitoring and protection of it. Regarding knowing the status of the water body of the Finnish territory, SYKE began long-term observation of inland waters, for instance, rivers, lakes, and groundwater from the 1960s. Actual monitoring work has been conducted by the ELY-Centers (Centers for Economic Development, Transport, and the Environment), however, the main coordination role belongs to SYKE (SYKE, 2023). Long-term observation discloses the effects of eutrophication, harmful substances, and climate change that have occurred in the water systems. The revealed information regarding the water quality assists in the assessment of the condition of water resources and helps to predict the future development plan, effectiveness of the protection action, and recommendation for new actions plan (SYKE, 2023).

In the case of marine biology including water, quality monitoring history is associated with Research Vessel Aranda. If we go back to the initial story of marine research in 1903 marine scientists accessed to steamship Nautilus which was used by the Institute of Marine Research established after Finland’s independence until 1938 (SYKE, 2023). Then after the first Aranda 1939-1945, the second Aranda 1953-1989 and the third Aranda is serving after

1989 to date. Different methods are used for coastal study for example, automatic measurement, research vessels, and boats walking and wading, diving and snorkeling, underwater videos, echo sounding, in the laboratory, and modeling (SYKE, 2023).

1.2 Purpose of water quality monitoring and its benefits

It is important to regularly monitor different sources of water, for instance, seas, rivers, water on the surface, and in ports, which is essential for both individuals and companies who use it. Monitoring programs help to assess the information regarding the water and how it changes. Furthermore, helps to analyze the trends and keep them updated to make plans and strategies to improve the quality of water to confirm the required standard (SINAY, 2021). Hence, according to the 'US Environmental Protection Agency' the reason or purpose for conducting monitoring is as follows (EPA, 2023):

- Identify variations or trends in water quality over time by characterizing waterways.
- Recognize particular present or emerging water quality issues.
- Gather data in order to create particular pollution control or remediation program's
- Establish the program's objectives.
- Respond to situations such as spills and floods.
- Meeting and exceeding international water quality criteria.

1.3 Water quality monitoring system

In general water quality parameters are divided into chemical, physical, and biological properties (Usali and Ismail, 2010). Temperature, Color, Turbidity, and Odor refer to physical properties of the water (Shifrin, 1998). Similarly, the water molecule, on the other hand, is affected by chemical properties, such as pH, dissolved oxygen, total solids, and suspended particles (Akinde and Obire 2011). The biological properties of water contain the factors that affect the obtainability of water as a solvent (Mohseni, et al., 2022). Furthermore, these three chemicals, physical, and biological parameters can also affect each other. For instance, Chlorophyll-*a* impacts the amount of vegetation, and the suspended particles influence the color and the temperature of the water (Mohseni, et al., 2022). Therefore, ‘‘water quality monitoring can be defined as a method for sampling and analyzing water condition and characteristics’’ (Adu-Manu et. al, 2017). Hence, if we take water quality monitoring as a system approach, then we can divide it into two systems i.e., manual and modern based on the activities that are practiced, technologies, and methods that have been used.

1.3.1 Manual water quality monitoring

During the period from 1960 to 2000 water quality monitoring was mainly based on the manual approach. Human resources would significantly mobilize to a water source, to take samples as necessary, and transport samples to a laboratory for analysis. The research regarding the water quality monitoring followed a general framework, that contained the identification of the objectives and strategies based on the specific techniques used for the analysis of the water quality. Furthermore, that framework includes designing the network, deciding to select the water quality variables going to be measured, and selecting sampling sites and the frequency of samples (Sanders 1983). Due to the difficulties of the entire task related to the water quality monitoring gradually researchers emphasized establishing **fixed monitoring stations** for easy access to the selected water body and consistency of the sample collection (Adu-Manu et. al, 2017). Hence, traditional manual water quality monitoring systems have several limitations, and remain errors due to different sources and factors that are listed below (Adu-Manu et. al, 2017).

- Human mistakes in the form of misidentification and cross-contamination during the collecting of water samples.
- Inaccuracy in the outcome due to several variables that were present from sample collection to testing, such as the kinds of containers used, storage, transit, and environmental elements like temperature.
- Errors that can be caused by malfunctioning or improperly calibrated laboratory equipment.
- Mistakes that may occur during the reporting phase, such as round-off mistakes, statistical flaws, and data manipulation possibilities.

1.3.2 Modern water quality monitoring

Beginning in 2000 new and advanced technologies were initiated to address the limitations that exist on manual water quality monitoring systems. The sensors that were developed to incorporate fiber optics, laser technology, biosensor, optical sensors, and microelectronic mechanical systems to detect water quality parameters at the time of sampling (Bhardwaj et al. 2015). In the meantime, obtaining and monitoring the data process also introduced computing and telemetry technologies. The objective of the new systems of water quality monitoring is to introduce updated automatic monitoring points that help to collect and analyze water samples continuously or periodically in comparison to the existing manual water sample collection from fixed sampling (Adu-Manu et. al, 2017). Furthermore, there is continuous improvement ongoing on the modern WQM systems and have been developed wireless sensor networks (WSNs). The main achievement of the WSNs is the effectiveness of capturing, analysis, and transmission of environmental data from several sampling points. Therefore, this method significantly helps decision makers to obtain the data from several remote sensor devices promptly. Hence, the goal of the modern approach to water quality monitoring is to overcome the limitations of both traditional manual lab-based (TMLB) and traditional manual in situ (TMIS) are as below (Adu-Manu et. al, 2017).

- Reach a high level of selectivity and sensitivity.
- Have on-site, real-time detection of water quality metrics.
- Enable local analysis of the data from the distributed sensors and provide distributed sensing of the water body.
- Offer an extended operational lifespan.

The method that had been practiced in initial days of the water quality monitoring system to the method that have been introduced these days contain several important phases. Hence, the evolution of the water quality monitoring system is described as below.

Traditional manual lab-based water quality monitoring approach

The role of the human is very important during the traditional manual lab-based water quality monitoring. Every single step of the monitoring process human should be the key factor. A person goes to the source of water, take sample of the water fulfilling all field and sampling protocol and finally bring the sample at the lab for measure the result is the summarization of the traditional manual lab-based water quality monitoring approach. At this stage there is not invented any sensor that can measure the quality of water at the source of water. Therefore, all measurement of the water quality sampling is only possible at laboratory (Adu-Manu et. al, 2017).

Traditional manual in situ water quality monitoring approach

Along with the time technological innovation rapidly happing in every sector. Hence, in this stage the sensor has been developed that can measure the water quality parameters at the source of water. To operate and measurement the quality of the water through this kind of sensor required the human effort. However, it makes possible to get the water quality result at the time of measurement (Adu-Manu et. al, 2017).

Wireless sensor network-based water quality monitoring approach

Continuous development and innovation breakthrough in water quality monitoring when the wireless sensor has been introduced. From here, wireless sensor helps to eliminate the role of the human that required in every step of the water quality monitoring in traditional manual lab-based approach. However, there is still applying both manual lab-based and manual in situ method as per the objective and requirement (Adu-Manu et. al, 2017).

2 Different water quality monitoring methods

In terms of technology, there are primarily three approaches to monitoring water quality that exist right now. These are labor-intensive manual sampling, remote sensing, and real-time water monitoring which contain mobile water quality monitoring (using an autonomous robot and cutting-edge technology), and fixed monitoring station building in water bodies (Chen et al., 2021). Hence, we are going to focus our discussion on fixed station and mobile monitoring in this chapter. Additionally, we are going to describe actual practice and some more information related to remote sensing.

2.1 Fixed station monitoring method

Most of the monitoring activities are conducted at regular sites i.e., ‘fixed stations’ continuously especially at the selected site based on the need to answer the specific questions. Moreover, the fixed stations are established based on the characteristics of the watershed, on a temporary or seasonal basis for example during the summer at bathing beaches, similarly random sites among the area or state, or on an emergency basis. Hence, the objective of the monitoring efforts is to conclude the condition of the entire watershed area drained by rivers, lakes, and estuaries. As a result of land-based activities, water drains off the land itself, and all kinds of water bodies are connected, marking the end of the impact discussed (EPA, 2023). The current monitoring systems, such as HELCOM's recommendation of 12 grab water samplings annually, are likely to miss most high-flow events, leading to inaccurate loading estimations. This inaccuracy is more pronounced in smaller basins with sharper flow peaks. The impact of protective measures is difficult to quantify using current monitoring techniques. New water quality sensors offer more accurate estimates, but more innovation is needed to monitor the overall effects of water protection initiatives (Lital & Tattari, 2022).

Therefore, we may split into the following two groups depending on the type of sample activities that are conducted using the fixed station technique and their practices.

2.1.1 Continuous monitoring method

Continuous monitoring often refers to fixed stations that keep an extracting continuous result and display instantly and visibly of the quality of the water. MONICOAST is one of the various methods and stations that have been set up for this type of monitoring (Tvärminne zoological station, 2023). The MONICOAST system is designed to monitor coastal water from its location and provide real-time data to an internet site. It is feasible to monitor changes in the sea's temperature, salinity, oxygen content, pH, and turbidity with this technique (Tvärminne zoological station, 2023). On the Hanko peninsula, outside the Tvärminne Zoological Station, there is one station of it. Furthermore, an automated data logger system has been implemented to record coastal ecosystems, such as bladderwrack belts, mussel beds, and seagrass meadows. With the latest technological advancements, MONICOAST can now transmit underwater images, movies, and 360-degree virtual reality films of coastal environments (Tvärminne zoological station, 2023). The online live data transfer mechanism has been disrupted due to the removal of the surface signal during the winter season. Still, there are loggers in the water that take measurements every fifteen minutes and save data that will be accessible in the spring when the sea ice melts (Tvärminne zoological station, 2023).

2.1.2 Time interval monitoring method

When looking up past data on water quality, we discovered that there is a fixed station where water monitoring is done regularly. The Finnish Environment Institute (SYKE) and the Finnish Meteorological Institute have been making similar observations on the water quality. An example of such data is descried in Table 1.

Table 1. Salinity data from the fixed station of the year 2022

time	analyteName	value	unit	siteId	site	siteLatitudeWGS84	siteLongitudeWGS84
2022-02-21T13:05:00+02:00	Salinity	2.4	psu	3563	Dragsviksfjärden 87	59.98012	23.50929
2022-06-01T11:29:00+02:00	Salinity	1.3	psu	3563	Dragsviksfjärden 87	59.98012	23.50929
2022-07-26T11:19:00+02:00	Salinity	2	psu	3563	Dragsviksfjärden 87	59.98012	23.50929
2022-08-24T10:31:00+02:00	Salinity	2.3	psu	3563	Dragsviksfjärden 87	59.98012	23.50929
2022-10-10T12:47:00+02:00	Salinity	3.5	psu	3563	Dragsviksfjärden 87	59.98012	23.50929

(Source: ITÄMERI.FI)

The table was obtained from the Itämeri.fi website, which offers the ability to select various water variables for various periods and stations. We have selected the "salinity" variable for the station called "Dragsviksfjärden 87" during the period of 2022-01-01 to 2022-12-31 for this purpose. Following all of the data retrieved above, salinity has only been measured five times a year; as a result, this is the ideal illustration of time interval measurement under fixed station conditions (Table 1).

2.2 Mobile monitoring method

The combination of route planning, self-navigating, remote monitoring, and real-time water quality monitoring results in a mobile water quality monitoring system. The shipboard system, the LoRa (long-range) gateway, and the monitoring terminal are the three primary steps of these systems (Chen et al., 2021).

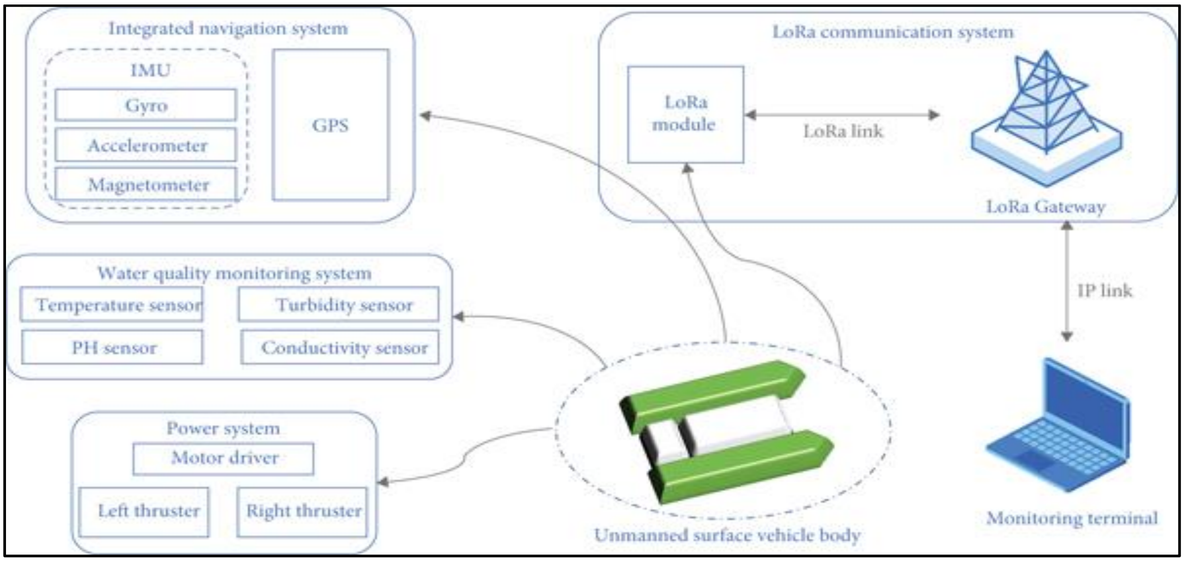

Figure 1. The mobile water quality monitoring system (Chen et. al, 2021)

The basic idea of a mobile monitoring system is represented by the steps in the above picture. Depending on the goal and extent of the monitoring, however, additional technologies may be added to or subtracted from each stage (figure 1). As a result, several practical monitoring techniques have been developed and possibilities of development many more based on the stated methods. Hence considering the objectives and unique characteristics of each landscape these techniques may contribute to each other. Among them, here we are going to describe two approaches that have already been developed and applied as follows.

