2022

Enhancing the ecological value of a brackish water system

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Date: June 10th 2022

version: 1.0

Title	Enhancing the ecological value of a brackish water system
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Internship period	February – July 2022
Document type	Report
Date	June 10th 2022
Version	Definitive

Abstract

The in 2000 established Water Framework Directive urges Member states to realize and maintain chemically clean and ecologically healthy water systems by 2027. Water Board Scheldestromen manages the water system of Zeeland which consists of mainly brackish waters. These types of waters have a variety of stressors, including salt fluctuations and excess nutrients, making it difficult for species to survive. The Water Board implemented nature-friendly banks for increasing the natural value of the system, however a relatively low ecological value with a bank dominated by reeds and/or an absence of submerged water plants was observed in brackish waters. Water plants provide underwater structure for different species to use as hiding area, breeding area or attachment substrate and are therefore important for the natural value of the system . By analysing the components “Assessment WFD”, “Implementation”, “Maintenance” and “Additional Measures” with the use of a survey, interviews and experiments a conclusion could be drawn on how to effectively maintain the natural value of nature-friendly banks in brackish waters. The “bad” to “moderate” water quality is an highly influencing factor and requires cooperation on national scale for improvement. For Water Board Scheldestromen it is advised to focus on waterbodies with potential for increasing the water quality until 2027. For brackish waters with a relatively low water quality it is recommended to do a chemical and/or biological analyses to find the problem causing the lack of ecological value of the specific system. With the outcomes of the analyses suitable measures could be taken locally. Creating heterogeneity within a bank is also recommended. The established experiments which focused on creating under water structures could not be implemented within the research period. It is however recommended to implement the experiments to see the effectiveness of these measures.

Content

Foreword

In February 2022 I got the opportunity to perform a research commissioned by Water Board Scheldestromen on possibilities for enhancing the ecological value of nature-friendly banks in brackish waters. This Bachelor thesis was written as part of my graduation for the Bachelor Water management Aquatic Eco-technology at the HZ in Middelburg. During the study I had the chance to learn about different topics such as aquaculture, climate change and water technology. Because I could experience a wide range of topics, I was able to find my main interests within the work field. I have always had a passion for animals and nature, however during the study I learned that nature restoration and climate adaptation interest me the most and therefore I want to focus on these topics in my future career.

The first idea for the research was to implement experiments within the management area of the Water Board during the research period. Unfortunately, the experiments could not be implemented within the internship period. However, with the permission of my supervisors, I broadened the research topic and focused on four components: WFD assessment, Implementation, Maintenance and Additional measures. I got the opportunity to do a qualitative research instead of a quantitative research, which was unknown territory for me. However during my internship I learned a lot about this way of doing research and it helped me improve on my professional and personal competences.

I want to thank my in-company supervisors Bernd van Broekhoven and Yvonne van Scheppingen for giving me the opportunity to work on this interesting topic. I also want to thank my in-company supervisors for guiding me during the internship period, providing me with useful feedback and helping me with improving on my professional and personal competences. I want to thank my colleagues from the water quality department for making me feel welcome within the team and always being available to help me with my research. I also want to thank all the respondents and interviewees for taking the time to provide me with relevant and useful information. Lastly, I want to thank my school supervisor Bram Verkruysse and my family members for supporting me during this crucial time and providing me with feedback on my report during the final steps.

Larissa Timman
Goes, 10th of June 2022

1. Introduction

1.1 The Water Framework Directive

In 2000, the European Union established the Water Framework Directive (WFD) with the aim to realize and maintain chemically clean and ecologically healthy water systems within EU countries. This to ensure long-term sustainable use of water for both people and nature. (European Commission, 2012) The policy includes environmental legislation and necessary measures to be taken by European member states to prevent a decline in water status (based on water quality measures) of the maintained waterbodies. The tool for assessing the water quality of a waterbody is the Ecological Quality Ratio (EQR). Furthermore, does the policy provide a wider and longer term perspective by motivating sustainable water use and long-term protection of the water sources, keeping in mind the (future) challenges of climate change. (Thieffry, n.d.)

