FINAL REPORT:
ROOM FOR SEAWEED CULTURE

Multiple and/or dynamic spatial use

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MULTIPLE AND / OR DYNAMIC SPATIAL USE

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Foreword

In the process of writing this report, I have had the opportunity to meet and talk with some incredible people that were always ready to answer my questions and help me further my research and guide me in my internship. I first want to thank Jouke Heringa, my in-company manager at the HZ who always challenged me to give more and work harder to achieve better results. I also want to thank Lukas Papenborg for being there for me when I met difficulties along the way during my internship and helped me get back on track. Finally, I want to thank Leo Volthoren, Gert-Jan Veen, Arthur Landa and John van Leeuwen for accepting my requests for interviews and being so honest with me about their trades and for the information they provided me.

Contents

Summary

After some initial research, it was decided to work out two tracks, one looking at short-term solutions (1.), and the other looking at long term solutions (2.). The geographical focus will be the two water bodies of the Grevelingen and Eastern Scheldt. The data was gathered through interviews and literature research.

1. ***What arrangements can be found where shellfish farmers in the Eastern Scheldt and Grevelingen agree to share or use part of their plots for seaweed farming?***

To answer this question, three different methods were researched:

- **Using unused bottom shellfish parcels (Bottom mussel, Oyster, Verwater)**. This solution increases the amount of available space for developments, but very little parcels are left unused or are suitable for seaweed farming, and the installations will disturb above water activities.
- **Using the MZI parcels that are unused all year round or only during winter**. 422.52 ha of MZI are currently not in use for anything and expanding their use will lead to crop diversification, a split on some capital costs like poles and lines, and an extended seasonal market. However, the effects of seaweed farming on mussel are unknown, the empty parcels could be reclaimed at any moment for mussel seed and harvesting seasons could overlap.
- **Combining seaweed and rope mussel culture**. The improved use of space will lead to crop diversification, a split on some capital costs like poles and lines, and an extended seasonal market and the nutrients produced by mussels will be consumed by the seaweed. Seaweed intensive farming is however impossible, and it will be difficult to harvest without harvesting mussels and could take feed (micro-algae) from mussels.

2. ***How can the concept of dynamic spatial use be applied in near shore situations in the Netherlands?***

A light and an extended version were made, with two methods each.

The light version focuses on solving the issue by looking at aquaculture and fisheries only:

- **Parcel rotation**. It allows for better recovery of parcels, diversification of crops, fairness in using the “best” parcels and would be easy to implement in the Grevelingen because of their similar system. It will be difficult to implement in the Eastern Scheldt because of mindsets and current regulations and does not create space for aquaculture innovations.
- **General aquaculture** concessions. It will create opportunities for farmers to diversify, will increase awareness about the impacts of functions on each other and provides opportunities for innovation. It will however be hard to regulate and it will be difficult to change mindsets and regulations.

The extended version, focuses on all functions in the Eastern Scheldt and the Grevelingen:

- **Rotation of all functions (including recreation, nature, etc…)**. It allows parcels to be used intensively as long as they have a good resting period afte rand provides tourists and locals with a constantyl changing scenery. It will however be difficult to change mindsets and regulations.
- **Multiple spatial use**. Wit hit, functions that have little or beneficial effects on each other can operate in the same place at the same time, awareness about the impacts of functions on each other will increase and new functions will have the opportunity to develop. It will however be difficult to change mindsets and regulations, and it might be impossible to know what function is happening where and when.

It must be noted that many factors were not considered in this report, namely carrying capacity, nutrient intake, light intake, etc… These factors were not considered in order to simplify the research, but also because the information on these factors in not available. These factors should be furthered investigated before implementing the solutions represented in this report. An additional category of stakeholders that should be interviewed in future research could be the recreational sector, as it could easily be affected by innovations like seaweed farming.

While many different options of making space for kelp and other innovations were looked at in this report, it would be better to aim towards a long-term solution, especially the one where all aquaculture and fishery activities are combined.

1. Introduction

The Dutch south-western Delta is an area that is famous being a sailing area, a nature reserve, as well as for the food production that happens in it. In order to sustain these functions, the use of saltwater needs to be optimised. To reach that end, new initiatives like seaweed farming and new ways of producing shellfish like off-bottom farming are starting to appear. It is however very difficult for these new initiatives to get started, mostly because of a big lack of space, combined with very restrictive regulations concerning spatial planning and use of water for new or different functions than the current ones.

The Living Lab Schouwen-Duiveland has taken up to this demand and has started looking for more production areas for seaweed cultivation in Zeeland. Within the Living Lab Schouwen-Duiveland program, one of the research themes explores the possibilities of using salted open water more for food production. The Living Lab Schouwen-Duiveland is a collaboration between administrators, citizens, business and knowledge institutions where sustainable economic impulses are developed by making use of the ecological wealth of Zeeland (Kints, 2019). The municipality of Schouwen-Duiveland, Rijkswaterstaat, the Waterboard Scheldestromen and the HZ University of Applied Sciences are the initiators. Other stakeholders are Naturalis, Hogeschool Rotterdam, Van Hall Larenstein University of Applied Sciences, HAS University of Applied Sciences, Deltares, the Koninklijk Nederlands Instituut voor Onderzoek der Zee, Wageningen University & Research, the Rijksinstituut voor Volksgezondheid en Milieu, Delft University of Technology, Erasmus University, Toegepast Natuurwetenschappelijk Onderzoek voeding, Proeftuin Zeeland, the Energy Research Centre of the Netherlands and partners in the business community.

As part of the Living Lab, two earlier studies have been carried out to the possible locations of seaweed growing in the south-western Delta (Trul, 2018 and van Kints, 2019). More specifically, the two types of seaweed that the researchers focussed on were *Ulva lactuca*, a green algae that grows in summer, and *Saccharina latissima*, a brown algae that grows in winter. The factors that they used to determine the suitability of an area were light, nutrients, water depth and velocity.

The research from Jasper van Kints discussed the specific environments in which seaweed could survive, and he transposed that information into GIS models of the south-western Netherlands. From that research, it appeared that the most suitable areas to grow seaweed were often areas where shellfish is currently being farmed, more specifically mussel and oyster plots that are deeper than 2 meters at low tide, mussel farms using the rope-culture method, unused Mussel seed capture installations (MZI), and shellfish storage areas, also known as verwater locations. Good and accurate results were however very difficult to get, mainly due to a very limited amount of data available.

After some initial research, it was decided to work out two tracks: one looking at a short-term solution, and the other looking at multiple potential solutions that would work better on the long-term. For this the focus lies on the two water bodies of the Grevelingen and Eastern Scheldt.

For the short-term track, the aim is to find solutions to find multiple use solutions for the previously mentioned seaweed types and shellfish. For this track the main question is:

1. ***What arrangements can be found where shellfish farmers in the Eastern Scheldt and Grevelingen agree to share or use part of their plots for seaweed farming?***

For the long-term track, the aim of the research is to find out how to apply the approach of dynamic spatial use in the two case studies. This second, more theoretical approach is designed around the idea rearranging the different functions of the two water bodies without considering current

legislation of spatial planning rules, and what the effects of such changes would be on the environment of these water bodies. For this track, the main research question is:

2. ***How can the concept of dynamic spatial use be applied in near shore situations in the Netherlands?***

In this report, you will first be introduced with a background of the two water bodies and of seaweed culture in the world and in the Netherlands. This will then be followed by a description of the method that was used. Following this, the results of each question will be described through two different parts, one for each question. Finally, this will be pursued with a discussion about the results, and a conclusion combining the results in bullet point form.

2. Method

In order to answer the two research questions, in-depth quantitative research, but also a lot of qualitative research to gather the information that was not readily available to the public, was required.

For the general information, many articles and online sources were used to gather data about shellfish and farming it, the two water bodies and seaweed farming. The information gathered from these articles was then used to help fill up a “table of functions” (Appendix c). This table, as well as additional information from the different articles and online sources is then used to make a map using ArcMap that shows the shellfish parcels that are suitable and available for seaweed farming (Appendix b).

Once that initial information was gathered, additional qualitative information was required. For this, four different stakeholders were interviewed to help finishing to fill up the table of functions, as well as to increase the accuracy of the map. Furthermore, the gathered information from the interviews was used to write the methods of the short- and long-term pathways. These ideas were also discussed during a meeting with several stakeholders of the Living Lab Schouwen-Duiveland.

To gather varied information and be as accurate as possible, the people who were interviewed were from different organisations and were responsible for different functions at different levels. Their answers were then used to detail the “table of functions” (Appendix c) and the map of suitability (Appendix b).

3. Background

3.1 Eastern Scheldt

The area that is considered here was a part of the former Eastern Scheldt estuary of the river Scheldt. It is a 350 km2 area and has an average depth of between 10 and 15 meters. In 1986 the Eastern Scheldt was landlocked by a storm surge barrier, which still allows tides to come in it to some extent. Fresh water inflow was diverted to Haringvliet and Volkerak Zoommeer to limit the amount of water arriving in the Eastern Scheldt, resulting in blocked freshwater river inflow to Eastern Scheldt. The only freshwater comes from pumping stations with surplus of water from agricultural land and leakage from dams (Slabbers, Brader, & Sorée, 2018). Today, it has been classified as a natural park.