2.2.1 Coastrider monitoring method

"Coastrider," is a method created and used by the organization Pro Litore, is an illustration of a mobile system. The Coastrider approach is a precise and thorough assessment of the loading of coastal waters at a particular time and location that is based on the measurement of water quality. By utilizing research and creative thinking, the project investigates water regions that have never been visited before, with a particular emphasis on inner and middle archipelagos, the climatic effects of marine settings, and delicate habitats.

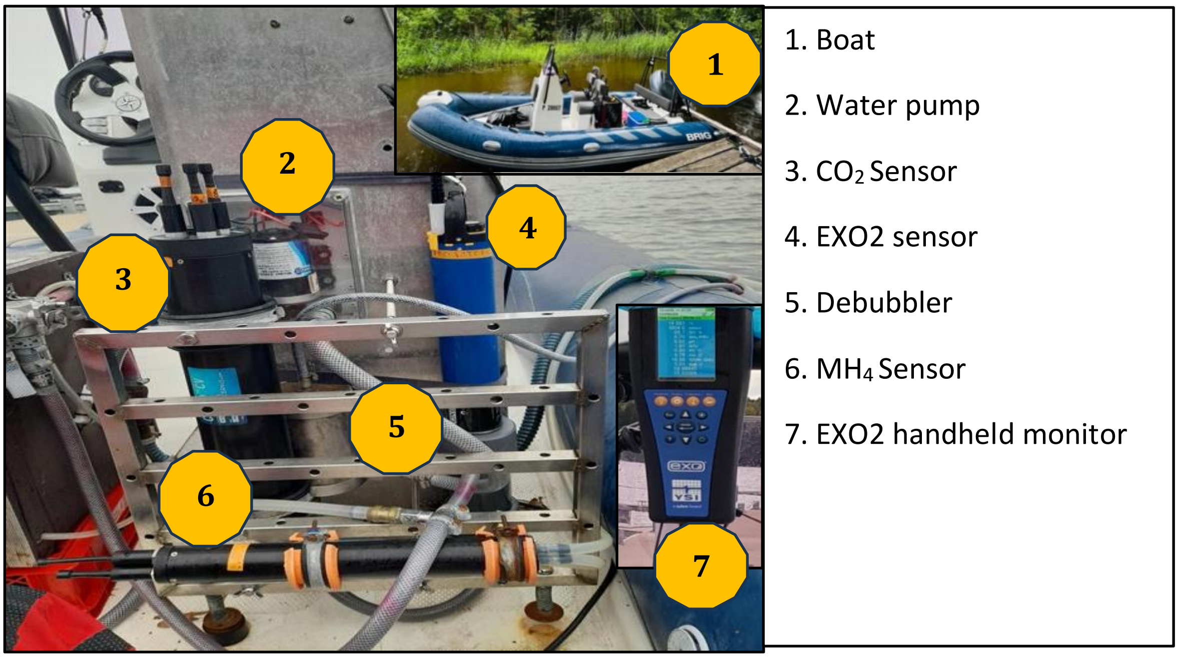

Figure 2. Assembled instruments and sensors.

When recording water variables on sensors, it's crucial to adjust the time lag to cover the anticipated regions and outcomes. The placement of the equipment in the boat has been designed by Dr Matias Scheinin and collaborators. One crucial component is the Debubbler, which removes bubbles from the water supply by pumping water down the pipe to the sensors.

The boat records observations for each variable at 5–60-meter apart, encompassing both the outer and inner archipelagos, shallow bays, and straits. The precisely designed and pre-determined route generates a considerable amount of data that must be processed thoroughly before examination. The data from multiple sensors is synchronized by GPS position and time. The hydraulic characteristics and reaction times of the sensors are adjusted by adjusting the flow-through system's hose length to 10 seconds difference (Scheinin and Asmala, 2020). The process involves adjusting measurement data for the total delay and dividing observations into five seconds intervals. Some variables, such as the concentration of soluble organic matter (fDOM), must be adjusted for temperature and turbidity. Other critical indicator variables, like chlorophyll-*a* and turbidity, are calibrated using water samples from the same flow-through system as the Coastrider sampling. Data can be analyzed using GAMs and PCA, with most analyses conducted in Rstudio. The data is then analyzed after all procedures have been completed. The analyses are visualized in

ArcGIS and interpolated using the diffusion kernel approach, considering land areas and measurement distance (Scheinin and Asmala, 2020).

The Coastrider approach, a precision-based method that complements remote sensing and model-based methods, is used to produce final items after completing various processes, thereby addressing significant gaps in coastal environment management (ProLitore, 2023. The material provides a robust foundation for assessing geographical and seasonal variations within a survey region through repeated measurements, as demonstrated in Havsmanualen 2 & 3 (ProLitore, 2023).

2.2.2 Ferry-box monitoring method

Another mobile monitoring device is the Ferry-box approach, which has flow-through systems—commonly referred to as "Ferry box"—with a 200-meter spatial measuring resolution. how the Global Positioning System (GPS) is used to capture data under geo-reference logging. The Alg@line network of the Finnish Environment Institute (SYKE) operates a ferry box in the Baltic Sea to monitor the water's condition and identify algal blooms. Millions of observations are gathered from the Baltic Sea every year with the assistance of the fleet of ferries run by shipping firms. Consequently, Ferry Box provides a laboratory analysis service in addition to real-time data collection based on mobile techniques (FINMARI, 2023).

2.3 Remote sensing monitoring method

In its simplest form, remote sensing of water quality monitoring refers to the process of gathering spatial and temporal data of vast waterbodies using optical and thermal sensors that may be installed on satellites, boats, or airplanes (Ritchie et al., 2003). Similarly, the technique of employing reflected and emitted radiation to locate and monitor physical attributes at a distance is known as remote sensing. More visibility is available than with ground-based approaches when researchers utilize cameras to take pictures of the Earth's surface, the ocean floor, and temperature fluctuations (USGS, 2023). Only data from a given time and place can be obtained by in-situ data collection, which involves measuring the water quality parameter at the moment of sampling. It is not feasible to extract the temporal and geographical fluctuations of water quality indicators in large-scale waterbodies using this method, though. The remote sensing technique of sampling, which is described below, must be adopted and used due to the many limitations connected with other methods of water quality sampling (Gholizadeh et al., 2016).

- On the other hand, compared to the in-situ sample technique, the remote sensing method needs less time, money, and labor.
- In large-scale waterbodies, it is challenging to use the in-situ approach to collect data on the temporal and geographical variations in water quality trends.
- It is impossible to routinely monitor, forecast, and manage the complete water bodies using other means because of the earth's diverse geography.
- The correctness of the data collected using the in-situ approach is unclear due to the possibility of error in both laboratory and field samples.

As a result, it is imperative to use remote sensing to overcome the mentioned limitations of existing water quality monitoring techniques. The quality of inland water, lakes, the open sea, and other bodies of water have all been monitored and assessed by researchers using this approach for many years. Apart from its inherent advantages, remote sensing is insufficient for evaluating the quality of water. Collaborating and coordinating with other conventional and contemporary methods of water quality monitoring was thus necessary to validate the findings (Gholizadeh et al., 2016). But as stated below, Kallio has listed the advantages of using remote sensing in conjunction with other potential techniques for monitoring water quality (Gholizadeh et. al, 2016).

- Provides a comprehensive collection of historical data records of the water quality of the required area that represents trends over time.
- Helps determine the sampling location and field surveying times.
- Unlocks the synoptic view of the entire water body for more effective and efficient spatial and temporal variation quality monitoring.
- Synchronizes the water quality from remote and large-scale water bodies like lakes, rivers, and open seas.

3 Objective

This thesis aims to explore the application and usefulness of different water quality monitoring methods such as manual, fixed, and mobile approaches for assessing the water quality in a fragmented, topographically complex coastal (archipelago) environment. We are particularly focusing on a comparison between the mobile-based and fixed-station monitoring methods.

The specific research questions we aim to answer are: 1) How do the methods differ and 2) for what purposes are they useful? 3) How is the mobile monitoring method perceived by students in the sustainable coastal management study program?

4 Research Methodology

In general, research means to search for knowledge, hence, research is a scientific and systematic search for knowledge of a specific topic. Therefore, research is the art of scientific investigation to figure out new knowledge regarding a specific topic. According to the Advanced Learners dictionary (1952), the definition of research is ‘‘a careful investigation or inquiry, particularly through the search for new facts in any branch of knowledge.’’ Similarly, according to Redman and Mory (1923), research is a ‘‘systematized effort to gain new knowledge’’. Research especially refers to academic activity or processes that contain technical senses or steps. Woody (1923) stated that ‘‘research comprises defining and redefining problems, formulating hypothesis or suggested solutions; collecting, organizing, and evaluating data; making specific and reaching assumption; and at last, carefully testing the conclusions to determine whether they fit the formulating hypothesis’’. In summary, research is finding knowledge through the specific objective and systematic method of finding the solution to a problem. On the other hand, a generalization, and the formulation of a theory through the systematic approach is also known as research (Kothari, 2004).

There are several types of research which are applied to conduct the research. According to the nature of the topic and objective of our research, we are going to follow the mixed (quantitative and qualitative) approach of research methods to answer of question.

In general, quantitative research is based on the measurement of the quantity or amount of data or information related to the research question, for instance, number of the responses to a specific question (Kothari, 2004). Quantitative research not only emphasizes the amount and quantity of the data but, it applies the **deduction approach** ‘‘the process of deriving logical conclusions about particular instances from general premises or statements’’. There are several methods of collection of data within quantitative research which are as follows.

- Surveys (questionnaire)
- Structured interviewing
- Structured observation
- Secondary analysis and official statistics
- Content analysis according to a coding system etc.

(Spratt, Walker, and Robinson, 2004)

Qualitative research is concerned with phenomenal issues that are far from the description of the quantity or amount of the data. Qualitative research aims to discover the underlying motives and desires related to the research topic, for instance, through in-depth interviews with authorized and experienced persons (Kothari, 2004). Furthermore, qualitative research emphasizes the meaning i.e., words rather than frequencies and distributions i.e., numbers during the gathering and evaluation of the data. Qualitative research tries to understand and describe the meaning, perspectives, and facts of the respective situation or event from the people involved in the respective research topic. Qualitative research applies the **inductive approach** ‘‘the process of inferring a generalized conclusion from particular instances’ that helps to generate a conclusion from the interpretation of the evidence. Hence, there are several methods of qualitative research which are as follows:

- Observation (unstructured, structured, participant)
- Interview (unstructured, semi-structured, individual, group)
- Case study
- Action Research
- Documentary analysis

  (Spratt, Walker, and Robinson, 2004)

4.1 Methods applied in this study

It is very important to have a specific method to stay on track to achieve the targeted goal and results. To answer the question of our topic of study for thesis we have set precise methods.

4.1.1 Study area

Arkona Deep inside the entrance to the Bornholm Deep, Baltic Sea, and the Gotland Deep furthest inwards are the core basins of the Baltic Sea. The source of saltier, heavier and oxygen rich water enters from the North Sea into the Baltic Sea. The oxygen-rich water inflow plays the vital role for the well-being and productivity of the biota as well as the entire environmental including aquatic ecosystem of the Baltic Sea. Many human activities in the region that is either in land or at sea, carrying serious threatening impacts existence on the Baltic Sea. Hence, current most serious human activities that impact to the Baltic Sea are lethal impurities, overfishing, eutrophication, and alien species such as non-indigenous, exotic, invasive, etc. (Thulin & Andrushaitis, 2003).
When we considering about the marine water surrounding to the Finnish coast, Baltic Sea can be divided into two main bodies, the Gulf of Finland, and the Gulf of Bothnia. The Baltic Proper direct extension remains as Gulf of Finland from where freshwater inflow is possible. The Gulf of Bothnia contains Bothnian Bay, Bothnian Sea, Åland Sea and Archipelago Sea has two main basin and two extensive archipelagos are remains in the northern and southeastern parts. Inflow of freshwater from the different source specially the rivers and precipitation cause comparatively low salinity of the respective sea area. Baltic Sea is known as cold sea and its temperature remains between 0 to 20 degrees Celsius. The ecological status especially coastal waters have been most important environmental issue of most the European countries. There is different long-term loading through waterway specially nutrients, in addition increasing indirect effects of different land activities such as agriculture, urban activities and construction in the catchment area have had worsening situation in many aspects. Destination of the loading gets into the coastal waters and affects the coastal zone. Remarkably the shallow Finnish coastal zone is in many ways suffered by the pollution and eutrophication (Kauppila & Bäck 2001).

In coastal water, Chlorophyll-*a*, Fluorescent Dissolved Organic Matter (fDOM) and turbidity are the visually identifiable variables which are interrelated with surface water salinity through the level of freshwater input and the amount of mixing with saline seawater (Asmala et al., 2014 cited on Gunko et al. 2022). Plants, algae, and cyanobacteria are the primary source of Chlorophyll-*a* that is remain as central photosynthetic pigment on them. Hence, as a proxy for phytoplankton biomass, chlorophyll-*a* concentration is the major indicator for eutrophication (Carlson, 1977 cited on Gunko et al., 2022). The situation described above is the reason behind to select the study area where we can find high turbid water and high organic compound runoff from the surrounding island.

