Technical
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Testing and developing manuals for citizen science monitoring of temperature, oxygen and fish biodiversity

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Bachelor Thesis

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Preface

This thesis is presented in candidacy for the B.Sc in Engineering (General Engineering) at the Technical University of Denmark. The work has been carried out at the Department of Aquatic Resources from September 2022 to February 2023. The project work was conducted at DTU Lyngby Campus and in collaboration with Projekt Kysthjælper under the supervision of Lecturer Mikael van Deurs and Marine biologist Erik Haar Nielsen.

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Signature

1. Februar 2023

Date

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A special thanks to VELUX FONDEN for making the field campaign a reality by sponsoring equipment and other expenses in connection with this thesis. I am very grateful for the help recieved by:

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At last I want to thank my friends and family, who have helped and supported me in the process of writing this thesis.

Abstract

The decline of eel grass within the past 100 years has resulted in loss of habitats for many species in Danish waters and the adjacent Baltic Sea, causing environmental disturbances, pressured fish populations and the collapse of coastal fisheries. In an attempt to get the eel grass back, Projekt Kysthjælper has planted an eel grass meadow in Kalø Vig using sprouts from nearby eel grass population. In order to test whether it will be possible to restore and whether the new bed will have the same biological benefits as a natural eel grass meadow.

In this thesis, a field campaign was carried out where the newly planted eel grass meadow at Kalø vig was compared with a nearby location where no eel grass occurred. The two locations were compared on temperature and oxygen content in the water during the day and overnight for a period of three days. Over the same period, fishing was carried out using lobster traps and fyke nets to survey fish abundance and the diversity of fish at the two locations.

It was evident that the lobster trap was the most effective method for examining fish abundance and diversity of fish in the two areas. It was clear that the cod in particular preferred the eel grass, as the cod was caught exclusively in the newly planted eel grass during the field campaign.

It was observed that the oxygen levels decreased at both locations during the night, caused by respiration from fish, benthic animals, small organisms, and plants. Based on this respiration rate, a simple model was created to predict the respiration rate at the same location but at a higher temperature, which is expected to occur during the summer, leading to more frequent oxygen depletion. The model is based on the temperature coefficient Q_{10} and will identify areas at risk of oxygen depletion during times of increased risk.

As a product of this thesis, a citizen science manual has been developed to investigate fish abundance and diversity of fish in desired areas using volunteering data collectors from Projekt Kysthjælper. As well as a manual for an optimized method to monitor the temperature and oxygen content in coastal habitats, which also can be used by volunteers from Projekt Kysthjælper. So that we can get a better overview and understanding of the state of the oceans around us.

Resume

Ålegræssets tilbagegang gennem de sidste 100 år, har resulteret i tab af levesteder for mange arter i de danske farvande og den tilstødende Østersø, der forårsager miljøforstyrrelser, pressede fiskebestande og kollaps af kystfiskeri. I et forsøg på at få ålegræsset tilbage, har Projekt Kysthjælper prøveudplantet et nyt ålegræsbed i Kalø Vig, ved brug af skud fra naturlig ålegræs i nærheden. Formålet er at teste om det vil kunne lade sig gøre at restaurere, og om det nye bed vil have de samme biologiske fordele som et naturligt bed.

I denne afhandling blev der foretaget en feltkampagne hvor det nyplantede ålegræsbed ved Kalø Vig blev sammenlignet med en nærtliggende lokation, hvor der ikke forekom ålegræs. De to lokationer blev sammenlignet på temperatur og iltindhold i vandet om dagen og henover natten i en periode af tre dage. Henover samme periode blev der fisket med hummertejner og åleruser for at bestemme fiskebestanden og diversiteten af fisk ved de to lokationer.

Det var her tydeligt at hummertejnen var den mest effektive metode til at undersøge diversitet og fiskebestand i de to områder. Det var særligt torsken der foretrak ålegræsset, da der udelukkende blev fanget torsk i det nyplantede ålegræs gennem feltkampagnen.

Det blev observeret, at iltniveauet faldt på begge lokationer i løbet af natten, grundet respiration fra fisk, bunddyr, små organismer og planter. Ud fra denne respirationsrate, blev der oprettet en simpel model, der kan forudsige respirationsraten på samme lokation ved en højere temperatur, som forventes at forekomme om sommeren, hvilket fører til hyppigere iltsvind. Modellen bygger på temperaturkoefficienten Q_{10} og vil identificere områder, der er i fare for iltsvind i perioder med øget risiko.

Som produkt af denne afhandling er en citizen science manual blevet udviklet for at finde diversitet og fiskebestand ved ønskede områder ved brug af frivillige dataindsamlere i Projekt Kysthjælper. Herudover en manual til en optimeret metode at moniturere temperaturen og iltindholdet i kystnære habitater, der ligeledes kan benyttes af frivillige i Projekt Kysthjælper, således at vi kan få et bedre overblik og forståelse for tilstanden i havene omkring os.

Contents

1 Introduction

Since the 1900, the area covered with eel grass in the ocean around Denmark have been reduced to a third of the original area[1]. This shortage of eel grass is critical, since it can be expected that a lack of eel grass will result in a scarcity of habitats for fish. As well as an absence of the oxygen stabilizing effect that eel grass provides.

During this paper a method to monitor and prove the positive effects of eel grass will be presented, as well as a simple model to predict the oxygen concentration based on the respiration rate, found in the data collected.

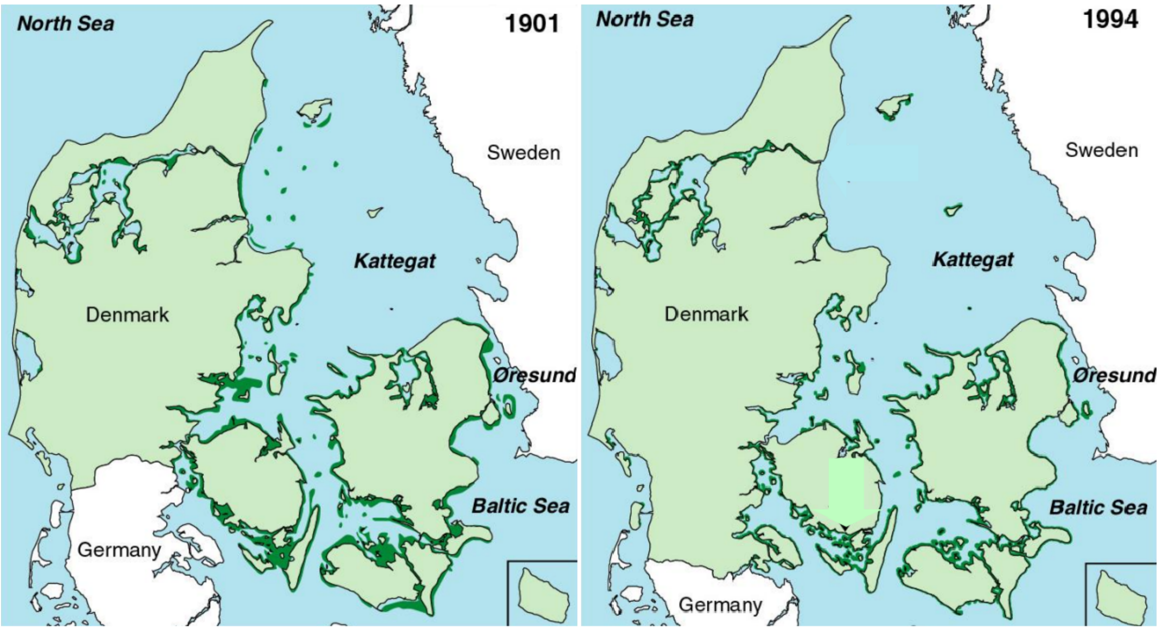


Figure 1: Reduction of area covered by eel grass from 1901 to 1994 [2].

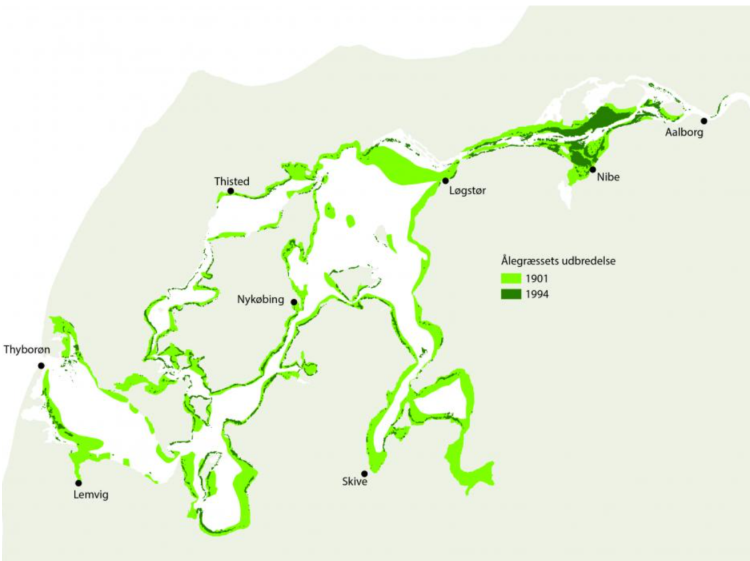


Figure 2: Reduction of area covered by eel grass in the Limfjord in nothern Jutland over the same time period [3].

2 Problem

Oxygen depletion, also known as anoxia, is a critical issue that can have severe consequences for aquatic life. Monitoring the oxygen levels over time can help detect long-term trends and understand the underlying causes of oxygen depletion, which can inform efforts to protect and restore vulnerable ecosystems.

The method currently being used to monitor the oxygen concentration in the ocean surrounding Denmark is the CTD (C = conductivity, T = temperature, D=depth). The CTD is made up of a set of small probes attached to a large metal rosette wheel. Sensors can be placed on the CTD so that dissolved oxygen, pH, turbidity, and fluorescence can be measured, depending on what the scientists wish to investigate[4]. The rosette is connected via a conducting cable to a computer on the ship performing the measurements at different locations. Once the ship is at a location the rosette will be lowered on a cable down to the seafloor. The scientists can then observe the water properties on the computer on the ship. For visualization a CTD-rosette can be seen on figure 3. This method have some glaring drawbacks, regarding the oxygen concentration.

1. The measurements are carried out from boat, which prevents measurements at locations with depths lower than the draft of the boat.
2. Only a few measurements are taken every year, since the method is expensive and time consuming.
3. Measurements primarely being carried out during the day could be misleading, since the respiration is disregarded.
4. This method disregards fish abundance and diversity completely.

Figure 3: CTD-rosette being retrieved after measurements are done.

3 Background information

3.1 Oxygen depletion

Oxygen depletion is the main focus of this thesis, thus a basic understanding of the causes, impacts as well as the consequences of the phenomenon is crucial.

3.1.1 What is oxygen depletion

Oxygen depletion occurs once the levels of oxygen in the waters declines to a point, where the fauna living in the area are forced to move to areas with more oxygen, or dies. Standard for oxygen concentrations set by the National Center for the Environment and Energy (DCE) are as follows[1]:

- No oxygen depletion (> 6 mg/l)
- Low oxygen concentration (4 - 6 mg/l)
- Moderate oxygen depletion (2 - 4 mg/l)
- Servere oxygen depletion (< 2 mg/l)

Oxygen depletion occurs when the oxygen consumption in the waters near the seabed exceeds the oxygen supply. Oxygen consumption is caused by respiration of benthic animals and plants once sunlight is inefficient [5]. As well as bacteria and other microorganisms during the breakdown of organic matter [1]. The amount of oxygen used in the breakdown of organic matter is dependent on three things. The degradability and amount of organic matter that is to be degraded, as well as the temperature during the process.
Stratification, being another major impact in oxygen depletion are frequent in the summer months. Therefore oxygen depletion, is most common in the warm months from July to November. However in some waters oxygen depletion is observed before July.