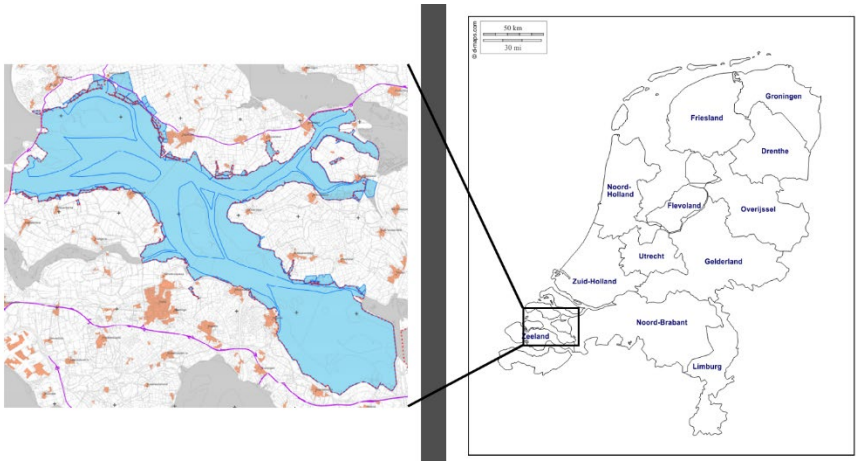

Figure 1: Location of the Eastern Scheldt

Because of the tidal currents, erosion and sedimentation mechanisms occur that create a diverse pattern of salt marshes, mud flats and shallow flats that are revealed at low tide, as well as shallow water and deep tidal channels. The mouth of the Eastern Scheldt has the deepest channels. They can reach depths of 45 meters. Between these channels and the east of the Zeelandbrug there are vast areas with shallow waters and sandbanks (Ministerie van Landbouw, Natuur en Voedselkwaliteit, 2019).

The great diversity of abiotic circumstances creates a great diversity in animal and plant species. The abiotic conditions are caused by tide, currents, water temperature, height, water quality and composition of the sediment (Pel-Roest, 2013).

All kinds of recreation take place: water recreation, angling and diving on and under the water as well as hiking, cycling and bird watching along the dikes. The delta works, such as the storm surge barrier with the artificial island Neeltje Jans halfway are tourist attractions.

The aquaculture sector is also very prominent in the Eastern Scheldt. For the sake of this report, it will here be divided in two categories, the first being the Fishing sector, and the second being the Shellfish sector.

For the Fishing industry, the following different types are licensed (Appendix 2):

- Mullet and Seabass are fished all year around plates and sandbanks. There is a total of 17 private fishing plots of varying sizes and open water fishing with 37 fishermen.
- Shrimp is fished in the period from May until February everywhere to the west of the imaginary lines between Ouwerkerk and Stavenisse and between Wissenkerke and the Yersekendam, and where there are no shipping lanes. A total of 8 permits can be allocated, of which 1 or 2 are active.
- Sole is fished everywhere where there are no shipping lanes. A total of 16 permits are allocated to it.
- Lobster fishing can happen from the first of April until the 15th of July in some very restricted areas that are 200 meters from the shore. 43 permits are allocated for these areas.

- Eel fisheries have very similar characteristics to Lobster fisheries as they happen in the same areas, and that only some of the lobster fisherman can also get a permit for fishing eel. Eel fisheries have a mandatory shutdown period from the 1st of September to the 1st of December.

For the Shellfish industry, the following types of shellfish farming are practiced (Appendix 1, 2 and 3):

- Mussel seed catchment installations, also known as MZI, are areas allocated for the catching of mussel seed from April to October in the specific locations decided by the Ministry of Agriculture, Nature and Fisheries. There is a total area of 681 ha dedicated to mussel seed catchment, but 422 ha is not being rented out by the government at this moment (July 2019). The parcels that are being put up for rental are set as a bundle rental for the PO Mossel.
- Mussel farming of the blue mussel *Mytilus edulis* happens in two different types, rope and bottom culture.
    - For bottom culture, there is a total space of about 10037 ha scattered as parcels to the west of the Yerseke bank. Each parcel is rented to individuals or companies. The process of growing mussels to market size takes maximum 4 years, with a minority being harvested in the second year, the majority in the 3rd year and the rest in the 4th year. The harvest season is from July until March. They then all get sold on the auction in Yerseke.
    - For rope culture, the processes for renting parcels and selling produce are similar to bottom culture. There are however less organisations that practice the activity. These organisations are Schot Mosselcultuur near Neeltje Jans, and Landa Mosselcultuur near Bruinisse and Bergse Diepsluis. Some rope mussel culture also happens in the privately-owned waters near Hoogbekken and Laagbekken. The harvest season in general is from May to June. Market prices are generally lower than for bottom culture mussels.
- Verwater areas are meant for storage after harvest for natural cleaning and spitting out of sand and other detritus as well as storage after the mussels are sold. There are around 11 ha, and they mostly located between the oyster parcels near Yerseke, but some other can be allocated from June to September in case of a TTX contamination. They are rented out as a bundle to the Vissers Vereniging Yerseke.
- Oyster farming of the pacific cupped (*Crassostrea gigas*) exist in the Eastern Scheldt. There are 2100 ha in total, divided in 5 ha parcels, with about 600 ha left unused. Plots for collecting seeds are used in July and August. In May, the oysters are fished from the bottom, and moved to another allotment of the grower, with the right conditions which fit best with the live phase of the oysters at that time. The growth is of about three years and the oyster can be moved several times a year to meet the best living conditions it can get. Parcels are rented on an individual basis. In the last few years, bottom culture of oysters has been difficult due to the appearance of a herpes virus and the oyster drill, a predator of the oyster. New off-bottom culture techniques are however being researched to overcome these problems.

3.2 Grevelingen

The Grevelingen is a former estuary, with a size of 140 km^2 and an average depth of 5.4 m. It was dammed from the north Sea in 1971 and from the Eastern Scheldt and rivers in 1965, to become the largest saltwater lake in Europe (Ministerie van Landbouw Natuur en Voedselkwaliteit, 2013).

Figure 2: Location of the Grevelingen

Refreshment of water in the Grevelingen is very limited. The Flakkeese spuisluis in Grevelingendam provides some exchange between the Eastern Scheldt and Grevelingen, but only in very limited amounts. Low oxygen concentrations in the deeper parts and bacteria mats ae the cause of dead zones. It is for that reason that an opening at the seaside dam is currently being planned out. The area is characterised by clear water, islands and extensive shores, among which the Slikken van Flakkee (Natuur- en recreatieschap de Grevelingen, 2012).

Salt tolerant pioneer vegetations can be found near the waterline. Dune slacks with species rich vegetations can be found on the islands and on the shores further inland from the waterline. The extensive mud flats, sandbanks and salt marshes of the past are now covered with grasslands, scrub and forest. The area is especially important for a great number of water bird and wader species (Pel-Roest, 2013).

The site is very important for visitors. It has functions for water recreation (diving, sailing, kitesurfing, fishing, speed boats etc.) and recreation on land (walking, cycling etc.) (Pel-Roest, 2013).

Similarly, as for the Eastern Scheldt, aquaculture activities will be split between the Fishing industry and the Shellfish industry.

For the Fishing industry, the following types of fishing are practiced (Appendix 1):

- Mullet and Seabass are fished all year around plates and sandbanks. Seven fishermen share the Grevelingen and switch locations every year. They all have the rights to fish what they want, as well as branch into different aquaculture types like shellfish farming.

For the Shellfish sector, the following types of shellfish farming are practiced (Appendix 2):

- Mussel farming of the blue mussel *Mytilus edulis* is being practiced as rope culture in an area near the Brouwersdam by the company Martin Bout (one of the seven fishermen). For bottom culture, the process of growing mussels to market size takes maximum 2-3 years. The harvest season is from May to June. It is slightly shorter for rope-culture.
- Oyster farms in the Grevelingen grow two types of oysters, the Flat (*Ostrea edulis)* and the Pacific cupped (*Crassostrea gigas)* on a total space of 550ha. Plots for collecting seeds are used in July and August. In May, the oysters are fished out of the bottom, and moved to another allotment of the grower, with the right conditions which fit best with the live phase of the oysters at that time. Oysters can also be transported/ relocated from the Grevelingen to the Eastern Scheldt and the other way around. The growth time for the Pacific cupped is of about three years and the oyster is moved twice a year to meet the best living conditions it can get. The growth time for the Flat is of about 4-5 years and the oyster is moved once a year to meet the best quality can be guaranteed. Parcels are rented on an individual basis.

3.3 Policy and future perspectives

The Eastern Scheldt is about 95% owned by the Dutch Federal government. The 5% that are left are the following private grounds (Appendix 2):

- The intertidal area location Kattendijke, owned by Koninklijke Maatschap Wilhelmina polder and rented by shellfish farmers (example: Roem van Yerseke)
- In the northern part of the Eastern Scheldt, some areas are owned by Stichting het Zeeuwse Landschap. These areas are rented by shellfish farmers (example: Albert van Nieuwenhuizen)

The Grevelingen is largely owned by the state (Dienst der Domeinen, Ministerie van Financiën).

Management authorities in the Grevelingen and Eastern Scheldt are split on different levels and responsibility types. They are as follows (Slabbers, Brader, & Sorée, 2018):

- General water quality and quantity and safety and infrastructure management:
    - Ministry of Infrastructure and Environment
        - Rijkswaterstaat,
    - The water boards:
        - Scheldestromen,
        - Hollandse Delta
- Nature management and conservation:
    - Natuurmonumenten (nature monuments),
    - Zeeuws Landschap (for the Eastern Scheldt),
    - Zuid-Hollands Landschap (for the Grevelingen),
    - Staatsbosbeheer.
- Fishery management:
    - Common fishery policy: European parliament
    - National fishery policy: Ministry of Agriculture, nature and food safety

Both the Eastern Scheldt and the Grevelingen have been designated under Natura 2000 as SAC and SPA sites. Natura 2000 is the centrepiece of EU nature & biodiversity policy. It is an EU-wide network of nature protection areas which aims to assure the long-term survival of Europe's most valuable and threatened species and habitats. It is comprised of Special Areas of Conservation (SAC) designated by Member States under the Habitats Directive and incorporates Special Protection Areas (SPAs) designated under the Birds Directive (European Environment Information and Observation Network, 2019). Natura 2000 applies to SACs and SPAs which are divided into biogeographical regions (Pel-Roest, 2013).