As we chose the study area and the reason behind it mentioned above, Raseborg, Finland's southwest coast research area, has 6400 summer villas, a significant water quality concern. With a population of around 28,000, summertime significantly impacts the area. The municipality's administrative structure, formed in 2009, consists of populated metropolitan regions with administrative hubs like Ekenäs, Karis, and Pojo, as well as rural areas with scattered settlements and residences. The summer season significantly impacts the population, with up to 50% of people on vacation (Gunko et al., 2022).

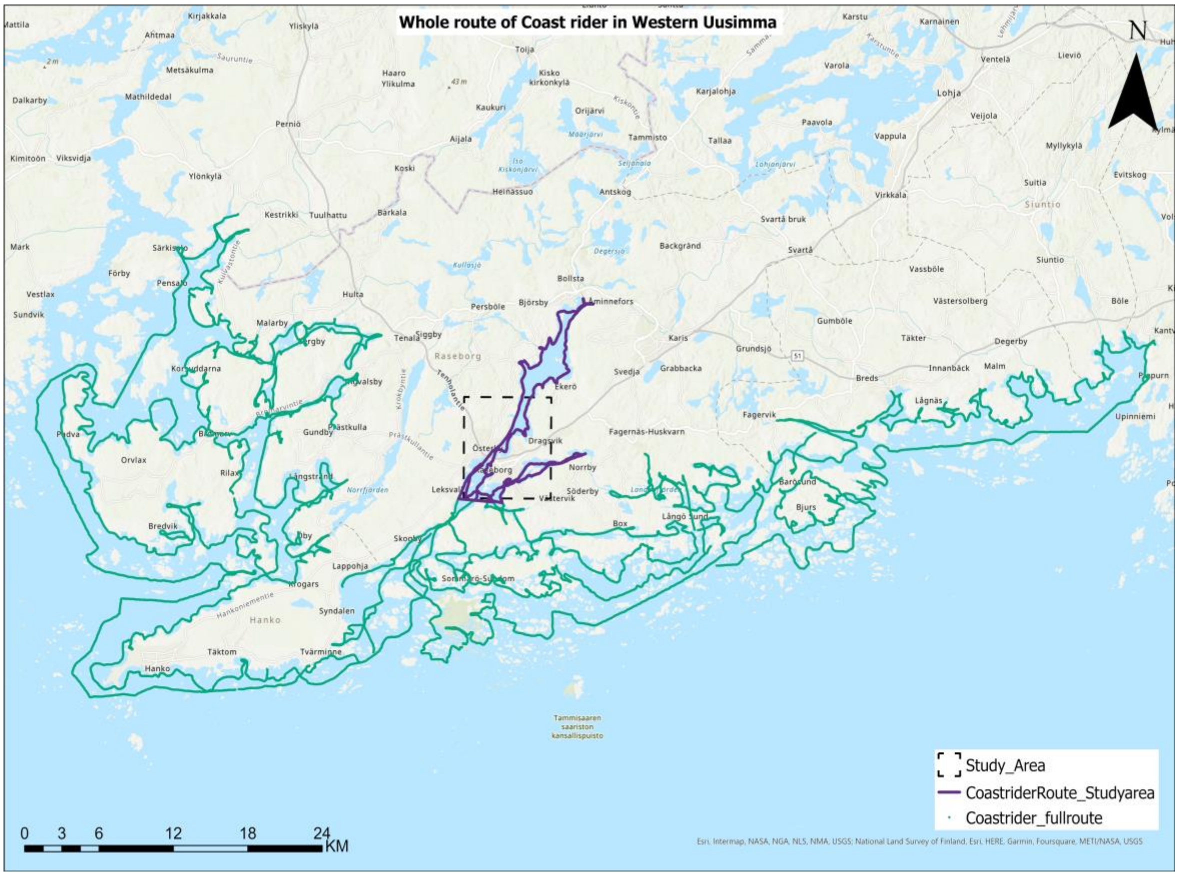

Figure 3. The complete route of the Coastrider data collection zone.

In the above map, we tried to present the whole week of fieldwork covered by Coastrider to collect the data around the Western Uusimaa which is indicated with a light green color.

The total number of observations was 29905 for the whole Uusimaa area between the 23rd to 27th of May 2023. The observations extracted from the data set, within the Raseborg study area was a total 2332 observations. Likewise, the purple color indicates the selection for the study area, and more specifically the study area is indicated by black break lines in a square shape which is around the Raseborg (figure 3).

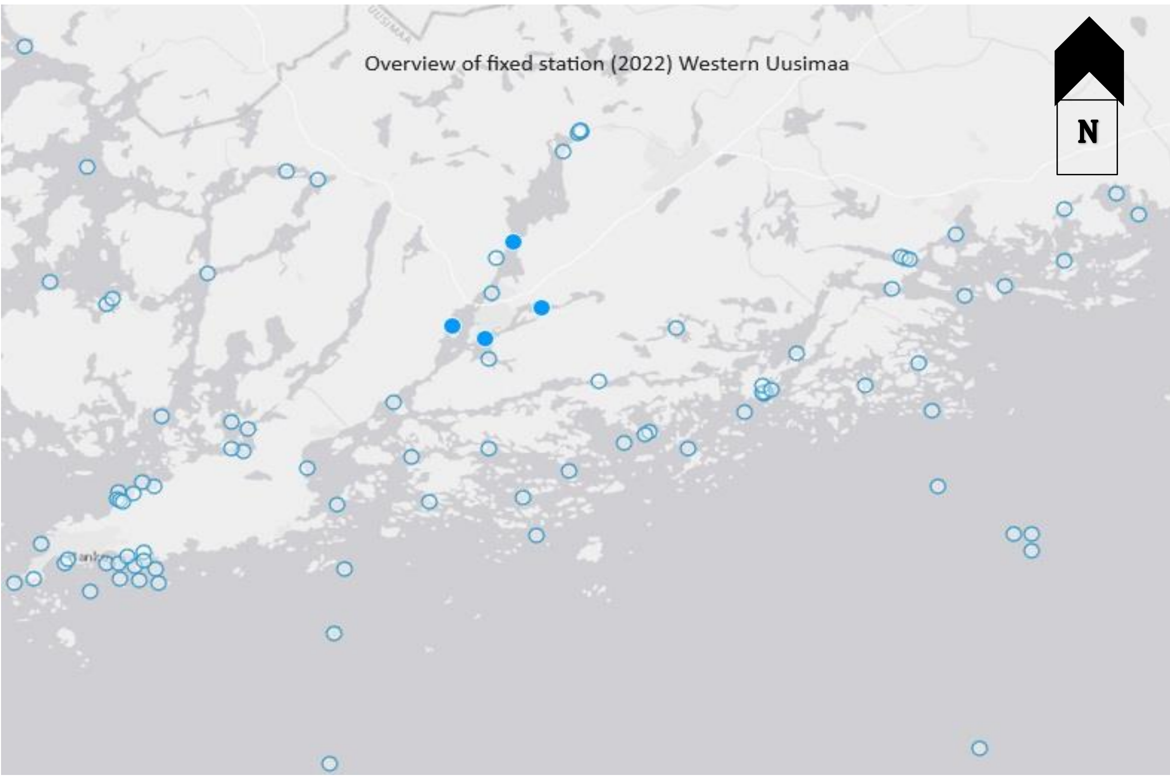

Figure 4. Fixed stations that are located around Western Uusimaa

The fixed station locations that serve to gather data are seen in the above image and are situated throughout the Western Uusimaa. To compare the four dark blue fixed stations with the coast rider mobile monitoring approach and obtain trustworthy responses to the research topic, these stations precisely fit inside our study region and matched our requirements (figure 4).

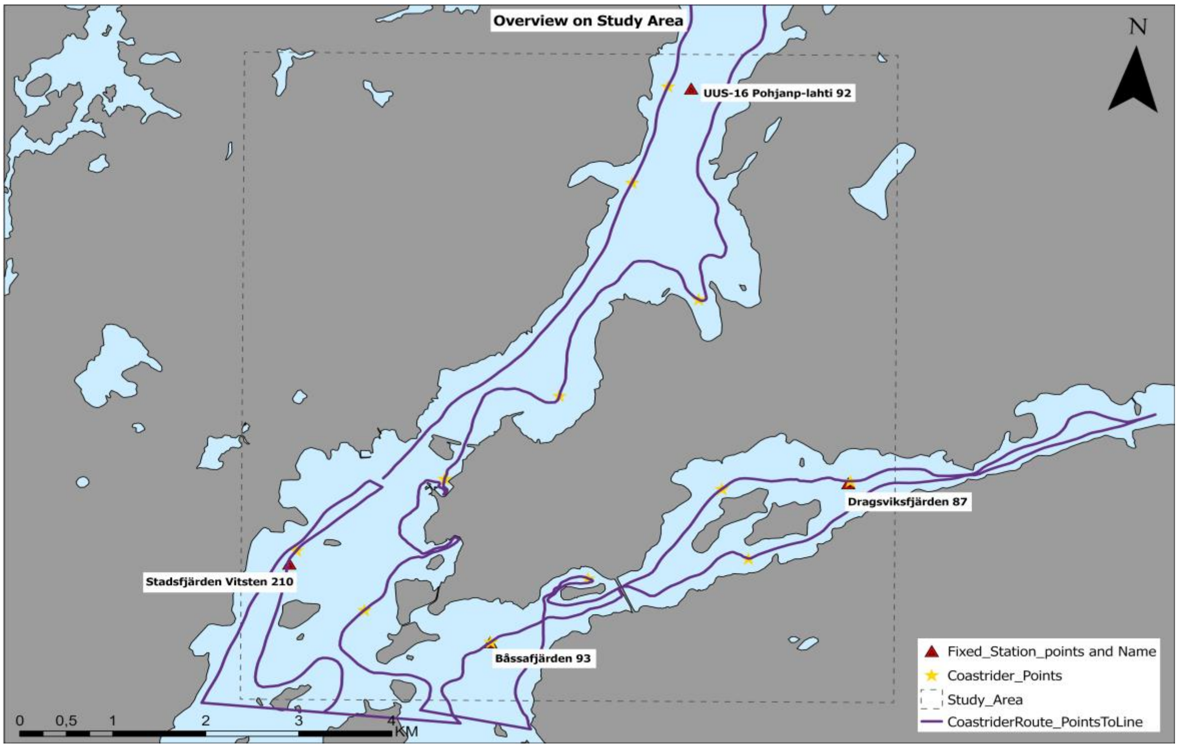

Figure 5. Comparing areas, stations, and points.

The above figure demonstrates the Coastrider route within the comparing area in which the four fixed stations are assigned four closest points as well allocated from the Coastride route. The reason behind choosing the closest points to the fixed station is to compare the results and also point out the eight locations between the four fixed stations to reflect the variation of the result that is neglected in the fixed station method whereas covered by the Coastrider approach (figure 5).

Also attempts to exhibit the comparing area which includes the four fixed stations with their name and points which are indicated in the red triangle symbol and the twelve points in the yellow star symbol that are allocated to compare and check the differences between the two different approaches of water quality monitoring (figure 5).

Hence, to answer how the different methods can be supplemented to each other for better clarification, we have taken different perspectives and tried to execute them here. So, to illustrate the result we have taken three water variables: salinity, temperature, and chlorophyll-*a*. These all variables are considered with the data that we extracted from the Coastrider approach and fixed station approach. We also tried to get the closest date and the nearest point that resembles quite similar, which helped to compare more accurately. Then, we used ArcGIS Pro to interpolate the extracted data from Coastrider and fixed station within the comparing area to showcase the result through maps.

Salinity is the dissolved salt component of the water body. Salinity is one of the robust contributors to conductivity and supports to determinant of several properties of the chemistry of natural waters and the biological processes within them. There are many important reasons behind the cause of measurement of salinity in the water (EPA, 2023).

Hence, different water bodies contain different levels of salinity (PSU: practical salinity unit).

Temperature is one of the important and most influential factors. The water temperature affects the physical, chemical, and biological processes of any type of water body, for example oceans, rivers, and lakes. Hence, the water temperature is a significant indicator of climate change (EPA, 2023). Undoubtedly, there is a strong relationship between the water temperature and aquatic ecosystems, therefore, it is essential to quantify or monitor closely the water temperature of each aquatic body. In the case of the history of water temperature monitoring, tradition had been started by using satellite water surface temperature measurement to know the status and the reaction of aquatic communities (reefs and macroalgae) (Rinne, 2014). Moreover, the objective of the monitoring was to measure the thermal stress that ultimately affects global warming. In the modern era there are very powerful and precise devices and technologies have been developed for water temperature monitoring for instance, Resistance Temperature Detectors (RTDs), Thermistors, several types of semiconductor sensors, Complementary Metal Oxide Semiconductor-CMOS (Wang et al.,2023).

Chlorophyll-*a* is a green pigment used by phytoplankton and algae during the photosynthesis process. The green pigment concentration reflects the levels of phytoplankton present in the water. Therefore, the total amount of phytoplankton in water is most generally measured by examination of the chlorophyll-*a* content of a water sample (Scheinin & Asmala, 2020). The importance of measurement of chlorophyll-*a* is to figure out the status of algae growing and categorize the trophic state of a water body. Although algae are a natural part of the freshwater ecosystem, however, a high quantity of algae can cause problems for example unnecessary harmful green layers and bad odors can result ultimately in decreased levels of dissolved oxygen (Waston et al, 2015). Moreover, some of the algae also produce toxins that can be harmful to public health when they are found in high concentrations of water bodies. The reason behind the degradation of the water quality condition is because of an increase in algae biomass. That can be disclosed by measurement of the chlorophyll-*a* (EPA,2023). There are several reasons behind to increase of significantly high amounts of chlorophyll-*a* concentration in water bodies. For instance, nutrients from fertilizers used in agriculture, septic systems, sewage treatment plants, urban runoff, etc. (EPA,2023).