During the last 100 years, Oxygen depletion have had an alarming increase in frequency, duration and intensity, as well as areas affected by it[1]. This increase is caused by eutrophication and climate change. Eutrophication is the process by which an entire body of water, or parts of it, becomes progressively enriched with minerals and nutrients, particularly nitrogen and phosphorus. Which are a result of agricultural runoff which ends up in the ocean via the water cycle[6].
Eutrophication in the ocean leads to an increase in production of fast-growing phytoplankton. The rapid increase in fast-growing phytoplankton also increases the amount of dead phytoplankton which sinks to the bottom and gets decomposed. The increase in organic matter to be decomposed results in an increase of oxygen consumption and therefore oxygen depletion becomes more apparent.

Rise in temperature, increased precipitation and changing wind conditions are some key consequences of climate change, these also affect oxygen conditions. The increase of precipitation leads to more minerals and nutrients ending up in the ocean which promotes eutrophication. Wind conditions affect the stratification of the water column, as well as the current conditions which is the key for oxygen supply to the oxygen deficient water near the bottom as illustrated in figure 4.

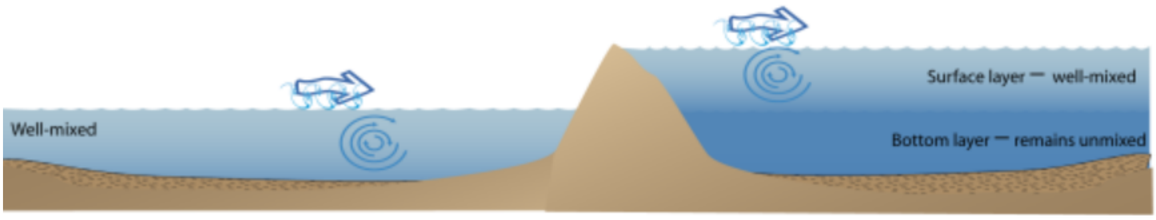


Figure 4: Illustration which demonstrates that stratification can prevent the bottom water for receiving oxygen.

The increase in temperature affects the stratification of the water column resulting in less oxygen exchange from the oxygenated layers to the deficient layers near the bottom. It is also known, that when the temperature of the water increases, its ability to contain oxygen decreases[7]. In addition the processes that consumes oxygen while decomposing organic material near the bottom is temperature dependent. As well as the fact that respiration rate of plants and fauna will increase at higher temperatures. These aspects combined is the reason that an increase in temperature in the waters will promote oxygen depletion.

It is worth mentioning that oxygen depletion can occur naturally, without eutrophication caused by agriculture. Or climate change as a result of an excessive release of greenhouse gasses to the atmosphere. However, in natural cases of oxygen depletion, it is very limited, and often in areas where the water is rarely stirred around[1].

On a yearly basis the severity of oxygen depletion is very dependent on the weather that same year, since the weather can promote, but also prevent oxygen depletion. The oxygen supply to the bottom water is mainly dependent on wind and currents which stirs oxygen rich water to the bottom.
Poor agitation and weak current can lead to stratification of the water column and insufficient oxygen supply to the bottom[1].

3.1.2 The effect of oxygen depletion on fauna and seabed

The oxygen content in the bottom-water is decisive for the living conditions of benthic plants, benthic animals and bottom-dwelling fish. Low oxygen levels in the benthic zone can lead to the death of these organisms, as they are unable to properly respire. This can have cascading effects on the entire ecosystem, as the loss of these species can disrupt the food chain and lead to imbalances in the population of other species. The larval stage of some benthic animals, such as clams and mussels, is particularly sensitive to low oxygen levels. These larvae require high levels of oxygen to properly develop, even before what was previously defined as no oxygen depletion occurs, insufficient oxygen to the larvae can result in high mortality rates[8]. At moderate oxygen depletion (2 - 4 mg/l) it is observed that many fish and more mobile benthic animals will try to evacuate the affected areas, and under longer periods with severe oxygen depletion the benthic animals will start to die.

Even though some fish and more mobile benthic fauna can escape the oxygen deficient areas, food for these fish can be much more scarce in these new environments that they migrate to, and thus they need to return to oxygen deficient areas to gather food. This have been observed for a number of fish including the Atlantic Cod(*Gadus morhua*)[9][10]. Tagging of the atlantic cod in the Bornholm Basin (Baltic Sea) has shown that some individuals voluntarily dove into severely hypoxic bottom waters to forage. These fish altogether spend 7% of their total time at low levels of oxygen, which falls below their critical level (P_{crit}) which resulted in an oxygen depth after which the fish returned to well-oxygenated water for physiological recovery and digestion[9]. The amount of time the fish can forage in the oxygen deficient waters depends on the individual aerobic scope in a fish. Fish with high aerobic scope can forage 3-4 times longer in severely hypoxic waters, compared with its counterparts[10]. Aerobic scope being the difference between minimal and maximum rate of aerobic metabolism. Fish with low aerobic scope are therefore very vulnerable once oxygen depletion occurs. Recurring years with oxygen depletion can therefore be dangerous for the Atlantic Cod, since it is specifically vulnerable to fluctuations in oxygen concentrations[11] which is part of the reason that specifically the cod is in focus during this thesis. A part from the atlantic cod, Benthic organisms are particularly vulnerable to coastal hypoxia because they live farthest from contact with atmospheric oxygen supply and because coastal sediments tend to be depleted in oxygen relative to the overlying water column [11].

Prolonged oxygen depletion can also lead to the formation of a white coating of sulfur bacteria on the seabed. This coating is the final defense against the poisonous gas hydrogen sulphide (H_2S). The sulfur bacteria's uses the last oxygen in the surrounding water to convert the hydrogen sulphide to the non-toxic sulfate (SO_4^{2-}). If all the oxygen is used in the surrounding water, and the sulfur bacteria are now unable to convert the poisonous gas. It will come up from the bottom as bubbles, and will be fatal for the living organisms in the vicinity[12]. The changed metabolism in connection with oxygen depletion also leads to a greater production of methane in the seabed. Methane is being produced constantly, however the lack of oxygen prevents the methane from forming into carbon dioxide (CO_2) and there will be forming methane bubbles, which flow out of the seabed. These bubbles can lift the upper part of the seabed into the water. This scenario is called a bottom turnover and as this happens, large amounts of hydrogen sulphite will be released and the event is fatal for almost all the living fish and benthic animals.

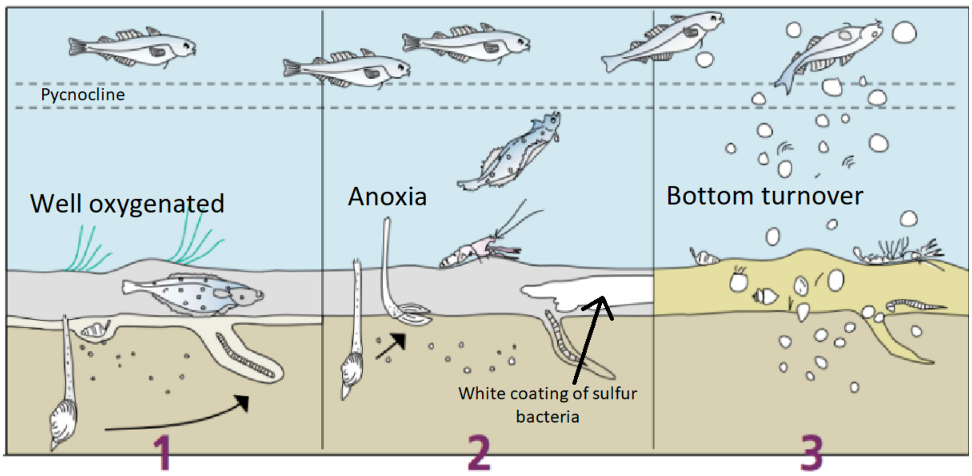


Figure 5: Illustration of a bottom turnover.

The pycnocline in figure 5 is the dividing surface in a water column as a result of stratification, conditioned by temperature and/or salinity differences between the bottom water and the top water.
After a bottom turnover has occured, it can take several years for the seabed to recover, since the bioturbation of the benthic animals have completely stopped[12].

3.2 Eel grass

During this thesis, we will investigate a coastal habitat scattered with eel grass, in comparison with an area close by without eel grass or alike vegetation. The purpose being to see the difference in fish abundance and biodiversity, as well as temperature differences and differences in oxygen levels.

Eel grass (*Zostera marina*) is a plant species that forms dense meadows in shallow waters. The eel grass meadows can be grown all the way out to a depth of 13-14 meters, if sufficient amounts of light is present, since it requires light for photosynthesis, as other plants. The plant consists of a branched rhizome, with thin green leafs, that can grow up to 120 cm towards the surface, but will never go above the surface. The plant reproduces using seeds from the flowers, but is also capable of reproducing using shoots from the rhizome, that allows new plants to grow vegetatively[13].

3.2.1 Benefits of eel grass

Eel grass is a key contributor to the well being of coastal habitats. A part from being an important food source for many overwintering birds such as geese, swans, piping ducks and mallards. The dense eel grass meadows are also home to a rich fauna of invertebrates and fish, while being a crucial nursing home for a large variety of fish. One of them being The Atlantic cod (*Gadus morhua*), which in recent years have seen rapid decline in population[14]. This further establishes the importance of these habitats.

The root networks of the eel grass meadows stabilizes the sediment in the seabed[15]. While the leafs dampens wave impact in that way acting as natural coastal protection, which prevents sediment erosion and sand migration[16].

A key characteristic of ell grass, is its ability to retain nutrients[17]. Studies show that ell grass meadows have higher denitrification than bare bottom areas[18]. The nutrients obtained by the eel grass is mainly put into growth of new leafs, the effect is thus most efficient during growing season. Over-nutrition being one of the main reasons for oxygen depletion in the danish waters could therefore be reduced by a large amount of eel grass. The eel grass would reduce nutrient availability for phytoplankton and opportunistic macroalgae, in turn reducing the risk of oxygen depletion.

Due to the light requirements eel grass need to produce photosynthesize. The depth of which eel grass can grow is used as an environmental indicator, that reflect the transparency of the water.

A part from being able to capture and store phosphor and nitrogen, eel grass also captures CO_2 and stores it, by converting it into biomass. Eel grass will have the most effect once a new eel grass meadow is being established, due to the fact that a net build up of biomass will occur, until a biomass climax is achieved[19]. Once the eel grass meadow has been established it will gradually capture and store CO_2 by having a net build-up of biomass during the growing season, which withers and partially breaks down in the winter season. Each year there will be a small surplus of built-up biomass. The CO_2 captured will be stored in the ribosome of the plant which is buried in the seabed, resulting in permanent immobilization of the CO_2. Newly established ell grass populations can absorb 0.25-0.8 tonnes of CO_2 per acres per year on a permanent basis. It is estimated that the existing eel grass in the danish waters has captured, and is currently storing around 5-21 million tons of CO_2[19]. Furthermore bacteria on the leafs of the plants promote the biological turnover in the water[16].

3.2.2 Difficulties when reestablishing eel grass meadows

Since the 1900, the area of eel grass meadows in the shallow waters in the danish coastline have been reduced to just below one third of its original area of approximately 670.000 acres[19]. The now 220.000 acres of eel grass meadows are crucial as mentioned above. Key aspects of the rapid decline of areas covered with eel grass meadows as well as difficulties for re-establishing new eel grass is thus important to understand.