A future perspective to look at in the Grevelingen will be the construction of a tidal power station at the Brouwersdam by 2024. A result of this would be the return of tidal movement in the Grevelingen (Zuidwestelijke Delta, 2019).

3.4 Features of Seaweed culture

Seaweeds (also called macroalgae) can be divided into three groups based on pigmentation: brown, red and green. Brown seaweeds are relatively large, ranging from species of 30 – 60 cm long to giant kelp of 20 m long. In total, the brown seaweeds include around 1,500 – 2,000 different species. Red and green seaweeds are usually smaller than brown seaweeds, from a few centimetres up to about a metre in length. There are around 4,000 – 10,000 red algae species and around 7,000 green algae species. (Carlsson, Beilen, Möller, & Clayton, 2007).

The value of the world seaweed market in 2004 was € 6 billion, in which over 90% was farmed. Seaweed production particularly takes place in Asia where China and Japan are responsible for most of the production (Linden, 2014).

Currently, there is no large-scale commercial seaweed production in the Netherlands. The 'Noordzeeboerderij' (Texel) and 'De Wierderij' (now part of Seaweed Harvest Holland) are small-scale, near shore pilot trials in the Netherlands to investigate the feasibility of offshore seaweed cultivation under North Sea conditions. The focus of these pilots is on species that are native in the North Sea. Integrated aquaculture (mussels, fish and seaweed) and the integration of seaweed production with wind parks are also explored, since they are considered as possibilities to enhance the economic feasibility of seaweed production (Linden, 2014).

Applications of seaweed can be (Linden, 2014):

- A source of proteins for human and animal consumption.
- the production of hydrocolloids,
- as a source of chemicals and medicines,
- as bioactive molecules,
- as a potential source of bioenergy.

The main obstacles for seaweed cultivation are (Linden, 2014):

- Short waves, storms, turbulent water;
- restricting regulations;
- relatively high costs;
- technical uncertainty; lacking infrastructure for attachment;
- uncertain impact on environment and risks;
- crop breeding required.

4. Short term possibilities for seaweed production

4.1 General introduction

Water management in the Grevelingen and Eastern Scheldt is made in such a way that each function is allocated a certain area in which it can operate. It is however very difficult for new initiatives to get started, mostly because of a big lack of space, combined with very restrictive regulations concerning spatial planning and use of land for new or different functions than the current ones. These spatial planning regulations are restrictive because of the following reasons:

- They limit the use of a certain area to a single type of function (ex.: Mussel farming, or Oyster farming, …) that is already in the list of authorised functions for the area through licenses.
- In Natura 2000 areas, an extensive research that shows the harmlessness of the new function (if it is not listed in the so called Beheerplan for the specific water system) to the surrounding environment must be given before a new function can get started.
- Parcels that have been allocated to certain farmers / companies before gives them priority on renting again the next time. This gives an unfair advantage to the "lucky few" who were the first renting the most profitable parcels in the area (ex.: the mussel parcels near the mouth of the Eastern Scheldt).

Areas that are allocated for certain functions are however not always used or could be used for other functions at the same time. As stated in the general introduction, the goal of the short-term track is to answer this main question:

What arrangements can be found where shellfish farmers in the Eastern Scheldt and Grevelingen agree to share or use part of their plots for seaweed farming?

As a result of preliminary research, the three following possibilities for answering the question were made:

1. Using unused bottom shellfish parcels. It was discovered in the interviews that a substantial part of the oyster parcels is left unused, as well as a few mussel parcels.
2. Using the MZI parcels that are unused all year round or only during winter. This idea came after some of the first interviews, as well as while doing quantitative research on the available and possible plots that exist in the Eastern Scheldt and Grevelingen. Not only would this benefit seaweed farmers by creating a new opportunity of creating income, but it would also maximise usage of the space available.
3. Combining seaweed and rope mussel culture. This idea comes from multiple examples around the World, as well as from different interviews in which the possibility was discussed.

4.2 Technical and economic feasibility

In this chapter, the technical and economic feasibility of each possibility will be discussed. It is however not a rating of which solution is best as they all work in different environments and time frames.

Inland locations like the Eastern Scheldt and Grevelingen are better production location for winter circumstances because it is protected from big waves compared to offshore locations (Appendix 11.1.a). Moreover, "seaweed, like terrestrial plants, removes carbon dioxide from the surrounding environment and takes up other nutrients of excess in coastal regions from runoff" (YOUNG, 2018).

A big issue with seaweed farming that is not considered in this chapter would be the carrying capacity of the nature and already existing aquaculture and fisheries.

When talking about seaweed farming, according to Seaweed Harvest Holland, some basic general requirements are necessary (Appendix 11.1.d):

- No seaweed farming can happen without an assessment of the environmental effects.
- In order for a farm to be viable for seaweed farming, it should be at least 5 meters deep (average NAP)
- The area should be of 10 ha minimum in the Eastern Scheldt for it to be viable economically.
- The distance to go outside the Eastern Scheldt would also mean that more than 10 ha would be necessary to make the trip worth it.
- The setup for growing seaweed is very similar to the setup used in MZIs. This means that the location specific equipment required for seaweed is buoys, poles and rope/cable.

a. Using unused bottom shellfish parcels

In the Eastern Scheldt and Grevelingen, mussels and oysters are farmed. There are however also two other types of shellfish parcels, namely Verwater (or storage) areas and MZIs. The focus in this paragraph is on the bottom culture mussel and oyster farms and the Verwaters, but not the MZIs or on the rope mussel farms.

For oyster farms, there are 550 ha in the Grevelingen and 2.100 ha in the Eastern Scheldt. While all the parcels in the Grevelingen are rented out and in use, the Eastern Scheldt has 600 ha of unrented, and therefore unused space. (Appendix 11.1.b) After conflicting the depth and locations of unrented farms in the Eastern Scheldt, some of the unused parcels seem to have enough depth to be suitable for seaweed farming. The parcels are however very rarely fully suitable and are sometimes on transport routes. According to Seaweed Harvest Holland, this means that none of the oyster parcels are suitable for farming seaweed (Appendix 11.1.d).

For mussel farms, there are a total of 10037 ha in the Eastern Scheldt, and none in the Grevelingen. Even though quite a few would be suitable for seaweed farming, as they meet the depth requirement, but very little of them are actually available (Appendix a.2) and the ones that are cannot be used as the water above the mussel farms are open for recreational sailing (Appendix 11.1.d).

For Verwater parcels, there are a 11 ha in the Eastern Scheldt, and none in the Grevelingen. Even though they are usually deeper than shellfish farms, they are all kept in use most of the year, and the ones that are not rented out by the government are in case of emergency, like TTX contamination for example (Appendix 11.1.b).

b. Using the MZI parcels that are unused all year round or only during winter.

Some of the MZI areas are not being rented out (about 62%) because the government keeps them as a backup in case of problems in other areas (like diseases), or in case of increasing demand for them. Of the ones that are rented out, some are simply not being used by the farmers to whom they are rented to. This is because some areas have become unusable because of the formation of sand banks and because capturing seeds in MZIs is still 5 to 6 times more expensive than mussel seed fishery from the bottom (Appendix 11.1.a). Other reasons why they are left unused are also the quality of the locations, the fact that mussel seed transport from the south to the north is forbidden to prevent the introduction of invasive species, and that growth has been better in the Wadden Sea (north of the Netherlands). Of the remaining MZI locations, all of them are left unused during the month of winter, as no seeding is taking place. This can be an opportunity for seaweed farmers to grow strains of seaweed that grow in winter.

Farming seaweed in MZIs in winter would however require the full cooperation of both the seaweed and mussel seed farmers, as the end and beginning of the farming seasons for the two activities are very close and will overlap if not managed properly (Figure 3).

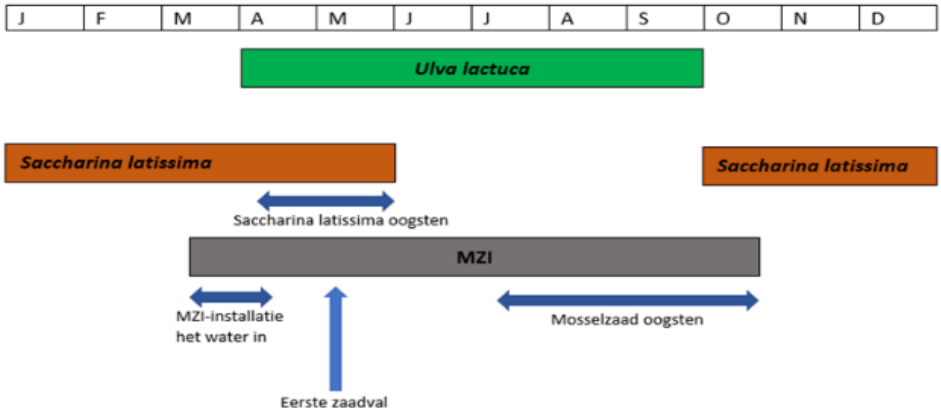

Figure 3: Timeline of growth and harvest for red and green seaweed and MZI (Kints, 2019)

Nature organisations must be considered, and thorough research must be done as they might have a problem with using MZIs for other functions because it could disturb the forming of ice, potentially breaking off and drifting away. Another issue might be the rental status of the parcels. In the future, 100% of the MZI locations might be used for capturing mussel seed, but that depends on multiple factors like whether or not transport of seed from the south to the north becomes allowed. It is however a realistic possibility that some of the unrented parcels could be rented out by 2021-22, as a result of the transition or the mussel sector becoming more independent on bottom seed fisheries. (Appendix 11.1.a).

c. Combining seaweed and rope mussel culture

All over the World, projects and innovations have started to appear for the combination of kelp and rope mussel culture. Some examples of these combinations can be found below:

1. In China, the setup shown in Figure 4 shows an example of the setup used. Here, stake ropes are attached to anchors and are kept floating with floats or buoys. This entire setup is constructed so it stays parallel to the flow of the water. Between each float, a hang rope is attached for the mussels, and a seeding rope is attached between the stake ropes to grow kelp. One disadvantage of this method is that the space between stake ropes needs to be large enough to allow the passage of a harvesting boat, potentially leaving some space unused.