4.1.2 Data collection

Data refers to the combination of the qualitative and quantitative variables. Data is defined as facts and figures from which help to reach a conclusion. Before executing and analyzing the information, there must be a specific process of collecting and sorting data. Firsthand data regarding the concerned topic is just raw material as trees are the raw material from which paper is produced (Ajayi, 2016 cited in Ajayi, 2017). Furthermore, data in common notion refers to the fact regarding the existing information or knowledge that has been associated with processing and usages for finding the better result.

Likewise, there is also a supporting way of collecting data where researchers are investigating, as Gunko, et al (2022) refer to citizen science as transforming society's involvement in global research initiatives, with non-specialists becoming active participants and sponsors. This approach allows for collecting extensive environmental data on a large scale. Locals can be trained to measure measurements, making citizen science a valuable tool accurately. However, comparing subjective assessments of the environment by volunteers and empirically evaluated estimates remains unclear. Recent research and work experiences convinced the potentiality of the portable WQM system that helped to find more precise data and its results of the specific location accordingly, which motivates us to perform more in-depth studies and portray how mobile monitoring methods can deliver problem-solving data analysis within the coastal water quality area (Gunko, et al, 2022).

Data as a raw material is insufficient before analyzed and connected to suitable information for decision-making purposes. Hence, according to accessibility, there are primary sources and secondary sources of data (Ajayi, 2017).

Primary data denotes the firsthand data accessed or collected by the researchers through their efforts. The main sources of primary data are surveys, observations, questionnaires, focus groups, case studies, and interviews. Similarly, secondary sources of data refer to the data collected by someone else earlier. Secondary data are those data collected by someone else who is not part of the research for their purpose and at different times. Hence, the data gathered and used by someone else on some occasion and that data used by the current users for their purposes become known as secondary data. The source of secondary data might be government publications, websites, books, journal articles, internal records, etc. (Ajayi, 2017).

For our study, the source of primary data was a questionnaire and practical fieldwork (Coastrider). The method of collecting the data from practical field work is to fulfill the mobile monitoring method, for this purpose, we have taken an improvised version of ''Coastrider''. The Coastrider data used for this comparison was from the 23rd and 24th of May in 2022. Similarly, the secondary source of data that we obtained for the fixed station method is from the Finnish Environment Institute (SYKE) and the Finnish Meteorological Institute. To make the comparison as realistic as possible data was obtained from the same year (2022) and closest date (23 and 24 May to 1 June), month (May and June), and location (see figure 7) of both methods. To be more specific, we have used data from fixed stations which was available as an open source on Itämeri, 2023, and chose the date as 01 of June 2022 which was the closest data of coast rider data which is as on 23 to 24 May 2022. Here follows a description of the Study area and method that we used to interpolate the data in ArcGIS Pro to present it in maps for a clear overview of the data results.

The objective of the comparison between the fixed station monitoring method and the mobile monitoring method is to figure out the gap between these methods. Under the fixed monitoring method there are certain locations to take water samples for example A, B, and C. Each station is located relatively far apart from each other. Therefore, there could be a gap in the result between the location A and B. Hence, the mobile monitoring method can fill the gap and also get a more comprehensive picture of the water quality in the area, since the fixed stations only have one station describing a larger area and also help to collect the data between both locations. Therefore, the mobile monitoring method can help to gather the data of respective locations that provides an opportunity for realistic analysis compared to the fixed station sample method. For example, if there is a certain distance of 1 km between stations A and B and both stations are affected differently by any kind of activities (agriculture or other human activities, natural causes). In this circumstance, the result of the water quality might be different in locations A and B. Furthermore, there could be fluctuation in the result between the distance A and B.

To compare fixed station and mobile monitoring methods, we have taken the most common water monitoring variables, for instance, salinity, chlorophyll-*a*, temperature which represent the quality of water. For this purpose, we will take reference data from both methods that can show which method could produce better results, therefore, helping to figure out the objective and meaningful result of the monitoring in the case of our study area.

4.1.3 Interpolation process

Firstly, we applied the interpolation tool Geostatistical Analyst (Diffusion technique with the barriers) in ArcGIS Pro to transfigure water quality data into raster. The distance between input points may be redefined by using raster and feature barriers, which can be applied to land and ocean barriers. Because it is the only kind of interpolation that considers barriers (island and mainland). Due to the numerous, dispersed bays and inlets, we must identify the obstacles to let ArcGIS professionals grasp the differences while interpolating within the study area.

To make it clearer in a sense how the maps had been created to represent this thesis and as well as can be used as a future reference, we tried to create a manual that everyone can follow to perform the task accordingly.

Step: 1 To set the coordinate system

- Open ArcGIS file
- Right-click on ''Map'' at left left-right corner inside the ''Contents'' Box
- Click on Properties and get inside ''Coordinate Systems''
- Search for the required coordinates systems ''UTM Zones'' under ''project coordinate systems''
- In the case of Finland search and select ''WGS 1984 UTM Zone 34N''

Step: 2 Import data from an Excel or CSV file

- Click on ''Add data'' on the option panel
- Choose ''XY Point Data'' will appear to Pop up a new box named ''Geoprocessing''
- Find the desired document from the ''Input Table'' Section

- Can choose the desired location to save the document and can change the name of the document as per requirement at ‘‘Output Features Class’’
- Ensure the X field ‘‘Longitude’’ and Y Field ‘‘Latitude’’ nothing to do with the Z field and the coordinate system should look like ‘‘GCS_WGS_1984’’
- After all, Click ‘‘Run’’ at bottom

Step: 3 Upload the vector files of water and land

- Go to the ‘‘Add Data’’ Option
- Need to create vector files of ‘‘water & land’’ for the specific area in advance and save it in accessible folder to import when required.

Step: 4 Find out “Diffusion Interpolation with barriers” under “Geoprocessing” tools

- Click on ‘‘Geoprocessing’’ tools
- Search by type ‘‘Diffusion interpolation with barriers’’
- A new pop-up windows will appear, with the following options

Parameters:

- Select your data at ‘‘Input features’’
- Select the variables one by one you want to interpolate at ‘‘Z value field’’
- Assign name to ‘‘Output geostatistical layer’’
- Give appropriate name at ‘‘Output raster’’ which is produced as a result of interpolation
- ‘‘Output cell Size’’ should be 0,2E-03 t0 0,8E-03 for the interpolation used for the Coastrider method (the smaller the value better resolution, however, takes longer time to proceed)
- Choose the ‘‘Land layer’’ at ‘‘Input barrier features’’

Environments:

- Choose ‘‘water layer’’ at ‘‘processing extent’’
- Choose ‘‘water layer’’ at the ‘‘Mask’’ option as well (to prevent extrapolation errors near big river mouths)

Step: 5 Create a layout

- Click on ‘’Insert’’
- Click on ‘’New Layout’’
- Choose the appropriate size of the layout, for instance, A3
- Choose ‘’Map Frame’’
- Right-click and select ‘’Activate’’ to zoom in/out and to move the map
- Click ‘’Close Activation’’ after done after each ‘’Activation’’ task
- Insert ‘’Scale Bar’’, ‘’North Arrow’’ and ‘’Legend’’
- Right click ‘’Scale Bar’’, ‘’North Arrow’’ and ‘’Legend’ to modify them

4.1.4 Questionnaire

The questionnaires can be found in (appendix 1) which is a very effective tool for collecting quantitative primary data for any kind of survey and research work. This powerful tool was invented by a British anthropologist Sir Francis Galton in late 1800. It is compulsory or minimum requirement is that the questionnaire should be designed with a specific objective that should be related to the objective of the research. Moreover, the finding of the questionnaire needs to be clear and meaningful about the respective research objective. According to the professor MS Rani, ‘’A questionnaire is simply a list of mimeographed or printed questions that is completed by or for a respondent to give his opinion’’. Indeed, it is very important to consider following certain steps to design the questionnaire, therefore, it is possible to gather meaningful and useful information. Hence, there are the stages of planning a questionnaire as below (Roopa and Rani, 2012).

- Initial considerations
- Question content, phrasing, and response format
- Question sequence and layout
- Pretest (pilot) and revision
- Final questionnaire

Theoretically and principally in terms of questionnaires, there are similarities, or we could say we have been adopting the principle directly or indirectly. When we had developed thoughts about the title of the thesis, we had already created a sketch of how we could verify our argument. Therefore, we note out every possible question after every discussion regarding the topic. Certainly, the questionnaire method is one of the very common and powerful tools for gathering information regarding a specific topic. Indeed, the number matters in this case, if we have a general topic, we could have the chance to collect a high number of respondents. However, in our case, we had a very limited number of respondents because the topic was unique. We were required to make an extra effort to collect the information besides developing the final questionnaire. One guest lecture regarding water quality monitoring including the outcomes through the Coastrider method was provided by its initiator Dr. Matias Scheinin during our course. However, this year our peers did not get the opportunity of that therefore, we initiated to developed brief presentation about the Coastrider method to help answer the questions. The procedure for gathering data involved creating forms from the questionnaire and sending the form link via email. In addition, we directly followed up with our colleagues to get their answers.

The questionnaire survey that we gathered from our peers who have some basic knowledge and opinions about water quality monitoring. For this purpose, we generated 10 questionnaires which we shared with our peers and received their opinion in a result form. We analyzed and discussed our research question and what they thought about it and their result supported to answer. The total number of responses is 16 however, out of 16, 1 person did not respond to question number 1. The results are graphed in a pie chart and will be examined further.

5 Results

In this section, we will be clarifying in depth the results that we obtained during the process to answer our research question. Similarly, we will be exploring the results from the comparison between the fixed station and Coastrider water quality monitoring methods.

5.1 Questionnaire

This section will address the results of the questionnaire that we gave to fellow classmates. For this reason, we made ten questionnaires, sent them to our peers, and received their input in the form of result forms. We discussed and looked over our research question, their opinions on it, and the supporting data they offered for our response. Out of the sixteen responses, one person chose not to respond to the initial query. We assume that the individual has addressed the other queries and was aware of the problem. The findings are shown in a pie chart below, which aids in illuminating the ratio.

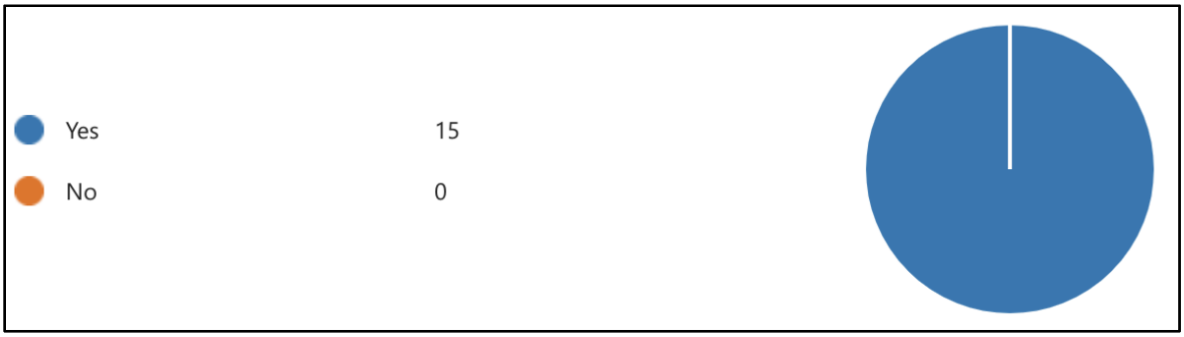

Figure 6. Question No. 1 "Have you heard (and know) about water quality monitoring?"

Of the 16 respondents, the first question was technically answered by 15, and the response "yes" indicates that the respondents had been informed about the monitoring of the water quality. We might state that every responder heard about or was aware of the water quality monitoring. Figure 6).

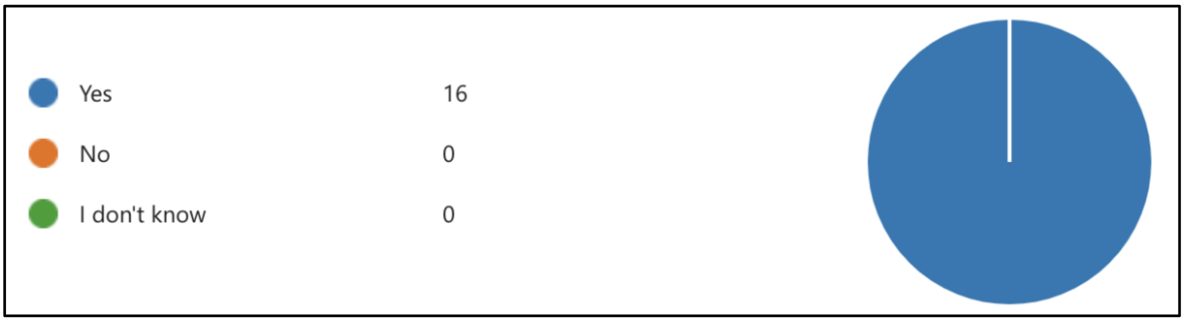

Figure 7. Question No. 2 "Do you think monitoring water resources is essential or not in terms of knowing the ecosystem?"

The purpose of question number two is to find out if the responder thinks that ecosystem services are so important that monitoring water supplies is crucial or not and 16 respondents agreed on it (Figure 7).