Change in sediment type
It is unlikely that it will be possible to re-plant all of the lost 450.000 acres of eel grass since the seabed that the ell grass once grew on are now either rocky or muddy, and therefore inhospitable for the growth of ell grass. This problem can in some cases be solved using sand-capping[20], where a new seabed of sand is placed for the eel grass to grow upon.

Insufficient light
Oxygen depletion in itself is a major risk for eel grass, however oxygen depletion is not the only negative effect eutrophication has on the eco system. The amount of light that can pass though the water is impacted by the amount of phytoplankton that is present in the water, - in other words the more phytoplankton there is, the less transparent will the water be. Due to the fundamental biology of plants that therefore is applicable for eel grass. It is dependent on sufficient amounts of light, so that it can make photosynthesis. In order to prevent eutrophication, the emissions of nutrients from land have to be reduced. Lack of sufficient light for the photosynthesis can also be caused by lose sediment and small organic material that is being stirred up from the seabed.

Physical stress
Another reason for the setback in eel grass is physical stress, where the eel grass simply gets pulled out of the sandy seabed, which can be a result of clam scraping, since it is done near the coast where the eel grass grow. If the meadows aren't fully established, the roots will not have created enough stability for the sediment, and even less impact is needed to pull the plant off the seabed[21].

Impact from fauna

Green shore crabs (*Carcinus maenas*) does damage to the eel grass, by either cutting the leaves or digging down in the sand around the eel grass, which can be expected, since they all are meant to be living in balance. But since the eel grass is a key nursing habitat for The Atlantic Cod (*Gadus morhua*). The loss of habitats, among other things, have resulted in a decline in the population of The Atlantic Cod. Which means that one of the key natural predators for the Green shore crabs have been reduced significantly, resulting in that the population of crabs have been increased to a point where they tear up the eel grass more than the eel grass grows, as shown in figure 6. A part from being a good nursery ground for juvenile cods, the eel grass keeps the oxygen stable which the cods prefers [14]. A reduction in eel grass, will therefore reduce the stabilizing effect on the oxygen content in the water and the larger cods will migrate to other areas to gather food, which will further increase the amount of green shore crabs not being eaten.

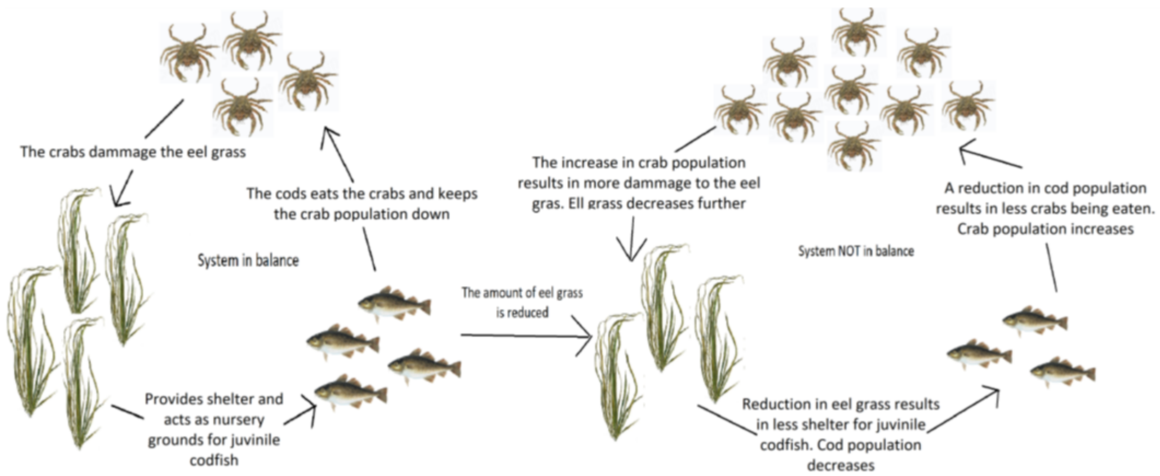


Figure 6: Simple figure that shows the negative feedback loop between cods, crabs and eel grass and the problem that follows an increase in crab population as the cod population decreases.

While the areas covered with eel grass meadows have decreased, another species have taken advantage of the now suitable environment, that once was covered in eel grass. This species being the sand worm(*Arenicola marina*) which usually thrives in the seabed next to eel grass meadows, and have thus expanded as the eel grass have decreased. Studies have shown that the sand worm buries the seeds from the eel grass at a depth that is too deep for the seeds to sprout into new eel grass, thus inhibits the eel grass from reproducing[21]. Ragworm(*Nereis diversicolor*) is another worm living in the same areas as the sand worm. The ragworm have the opposite effect. It also buries the eel grass seeds, but does it at an ideal depth, thus enhances the ability for the seed to successfully become a new plant of eel grass.

3.2.3 Re-establishing of eel grass

The most successful method to re-establish eel grass meadows as well as the method used to rebuild the eel grass in the area where the field campaign took place, is using healthy eel grass sprouts from a nearby eel grass bed. The sprouts are harvested using a rake and can be stored in seawater in up to a day. The sprouts are then attached with ungalvanized iron wire to an 8 cm ungalvanized iron nail. The purpose of the nail is to keep the sprouts in the sand until the plant can develop its own root network. By the time the root network is established the nail will be rusted away[16]. An alternative to the approach with nails is the use of bamboo sticks. The purpose being the same as for the ungalvanized nails.

The sprouts are then planted in circles with a diameter of one meter, formed in a chess board pattern to stabilize the seabed as well as leaving place for the eel grass to expand[17]. The seabed for new eel grass has to be stable and consist of sand or a mixture of sand and gravel or seashells. The growth rate of the newly planted sprouts are dependent on temperature, the optimal period for the planting of new eel grass is therefore in the spring, once the water is at a temperature where it is warm enough to work in.

4 Solution ideas

4.1 Citizen science

The solution this paper presents, to have an insight on the well being of the coastal waters surrounding Denmark in terms of oxygen concentration, temperature, fish abundance and fish diversity. The idea being to use citizen science to monitor oxygen concentration, as well as fish abundance and diversity in locations selected by "Projekt Kysthjælper".

Citizen science is a term used to describe the collection and analysis of data by the general public, citizen science is often done in collaboration with professional scientists. Projects can range from collecting data on local plant and animal populations to analyzing data from space telescopes. Citizen science allows people who may not have a scientific background to get involved in scientific research and make a contribution to our understanding of the world.

Projekt Kysthjælper (See section 5.1) already have a significant amount of volunteers, who would like to participate in data collection, such as one of the tasks, carried out in the field campaign which was performed in relation with this thesis.

4.1.1 Citizen science manuals

In addition to this thesis, two manuals for citizen science have been developed. One manual on how to set up and empty lobster traps to monitor fish abundance and diversity, similar to the manual that uses fyke nets. Aswell as another manual on how to set up a device that logs the oxygen concentration and the temperature over a given time period. The overall layout for the two manuals, is inspired by the manual to survey fish abundance using fyke nets, provided before the field campaign which was developed by Sissel Kolls Bertelsen in a project prior to this thesis. The reasoning behind this decision is that there now exist three similar manuals, that can be used by volunteers to perform citizen science. These manuals can be used in collaboration if one is interested in all of the three methods together as performed in the field campaign in this thesis. In such case it is favourable that the overall layout is similar so that the reader gets familiar with the way that the instructions are given.

On the other hand if one is interested in only one of the three methods. It is impractical to overload the volunteer with instructions for data collections, that they aren't supposed to perform. And a single manual tailored to the task is preferable.

Setting up the fyke nets, lobster traps and oxygen loggers can be quite a difficult and very physically demanding task. Being assisted by the volunteer Per Nicolai Andersen from Projekt Kysthjælper, when carrying out the field campaign where the citizen science manuals were being developed was a relief. Not only because of an extra pair of hands to do the heavy lifting, but having a sparring partner to discuss choices when faced with a difficult decisions was very beneficial. Performing the citizen science tasks in groups, could therefore be beneficial, not only to distribute the physically demanding workload. But giving the volunteers responsibilities for leading on one of the three main tasks, can prove to be beneficial for volunteers, and help them develop project management competences, without necessarily needing to understand the science behind the task given.

Furthermore there is several theories that supports the idea that individuals may be more motivated to participate in group projects. One of these could be goal setting theory[22] where the participants are motivated by reaching goals such as the catch and registration of a fish in one of the lobster traps and/or fyke nets in connection with surveying fish abundance. Vrooms expectancy theory is another theory, which suggest that individuals are more motivated to participate in group projects when they believe that their efforts will lead to successful outcomes[23]. These theories are important to take into account when developing the manuals.

There exist some key differences between a manual for fellow scientists, and a manual written for people without the scientific background and thus the knowledge to understand the reasoning behind the different steps of the manual. It is however important to mention that the volunteers who are likely to participate in the citizen science solution will have some key understanding of the science that applies to this study, since that it can be expected that they will be participating based on their own interests in the well being of the ocean. We can therefore assume that the target audience for volunteers will have some basic knowledge on the interplay between habitat type, oxygen, temperature, and fish biodiversity.

The following elements have thought to be important when developing manuals for individuals without a scientific background.

Use of images: Large companies who are dependent on their customers having the ability to assemble the products themselves such as IKEA or LEGO are known for their manuals, which almost exclusively use 3D drawings and pictograms to illustrate how the various parts must be put together. For the citizen science manuals developed during this thesis, 3D drawings can be quite difficult to create so that they fit the purpose of the manual, however the idea of illustrating the way that the product is supposed to be used can still be implemented in the manuals. Images have therefore been used in the manuals in order to avoid confusion for the reader, as well as a check-up for the user to see that what they have done looks similar to the pictures provided in the manual.

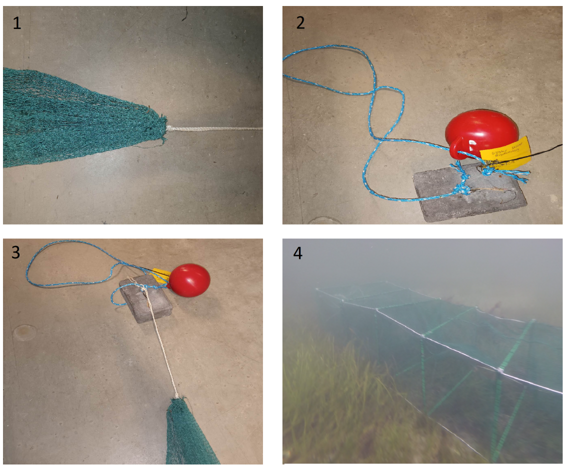


Figure 7: Images from citizen science manual for measuring fish abundance using lobster trap.

The other manuals have been attached, and the remaining images can be seen in there.

Clear goal of the task: It is important that the goal is clear for the individuals taking part in the citizen science data collection, so that they know when they have done the required work that is expected of them. A fellow scientist would be included in the overall scope of the task, and would therefore be able to deduct themselves when the task was successfully completed. It is therefore important that the goal of the manual is well defined.

Step-wise approach to task: A step-wise approach to the task have been chosen, since it divides what can be seen as an unmanageable task into a set of smaller, easy to do assignments, which in turn makes the whole task appear more manageable.

5 Field campaign

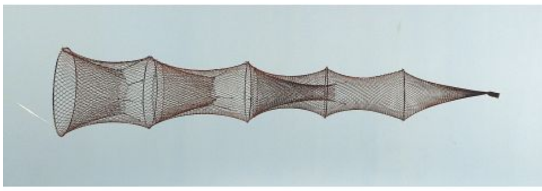
A field campaign to test and develop the methods, later to be used by volunteers in Project Kysthjælper was carried out from Monday 3rd. to Friday 7th. of October 2022.