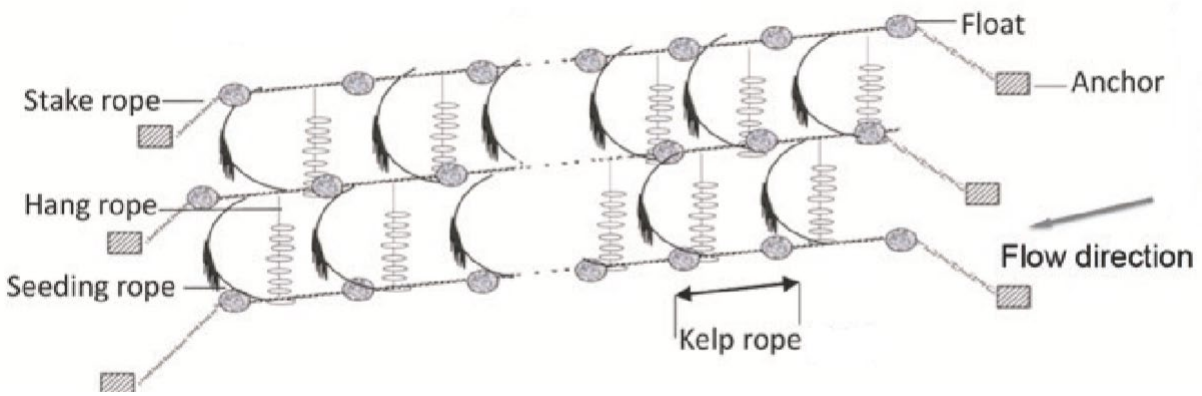

Figure 4: Example of a setup for combining rope culture and seaweed culture in China (Mao, et al., 2018)

2. The dual-use single headrope system design (Figure 5) has been implemented in Long Island Sound, in southern New England in the USA. In this setup, kelp seed strings are planted first in order for the kelp to properly establish. About 4 weeks later, mussel socks are added every meter along the headrope. Appropriate counter-buoyancy is added, and sub-surface tension is applied to provide a stable platform that can withstand storms. Once a month during the 6-month kelp growing season, the longline is lifted via a small centre pick-up line to the surface. Additional buoys are then added to counterbalance the growing crop mass. At harvest time in the spring, the kelp is cut from the longline in 1 m sections between mussel socks. The mussels will continue to grow to be harvested at market size in late summer and early fall (Lindell, 2016).

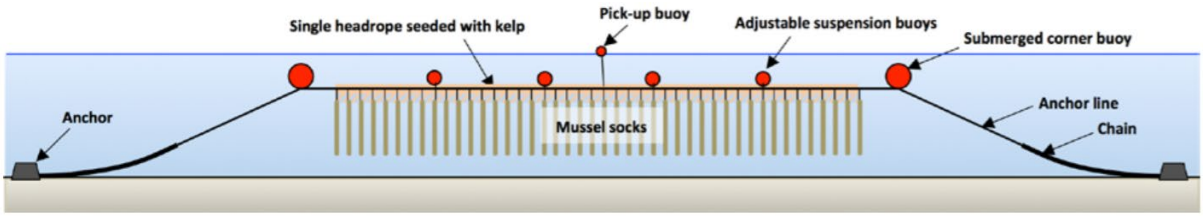

Figure 5: The dual-use single headrope system design (Lindell, 2016)

3. The double-headrope longline design (Figure 6) has been implemented in Long Island Sound, in southern New England in the USA. In this setup, the mussels are planted first in the autumn on the lower headrope followed by kelp on a lighter parallel headrope it. Separating the two parallel lines will be sheeted hard plastic (HDPE) in vertical lines that help keep the two lines apart when the mussel line is pulled to the surface with the centre pick-up buoy for monthly maintenance where additional buoys are added to counterbalance the growing crop mass. The kelp line deflects away from the mussel line as it is pulled up. Additional submerged buoys

are tied close to the mussel line to counter their weight and does not interfere with the kelp line above. Proper subsurface tension is be applied to provide a stable platform that can withstand storms. At harvest time in the spring, the kelp headrope is disengaged from the longline and hauled ashore for processing, leaving a single mussel longline. The mussels continue to grow to be harvested at market size in late summer and early fall. Lines can then be cleaned and prepared for another annual planting cycle (Lindell, 2016).

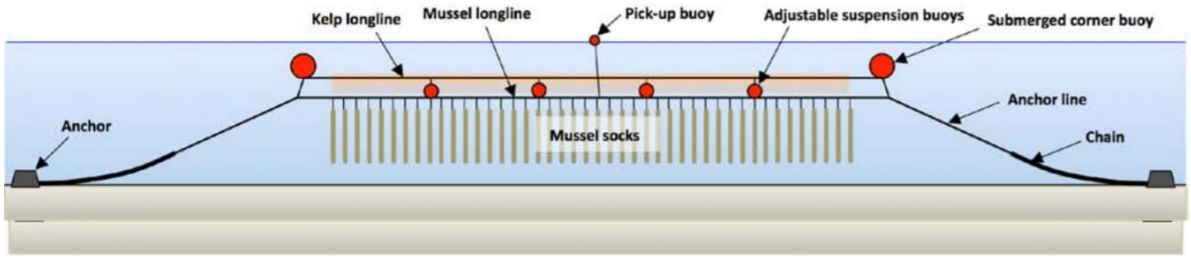

Figure 6: The double-headrope longline design (Lindell, 2016)

Integrating seaweed in rope mussel farms has many benefits (Lindell, 2016):

1. better space utilization of limited permitted sites;
2. shared use of the capital costs of expensive anchors, lines, buoys;
3. better risk management via crop diversification;
4. lower risk to protected species by using fewer vertical lines per unit of production;
5. Farmers growing both crops would enjoy an expanded seasonal market.

The research also mentions a few ecosystem service improvements from the practice, such as:

1. improved water quality, as the nutrients produced by mussel can be consumed by the seaweed;
2. provision of structure resulting in nursery and foraging habitat for other species;
3. a sustainable seafood supply.

Moreover, in the last few years a lot of seaweed (*Undaria* (*Wakeme*)) has been growing naturally on the mussel lines (especially Bruinisse). Some additional research would be required, but growing seaweed might reduce the rate at which that seaweed grows on the mussel lines if they are grown on specifically separate lines.

Some issues might appear when trying to apply the previous models in the Netherlands. For example:

- Prices paid on the Belgian market are lower for rope culture, because they prefer bottom culture. Growing seaweed would diversify the portfolio of farmers
- Some of the locations where rope mussel culture is currently happening are privately owned. One of the drawbacks from that fact is that renting rights in the Netherlands make it expensive to kick out renter if they don't want to leave, which might make owners reluctant.
- According Arthur Landa, a rope mussel culture farmer, it is difficult to make growing seaweed economical feasible because the costs, space and time you need to dry to get a kilo of product is high. It is, in his opinion, much cheaper to just order it from China (Appendix 11.1.c). If a solution to this issue were to be found, the equipment on rope culture mussel farmers' boats is suitable for seaweed culture, and there is still quite a bit of space on board the boats for something with as little weight as seaweed.

- In winter, there is a risk of frosting of the water, which would damage the buoys used to hold the seaweed. One of the solutions is to let the buoys partially sink until they are just under the water level where they would be affected by frost. There are however issues with having the setup sink under the ice, as the continually growing seaweed might gain too much weight and could make the setup completely sink to the bottom. A proper system that prevents this from happening would need to be designed.

6. Long term possibilities for seaweed production: Dynamic spatial planning

6.1 General introduction

As stated in the previous chapter, water management in the Grevelingen and Eastern Scheldt is made in such a way that each function is allocated a certain area in which it can operate through concessions. Not only does that make it difficult for new functions to get, as most of the space has already been rented out, but it also creates an unsustainable environment.

From this issue stemmed the idea of dynamic spatial use, or a modification of the spatial regulations in the two water bodies. The goal of dynamic spatial use is to look at all the functions of an area and assign them work times and rotation periods in the area to increase effectiveness of land use. It is however very theoretic and long term, as laws and mindsets would need to be heavily modified to use this method. The main research question is:

How can the concept of dynamic spatial use be applied in near shore situations in the Netherlands?

After some online desk research on similar issues around the world, as well as several discussions on the topic, two pathways were thought out. The first one would be a light version of dynamic spatial use, where only aquaculture and fishery will be considered. The second will be more extended and on an even longer term, where all the functions in the water bodies will be considered.