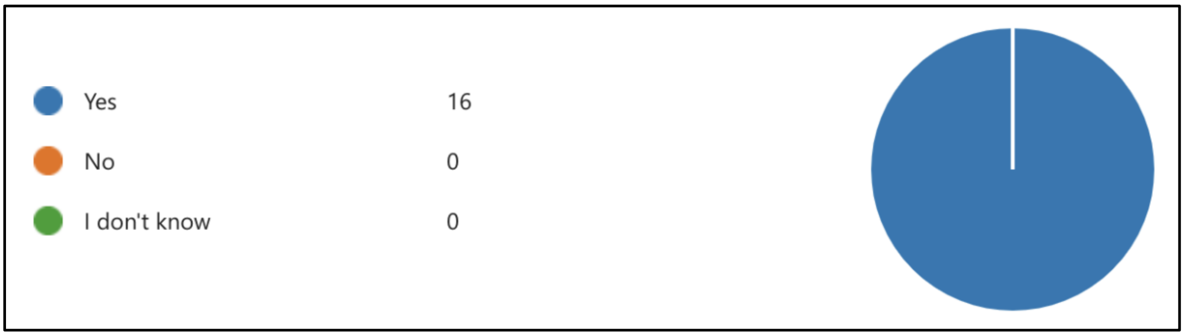

Figure 8. Question No. 3 "Do you think it is important to conduct coastal water monitoring?"

Here in question number 3, we are concentrating on coastal water, therefore, we asked respondents how they think in terms of the importance of monitoring coastal water (Figure 8).

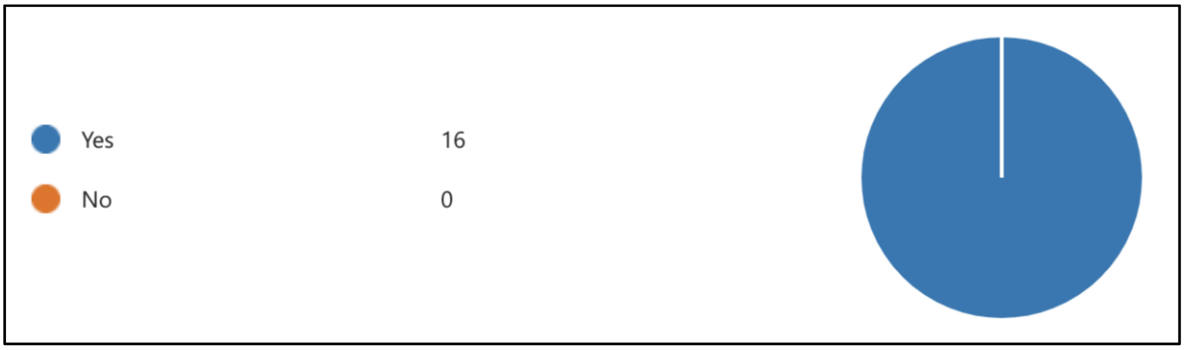

Figure 9. Question No. 4 "Have you heard about water quality sampling methods?"

We are attempting to specifically address the issue that supports our task's theme through question number 4. The purpose of this inquiry is to find out if they have heard of or are familiar with water sampling techniques (Figure 9).

Figure 10. Question No. 5 "Have you participated in water quality sampling?"

The purpose of this question is to find out if the responder is familiar with any type of water quality sampling technique or not. The responses provided up until question number five are legitimate because as out of the 16 respondents, 15 indicated that they have engaged in water sampling. Additionally, they will respond to the remaining queries with understanding. (Figure 10).

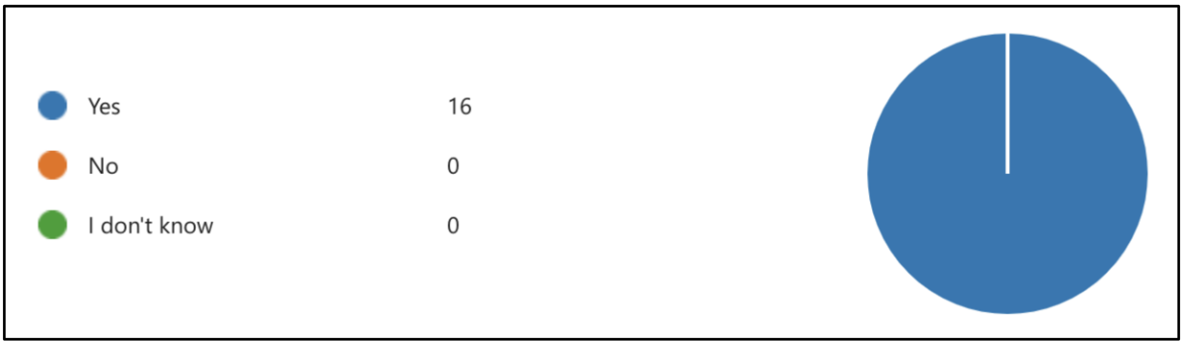

Figure 11. Question No. 6 "Do you think that water quality monitoring is important?"

Based on their preliminary understanding of water quality monitoring and sampling, we asked our peers if they think water quality monitoring is an important task or not. 100% of respondents answered that it is important to conduct water quality monitoring (Figure 11).

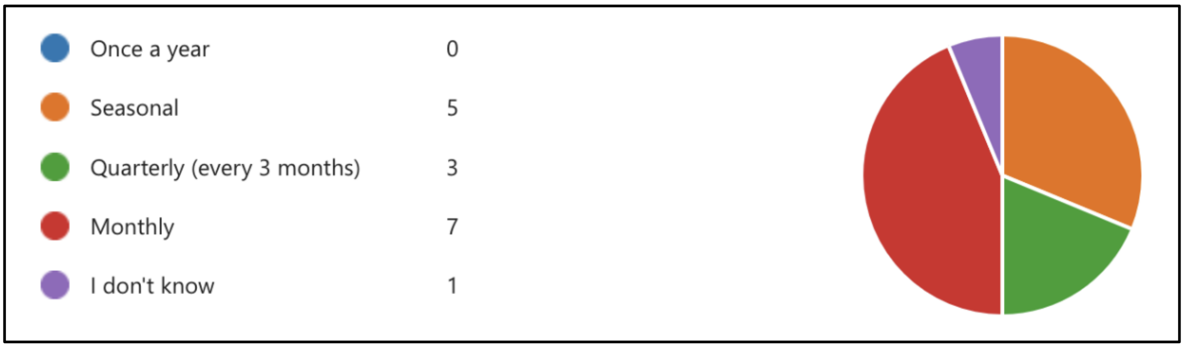

Figure 12. Question No. 7 "How often should monitoring be conducted for being effective?"

We have found different perspectives of respondents through question number 7. Indeed, it was obvious that there might be different perspectives on this question because there is no universal truth answer to this question (Figure 12).

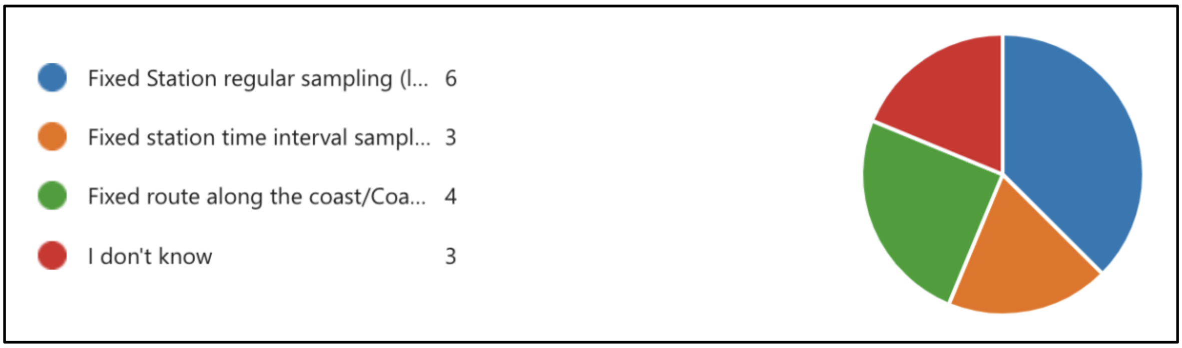

Figure 13. Question No. 8 "Which method do you think is better in terms of the efficiency of the result?"

The majority of respondents believe that the efficiency of the result has been produced from the fixed station regular sampling method. 4 out of 16 respondents believe that the fixed route along the coast that we indicate here as a Coastrider method also produces efficient results. The notion of developing this question was which method of sampling might cover the specific area properly and, therefore, can produce factful results according to the possible different landscapes (Figure 13).

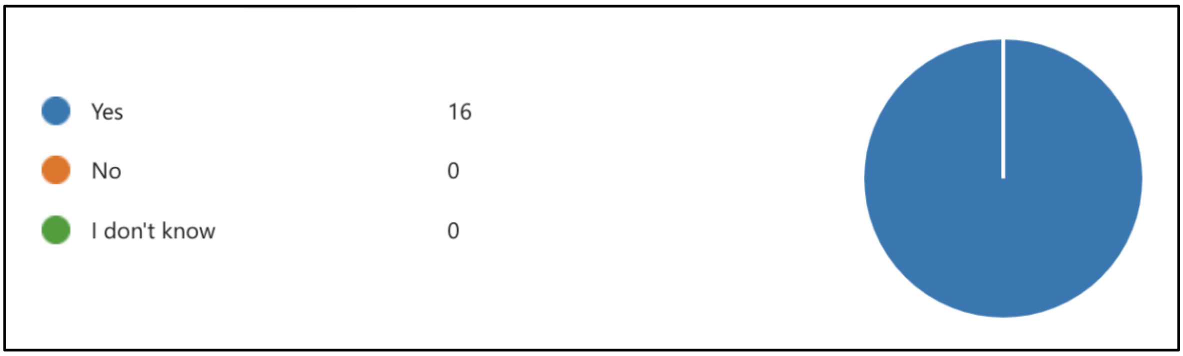

Figure 14. Question No. 9 "Do you think monitoring is important to contributing to possible remedies (for example, to know the status of carbon and nutrient loads, construct wetland in agriculture area)?"

100% of respondents agree that monitoring activities are important for contributing to developing a remedy plan because monitoring programs provide the real status of water quality of the specific area. The available result from the monitoring helps to figure out the cause of the result and helps to make a plan accordingly (Figure 14).

Figure 15. Question No. 10 "Which method helps obtain information for possible remedies (for example, to know the status of carbon and nutrient loads, construct wetland in agricultural area)?"

The purpose of this question is to find out what approach to water quality monitoring respondents believe can cover a certain distance between water regions. This is due to the possibility of various physical features, such as rivers, forests, industrial areas, and agricultural areas, as well as various human activities. In these situations, among other methods, the fixed route Coastrider approach may be useful to obtain the factual result needed to build a firm strategy. As a result, 7 out of 16 respondents, or the majority, believe it (Figure 15).

5.2 Comparison between the fixed station and coast-rider method

In this section, we will be taking reference data from both methods that can show which can reflect how the methods can supplement each other for a better understanding of the study area and can be used for various purposes in different approaches.

5.2.1 Salinity

The map and graph present below the value of the salinity at the end of spring (23-24 May) 2022, which was sampled by the Coastrider approach. The value of salinity ranges from 0,05 to 2,2 PSU within the comparing zone. Likewise, in the map, the values are generated by a fixed station monitoring approach during the first day of summer whose result ranges from 0,08 to 2,1 PSU (figure 16). Similarly, the graph shows the distinct gap between the results gathered from different methods. The difference between the distance between the two points is visible (figure 17).