5.1 Projekt Kysthjælper

"Projekt Kysthjælper" is a volunteer-based project financed by VELUX FONDEN, that does marine nature restoration in specific locations in coastal waters, along the 7300 km coastline around Denmark. The project started in back in 2021 and is going to continue until 2025. During this period local volunteers will help restore habitats for the marine life near the danish coast. By either placing large rocks for the fish, establishing mussel reefs or as we are going to investigate further in this thesis, planting eel grass on the seabed.

5.2 Equipment for field campaign

(a) Lobster trap



(b) Fyke net

Figure 8: Picture of lobster trap & fyke net for visualization.

The same exact equipment were used in both the control location, as well as in the location with the newly planted eel grass. For catching fish on each location were used two fyke nets as presented in figure 8b as well as one lobster trap figure 8a. In addition the required concrete loads and buoys according to danish law were also used. For the measurement of oxygen were used two Polaris C oxygen loggers from OxyGuard.

Table 1: Specs for the two different methods of fishing used during field campaign.

Type of trap	Lobster trap	Fyke net
Price	2499 DKK	1757 DKK
Mesh size	10 mm	18 mm - 11 mm
Net	210/12 Green	Knotless net
Ring size	21 pcs 60 x 40 cm	10 pcs 52.5 - 42.5 - 37.5 - 32.5 - 27.5 cm∅
Ring material	Plastic covered steel (Green)	Stainless steel
Total length	10 m	10.2 m
Fish caught	33 Fish	8 Fish

Table 2: Rating advantages and disadvantages found for the two methods during field campaign.

Type of trap	Lobster trap	Fyke net
Overall effectiveness	8	2
Small fish effectivity	9	1
Separation of fish and crabs	7	3
Depletion of crabs	3	7
First time setup	6	4
Routine check-up	2	8
Fish survivability	7	3
Total rating	42	28

The rating in table 2 is based on the performances of the different methods during the field campaign with respect to fish caught, and my own experiences working with the equipment as an inexperienced fisherman in terms of fishing with fyke nets and lobster traps. Each category having a total of 10 points, to be distributed between the two types of traps based in the performance. An in depth assessment of the two methods will be carried out in section 6.1.

5.3 Destination of field campaign

The location for the campaign was one of the areas that were restored in connection with Projekt Kysthjælper. Located just south of Vosnæs Fjord, and about 800 meters north of Kaløvig school in eastern Jutland.

The reason this specific location was chosen for the field campaign is that the conditions in the coastal area were ideal to reestablish a new eel grass meadow. In april-juni 2022 the test site on figure 9 had been selected as a test location for restoration of eel grass meadows. 30 volunteers from Projekt Kysthjælper had planted 1350 eel grass sprouts at the eel grass site seen in figure 9, using the method described in section 3.2.3 (Reestablishing of eel grass). The scope of this campaign was therefore not only to test and develop citizen science manuals. But also to investigate whether "artificially produced" eel grass meadows have the same biological advantages as the naturally occurring eel grass meadows.

Figure 9: Location for field campaign. eel grass site is located in the green square, control site is located in the yellow square.

The location proved more difficult than initially anticipated due to the fact that the test area were 800 meters from the nearest possible parking spot for the car, being the Kaløvig school. During the planting of the eel grass, Projekt Kysthjælper had been using a small boat to transport the equipment needed to the location. This was not possible and a wheelbarrow was the second most favourable choice. The location for the newly planted eel grass is approximately in the green square on figure 9, where the location selected as the control area, are in the yellow square. The two test areas being at least 200 meters separate of each-other, in order to have them as far away from each other, while still having the time to manually set up the equipment in the time available during low tide.

5.4 Weather and tide during field campaign

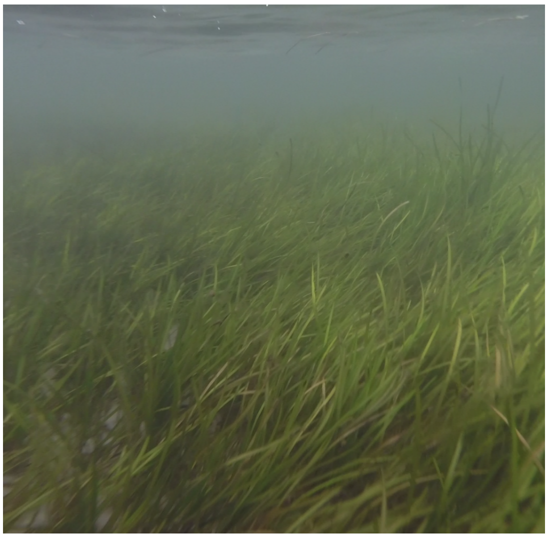
During the 4-day period the wind were from a W to SW direction with speeds of 6-7 m/s, where the 2nd day had a speed of 9 m/s, all of them being offshore wind, making it possible to check on the fishing traps daily. The tide-cycle during the experiment were having low tide during mid day and midnight, which made it impossible to check on the fishing-traps more than once every day.

5.5 Data collection

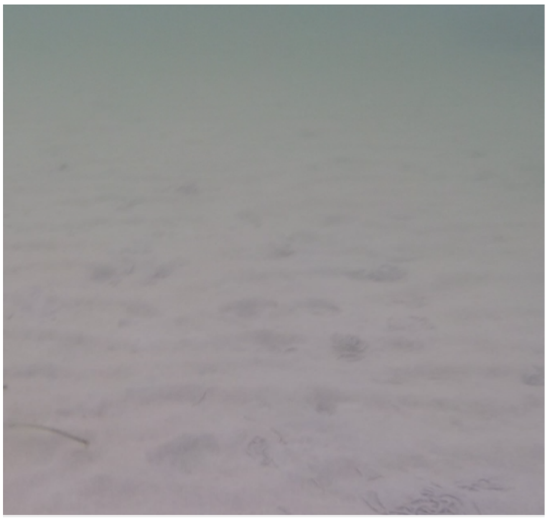
In the following section the data that was gathered during the field campaign will be presented. As if it was carried out by one of the volunteers in the citizen science solution.

5.6 Setup

The control site and the site with newly planted eel grass, were located at a distance of 200 meter from one another. On respective sites, fyke nets and lobster traps were placed with a distance of at least 10 meters to each other.
Bladder forceps and other species of seaweed was in attendance, at both locations. Fyke nets and lobster traps were placed no less than 5 meters from the nearest sample of bladder forceps in the control site. But since seaweed were far more abundant in the eel grass site, the distance to the nearest bladder forceps was at approximately 2 meters from where the fyke nets and lobster traps were placed. The traps and fyke nets were set up as close to the eel grass apparent, without damaging the eel grass.



(a) Underwater view from site with newly planted eel grass.



(b) Underwater view from control site, without any vegetation.

Figure 10: Underwater images from sites investigated during the field campaign.

The newly planted eel grass was in overall good condition, however the eel grass were not thriving as much as in figure 10a everywhere throughout the whole site, areas where the eel grass was in bad shape was avoided.

Oxygen loggers were fastened to one of the flag buoys for the fyke nets. The computer itself was kept in a tightly tied up plastic bag that was then put into another plastic back and tied to the buoy with strips, while the probe was submerged in the water and tied to the rope of the buoy approximately 15-20 cm above the seabed as seen on figure 11.

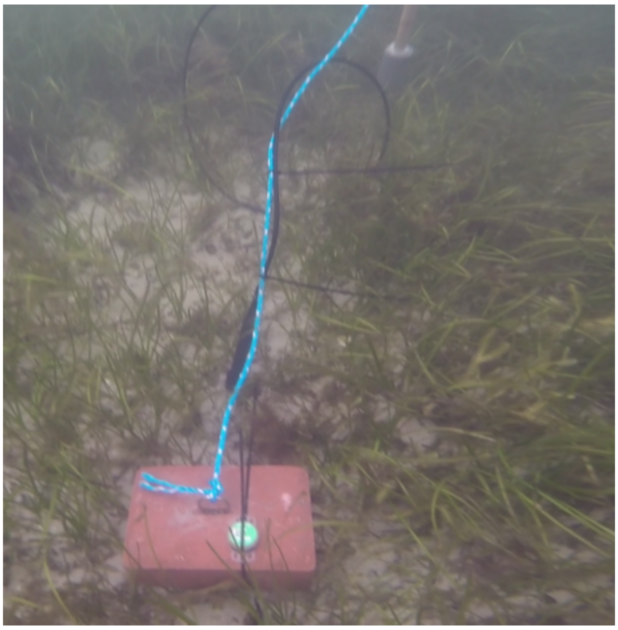


Figure 11: Setup of probe from OxyGuards oxygen logger on test site with eel grass from field campaign.

Oxygen concentration was monitored at all time from the start of the field campaign to the end of day two. Fyke nets and lobster traps were emptied for fish and crabs once a day, during low tide (once every 23.5 hours).

5.6.1 Fish caught

A large variation of fish were caught during the field campaign both in species of fish, as well as sizes.

Table 3: Fish caught in respective sites during field campaign.

Species of fish	Eel grass site	Control site
Atlantic Cod (*Gadus morhua)*	17	0
Shorthorn sculpin (*Myoxocephalus scorpius*)	4	3
European flounder (*Platichthys flesus*)	5	5
Black goby (*Gobius niger*)	1	1
Goldsinny wrasse (*Ctenolabrus rupestris*	2	0
Broadnosed pipefish (*Syngnathus typhle*)	0	1
Sea trout (*Salmo trutta*)	1	0
Corkwing wrasse (*Symphodus melops*)	1	0
Crab (*Brachyura*)	+100	+100
Total fish	31	10

Not all the fish were alive and well due to the large amount of crabs in the nets. However it was possible to determine species for all of the fish that was caught.

Flounders were more often victims to the attacks of the crabs than the rest of the fish. 9 of the 10 caught were dead and being eaten when the nets were checked. 3 of the 7 Shorthorn sculpins were being attacked by crabs when found. Not one single Atlantic cod was found with injuries from crab attacks.

5.6.2 Oxygen measurements

The data we were interested in during the field campaign apart from abundance and diversity of fish were oxygen concentration and temperature. It was expected that the temperature would be near constant throughout the whole period, since the measurements are taken close to the bottom, and the water is not expected to be heated significantly by the sun during the day. Oxygen concentration was expected to be higher during the day, and decrease once the sun would no longer provide light, and all the plants and organisms would transition to only respire, which would consume additional oxygen. Since the experiment was carried out during fall season, the risk of oxygen depletion are low, and it was therefore not anticipated that the oxygen concentration would drop significantly. It was expected that the oxygen concentration at the two sites would be similar, or that the oxygen level at the eel grass would be a little higher. The measurements from the field campaign are displayed in the same plot in order to compare the oxygen levels at the respective sites, at different times during the two day, alongside with temperatures to the corresponding time of the day, for the respective sites.