6.2 Light version: combining aquaculture and fishery activities

The light version of dynamic spatial use takes only aquaculture and fishery activities into account, with the goal of helping balance and optimise the use of resources on the long term without potentially overcomplicating the research. From this, several already existing examples helped shape two options that could benefit the water bodies.

The first option is following the idea of parcel rotation. Parcel rotation is the same idea that is already applied in the Grevelingen, as its main goal is to have farmers move around in the water bodies, giving everyone a chance at having the “best” parcels. As people and functions would move around, a sort of crop rotation would happen, where a switch of functions on specific intervals would allow the water and ecosystem around it to recover. It also provides the opportunity for farmers to diversify their trade and start thinking about different techniques that could be used in different areas.

This option however has a few drawbacks. While it might be easy to convince the current occupants of the Grevelingen to follow a system that already see working through the 7 fisherman, it will be much harder to convince people in the Eastern Scheldt to abandon the parcels that they are currently using. It might also be difficult to convince government officials to apply this idea, as many regulations will have to be changed. Moreover, it does not solve the main issue of this report, which is the lack of space for expanding aquaculture production.

The second option is to create a general aquaculture concession. Over-licensing, while it has regulatory benefits and creates a more understandable environment, can become very detrimental to its environment. A good example of licensing gone wrong would be the Gulf of Maine, where geographic boundaries and over-licensing led to social, economic and ecologic issues. The historical chart of how specific these licenses became can be found the Figure 6 below.

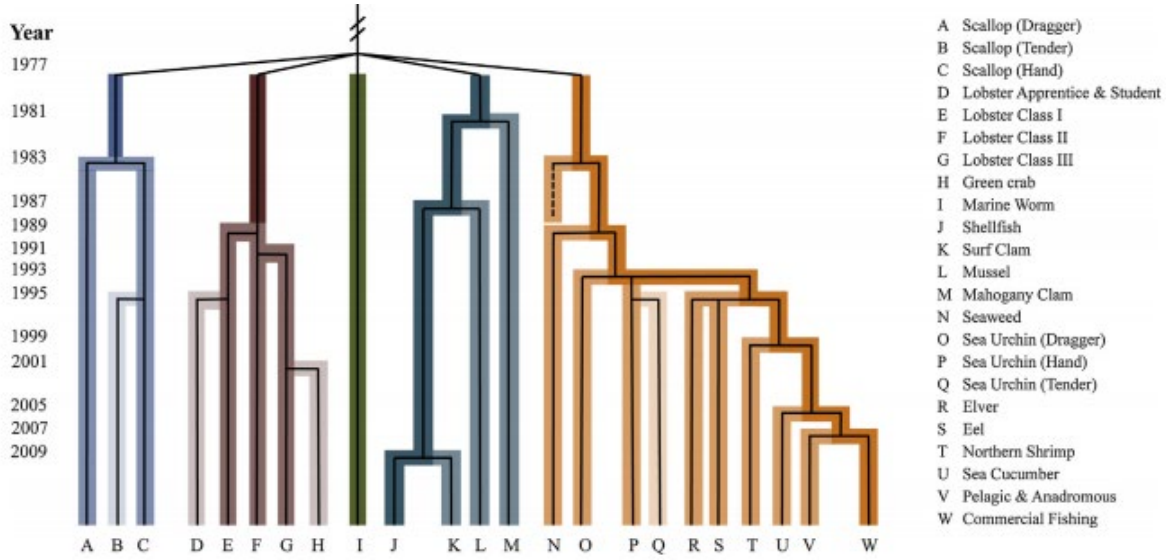

Figure 7: Evolution of licensing system in Maine. Colours denote initial license types, whereas lighter shapes reflect subdivisions (Stoll, Beitl, & Wilson, 2016)

The report classifies the issues as follows (Stoll, Beitl, & Wilson, 2016):

- Decreased livelihood diversification leads to economic instability. This means that obliging farmers to focus on a single very specific product has exposed them to economic uncertainty because an infection that targets the crop that they produce leads to the destruction of the entire livelihood of that farmer.
- Decreased mobility leads to less abidance. This means that forcing people in a limited area to do a singular type of activity will lead to those people being more prone to breaking the law. An example of this could be rope mussel culture farmers selling their products as bottom mussel culture products because they are worth more.
- Decreased engagement undermines local ecological knowledge. This means that by focusing peoples view on a singular activity, they forget about the effects of their activity on others. Because of this lack of knowledge and awareness, they could deplete certain resources that would be needed for the survival of certain species.

In order to solve the issue, generalising aquaculture licenses to let farmers farm species more broadly came to mind. Giving the opportunity to farmers to diversify their trade might also lead to innovation in the industry to optimise the space and techniques. A similar idea is currently being implemented in the North Sea in the windmill parks.

Such a change would however again be difficult to implement, as mindsets and regulations would be difficult to change. It would also be very difficult to regulate what happens and where, creating the risk of ecological damage.

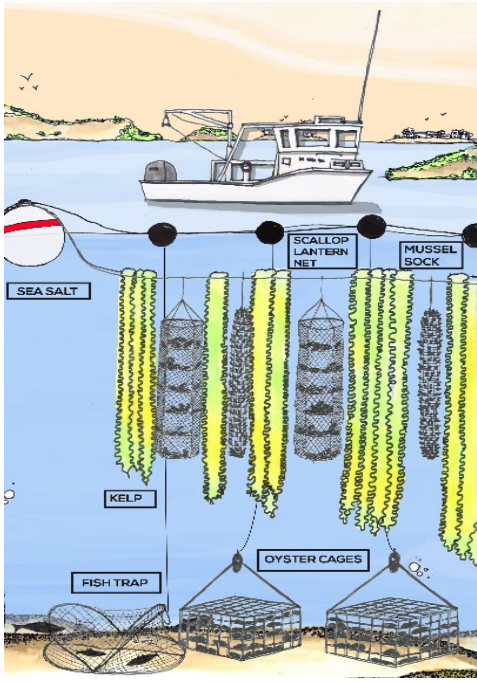

Figure 8: Example of 3D farming (Connecticut Magazine, 2018)

6.3 Extended version: taking all functions in account

In the previous chapter, the idea of making all aquaculture and fishery types work together was analysed. The goal of this chapter is to expand the idea to all the other functions of these water bodies, like recreation, nature, commerce … In order to achieve this, the table in Appendix c was created. This table considers many functions that currently take place in the Grevelingen and Eastern Scheldt. Many factors of these functions are then looked at, like the amount of space they have and where they are currently have it, their time frames every year and the amount of time they need to stay at the same location, the investments relevant to them, and finally who owns the renting rights for these places and what type of rentals are proposed to whom.

As a first option, the idea of functions rotation came to mind once again. An example of how this bigger scale rotation would work can be found in the Netherlands, where some fields that are used for farming in summer are then covered with water in winter and used as ice skating platforms, therefore becoming recreational areas. This practise would however be able to benefit all sectors in different ways. While the commercial shipping lanes cannot be moved, other functions can. This could allow for periods of intense use by the fishing or aquaculture industry, followed by a period of rest where the area would be used by either nature or recreation.

When overlapping the time frames of each functions (Figure 9), it is difficult to see how any functions could work in rotation on the span of a year, except the ones mentioned in the Light version chapter. All the types of recreational sailing could make use of the space when it is not used for other functions.

	January	February	March	April	May	June	July	August	September	October	November	December	Time frame
Mussel													All year until harvest or until move.
MZI													From April to October. First seeds in May.
Verwater													All year until sold.
Oyster													All year until harvest or until move.
G Kelp													From April to September.
B Kelp													From October to May.
Mulet													All year.
Shrimp													From May to Januray.
Lobster													From April to July.
Eel													From December to August.
Commercial transport													All year.
Sailing													When the weather is clear. Mostly in summer.
Windsurfing													
Stand Up Paddle Surfing													
Diving													

Figure 9: Table of time frames of functions in the Grevelingen and Eastern Scheldt in year (Appendix c)

On a larger timescale of 5 years (Figure 10), more possibilities for rotation are visible. Except for commercial transport which cannot move as it uses the shortest quickest route possible, all functions have the potential to be moved at least every five years. This time scale would allow for intensive use of the areas by one function followed by another one that would give the area time to recuperate.

	Year 1	Year 2	Year 3	Year 4	Year 5	Period in the same place
Mussel						For 3 to 5 years (growth time)
MZI						For one harvest season
Verwater						For one harvest and selling season
Oyster						For 4 to 5 years (growth time)
G Kelp						A full growth and harvest season
B Kelp						
Mulet						A single fishing season
Shrimp						
Lobster						
Eel						
Commercial transport						Cannot change
Sailing						Can change as long as buoys are replaced and the areas where it is allowed are deep enough
Windsurfing						One touristic season to process the changes
Stand Up Paddle Surfing						
Diving						These areas can be of historical value and cannot always change

Figure 10: Table of periods each function needs in a singular location on a 5 year scale (Appendix c)

Another option is to look at multiple spatial use, with the goal to provides opportunity for multiple functions that have only little effect on each other to operate in the same place. For certain functions, that is already the case, as bottom shellfish culture already cohabits with recreational sailing. Favouring other combinations of functions would create bigger opportunities for innovation and would create awareness of the impacts of functions on one another. While it might be as difficult to implement as other methods, the problem lies in the strict licensing of areas to specific functions, and the difficulty to regulate an "open space" like this.

Figure 11 gives an overview of functions that could function in the same place at the same time in terms of which areas of the water column they require to function. It can be noted that most functions could be practised above oyster, verwater and bottom mussel farming areas. It is however not recommended to do any function below commercial transport lines as they should not be disrupted. It is also not recommended to have any activity running in the same areas as diving is taking place in at the same time as it could be a danger to the lives of the divers.