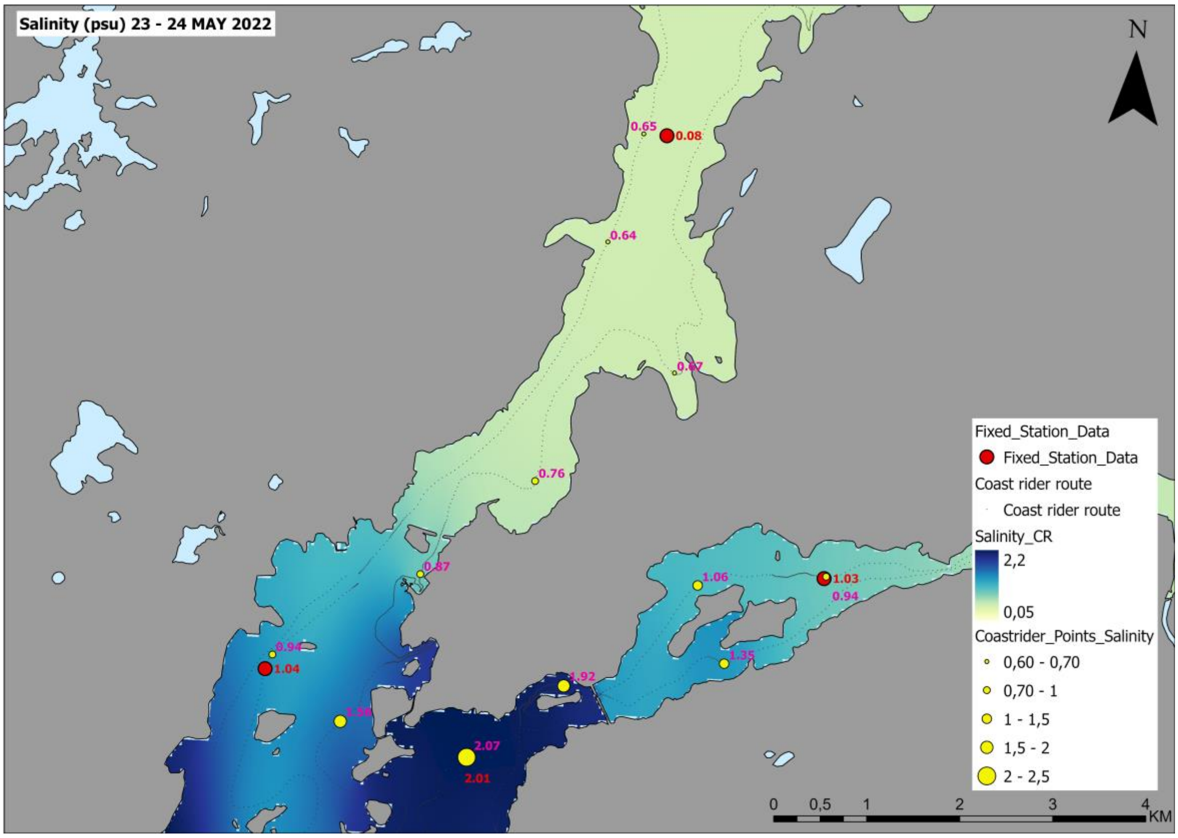

Figure 16. Result of Salinity from Coast Rider and Fixed Station method

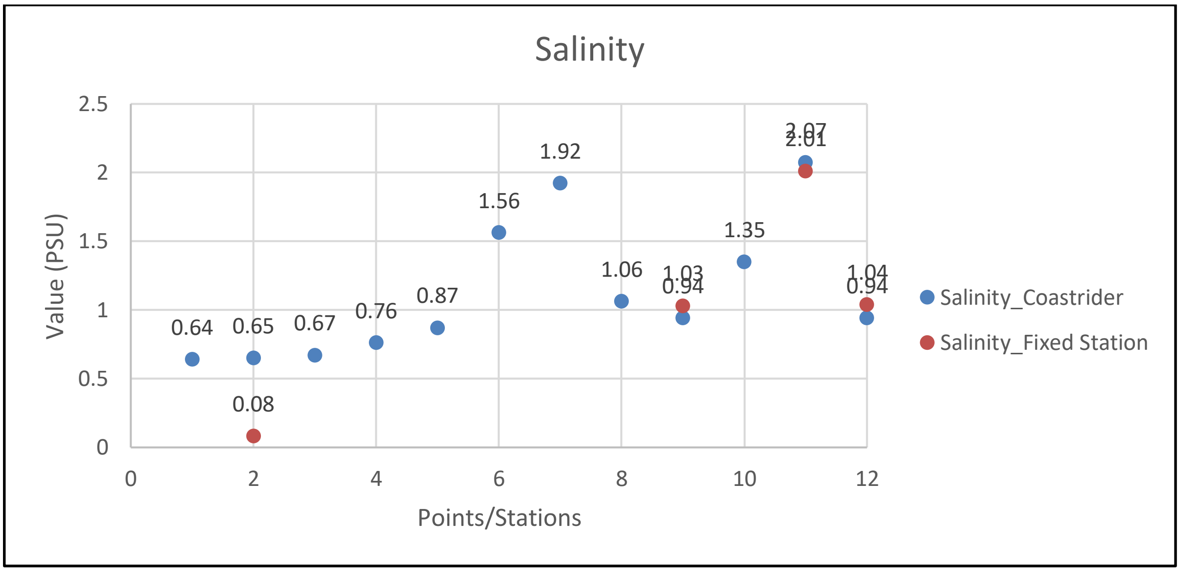

Figure 17. Graphs represent the results of Salinity from both methods.

5.2.2 Temperature

The map and graphs below uncover the different points that represent the value of the temperature that was collected during the end of spring. The surface temperature ranges from 11 degrees to 14 degrees Celsius. Whereas, in the initial phase of summer the temperature ranges from 13 to 15 degrees Celsius (figure 18). In the same way, the graph displays the clear discrepancy between the data obtained using various techniques. There is a discernible variation in the two places' distances (figure 19).

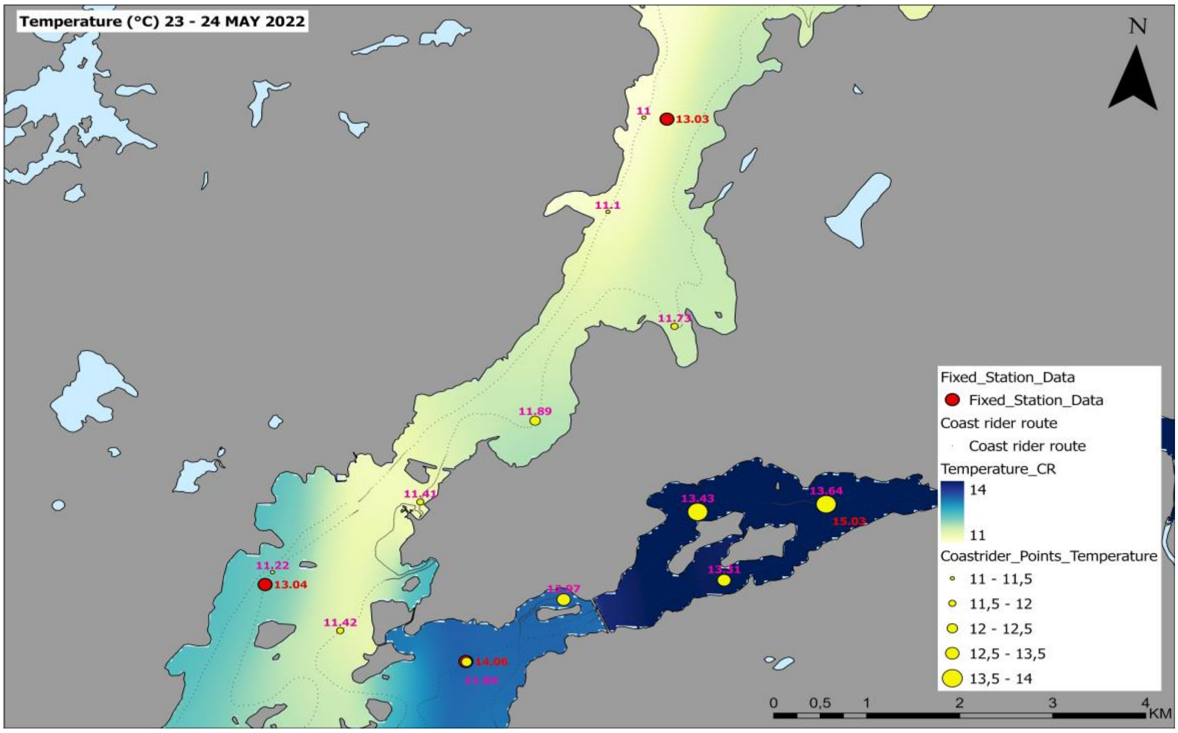

Figure 18. Result of Temperature from Coastrider and Fixed Station method.

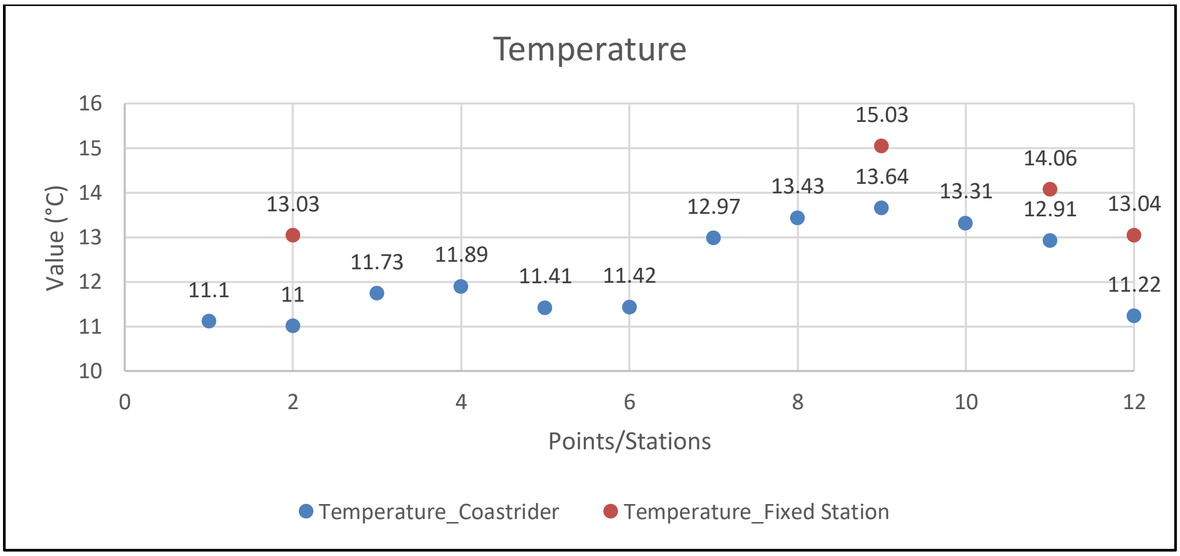

Figure 19. Graphs represent the results of Temperature from both methods.

5.2.3 Chlorophyll-*a*

The map and graph below show the value of chlorophyll-*a* was sampled during the end of spring which ranges from 9 to 15,5 µg/L. Similarly, the value of chlorophyll-*a* was extracted from the fixed station during the first day of the summer, and its values ranged from 22 to 16 µg/L (figure 20). The graph also demonstrates the clear disparity between the data obtained using various techniques. It is evident how far apart the two locations are from one another (figure 21).

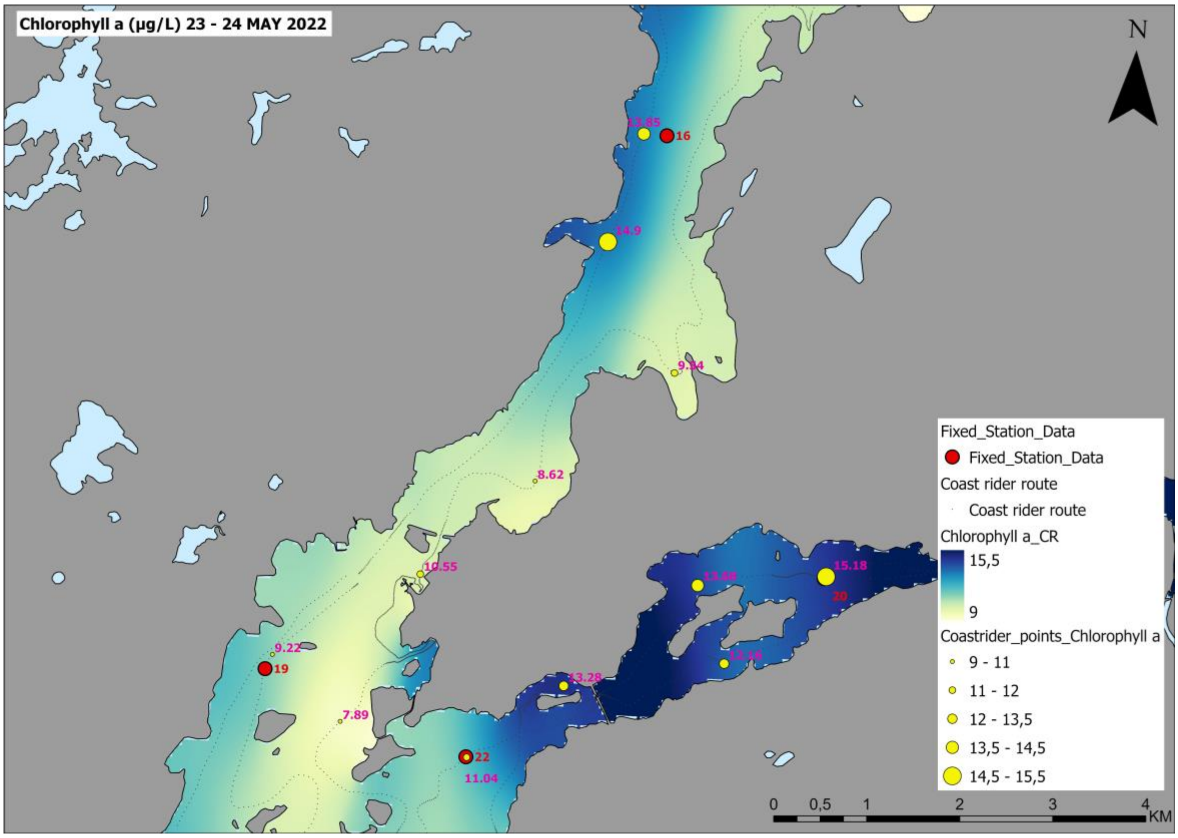

Figure 20. Result of Chlorophyl-*a* from Coast Rider and Fixed Station method

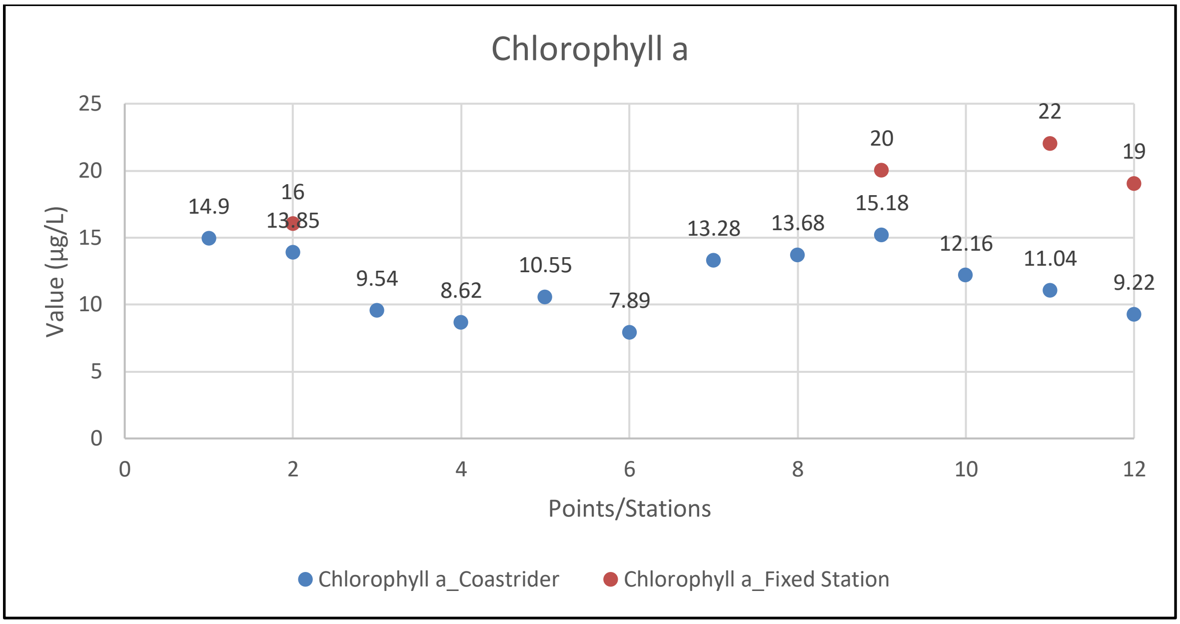

Figure 21. Graphs represent the results of Chlorophyll-*a* from both methods.