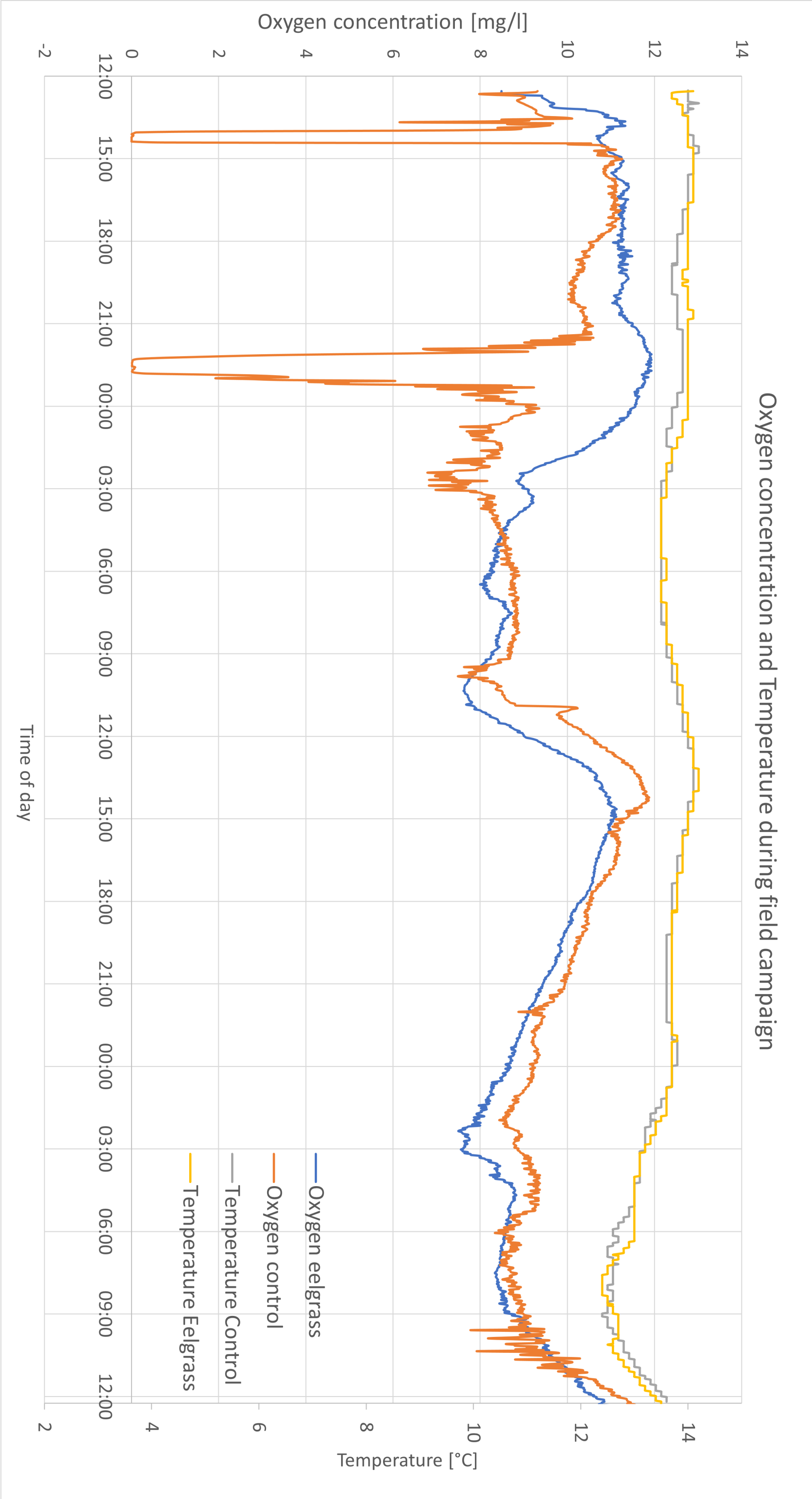


Figure 12: Oxygen concentration measurements during field campaign. Blue data is obtained at the eel grass site. Orange data is obtained at the control site. Temperatures from the two sites are plotted as well with grey being control site and yellow being ell grass site.

Disregarded the two major descends in oxygen, which will be discussed more in depth in the section 5.10 (Potential errors). It is seen that the oxygen measurements from the control site appears to be fluctuating more than the oxygen measurements obtained from the site with newly planted eel grass. It is also seen that the oxygen concentration never falls below 7 mg/l, which is as we expected, since there was plenty of wind during the field campaign. Disregarded the fluctuations, the oxygen concentrations at the two sites were fairly similar. The temperature remained fairly constant throughout the first day, but decreased at the second day as a result of colder weather. The coldest measurement being 12.4°C and the warmest being 14.2°C. Next to no difference in temperature between the two sites was observed.

It is seen that the oxygen saturation drops for both sites once sunlight is inefficient, as is expected since autotrophic organisms switches from photosynthesis to respiration in these periods[5]. Which further clarifies the importance of a method to monitor oxygen in the coastal habitats surrounding the danish shores, in a new way that accounts for the decrease in oxygen concentration once sunlight is unavailable. A major difference between oxygen concentration between the two sites is not apparent, likely due to the weather during the field campaign and the seasonal consequences of autumn.

5.7 Respiration rate

From the data collected, we can see some interesting things, one of which being the respiration rate for the two sites. On figure 12 we can clearly see when respiration starts. The data at the first day has some disturbance, which will be discussed further in section 5.10 (Potential errors), however at the second day, a downward linear slope begins at around 15:00. A separate plot have been made with the data from 15:00 to 02:30 where the respiration rate continues linearly as it can be seen below.

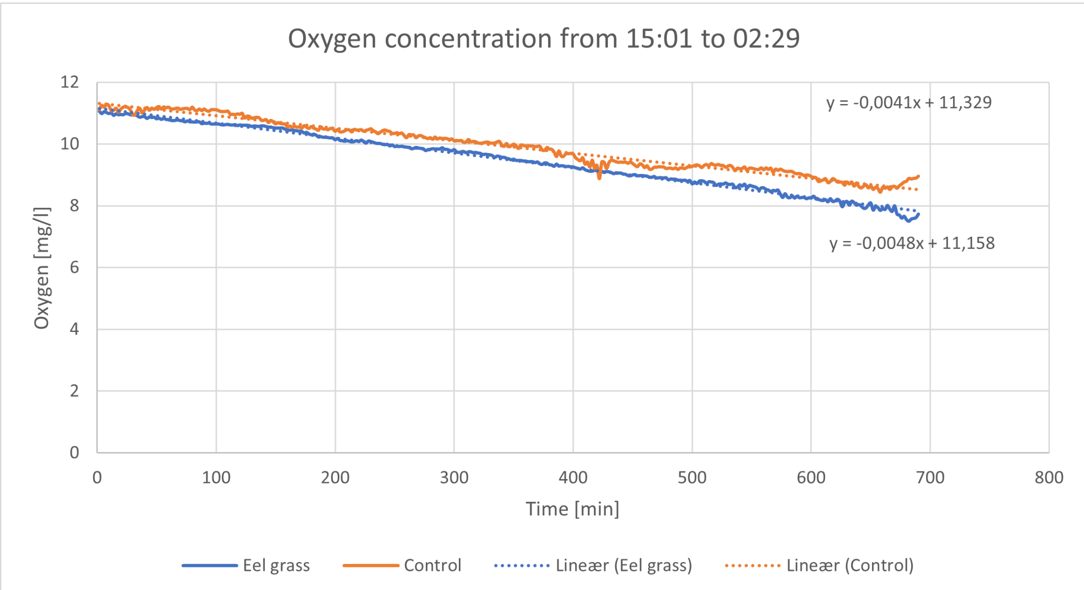


Figure 13: Oxygen measurements from both sites to find respiration rate.

The oxygen loggers were set to log data in an interval of 2 minutes, the respiration rate can therefore be found using linear regression on the slopes from figure 13. For the site with eel grass, the respiration rate was found as follows:

$$-0.0048mg/l/min \cdot 60min = 0.288mg/l/h \tag{1}$$

With the respiration rate known, we can calculate the time it would take in order for oxygen depletion to occur. Assuming that the respiration rate remains constant. For this simple example we will calculate the time it would take to reach 0 mg/l, using the respiration rate that was found for the eel grass site above, and the oxygen concentration once respiration occurs which was 10.6 mg/l.

$$\frac{10.6mg/l}{0.288mg/l/h} = 36.8Hours \tag{2}$$

What that is interesting with this, is that we now have a simple model that can give an estimate of how long it would take for complete for oxygen depletion to occur, furthermore we can predict with this simple model what the rate would be in the summer, where temperature of the water is higher. Based on the Arrhenius equation an equation for the temperature dependence of the respiration rate has been established[24]. The temperature coefficient Q_{10} can be used to predict the effect of temperature changes on the rate of a biological or chemical process. It is often used to study the effects of temperature on metabolic processes in living organisms, and can therefore be used to predict the respiration rate for our simple model. For most biological systems the Q_{10} value is $\sim 2 - 3$. We find the new rate using the following formula:

$$R_2 = R_1 \cdot Q_{10}^{T_2 - T_1/10°\mathrm{C}} \tag{3}$$

Where:
R_1 is our initial respiration rate
R_2 is the Q_{10} estimated new rate
T_1 is the temperature while our initial respiration rate was found
T_2 is the temperature we want an estimate for
Q_{10} is a unitless factor where we will use 2.

Our respiration rate was found to be 0.228 mg/l/hour. The temperature during the interval where the respiration rate was found were ranging from 13.7°C to 13.3°C, hence we use 13.5°C. Q_{10} is 2 due to the nature of the process and the temperature of the water which we want to find a new respiration rate is 18 °C.

In order to find the starting oxygen concentration for the water, when 100% saturated with oxygen, at the time photosynthesis stops at 18 °C. We need to know the salinity of the water.
For this simple model we assume that salinity is 10. This yields an oxygen concentration of 9.5 mg/l.

(*Spreadsheet for oxygen conversion from mg/l to % & oxygen conversion from % to mg/l will be attached.*)

The new rate can be found by inserting the above mentioned values in formula 3, and we get the following rate:

$$R_2 = 0.288mg/l/h \cdot 2^{\frac{(18^\circ C - 13.5^\circ C)}{10^\circ C}} = 0.393mg/l/h \qquad (4)$$

With this new estimated respiration rate for warmer water, we can calculate the time it would take for oxygen depletion to occur, again assuming salinity is 10 and that the water is 100% saturated when photosynthesis stops gives us an oxygen concentration of 9.5mg/l.

$$\frac{9.5mg/l}{0.393mg/l/h} = 24.1hours \qquad (5)$$

5.8 Net oxygen production of eel grass

From the oxygen data collected at the two sites during the field campaign, the net oxygen production of the eel grass can be found. But since the measurements have some significant flaws as presented in section 5.10. Some adjustments have to be made with the raw data, so that the spikes with no oxygen that occured at the control site will be equalized, and a comparison of the oxygen concentration between the two sites can be made.

Replacement data for the two instances with no oxygen is based on a respiration rate that was found to be somewhat similar with the respiration rate of the eel grass. Once this was done, The data was smoothed out using the standard moving average on 17 points of data, for both the eel grass site, and the control data.