	On bottom	Off bottom	Comment
Mussel			Can be both. Currently mostly on bottom
MZI			Off bottom ropes
Verwater			Bottom storage
Oyster			Bottom cages
G Kelp			Off bottom ropes
B Kelp			
Mulet			Off bottom nets
Shrimp			
Lobster			
Eel			
Commercial transport			Off bottom
Sailing			Off bottom
Windsurfing			
Stand Up Paddle Surfing			
Diving			All levels of water

Figure 11: Table of location of functions in the water column 11.3

7. Discussion

From the different chapters within this report, it could be concluded that more areas are available and suitable for new functions, like seaweed farming than first predicted in the introduction. It must however be noted that many factors were not considered in this report. Examples of factors that were not considered are carrying capacity, nutrient intake, light intake, etc These factors were not considered in order to simplify the research, but also because the information on these factors in not available. These factors should be furthered investigated before implementing the solutions represented in this report.

In the information and data gathering process of this report, qualitative research under the form of interviews was done. While the number of interviewees only amounts to 4 people, they represent most categories of stakeholders affected by this report and the integration of new spatial solution in the Dutch south-western Delta. An additional category of stakeholders that could be interviewed in future research could be the recreational sector, as it could easily be affected by innovations like seaweed farming.

8. Conclusions

What arrangements can be found where shellfish farmers in the Eastern Scheldt and Grevelingen agree to share or use part of their plots for seaweed farming?

To answer this question, three different methods were researched. They are listed below along with their advantages and drawbacks:

1. Using unused bottom shellfish parcels (Bottom mussel, Oyster, Verwater):

   Advantage:

   - The use of space will be improved on the limited permitted sites for development.

   Drawbacks:

   - The amount of unused mussel parcels is negligible;
   - Because the seaweed installation floats, it will disturb the above water functions, like recreation;
   - The amount of Verwater and oyster parcels left unused is larger than mussels, but very few are suitable for seaweed farming because of their depth.

2. Using the MZI parcels that are unused all year round or only during winter

   Advantages:

   - The use of space will be improved on the limited permitted sites for development;
   - Capital costs of expensive poles and lines can be shared;
   - Crop diversification leads to better risk management;
   - Farmers growing both crops would enjoy an expanded seasonal market;
   - There are currently about 422,52 ha unused MZI.

   Drawbacks:

   - Research must be done to see on which unused parcels can be used without interfering with mussel seed;
   - The currently unused parcels could soon be in use;
   - The parcels used only in winter have a harvesting season that could overlap the mussel seed catching season.

3. Combining seaweed and rope mussel culture

Advantages:

- The use of space will be improved on the limited permitted sites for development;
- Capital costs of expensive poles and lines can be shared;
- Crop diversification leads to better risk management;
- Farmers growing both crops would enjoy an expanded seasonal market;
- The nutrients that mussel produce can be consumed by the seaweed.

Drawbacks:

- The space for intensive seaweed farming is reduced compared to other solutions;
- The seaweed lines must be harvestable without disturbing the mussels (different harvesting seasons and speed);
- Seaweed could take essential nutrients needed for the feed (micro-algae) of mussels.

How can the concept of dynamic spatial use be applied in near shore situations in the Netherlands?

To answer this question, the following two versions were devised, and each version has two methods. They are listed below along with their advantages and drawbacks:

The light version focuses on solving the issue by looking at aquaculture and fisheries only:

1. Parcel rotation:

   Advantages:

   - A switch functions can lead to better and quicker recovery of the water from intensive farming;
   - Farmers are provided with an opportunity to diversify their trade;
   - All stakeholders get to have a chance at renting most profitable parcels after each rotation;
   - It is easy to implement in the Grevelingen, as stakeholders there already have a similar system.

   Drawbacks:

   - It will be hard to implement in the Eastern Scheldt because of mindsets and current regulations;
   - It does not solve the issue of lack of space for expanding aquaculture production.

2. General aquaculture concessions:

   Advantages:

   - Farmers are provided with an opportunity to diversify their trade and mix aquaculture and fishery in “free zones”;
   - It can help increases awareness of the impacts of certain functions on others;
   - A similar solution is currently being implemented in the North Sea in the windmill parks;
   - It provides bigger opportunities for innovations.

   Drawbacks:

   - It will be difficult to regulate what happens in the “free zones”;
   - It will be difficult to change mindsets and regulations.

The extended version, focuses on the broader scale, including all functions in the Eastern Scheldt and the Grevelingen:

1. Rotation of all functions (including recreation, nature, etc…)

   Advantages:

   - The parcels can be used intensively by one function and be given a rest period while being used by another function;
   - It provides locals and tourists with a change of scenery after every rotation.

   Drawbacks:

   - It will be difficult to change mindsets and regulations.

2. Multiple spatial use:

   Advantages:

   - Multiple functions that have little or beneficial effects on each other can operate in the same place at the same time;
   - It can help increases awareness of the impacts of certain functions on others;
   - New functions that do not exist yet are provided with more opportunities to develop.

   Drawbacks:

   - It will be difficult to regulate what happens where and could lead to confusion;
   - It will be difficult to change mindsets and regulations.

9. Recommendations

The goal of this report was to find space and solutions to optimise the use of space to integrate new functions. Throughout the report, the issue was approached by on one hand, looking at short term integration of seaweed in shellfish farming parcels, and on the other hand at a long-term modification of spatial planning for the water bodies. The areas of focus were the Grevelingen and the Eastern Scheldt. As stated in the discussion chapter, there are however a few points that were not approached throughout this report. The following recommendations are therefore advised for anyone who would continue this research, or make use of it:

- A factor which has not been approached in this report is the carrying capacity of the different functions when combined with seaweed farming. It is therefore recommended to look if the work by Henrice Janssen has been published on the subject, or to research in more in depth before applying the solutions presented in the report.
- In this report, the water bodies of the Eastern Scheldt and Grevelingen are the areas of focus. The space in these areas is very limited, and most of it already developed and has a function assigned. In future research, it might be interesting to also take the Voordelta into consideration, which is much less developed and still has a lot of open and suitable space.

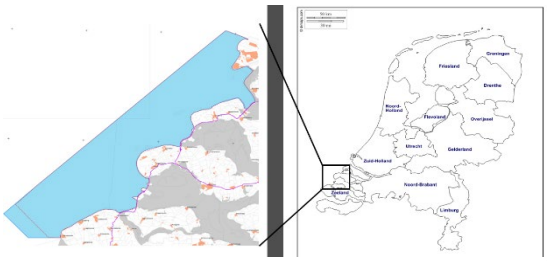

Figure 12: Location of the Voordelta

- The initial research by Dorieneke Trul and Jasper van Kints took many factors into account to calculate the suitability of an area to seaweed farming. These factors were: the light level; the nutrient level; the depth of the water; the velocity of the water. Their research was however inconclusive because of a lack of accurate data on most of these factors, except water depth. More research on these factors would be required to confirm if any of the areas described through this report are truly suitable or not.

While many different options of making space for kelp and other innovations were looked at in this report, it would be better to aim towards a long-term solution, especially the one where all aquaculture and fishery activities are combined. This solution would help the Eastern Scheldt and Grevelingen by increasing the potential for collaboration between stakeholders and increase the chance for new innovations. The first steps towards implementing that solution should probably be to first monitor similar projects like the one in the North Sea windmill park while implementing collaborative projects like combining rope mussel culture and kelp farming and pushing for new regulations and policies in the two water bodies.

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11. Appendices

11.1 Minutes of interviews

a. Leo Volthoren - PO Mossel - 27/05/2019

I. Seaweed farming and other functions

- It is unsure how many bottom culture mussel parcels are left unused in the Oosterschelde, but there are not many.
- A big issue with seaweed farming would be the carrying capacity of the nature and already existing aquaculture and fisheries.
- For the carrying capacity of seaweed and rope mussel culture, a report is being written by Henrice Janssen.

II. Seaweed and MZIs

a. For

- The Oosterschelde is a better production location for winter circumstances because it is protected from big waves compared to offshore locations.
- Capturing seeds in MZIs still 5 to 6 times more expensive than mussel seed fishery from the bottom
- Some MZI areas are not being rented out (about 62%), and some are not being used by the farmers
- Of the rented MZI parcels, some areas have become unusable because of the formation of sand banks.
- The MZI parcel west of the Grevelingen is very probably used. The western parcel (BH1) is rented by Marinus Padmos and the eastern is rented by Willy van Stee.

b. Against

- Nature organisations might have a problem with using MZIs for other functions because it will take nutrients out of the water
- Some of the unrented parcels could be rented out by 2021-22.
- In the future, 100% of the MZI locations might be used for capturing seed, but that depends on multiple factors like whether or not transport of seed from the South to the North becomes allowed.

III. Dynamic spatial use

For a rotational spatial strategy, the big issue is the big difference in quality of parcels at different locations that companies currently own: ‘ there are very productive parcels near the storm surge barrier and bad productive parcels more eastward’

At the same time, the amount of people realizing that they have a chance every 5 years to get a really good plot is much higher than the people who have to give it up.

b. Gert-Jan Veen – Ministry of Agriculture, Nature and Fisheries – 26/03/2019

I. General Eastern Scheldt Facts

About 95% of the Oosterschelde is owned by the Dutch Federal government.
The 5% that are left are the following private grounds:

- The intertidal area location Kattendijke, owned by Koninklijke Maatschap Wilhelminapolder and rented by shellfish farmers (example: Roem van Yerseke)
- In the northern part of the Oosterschelde, some areas are owned by Stichting het Zeeuwse Landschap. These areas are rented by shellfish farmers (example: Albert van Nieuwenhuizen)

II. Short term

a. Oysters

i. Eastern Scheldt

There are 2.1k hectares (ha) of oyster farming areas, of which 600 ha are not rented.
The specifics for rentals of parcels are as follows:

- Permissions for renting a parcel are given on an individual basis.
- Each parcel has a size of 5 ha.
- Rental periods are between 3 and 5 years.