6 Discussion

Based on the results we have found according to the data of each method in the previous section, here in this section we are trying to present the **benefits and limitations** of the methods. Indeed, the monitoring method is designed, developed, and followed based on the goal, objective, and nature of the monitoring plan. According to our thesis question, there could be a question that arises why the fixed station monitoring method was taken to compare with the Coastrider method. Why not other methods? Because of the important factors i.e., the nature of both the Coastrider method and fixed station monitoring method which described in the introduction section. Hence, the Coastrider monitoring method could be a supplementing method of the fixed station monitoring method that can fulfill the limitation of the fixed station monitoring method.

The Baltic Sea's surface layers have an average salinity of seven grams per kilogram, with regional variations in Finnish maritime areas, ranging from the lowest in the northern Bay of Bothnia to the highest in the southern Archipelago Sea (Kautsky & Kautsky, 2000). Thus, results from a different approach exhibit a similar range from low to high, however, the fixed station misses some value in comparison to the Coastrider as the range from 0.7 to 2 PSU does not appear in the fixed station monitoring. For instance, let's say point A has a value of 0,08 PSU and point B is 1,04 PSU in the fixed station whereas, in the same location, the value ranges from 0,64 to 1,92 PSU data collected by the Coastrider method. Thus, the figure explains well that the Coastrider generates various results and helps answer correspondingly to the location.

Water temperature has a major impact on marine ecosystems and varies greatly with the seasons and other weather conditions. While coastal waters can reach above 20°C, summertime temperatures typically range from 15-20°C. Surface water temperatures can fall below freezing throughout the winter (Rautiainen et al, 2023). Thus, the result may vary because of the different days and different times however the most important part is that the fixed station assumes the big portion of the area within the sampling station having the same temperature which eventually interpolates inaccurately that is located quite far from the station radius. So, the Coastrider method of collecting sampling will be more effective in covering the unreachable area by the fixed station approach.

Likewise, the amounts of chlorophyll-*a* in open waters range from 2-3 µg/l in the Gulf of Bothnia to 3-6 µg/l in the Gulf of Finland, with coastal seas having the highest quantities. During spring algae maximums and summer cyanobacterial blooms, short-term concentrations can increase by ten times (Wasmund & Zettler, 2023). However, the fluctuation of chlorophyll-*a* is so rapid that it takes a while to be constant to have accurate values. Also like to add that, during our internship we used the Coastrider monitoring method to collect variables, as well we did manual sample collection to verify the values collected via sensors. During this period, we observe the instability of chlorophyll-*a* regarding time and location. Thus, in terms of chlorophyll-*a,* the value produced through fixed stations will vary several times between the two stations and the interpolation could be biased in the location.

6.1 Comparison of different water quality monitoring methods

6.1.1 Fixed station monitoring method

As per our research question, we chose the fixed station monitoring method to compare, since it was widely used by the Finnish environment organization (SYKE), and when we analyzed the data, we discovered it does not cover a huge area that could have potential issues and become invisible. For instance, station UUS-16 Pohjanp.Lahti 92 to Stadsfjärden Vitsten 210 station have approximately 10 km distance differences, which typically neglects numerous elements that impact water quality. So, in this sense, the limitation of the fixed station approach could be beneficial for the coast rider approach to compensate for the neglected areas by gathering meter-to-meter data that have been lost in kilometers. However, the better part of the fixed station sampling is that the data collecting point will be precise and monitored continuously to follow the graph and visualize accurately. In addition, as stated by Bella & Hughes, 1983, fixed station monitoring can offer reliable data on regional and national water quality trends. Also, they mention that accurate estimates of water quality may be biased but accurate estimates of trends with lower variability can be obtained.

Thus, to emphasize the fixed station method we categorize it as below.

Benefits:

- Possible to measure different depth samples.
- Sampling routinely of a well-defined, fixed number of parameters and time can significantly reduce sampling costs (Belle & James, 1983).
- It helps to represent valid local and national data about the trends in water quality (Belle & James, 1983).

Limitations:

- Might not match or apply to the result of 2 stations in the case of the area between them.
- The data needs to be compared between field and laboratory to be more uniform and quality.

6.1.2 Coastrider monitoring method

Since the Coastrider monitoring method operates along the route, which is quite huge to compare, we selected the specific area that closely matches the fixed station within its closest points. As well as taking into account several points between those fixed stations to investigate how much data are neglected and what it means in terms of water monitoring analysis.

This method can be taken as an intensive process which is a prohibitive cost as it is used in a specific region and for more specific issues to answer. However, this method fills the gap that fixed station sampling data collection from a particular location but not from the whole area to generate variability of data. Likewise, it can be used for researching the cause-and-effect links of pollution, short-term fluctuations in water quality, and the relationship between these fluctuations and other hydrological phenomena (Belle & Hughes, 1983).

Thus, we can conclude that the benefits and limitations of the Coastrider method are the following:

Benefits:

- Can cover the shallow coastline and specific focused catchment areas
- Fulfill the distance gap between two fixed stations.
- Handy to conduct monitoring as per necessity.
- Help to study short-term fluctuations in water quality, cause and effect relationship of contamination (Belle & James, 1983).

Limitations:

- Can measure one depth at a time.
- Difficult to drive along the coast because of different barriers like stone, and vegetation.
- Does not provide a valid and effective long-term trendline presentation of water quality status (Belle & James, 1983).

6.1.3 Remote sensing monitoring method

Remote sensing monitoring is also not appropriate to perform all complicated work or in any circumstance perfectly. Depending on the precise demands and specifications, it can either supplement traditional methods or replace field work, lab tests, or office-based work (Certi, 2020). To help mitigate climate change, manage resources, and develop environmental policy, remote sensing is a useful tool for tracking and evaluating environmental changes such as changes in water quality, land use, glacier retreat, and deforestation (Machireddy, 2023). Constraints and uncertainties reduce the trustworthiness of remote sensing data in large-area applications. A significant barrier to creating trustworthy classifications is cloud pollution, which affects more than 50% of the planet. Estimates of vegetation and climatic systems can be impacted by optical perception distortion caused by clouds and shadows (Esche & Franklin, 2022). Since seasonal effects influence climate systems on a range of temporal and geographical scales, accurate categorization is difficult. Similarly, a detailed examination of our research location and the time we selected undoubtedly imposed some constraints to augment the remote sensing data in our comparison, since the majority of the region is shallow and has a lot of vegetation because the seasonal period falls at the start of summer.

Thus, we like to feature the following;

Benefits:

- Helps monitor and analyze environmental changes such as land-use changes, and climate change mitigation.
- Used to monitor and manage water resources, such as water quality, availability, and changes in water levels.
- Efficient means of collecting data from vast geographical areas in a short time (Neyns & Canters, 2022).

Limitations:

- It can be expensive to implement and maintain.
- A lack of trained people and skills can limit the application in general use.
- Atmospheric conditions such as clouds, haze, etc. can limit the accuracy and usefulness of the data.

6.1.4 Method usefulness

Table 2. Description of importance and usefulness of three different water quality monitoring methods.

Mobile	Fixed Station	Remote Sensing
1. Flexibility to customization the monitoring method as per necessity. 2. Opportunity to have combination of route planning, self-navigating, remote monitoring, and real-time water quality monitoring. 3. Can be applicable to the area where manual and fixed station method is not sufficient and remote sensing is not working enough. 4. Useful when fixed station sampling is not sufficient and remote sensing is not possible due to weather and topographical barriers.	1. Water sampling required to follow the certain framework that includes designing the network, deciding to select the water quality variables going to be measured, and selecting sampling sites and the frequency of samples (Sanders 1983). Hence, fixed station method helps to eliminate mentioned above difficulties. 2. Capturing consistency and long-term data trend. 3. In some cases, be able to detect water quality parameters in real-time and on-site (Adu-Manu et. al, 2017). 4. Researchers emphasized the need for fixed sampling stations for convenient access and consistency in sample collection (Sanders, 1983; WHO, 2011; Strobl and Robillard, 2008).	1. It provides efficient in collecting data from bigger picture in a minimal time frame, making it a usefulness tool for environment monitoring. 2. It can capture data from the areas that are threatening and challenging to access such as, volcanic zone, deep oceans, conflict area, hazardous pollutants, etc (Spatialpost, 2023). 3. It can capture various and different angles and wavelengths images that can be useful in agricultural aspect, wildlife monitoring, geological investigation, etc. (Neyns & Canters, 2022).

6.2 Questionnaire discussion

Based on the results receive from survey we can conclude that they are all aware of the various techniques used to monitor water quality and that they all concur that the monitoring should be put into practice. About half of the respondents think that monitoring should happen once a month, and most of them think that using a fixed-station regular approach would yield better results than using a time interval method. However, 25% of respondents also think that using a coast rider yields more varied and improved results. Thus, once more, 50% of respondents think that the Coastrider approach aids in obtaining enhanced evidence to gather potential solutions, such as understanding the state of the nutrient load and carbon emissions, among other things. Majority of respondent believed that the Coastrider helps to acquire comprehensive results. Thus, in general, it seems that the coast rider method could have been more conceivable and broadly used for supplementing the fixed station approach.

Since all the respondents during the questionnaire process are from the relevant field, therefore, it is understandable that they all answered with knowledge of it. In case of how often should monitoring be conducted for effective monitoring purpose. Indeed, there might not be universal answer of the question because based on different research areas, landscapes, and objective of monitoring might be several options as we could consider based on various aspects. However, substantial respondents believe monthly monitoring might be effective among other options i.e., seasonal, quarterly, and yearly. If it is possible to conduct monitoring monthly basis in any type of water resource, it could be good to know the status of respective water resources.

7 Conclusion

The research question aims to find out the answer of how the methods differ, for what purposes are they useful and how is the mobile monitoring method perceived in comparison to the fixed station monitoring. Based on a comparison between both methods, available evidence and facts from several perspectives lead us to carry out the conclusion as follows.

- Both methods are not alternatives to each other, however, complement each other according to the objective, landscape, and other relevant factors of the study.
- Whenever a choice is made for a specific region, i.e., the area between two fixed stations that are significantly apart, it may be impacted by several factors. Nonetheless, the mobile-based monitoring approach accounts for every outcome along the path, potentially yielding consistent outcomes.
- The mobile-based monitoring method result might be more effective and applicable for specific area monitoring for specific reasons, for example, to figure out the status of the area surrounding a fish farm, effects of the agricultural landscape, etc.
- The mobile-based monitoring method result might be more convincing to the general public in comparison to the fixed station monitoring method because the significant amount and consistent data make them realistic.
- Mobile monitoring methods can be a better tool to improve water quality at a local level.

8 Limitations and suggestions for further study

Indeed, every task has limitations and the possibility of improvement, which means there is not anything that is a hundred percent perfect. Our thesis is based on our internship therefore, we have been experiencing many difficulties and limitations from the period of internship which is ultimately associated with the thesis. Hence, the difficulties and limitations that we have experienced on this academic task are as follows:

- **Time:** Time is a crucial fact that is not under our control in that sense we wouldn't be able to hold it in our favor. We need to be dynamic and adjust to be adjusted with the flow of time. In terms of sum of the knowledge into thesis based on the practical work we were only 5 months for the internship period. Therefore, we were optimum utilize our time to get knowledge as much as possible within this period which might not have been sufficient to come up with a clear idea. It was not mandatory to have a thesis based on the internship. However, we thought that it could best idea to document the knowledge of practice work instead of finding new topic which absolutely required sufficient time again.

- **Resources:** A direct reference to funds or money has been made about resources. It was possible to conduct monitoring ourselves to obtain the updated data of same day or closest day, if we have had been granted money somehow for this thesis task. Besides the data access on mobile based monitoring, indeed, we have been used open source of data for fixed station, if there was not financial limitation it was possible to conduct monitoring at those station as well. Hence, resources may be of the highest caliber that impact significantly to generate the thesis work.
- **Knowledge:** Knowledge is one of the key elements that decide the quality of work. The notion of summarization and outcome of the internship task as thesis. Indeed, as a trainee or a student of bachelor the level of knowledge matters to come up with the outcome of the project and entire learning process. Therefore, our level of knowledge is one of the key limitations of the complete performance of the internship and ultimately thesis as a outcome of it.