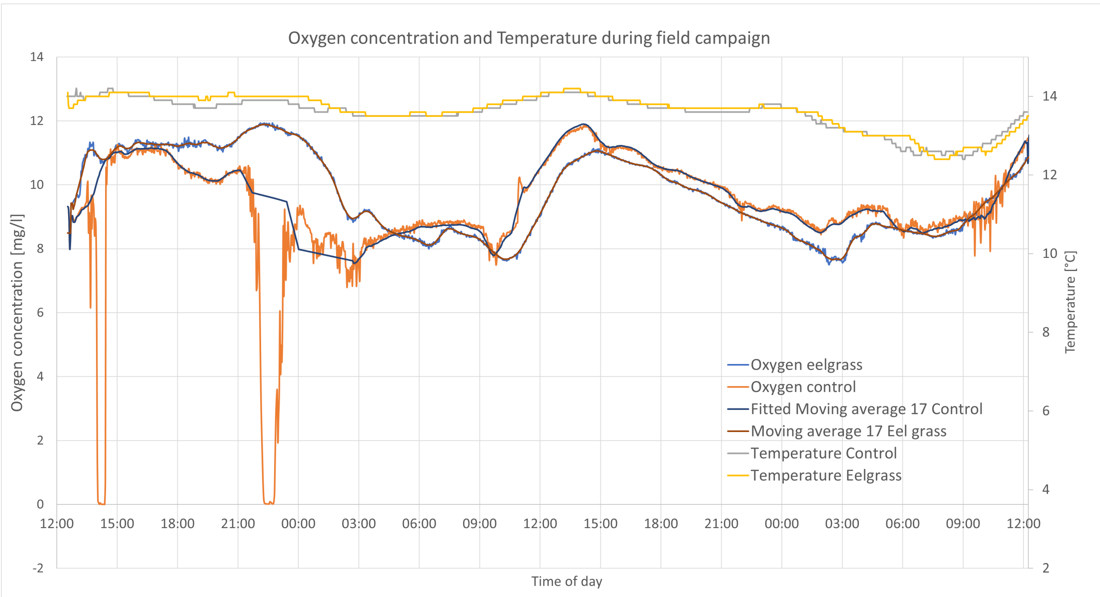


Figure 14: Replacement data plotted on top of original data to illustrate how well it fits.

The smoothened data, can now be compared, by subtracting the oxygen concentration at the control site at a certain time of day, with the oxygen concentration at the eel grass site at the same time, resulting in a difference in oxygen concentration being the net oxygen production of the eel grass.

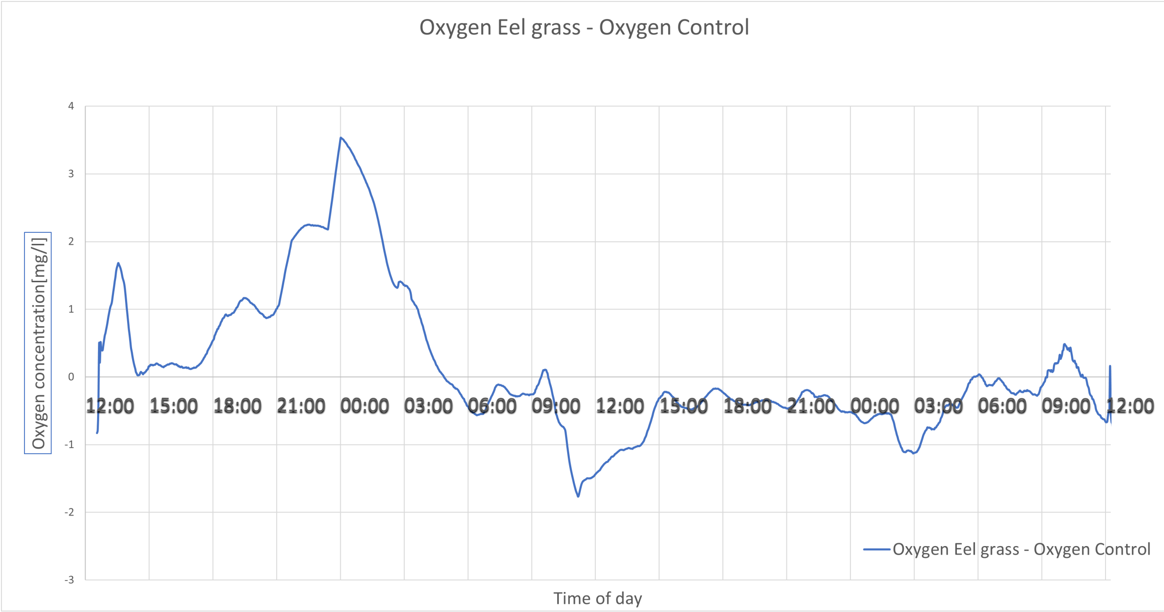


Figure 15: Net production of oxygen by the eel grass.

It would be expected, that during hours with sufficient sunlight, photosynthesis at the eel grass site would result in excess oxygen production, which should be visible at figure 15. This is however not the case. Since the two largest peaks in oxygen surplus at the eel grass sites, are at the same instances where the oxygen loggers failed, and replacement data have been used. This could indicate, that the replacement data was too unenthusiastic, given that the oxygen measurements at the eel grass site were higher than expected at the same time, likely due to the weather at the time.

Due to the equipment failure in connection with the data collection, final conclusions cannot be drawn based on the available data.

5.9 Evaluation of field campaign

Overall the field campaign was a success. It was evident that the location for the campaign, has to be easily accessible from land or that a boat is available to carry the equipment to the location. The manual which were created by Sissel Kolls Bertelsen, were tested and proved sufficient and a lot of experiences were learned which were useful when developing the additional manuals for this thesis.

Based on the fish caught during the campaign it is evident that the juvenile cod fish preferred the newly planted eel grass, which indicates that artificially produced eel grass beds have the same biological benefits, as naturally occurring eel grass beds.

From the data collected a simple model which can predict oxygen depletion based on the respiration rate during the night at the sites has been developed. As well as a method to find the net production of oxygen by the eel grass compared to the control site.

5.10 Potential errors

During the field campaign some difficulties in the methods that were planned and executed were realized. As well as some flaws in the equipment that made it non-ideal for the task at hand.

5.10.1 Oxygen meters

The Polaris C from OxyGuard has a display that constantly shows the data received by the probes from the logger. It was evident once the field campaign was near its end, that there was something wrong with the loggers. They were therefore brought into land, and once the devices were kept next to each-other it would be expected that the measurements from the two devices would be somewhat similar. This however was proven not to be the case, as seen on figure 16b. When kept next to each other, the two devices measured different oxygen concentrations, saturation and temperatures. It can therefore be concluded, that they must at some point during the campaign have started measuring different levels of oxygen, than the concentration in the water. The oxygen loggers were not used for the final day of the field campaign due to this issue.

The theory of difference in measurements of the oxygen loggers was tested after the field campaign using a large bowl of water where the two devices were put in, including a new device that can be seen on figure 16a.

(a) The New oxygen logger (miniDOT) that is being used for the final oxygen method.

(b) Polaris C loggers showing different measurements at the end of the field campaign.

Figure 16: Picture of the loggers used in connection with this thesis.

A small amount of sugar and yeast was added to the water, and then the top of the bowl was covered in plastic foil, to prevent oxygen from entering the system.

While oxygen is present respiration will occur until the yeast have used up all of the oxygen, and it will then begin fermentation.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O \tag{6}$$

For this experiment we are only interested in respiration, since this can be used to simulate oxygen depletion, and this is therefore an ideal method, to test the different devices against each-other.

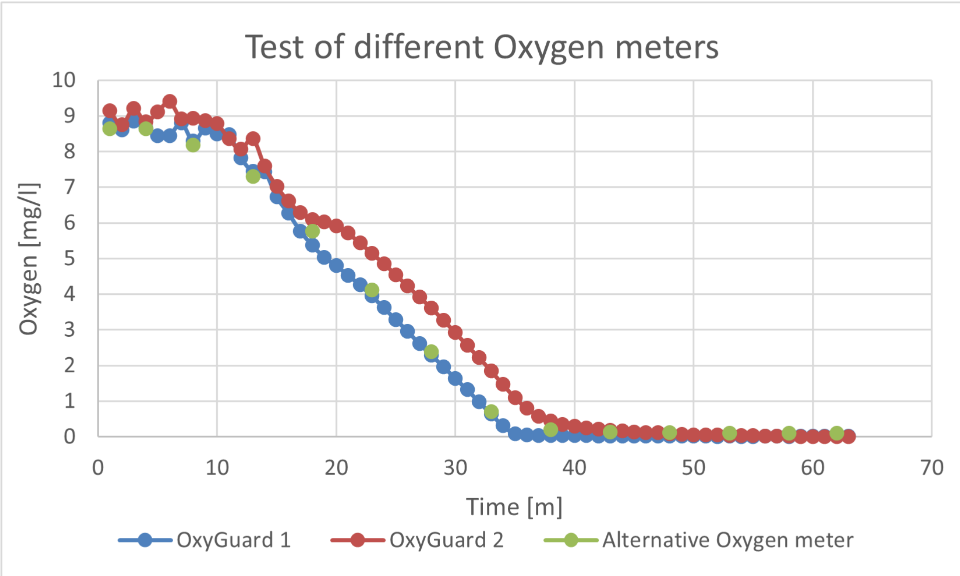
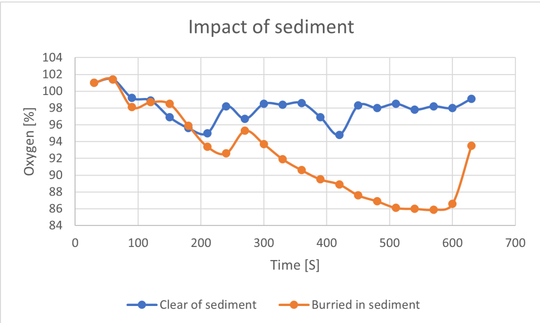


Figure 17: The three different oxygen logger tested against each other in oxygen depletion caused by respiration with yeast.

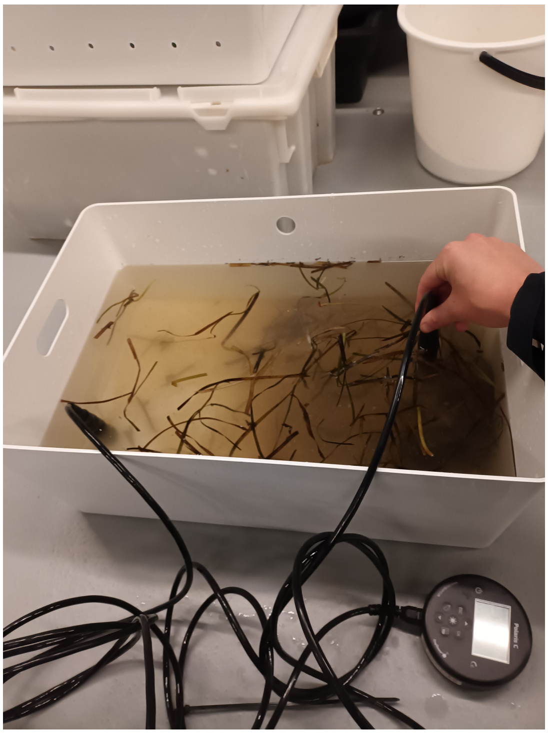
It is here evident that the two devices from OxyGuard fluctuates. Especially OxyGuard 2 shows higher amount of oxygen in the water, where the data collected with OxyGuard 1 and the alternative oxygen logger (miniDOT) are more aligned. It is worth noting that the interval of measurements can be changed in either device, but it seemed irrelevant for this simple experiment.

5.10.2 Risk in method used during field campaign

During the collection of data, a sudden fall in the oxygen measurements were observed on the oxygen logger, located at the control site. This phenomenon occurred twice, approximately 500 minutes apart seen on figure 12, which could indicate that the cause of the sudden drop in oxygen could be a result of the probe getting tucked into the sediment during low tide, and thus showing no oxygen, even though there is plenty of oxygen in the water. To test this hypothesis an experimental recreation, of the scenario where one of the probes are getting tucked into the sediment was made. This was done by creating an artificial seabed, with different kinds of sand and clay as well as some pre-frozen eel grass, to keep the environment as realistic as possible.



(a) Data from sediment test, Orange being submerged in the sediment and blue being kept moving to ensure flow of water.



(b) Artificial seabed for testing if the placement of the Oxygen-meter can be impacted if in contact with sediment. on the right (Orange data) is burried in sediment and on the left (Blue data) is kept in motion to ensure flow of water.

Figure 18: Potential error source being investigated.