Some vacant parcels have sufficient depth for seaweed farming (example: plot 565), but some are on transport routes (example: from Yerseke Bank back to Yerseke), making them unusable for seaweed farming.

ii. Grevelingen

There are 550 ha of oyster farming areas, but they are all rented out.

b. Verwaters

There are 11.44 ha of verwater areas, that are all located in the Eastern Scheldt.
The specifics for rentals of parcels are as follows:

- The parcels are rented out as a bundle to the Vissers Vereniging Yerseke.
- Each parcel has a size of 5 ha.

Verwater parcels are usually deeper than parcels used for different shellfish farming.
Some temporary verwater parcels have been created near Vondelingen Noord and West with periods from June to September in case of TTX contamination near the Yerseke bank.

c. Mussels

i. Bottom culture

They are all located in the Eastern Scheldt, but there are some talks about implementing it in the Grevelingen.

The specifics for rentals of parcels are as follows:

- Permissions are given on an individual basis.
- The size of parcels is variable.
- Rental periods are between 3 and 5 years.

Most mussel farmers rent 4 parcels or more. The mussels are often translocated 3 times per production period. The production time is between 2 and 3 years.
There is a certain amount of unused parcels that could host seaweed farming. Some of them are however located on transport routes.
As a result of a sand nourishment project at Roggenplaat and its possibly negative effects on the parcels nearby, some extra parcels (wisselpercelen) for mussel farming have been designated. These parcels will be rented for a period between 5 and 10 years.

i. Rope Culture

1. Eastern Scheldt

The specifics for rentals of parcels are as follows:

- Permissions are given on an individual basis.
- Rental periods are between 3 and 5 years.

The known locations for rope culture are:

- Neeltje Jans. This location is rented out to the Schot company.
- Bruinisse + Bergse Diepsluis. It is rented out to the Landa company.
- At the location Bergse Diepsluis, there is a permit for the combination of seaweed and rope culture.

Another potential area might be the “private” waters near Hoogbekken and Laagbekken.

2. Grevelingen

There is a single location for rope culture:

- Near Brouwersdam: company Martin Bout.

b. MZI

The specifics for rentals of parcels are as follows:

- MZI are allocated through a bundle rental to PO Mossel.
- The size of parcels is variable.

Most MZI locations are unoccupied or unassigned, but there might also not be any installations in those areas.
On the map (that was shown during the interview), a few areas are missing.
In 2009 there was transition policy when the long term MZI (MSC) locations were not designated. In this policy, MZI installations could be installed above mussel bottom culture plots.

II. Long term

Fishing

i. Eastern Scheldt

In the Eastern Scheldt, fishing is taking place in the following different ways:
Sleepnet is used for fishing shrimp. 8 permits are available, from which 1-2 are active. The periods for fishing shrimp are from May to February, and the locations where fishing is

- allowed are everywhere to the West of the imaginary lines between Ouwerkerk and Stavenisse and between Westkerke and the Yersekendam, and where there are no shipping lanes.
- Stand want visserij (500 m long) is used mainly for fishing sole. 16 permits are available. The period for fishing sole is spring, and the locations where fishing is allowed are everywhere where there are no shipping lanes.
- For lobster fishing, areas of 200 meters at the shore are allocated. 43 permits are available. The period for fishing lobster is between the 1st of April and the 15th of July.
    - Some of lobster fishermen also have a permit for eel fishery with schietfuiken or kubben. The period for fishing eel is between September and November.
- Zegen is used for fishing mullet and seabass around plates. The period for fishing mullet and seabass is between May and October.

i. Grevelingen

Fishing rights in Grevelingen are in the hands of 6-7 beroepsvissers. They have a combination of fixed areas and flexible areas. The flexible areas rotate every year. They mainly fish lobster and eel.

c. Arthur Landa – Mussel farmer BRU 5 – 27/05/2019

I. The business

- 2 mussel rope culture mussel parcels a 2 different locations (Bruinisse: 75 ha and Bergse Diepsluis (17 ha)
- 20 years of experience with MZI and rope culture (1997)
- Also some bottom culture mussel parcels (2008).

II. (Changing) mussel farming environment

- Effects of climate change will have big effects on mussel culture in the Netherlands, advantaging the German mussel culture where temperatures stay lower.
- Rope culture mussels season is short (May-June). Prices paid on the Belgian market are lower for rope culture, because they prefer bottom culture.
- Recently, in the Northern part of the Eastern Scheldt, shell growth but low meat contents have been observed.
- Near Bergse diepsluis, an experiment was done where extra fresh water was added to the area, also leading to lower growth of shellfish.
- The last few year a lot of seaweed (Undaria (Wakeme)) is growing on the mussel lines (especially Bruinisse).
- Landas' parcel in the south of the Oosterschelde (Bergse Diepsluis) was difficult to grow on due to lack of food and bad quality of the area, even though it had worked really well for 2 years before.

III. Combining shellfish and seaweed farming

a. Difficulties

- Renting rights in the Netherlands make it expensive to kick out renter if they don't want to leave, which might make owners reluctant.
- It is difficult to make growing seaweed economical feasible because the costs ,space and time you need to dry to get a kilo of product is high.
- It is much cheaper to just order seaweed from china.
- In winter, there is a risk of frosting of the water, which would damage the buoys used to hold the seaweed. One of the solutions is to let the buoys partially sink until they are just under the water level where they would be affected by frost. There are however issues with having the setup sink under the ice, as the continually growing seaweed might gain too much weight, and could make the setup completely sink to the bottom.

b. Opportunities

- The equipment on rope culture mussel farmers' boats is suitable for seaweed culture.
- There is still quite a bit of space on board the boats for something with as little weight as seaweed.
- There is a need for a system to dry or freeze the product quickly without too much space, even possibly on board the boat.

d. John van Leeuwen - Seaweed Harvest Holland - 27/05/2019

I. Seaweed

a. Requirements for seaweed farming

- No seaweed farming can happen without an assessment of the environmental effects.
- In order for a farm to be viable for seaweed farming, it should be at least 5 meters deep (average NAP)
    - None of the oyster parcels are suitable for seaweed farming because their average NAP depth bellow 5 meters.
- The area should be of 10ha minimum in the Oosterschelde for it to be viable economically.
- The distance to go outside the Oosterschelde would also mean that more than 10ha would be necessary to make the trip worth it.
- When talking about seaweed farming in MZI parcels, different tinier buoys than the ones used for capturing mussel seed are required. Also the buoys are located at a different place. In case of mussels, buoys are used to create floating capacity (buoyance) because of the weight of mussels. In case of seaweed, which is much lighter we want to create stability in the lines. The rest of the material, like the poles and ropes can however stay the same.
- The MZI location have potential if they can be used all year round because temperatures may alter growing and harvesting seasons, making seaweed farming and mussel seed harvesting overlap each other in Spring.
- Even though Landas' parcels in the Southern Oosterschelde (Bergse Diepsluis) is very suitable for seaweed farming but not for shellfish, some issues related to the way they want to rent the parcel prevents deals to go through.

b. Potential obstacles

- The waves and wind outside the Oosterschelde means that the production would be reduced.
- The Oosterschelde has many boundaries for each of its functions and massive competition between them, making it very difficult to start new functions like seaweed culture.
- Bottom culture mussel parcels would be difficult to work with because the areas above them are currently open for recreational sailing.

c. Potential interest

- The shellfish produce so much ammonia that it might give opportunities to grow seaweed with rope culture mussels.

II. The business

- Owns 6ha of water for seaweed farming at the location "Schelphoek" .
- Staatsbosbeheer provided permission for an extra 10 ha at the same location .

- Also owns another 4 ha in the Mattenhaven at Neeltje Jans, which is currently not in use. In this one, some mussel rope culture takes place.
- Is developing a harvesting machine that allows him to harvest semi-automatically. This machine has to optimized further and will probably be done within a few month.
- Seaweed is used for proteins, carrageen's and for biogas (cascading).
- Currently planning to build a pilot plant for the processing at Stellendam
- Current project with the Wageningen University to calculate the nutrient uptake rates for seaweed in the North sea as part of MMIP project
- He sees mostly Saccharina in the Western part of Oosterschelde and Undaria in the eastern part
- Sees the value and opportunity of working with rope mussel farming organisations like Schot in the future.