Within the Netherlands, the Water Framework Directive is translated to the Dutch water system by the Department of Waterways and Public works, together with regional water boards and municipalities, by implementing national and regional measures to ensure achievement of the policy's objectives. For example, measures for enhancing the water quality include the construction of secondary river channels, fish passages and nature-friendly banks (Ministerie van Infrastructuur en Waterstaat, 2022). All these measures have a mutual aim of providing a healthy and safe habitat for both aquatic and terrestrial species within and surrounding the water system, while at the same time providing clean water for common and industrial use.

1.2 The water system in Zeeland

In the province of Zeeland, Water Board Scheldestromen is responsible for the regional water system. Ground waters and surface waters are all interconnected and form the water system of Zeeland. This water system includes ditches, creeks, channels but also dikes and polder roads are being maintained by the Water Board. Zeeland is situated in a deltaic area and therefore mainly influenced by the sea. This can be seen back as the water system in Zeeland covers a complete range of salinity from freshwater (<0,1 g CL/L) to strongly brackish waters (>10 g Cl/L), due to both the large impact of the sea and the absence of a freshwater source, such as a river running through the province (an exception is Zeeuws-Vlaanderen, some waterbodies there are connected with fresh waterbodies in Vlaanderen, Belgium).

The daily challenge for the Water Board is to ensure water safety for the inhabitants of Zeeland and maintain water of good quality for both nature and people. To ensure lawful compliance, this management is in cooperation with the regional municipalities and the government. The water system is being used and influenced by a number of stakeholders including farmers, fishermen and companies and it is important that this is being managed effectively to prevent conflicts, decrease in water quality or negatively influencing ecological values.

1.3 Nature-friendly banks

Traditionally, ditches as part of the maintained water system are being constructed as efficient as possible in terms of taking up as little space as possible and being easy in maintenance. This way of constructing does also have disadvantages such as the risk of a collapsing bank due to the absence of bank protection and the presence of a steep sloop. Another downfall is the limited retention capacity. Nowadays, awareness is raised on the importance of including nature and the subsequent benefits that this can bring to the water system. The introduction of nature-friendly banks as replacement for the traditional banks was one of the proposed measures. The ambition of this concept is to improve the ecological value of water systems. (Waterschap Scheldestromen, 2021a)

Nature-friendly banks have a more gradual slope, subsequently also having a more gradual transition from water to land, compared to a traditional bank. The benefit of this is the provision of space for nature to thrive, such as a diversity of shore plants. Not only the bank is wider, the waterbody itself as well, providing more space for water and an increase in retention capacity. This extra capacity could be supportive in having a sustainable and climate adaptive water system. Moreover, does the width of the bank lead to a decrease in agricultural runoff because the water is situated further away from the adjacent agricultural land. This is beneficial for the water quality in the ditch (less nutrients). (Waterschap Scheldestromen, 2021a) The difference between a conventional bank and a nature-friendly bank can be seen in Figure 1.