During this experiment, a complete disappearance of the the oxygen as was observed during the field campaign was not observed, however it did show that the probe that was tucked into the sediment did show significantly lower oxygen concentration, than the one that was out in the open, as seen in figure 18a. The sudden increase in oxygen at the last point is due to the fact that both hands were required to stop the measurements, resulting in the orange device no longer was submerged in the artificial sediment. Likewise the drop in oxygen for the blue device around 400 seconds is a result of the probe being without flow of water, since I took the picture to illustrate the setup that is seen on figure 18b.

Based on the observation of the uncertainty of the devices from Oxyguard and the simple experiment described in figure 18. The method used in the field campaign clearly have some difficulties, and might therefore not be the best solution to monitor oxygen and temperature for coastal habitats as part of the citizen science solution.

5.11 Alternative approach to measure oxygen

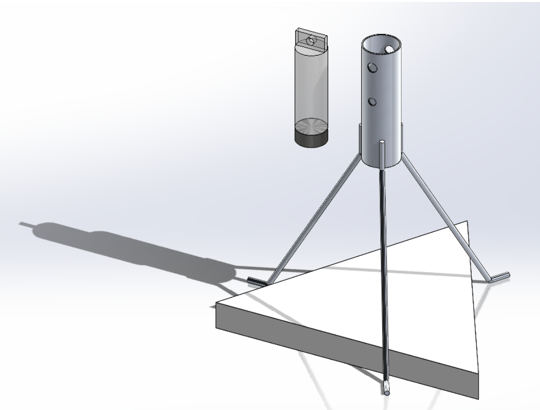
Due to the difficulties mentioned earlier, another alternative to monitor the oxygen-levels in the oceans using volunteers is needed. Therefore another Oxygen logger was considered (miniDOT).
On table 4 the specs for the two oxygen loggers are compared with one another.

Table 4: Specs for the two different oxygen loggers that was considered.

Type of Oxygen logger	miniDOT (PME)	Polaris C (OxyGuard)
Price	12,000 DKK	10,000 DKK
Temperature logger	Yes	Yes
Unit of data	Mg/l	Mg/l & (Concentration %)
Weight	0.5 kg	0.6 kg
Power	2 x AA alkine battery	1 x AA alkine battery
Waterproof	100 m depth rating	Short-term immersion 5 m
Probe type	Membrane	Electrocemical
Data transfer	USB cable	Bluetooth
Data format	TXT file	Online with different options
Accuracy on data	3 decimals	1 decimal

Most noteworthy of the differences in specs on the two different oxygen loggers are the accuracy of the data provided by the loggers, and the difference in the loggers ability to be submerged in water. For the task at hand it is near unavoidable that the devices will be in contact with water, as seen during the field campaign. Since the miniDOT logger is tested to withstand the pressure submerged in water to a depth of 100 meters, there is next to no risk that it will be damaged during the Oxygen logging. Thus the miniDOT is the preferred oxygen logger for the task at hand. Changing logger does not remove the source of error presented in figure 18. In order to avoid the recurrence of this scenario, a stand has been designed with the purpose of keeping the oxygen-logger fixed in the same location and height above the seabed regardless of tide and weather.

5.11.1 New design for oxygen monitoring



(a) 3D Drawing of the stand that is to hold the oxygen logger with rough drawing of concrete base as well as oxygen logger.

(b) Image of the actual aluminum holder before testing.

Figure 19: 3D drawing of the stand for the logger, and the final product.

Figure 19 displays some sketches of the stand. The stand itself will be made by sea-resistant aluminum, with the "tube" surrounding the oxygen logger is made of a standard 56 mm x 60 mm aluminum tube, in order to make the stand easier to mass produce, which is beneficial since the purpose of the stand is to be used in the citizen science project. Thus making reconstruction of this "prototype" a necessity. Some key design features of this design will be explained using figure 20.

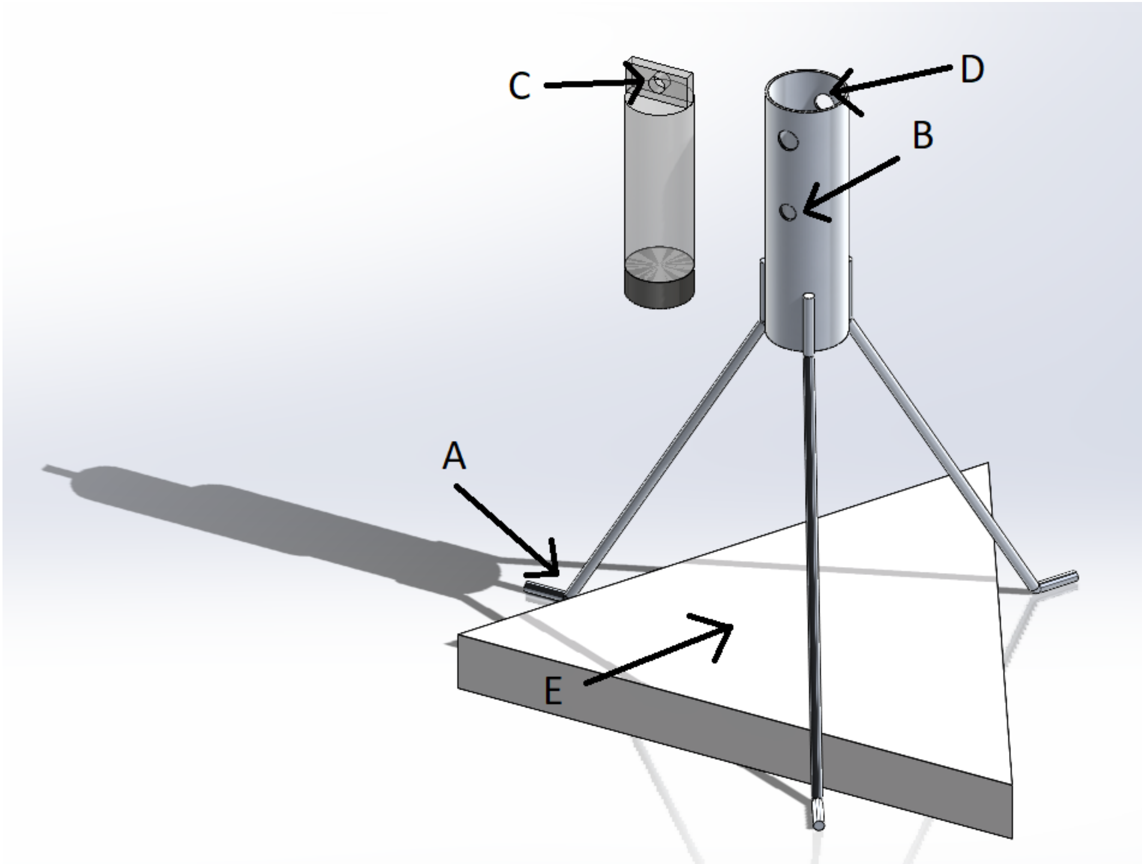


Figure 20: 3D drawing with key elements marked.

A) The purpose of the pointed ends on the end of the legs is to ensure that the stand will stand firm when cast in the concrete foundation.
B) Hole to a bolt that is meant to go though **C)** on the oxygen logger. To keep it in the correct place in the aluminum tube.
D) Is a hole in the aluminum tube, meant for a snap hook, the edge on the aluminum tube is sharp, thus by using a snap hook, wear and tear on the rope is reduced significantly and the risk of losing the stand and oxygen logger on the seabed due to failure in the rope is minimized.
E) Concrete foundation is to ensure that the stand does not get dragged along with currents, as well as to ensure that the oxygen logger always stays the same distance above the seabed.

5.11.2 Building the stand and testing the miniDOT

The stand for the miniDOT was designed in the open source program DeltaCAD which helps with finding the proper dimensions for a new drawing. Afterwards a sketch was made in Solid Works, which is one of the 3D drawing programs available for students at DTU.

Choice of material
A matrix with different aluminum alloys were set up, to compare the different properties, in order to find the most suitable for the task at hand.

Table 5: Matrix with properties for different aluminum alloys.

Aluminum alloy	Sea water	Corrosion	Wieldable
EN AW-3003		X	X
EN AW-3005		X	X
EN AW-3103		X	X
EN AW+5005		X	X
EN AW+5005A		X	X
EN AW 5052		X	X
EN AW+5083		X	X
EN AW+5086	X		X
EN AW+5754	X		X
EN AW-6082		X	X
EN AW-6101B		X	X

On account of this being more of a proof of concept, than a final product. The choice of alloy for the prototype was of minor importance. A requests for a specific alloy would have been an unnecessary expense and a delay in the production of the prototype. A basic alloy that was in stock at DTU Aquas workshop where the prototype was build, was therefore selected.

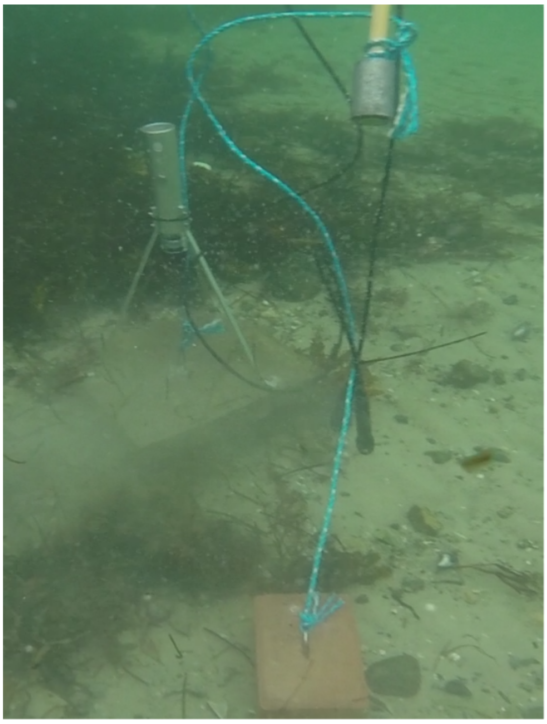
The workshop at DTU aqua managed to build the stand in 4 hours but since the workshop did not have the proper equipment for wielding, the legs on the stand were assembled, using small screws, as seen in figure 21a.

Testing

The miniDOT was tested against the two Polaris C devices, that have been used in the field campaign. It was done overnight from Saturday 14th to Sunday the 15th January 2023. The location used was the water just outside Charlottenlund Fort. The weather was windy and temperature of the water was between 5°C and 7°C. It was therefore not expected that a significant reduction in oxygen concentration would be observed during the night where the test was performed.

On the original design, the base of the stand was meant to be cast in concrete. But for the proof of concept, this was avoided, instead an old 40 cm x 40 cm concrete tile was used as base. Holes were drilled so that the stand could be fastened to the tile using plastic strips. In addition holes were drilled in the center of gravity of the tile to fasten the rope, to retrieve the tile and stand once the test was done.

(a) Stand with miniDOT and 40 cm x 40 cm concrete tile used as base.



(b) Underwater view of the stand with miniDOT compared to the two Polaris C tied to a flag buy as done during field campaign.

Figure 21: Proof of concept of miniDOT with stand method.

One of the two Polaris C oxygen loggers that was used against the tripod stand and miniDOT oxygen logger, had stopped recording after 25 minutes of logging, while the other Polaris C logger had kept logging, as it should. For unknown reasons, the Polaris C logger that had kept logging was unable to connect to Bluetooth after the proof of concept test was done. The data could therefore not be uploaded, and had to be read off the display, and added to a file on a computer manually. The method using the tripod stand and the miniDOT logger had worked flawless, and the data from the the Polaris C is here compared with the data from the miniDOT logger in figure 22.