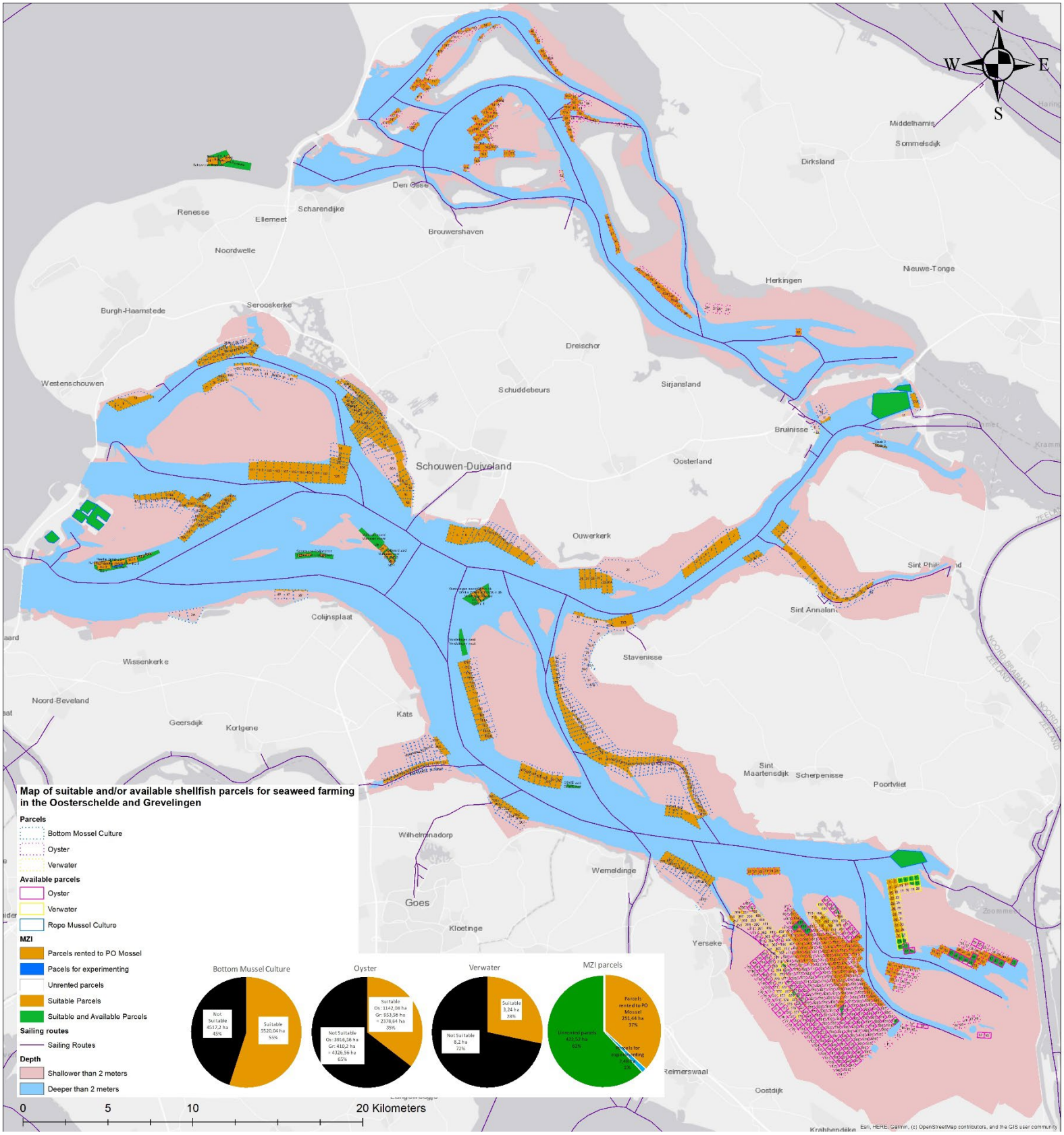
I. Dynamic spatial use

- The idea is currently being applied in the North sea where all aquaculture is being put under that single classification, allowing farmers to diversify their production
- A parcel rotation of about 5 years would be good, as the poles and ropes would need to be inspected and taken out of the water anyways.

- A piece of advice:

  I should first try to create singular aquaculture system (mid-long term) and then it will be easier to get other functions to cooperate in a rotation of functions.

11.2 Map of suitable and/or available shellfish parcels for seaweed farming in the Eastern Scheldt and Grevelingen



11.3 Table of functions

Functions			Currently used		Specific locations (good or not?)	Space used in hectares	Time Frame		Relevant investments (location specific)	Period at same location	Owner of the land	Type of rental	Renter of the land
			Oosterschelde	Grevelingen									
Shell Fish	Blue mussel (Mytilus edulis)	Rope Culture	Yes	Yes	Oosterschelde: Neeltje Jans (Schot company). Bruinisse + Bergse Diepsluis (Landa). "Private" water near Hoogbekken and Laagbekken. Grevelingen: Area near Brouwersdam (Martin Bout)		4 years growth, **with some rest time for the land after growth.** Grow-out to market size (6 – 8 cm) mussels takes 1 to 2 years. A minority of the mussels are harvested when in their second year class. The majority of mussels are harvested when in their third year class, and the remainder in the fourth year class. The harvest season is between May and June.		Poles, ropes, buoys, anchors,	To be economically viable, the plots have to be used for 3 to 5 years, which represents one full rental period	National Government ; KMWP ; Stichting Zeeuwse Landschap	Each are rented individually for a period of 3 to 5 years	Schot company ; Landa
		Bottom culture	Yes	No	Scattered to the west of the Yerseke bank	10037.24 ha with very little unused							Individuals or companies
	Mussel seed catchment Installations (MZI)		Yes	No	In specific locations decided by the Ministry of Agriculture, Nature and Fisheries	681.44 ha, with 422.52 ha unused	From April to October every year. First seeds in beginning of May.		Poles, ropes, buoys, anchors,	The areas used must be available at the catching season every year to be economically viable, as they are the areas that were deemed most effective.	National Government	Bundle rental	PO mosselen
	Verwater		Yes	No	Between the Oyster plots close to Yerseke, but some temporary ones can be alocated near Vondelingen	11.44 ha	Storage after harvest for natural cleaning and spitting out of sand and other detritus as well as storage until sold. For the temporary plots, the time periods are from June to September in case of TTX contamination			Must be clean and available at the beginning of each harvest season. They need one year to sell all the produce to stay economically viable.	National Government	Bundle rental	Vissers Vereniging Yerseke
	Oyster	Flat (Ostrea edulis)	No	Yes	To the East of the Yerskeke Bank for the Oosterschelde, and scattered in the Grevelingen	550 ha but completely rented out	4-5 years growth moved at least once a year to another location so that the the very best quality is guaranteed.	The plots are prepared by cleaning them and by spreading mussel shells, which is a substrate suitable for the settlement of the oyster spat.		Plots for collecting seeds are used in July and August. In May, the oysters are fished out of the bottom, and moved to another allotment of the grower, with the right conditions which fit best with the live-phase of the oysters at that time. One full growth and harvest process is necessary for economic viability.	National Governemnt; KMWP ; Stichting Zeeuwse Landschap	Individual rental	
		Pacific cupped (Crassostrea gigas)	Yes	Yes		2100 hectares. With 600 hectares not rented. (1parcel = 5ha)	3 years growth moved at least twice per year to another location where the best living conditions are at that moment.						

Sailing	**Recreational**	**Sailing**	Yes	Yes			Mostly during weekends or holidays and when the weather is appropriate (less than force 6, 30-35 knots) They are a very important stakeholder. (Based on personal knowledge, need to check with vereniging)	Buoys	Very little information can be found on ROIs for recreational sailing. They however need to be dredged again every 7 to 15 years, therefore an educated guess would be that they are economically viable after 7 to 15 years.	National Government	Not applicable	Not applicable
		Windsurfing	Yes	Yes					These activities do not require a certain amount of time to be economically viable, except for businesses that would rely on it. They also do not need particularly deep waters to be performed.			
		Stand Up Paddle Surfing	Yes	Yes								
		Diving	Yes	Yes					The areas used for commercial diving are usually areas of protected historical value or natural value. They cannot be harmed and need to stay in existence to be economicaly viable.			
	Comercial	**Transport**	Yes	Yes			All day long, all year long through the shortest route possible		Very little information can be found on ROI of commercial dredging. They however need to be dredged again every 7 to 15 years, therefore an educated guess would be that they are economically viable after 7 to 15 years.			
Macro-Algae	**Green (Ulva lactuca)**		No	No			From the beginning of April to the end of September		A full growth and harvest season (6 to 8 month) must go by in order for the plot to have been economically viable			
	Brown (Saccharina latissima)		No	No			From the Beginning of October to May					
Natura 2000 – governmental organisations			Yes	Yes			All year, compensation needed or proof of no damage is also required when changes are made		These plots do not need a specific time to be economically viable, but are however very costly to modify, as they require compensation for the land used, and need full reports on impact of the new function on the area			

Fishing	**Recreational**		Yes	Yes			Mostly during evenings, weekends or holidays **(Need to check with vereniging)**		A single fishing season	National Government	Need to aquire a fishing permit	
	Commercial	**Mulet and Seabass**	Yes	Yes	Around plates	Not applicable	Switch every year between 7 fisherman in the Grevelingen. In the Oosteschelde, the situation is much more complicated with 17 private plots of varying sizes and 37 fisherman on open water fishing.	Zegen		National Government		
		Shrimp	Yes		Everywhere to the West of the imaginary lines between Ouwerkerk and Stavenisse and between Westkerke and the Yersekendam, and where there are no shipping lanes	Not applicable	Fishing period from may un til february	Sleepnet		National Government	8 permits, from which 1 or 2 arce active	
		Sole	Yes		Everywhere where there are no shipping lanes	Not applicable		Stand want (500 m long)		National Government	16 permits	
		Lobster	Yes	No?	200 meter at the shores		From the 1st of April to the 15th of July with some very specific restricted areas.			National Government	43 permits near the shore	
		Eel	Yes	No			Eel fisheries have a mendatory shutdown period from the 1st of September until the 1st of December.	Schietfuiken or Kubben		National Government	Rental	Some of the lobster fisherman also get a permit for fishing eel
Ecosystem services			Yes	Yes			All year long and everywhere.		These services happen everywhere and cannot be removed as that might cause damage to other functions. Some of them are protected as Natura 2000.			