There is always the next opportunity for improved and better outcomes. Indeed, we know about the fact that continuous and repeated research in a certain field only makes it possible to have a solid result that is useful for the entire human and the whole universe. Hence based on our study and findings we are figuring out some possible aspects and perspectives for further study and research in this field as per the following.

- There are thousands of data have been collected on different water variables i.e., Salinity, fDOM, turbidity, Chlorophyll-*a*, and Temperature in between Kirkkonummi to Bromarv, Hanko. Therefore, there are various possibilities for research in different aspects through the help of different water variables. For example, where is the requirement for wetlands in agriculture sites and possible precautions for other human activities such as industrial sites, highly populated are, etc.?

If any project has already been implemented for contribution to coastal water quality improvement in that case this mobile-based monitoring method such as “Coastrider” might be useful for following up on the effectiveness of the project.

References

Abbaspour, S. (2011). Water quality in developing countries, South Asia, South Africa, water quality management, and activities that cause water pollution. *IPCBEE*, *15*(94), e102.

Adu-Manu, K. S., Tapparello, C., Heinzelman, W., Katsriku, F. A., & Abdulai, J. D. (2017). Water quality monitoring using wireless sensor networks: Current trends and future research directions. *ACM Transactions on Sensor Networks (TOSN)*, *13*(1), 1-41.

Ajayi, V. O. (2017). Primary sources of data and secondary sources of data. Benue State University, 1(1), 1-6.

Akinde, S. B., & Obire, O. (2011). In-situ physico-chemical properties of the deep Atlantic Ocean water column and their implications on heterotrophic bacterial distribution in the Gulf of Guinea. Advances in Applied Science Research, 2(6), 470-482.

An introduction to water quality monitoring (2012) *EPA*. Available at: https://archive.epa.gov/water/archive/web/html/monintr.html (Accessed: 24 September 2023).

Alg@line Ferrybox (no date) *FINMARI*. Available at: https://www.finmari-infrastructure.fi/ferrybox/ (Accessed: 29 November 2023).

Bhardwaj, J., Gupta, K. K., & Gupta, R. (2015, February). A review of emerging trends on water quality measurement sensors. In 2015 International Conference on Technologies for Sustainable Development (ICTSD) (pp. 1-6). IEEE.

Bogdan, R., Paliuc, C., Crisan-Vida, M., Nimara, S., & Barmayoun, D. (2023). Low-Cost Internet-of-Things Water-Quality Monitoring System for Rural Areas. *Sensors*, *23*(8), 3919.

Certi.org, 2020. Environmental monitoring by remote sensing, available at https://certi.org.br/blog/en/environmental-monitoring-by-remote-sensing/, accessed on 08 December 2023

Chen, Wei & Hao, Xiao & Yan, Kui & Lu, JianRong & Liu, Jin & He, ChenYu & Zhou, Feng & Xu, Xin. (2021). The Mobile Water Quality Monitoring System Based on Low-Power Wide Area Network and Unmanned Surface Vehicle. Wireless Communications and Mobile Computing. 2021. 10.1155/2021/1609612.

Coastrider. Available at: https://prolitore.fi/fi/coastrider/ (Accessed: 25 September 2023).

Esche, H. A., & Franklin, S. E. (2002, June). Assessing cloud contamination effects on K-means unsupervised classifications of Landsat data. In *IEEE International Geoscience and Remote Sensing Symposium* (Vol. 6, pp. 3387-3389). IEEE.

Finnish Environment Institute > Monitoring related to the WA (no date) *Finnish Environment Institute >*. Available at: https://www.syke.fi/en-US/Research__development/Water/Monitoring (Accessed: 24 September 2023).

Finnish research vessels – over one hundred years of history. Available at: https://www.marinefinland.fi/en-US/Research_and_methods/Research_vessel_Aranda/100_years_of_history (Accessed: 25 September 2023).

Fontana, A. and Frey, J.H., 2005. The interview. *The Sage Handbook of Qualitative Research*, *3*, pp.695-727.

Gholizadeh, M. H., Melesse, A. M., & Reddi, L. (2016). A comprehensive review on water quality parameters estimation using remote sensing techniques. *Sensors*, *16*(8), 1298.

Gunko, R., Rapeli, L., Scheinin, M., Vuorisalo, T., & Karell, P. (2022). How accurate is citizen science? Evaluating public assessments of coastal water quality. *Environmental Policy and Governance*, *32*(2), 149-157.

EPA, 2023, Indicators: Chlorophyll a | U.S. Environmental Protection Agency. Available at: https://www.epa.gov/national-aquatic-resource-surveys/indicators-chlorophyll (Accessed: 26 October 2023).

EPA, 2023, Indicators: Salinity | U.S. Environmental Protection Agency. Available at: https://www.epa.gov/national-aquatic-resource-surveys/indicators-salinity (Accessed: 26 October 2023).

Itämeri, 2023, Download data of the Baltic Sea state, available at https://merihavainnot.ymparisto.fi/merihavainnot/, accessed on 09 October, 2023

Kauppila, P., & Bäck, S. (2001). The state of Finnish coastal waters in the 1990s.

Kothari, C.R., 2004, Research Methodolog : Methods and Techniques. Available at: https://ds.amu.edu.et/xmlui/bitstream/handle/123456789/9330/Research%20Methodology.pdf?sequence=1 (Accessed: 19 September 2023).

Kautsky, L., & Kautsky, N. (2000). The baltic sea, including bothnian sea and bothnian bay. Seas at the millennium: an environmental evaluation, 1, 121-133.

Lital, A., & Tattari, S. (2012). Guidelines for surface and drainage water quality monitoring in agriculture-dominated areas.

Li, D., & Liu, S. (2018). *Water quality monitoring and management: Basis, technology and case studies*. Academic Press.

Machireddy, S. R. Natural Resource Management using Remote Sensing and Geographic Information Systems.

McCain, C., Hooker, S., Feldman, G., & Bontempi, P. (2006). Satellite data for ocean biology, biogeochemistry, and climate research. Eos, Transactions American Geophysical Union, 87(34), 337-343.

Mohseni, F., Saba, F., Mirmazloumi, S. M., Amani, M., Mokhtarzade, M., Jamali, S., & Mahdavi, S. (2022). Ocean water quality monitoring using remote sensing techniques: A review. *Marine Environmental Research*, 105701.

Neyns, R., & Canters, F. (2022). Mapping of urban vegetation with high-resolution remote sensing: A review. Remote sensing, 14(4), 1031.

Quiz & worksheet – effects of salinity | study.com (no date) *Study.com*. Available at: https://study.com/academy/practice/quiz-worksheet-effects-of-salinity.html (Accessed: 26 October 2023).

Rautiainen, L., Tyynelä, J., Lensu, M., Siiriä, S., Vakkari, V., O'Connor, E., ... & Laakso, L. (2023). Utö Observatory for Analysing Atmospheric Ducting Events over Baltic Coastal and Marine Waters. Remote Sensing, 15(12), 2989.

Redman, LV, & Mory, AVH (1923). The Romance of Research, 1923. *P-10* .

Ritchie, J. C., Zimba, P. V., & Everitt, J. H. (2003). Remote sensing techniques to assess water quality. *Photogrammetric engineering & remote sensing*, *69*(6), 695-704.

Rinne, H. (2014). Macroalgae across environmental gradients: tools for managing rocky coastal areas of the northern Baltic Sea.

Roopa, S. and Rani, M.S., 2012. Questionnaire designing for a survey. *Journal of Indian Orthodontic Society*, *46*(4_suppl1), pp.273-277.

Sanders, T. G. (1983). *Design of networks for monitoring water quality*. Water Resources Publication.

Scheinin, M., & Asmala, E. (2020). Ubiquitous patchiness in chlorophyll a concentration in coastal archipelago of Baltic Sea. Frontiers in Marine Science, 7, 563.

Shifrin, K. S. (1998). Physical optics of ocean water. Springer Science & Business Media.

Spatialpost, (2023). Exploring the Pros and Cons: Advantages and disadvantages of Remote Sensing, available at https://www.spatialpost.com/advantages-and-disadvantages-of-remote-sensing/, accessed on 08 December 2023

Spratt, C., Walker, R. and Robinson, B., 2004. Mixed research methods. Practitioner Research and Evaluation Skills Training in Open and Distance Learning. Commonwealth of Learning. (Accessed: 20 September 2023).

Strobl, R. O., & Robillard, P. D. (2008). Network design for water quality monitoring of surface freshwaters: A review. *Journal of Environmental Management*, *87*(4), 639-648.

van Belle, G., & Hughes, J. P. (1983). Monitoring for water quality: fixed stations versus intensive surveys. *Journal (Water Pollution Control Federation)*, 400-404.

The Advanced Learner's Dictionary of Current English, Oxford, 1952

Thulin, J., & Andrushaitis, A. (2003). The Baltic Sea: its past, present and future. In *print in the proceedings of the Religion, Science & the Environment Symposium V on the Baltic Sea*.

TOYIN, F. B. (2019). IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES.

Tvärminne zoological station, 2023. MONICOAST: Tvärminne Zoological Station, *University of Helsinki*. Available at: https://www.helsinki.fi/en/research-stations/tvarminne-zoological-station/research/monicoast (Accessed: 29 November 2023).

USGS, 2023 What is remote sensing and what is it used for? Available at https://www.usgs.gov/faqs/what-remote-sensing-and-what-it-used, accessed on 8 December 2023

Usali, N., & Ismail, M. H. (2010). Use of remote sensing and GIS in monitoring water quality. Journal of sustainable development, 3(3), 228.

Wang, B., Cai, H., Jia, Q., Pan, H., Li, B. and Fu, L., 2023. Smart Temperature Sensor Design and High-Density Water Temperature Monitoring in Estuarine and Coastal Areas. *Sensors*, *23*(17), p.7659.

Water quality monitoring : A practical guide to the design and implementation of freshwater quality studies and Monitoring Programs / edited by Jamie Bartram and Richard Balance (1996) *World Health Organization*. Available at: https://apps.who.int/iris/handle/10665/41851 (Accessed: 24 September 2023).

Watson, S. B., Whitton, B. A., Higgins, S. N., Paerl, H. W., Brooks, B. W., & Wehr, J. D. (2015). Harmful algal blooms. In Freshwater Algae of North America (pp. 873-920). Academic Press.

Wasmund, N., & Zettler, M. L. (2023). Long-Term Trends of the Offshore Ecosystems. In Southern Baltic Coastal Systems Analysis (pp. 163-174). Cham: Springer International Publishing.

Why monitoring water quality is important. (2021, May 11). Sinay.

https://sinay.ai/en/why-monitoring-water-quality-is-important/

Woody, Clifford. "A survey of educational research in 1923." *The Journal of Educational Research* 9.5 (1924): 357-381.

Appendices

Appendix 1: Questionnaire

1. Have you heard (and know) about water quality monitoring?

- *Yes*
- *No*

2. Do you think monitoring water resources is essential or not in terms of knowing the ecosystem?

- *Yes*
- *No*
- *I don't know.*

3. Do you think it is important to conduct coastal water monitoring?

- *Yes*
- *No*
- *I don't know.*

4. Have you heard about water quality sampling methods?

- *Yes*
- *No*

5. Have you participated in water quality sampling?

- *Yes*
- *No*

6. Do you think that water quality monitoring is important?

- *Yes*
- *No*
- *I don't know.*

7. How often should monitoring be conducted for being effective?

- *Once a year*
- *Seasonal*
- *Quarterly (every 3 months)*
- *Monthly*
- *I don't know.*

8. Which method do you think is better in terms of the efficiency of the result?

- *Fixed Station regular sampling (like monicoast at Tvärminne Zoological Station)/Link: https://www.helsinki.fi/en/research-stations/tvarminne-zoological-station/research/monicoast*
- *Fixed station time interval sampling method / (Note:If you download data from given link and see the structure of data you understand about it)Link: https://merihavainnot.ymparisto.fi/merihavainnot/*
- *Fixed route along the coast/Coastrider sampling method/Link: https://prolitore.fi/fi/coastrider/*
- *I don't know.*

9. Do you think monitoring is important to contributing to possible remedies (for example, to know the status of carbon and nutrient loads, construct wetland in agriculture area)?

- *Yes*
- *No*
- *I don't know.*

10. Which method helps obtain information for possible remedies (for example, to know the status of carbon and nutrient loads, construct a wetland in agriculture area)?

- *Fixed Station regular sampling*
- *Fixed station time interval sampling method*
- *Fixed route along the coast/Coastrider sampling method*
- *No Idea*

Appendix 2

Coast rider comparing 12 points.

OBJECTID	Salinity_Coastrider	Temperature_Coastrider	Chlorophyll-*a*_Coastrider
1	0,64	11,1	14,9
2	0,65	11	13,85
3	0,67	11,73	9,54
4	0,76	11,89	8,62
5	0,87	11,41	10,55
6	1,56	11,42	7,89
7	1,92	12,97	13,28
8	1,06	13,43	13,68
9	0,94	13,64	15,18
10	1,35	13,31	12,16
11	2,07	12,91	11,04
12	0,94	11,22	9,22

(Scheinin, By Email, 2023)

Fixed Station 4 points

OBJECTID__	Salinity_Fixed Station	Temperature_Fixed Station	Chlorophyll-*a*_Fixed Station
2	0,08	13,03	16
9	1,03	15,03	20
11	2,01	14,06	22
12	1,04	13,04	19

(Itämeri, 2023)