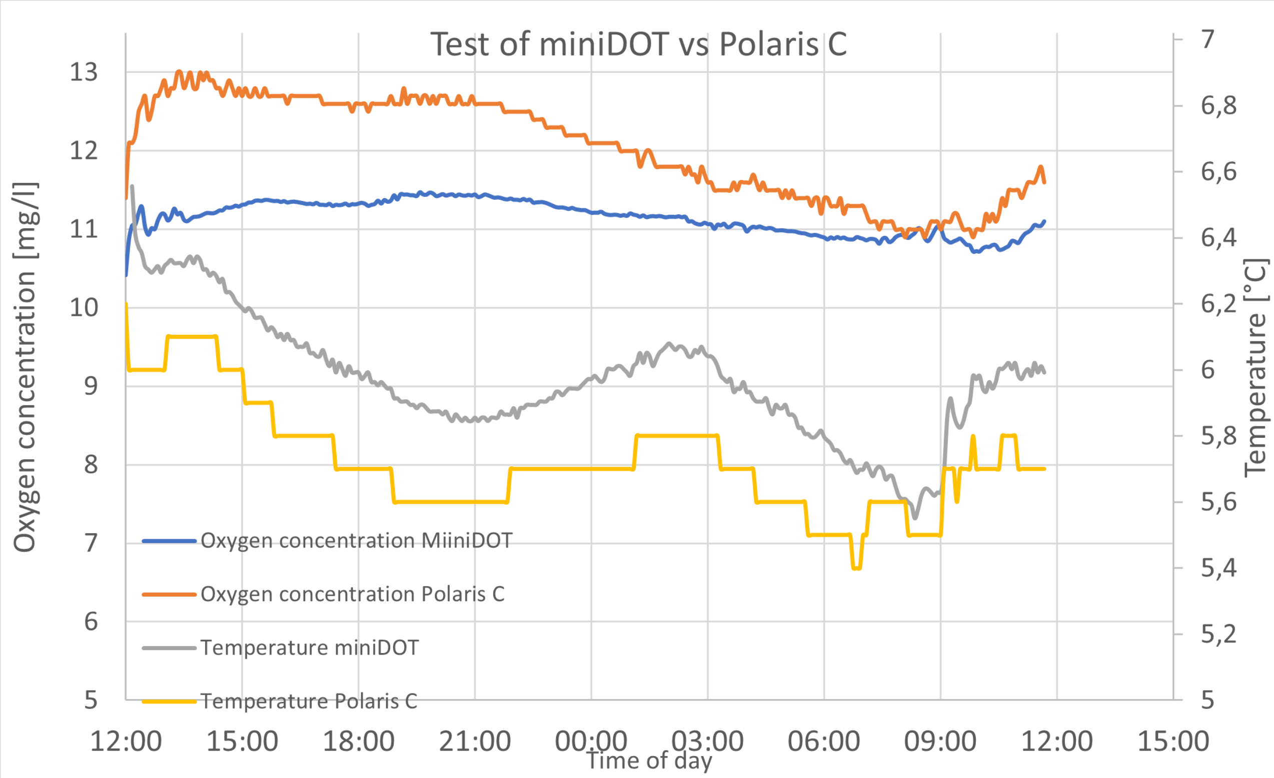


Figure 22: Data collected during the the test for the final method using miniDOT and a stand plotted with the data from the Polaris C fastened in the same way that was done during field campaign for comparison.

Despite the location for the proof of concept is less interesting than the location of the field campaign, some key differences is still notable between the data from the two devices. The superior accuracy from the miniDOT is clearly seen, especially when logging the temperature, where the measurements almost doesn't vary. It would be expected that the measurements of oxygen concentration were more aligned, where it is seen that Polaris C measures significantly larger concentrations of oxygen, even though the loggers were located next to one another, as seen in figure 21b. The tendency correlates with the difference in temperature between the two devices. It is seen that at 09:00 the two devices agrees on the temperature as well as the oxygen concentration of the water. Therefore the difference elsewhere could be a result of the devices needing calibration.

5.12 Evaluation of experiments after the field campaign

Some potential errors were observed during the field campaign. It was attempted to recreate these flaws afterwards, using different setups under controlled environments, to confirm the causes of the errors. A complete recreation of the two drops in oxygen concentration was not possible to perform in the lab. The importance of the probe being free from the sediment was however proven, which lead to the creation of a new method using the miniDOT and a tripod stand, engineered to avoid it from being submerged in the sediment and giving false data at low tides or extreme weather. Overall the test of the miniDOT logger was a success, and it have been selected as the preferred method to measure oxygen concentrations and temperatures, for the manuals used in citizen science. The proof of concept for the miniDOT with stand was a major success, and the concept can be used to monitor oxygen concentrations in coastal habitats. However the error which occurred during the field campaign for the Polaris C method, did not occur during the proof of concept. It can therefore not be concluded that the stand had influence on the data collected, since the only visible difference in the data, is the different accuracy of the two type of loggers. However due to the nature of the stand, the measurements from the miniDOT logger will remain accurate unless the depth of the water falls below the desired height above seabed of measuring. In which case the logger will measure the oxygen concentration in the air above the water.

6 Recommendations

6.1 Choice of fish capture method

During the field campaign two different type of fishing traps were used to survey the fish abundance in the two different coastal habitats that were investigated. The raw specs and rating are presented for the fyke net and the lobster trap respectively in section 5.2. But a more thorough review of the two options will be carried out.

Considering the overall assessment in table 2. The lobster trap was awarded 42 of the 70 total points. Most of the points were in the category based on the performances of the fishing method, since it was very effective with 33 fish caught of a total pool of 41 fish.

6.1.1 Mesh size

This effectiveness can be explained by two things. The first of which being the mesh size difference of the two methods. Since the mesh size were 10 mm throughout the whole lobster trap, where the fyke nets were 18 mm at the first openings, and gradually reducing to a mesh size of 11 mm at the final bag.
It is expected that with a smaller mesh size, it is possible to catch smaller fish such as the smallest juvenile cods and the Broadnosed pipefish which can be seen on figure 23. This increases the diversity of fish that can be caught, leading to a larger pool of fish that is possible to catch. Since the small and slim fish would be able to swim though the larger meshes on the fyke nets. Since the location that the fish abundance survey was carried out at, were in a habitat close to the coast. It is to be expected that the vast majority of fish present, is either fry of larger species, such as the Atlantic cod, or species which by nature are smaller even when fully grown.

(a) Juvinile cod (*Gadus morhua*), caught in lobster trap at eel grass habitat.

(b) Broadnosed pipefish (*Syngnathus typhle*), caught in lobster trap located at the control site.

Figure 23: Fish caught in lobster trap, that were small enough to swim though the mesh size of the fyke nets.

If the purpose of the campaign is to survey larger fish in the area such as the predators for the smaller fish. A larger mesh size could be beneficial, in that it would prevent bycatch since the smaller fish would escape though the meshes.

6.1.2 Differences

The other explanation being the difference in the method the fish are lured into the respective traps. Even though the total length of the two traps are almost identical. The lobster trap consists of several openings where fish can get stuck. Where the fyke net uses a large amount of its length on the leader-net which connects the openings on the two fykes and guides fish towards the entrance of the bags. The area of which the fish can be caught is therefore much larger on the lobster trap, compared to the fyke net, and the difference in mesh size is therefore not the sole course for the difference in effectivity of the respective methods. If one were to investigate the difference in catches when adjusting mesh size, two identical methods is to be used. However it is to be expected that the method with the smallest mesh size catches a larger amount of fish when fishing in coastal habitats, due to size and species of the fish pool present.

6.1.3 Practicality

The performance of the lobster trap does not come without a downside. The downside being that it is significantly less user-friendly than the fyke net. The large amount of openings to catch fish means that the weight of the lobster trap is higher. Once the trap is filled with catch as well as bycatch, it is near impossible to empty on the location where it was initially set in the survey, the trap must therefore be carried into low water near the coast whenever it has to be emptied. This is also reflected in table 2, where the lobster trap scores a two in routine check-up. The two traps are similar in difficulties when setting up at first, but if the survey is meant to be long-term, the fyke net have a clear advantage, since it can be emptied on location, as described in the manual created by Sissel Kolls Bertelsen, which is why the fyke net scores an eigtht in routine check-up. The upside of the method to empty the lobster trap is in the difficulty to separate the fish from the crabs and other by-catch. Since the trap has to be carried into low water near the coast no matter what, and it therefore is easy to work with the trap once the heavy lifting is completed.

The fish were more likely to survive if they were caught in the lobster trap, than if they were caught in the fyke net. This however can be a result of the high population of crabs, which completely filled up the nets, so that the fish caught had no room for movement, thus becoming easy pray for the crabs. It is worth mentioning that the sample size of fish caught in the fyke net were low, and the results can be deceptive.

6.1.4 Overall assessment

As mentioned in the solution ideas, these two methods are meant to collect data on fish abundance and diversity using citizen science, meaning that volunteers are to perform the data collections. The methods have unique advantages, as well as disadvantages. But since the data returned to the scientist is similar, regardless what method the survey was carried out using. The two methods can be used together, as long as it is noted that the lobster traps are significantly more effective.
If only one of the two methods tested on the field campaign were to be used to survey fish abundance. The results presented in this thesis suggests that the lobster trap should be used to monitor fish abundances in coastal habitats.
A special case where the location to be investigated are impassable from the coast using waders or a wetsuit, and shortage of volunteers to perform the survey. The fyke net would naturally be preferable, since they can be easily handled from a small boat.

6.2 Oxygen loggers

The flaws of the Polaris C logger presented in section 5.10 indicate that the solution used during the field campaign is sub-optimal, compared to the miniDOT solution that was created within this thesis. Which entails that the citizen science manual for oxygen and temperature logging for is based on the miniDOT with tripod stand solution. The error that occurred during the field campaign could prove to be a rare anomaly, and the method could be successfully applied in correlation with the survey using fyke nets to log the temperature and oxygen concentration.

The choice of oxygen logger is dependent on what the data collected is used for. If the oxygen and temperature data is to be used as a base in an advanced model, the quality of data is essential for the success of the model. In such case the uncertainties that follows using the Polaris C logger a deal-breaker, and the miniDOT solution would be preferable.
However as it is shown throughout this thesis, the data collected using the Polaris C is sufficient to get an insight in the temperature and oxygen concentration of the coastal habitat under surveillance. The data is even precise enough to be foundation of a simple model.

7 Conclusion

Throughout this thesis a solution to the problem stated has been found. In the form of two citizen science manuals. These manuals enables volunteers from Projekt Kysthjælper to participate in filling the gaps of knowledge and cover the shortcomings included in the current method of surveying the well being of the ocean in regards of oxygen concentration, temperature, fish abundance and diversity.

Despite the data on oxygen concentration at the respective sites obtained during the field campaign in connection with this thesis, did not show a significant difference on the impact of eel grass. The catch of fish in the same period supports the significance of eel grass, as a key part of the ecosystem in the coastal habitats. Furthermore it confirms that a reconstruction of an eel grass meadow maintains the same biological benefits in serving as a nursery for juvenile fish, as a natural eel grass meadow.
The importance of long-term monitoring has been illuminated, by showing that respiration causes the oxygen concentration near the bottom to decline.

It was observed during the field campaign, as well as demonstrated using different setups, under controlled conditions in a lab. That tide and weather have a significant impact on the loggers, when collecting data in the ocean. Equipment used for data collecting in these very environments, must therefore be specifically engineered for that purpose. The stand which was designed, build and tested in connection with this thesis is an example on how to construct a device which works amidst challenging environmental conditions inherent to aquatic operations.

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