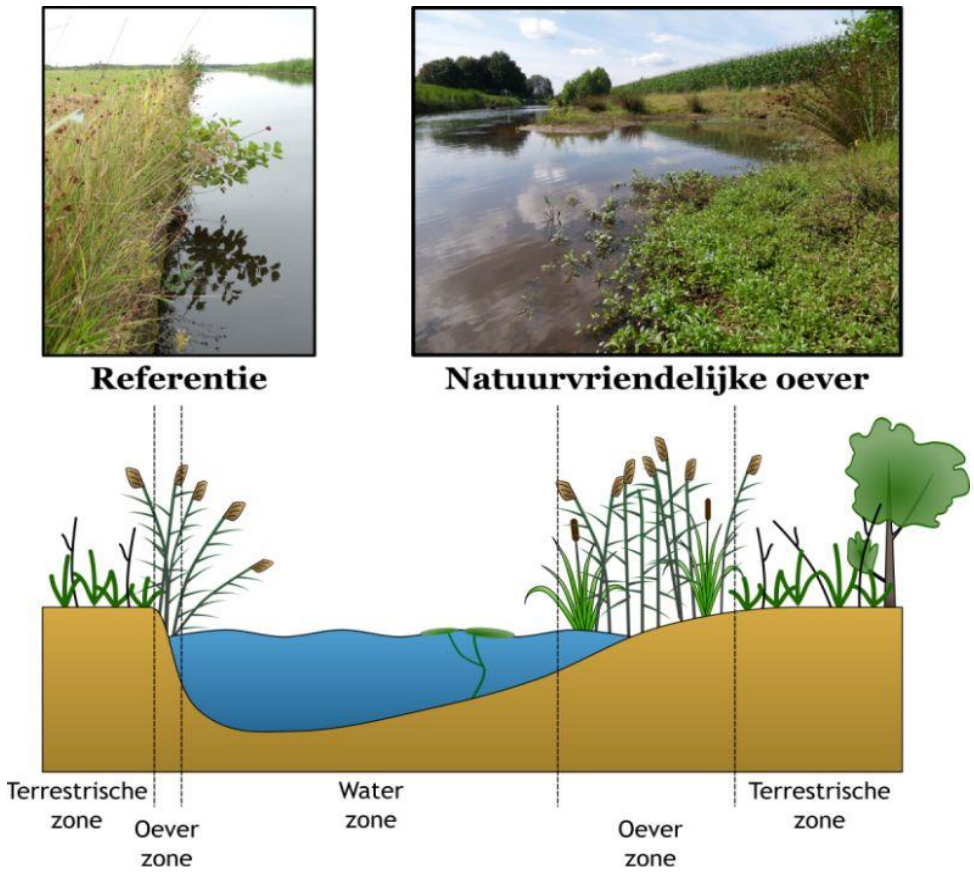

FIGURE 1 DRAWING AND PICTURE SHOWING THE DIFFERENCE BETWEEN A CONVENTIONAL BANK (LEFT) AND A NATURE-FRIENDLY BANK (RIGHT). (DORPSBELANG GOUTUM, 2019)

The implementation of nature-friendly banks in Zeeland did not give the expected results. The regional Water Board observed an absence/limited amount of (submerged) water plants and/or the waterbodies were being dominated by reeds. This barely enhances the biodiversity and the ecological water quality of a waterbody. Even though the constructed nature-friendly banks did not show the wanted results, an additional 38,2 km is planned for 2022-2027. The reason for this mainly being the obligations of the WFD in reaching the water quality goals. It is however questionable whether the objectives are realistic for brackish water systems. (Waterschap Scheldestromen, 2021b) Figure 2 shows a nature-friendly bank situated within the management area of Water Board Scheldestromen.

FIGURE 2 A NATURE-FRIENDLY BANK SITUATED IN KRUININGEN, ZEELAND.

1.4 Knowledge gap

More research is needed into why nature-friendly banks of brackish waters lack natural value. This is important because, due to the relatively low ecological value of the water system in Zeeland, the Water Board fails to meet the objectives of the WFD for brackish waters. It is important to investigate what exactly causes the lacking behind of natural values when implementing nature-friendly banks in brackish waters and how these natural values can be increased. Another problem is the absence of a proper desirable image and a reference frame for brackish waters in the WFD. The proposed measures do barely or not connect to the unique conditions in Zeeland. The water system in Zeeland is a strongly dynamic system where natural fresh-to-salt gradients are lacking. Just because of the lack of this natural gradient, the water system already does not comply with the established WFD goals. It is also yet unknown what additional measures could be taken to support nature-friendly banks in improving the natural value and water quality of brackish waters. However, there is ongoing research on the exact biological and physicochemical conditions of brackish waters. An example is the “Kennisimpuls brakke wateren” (Kennisimpuls Waterkwaliteit, 2021).

A research from Van Dijk et al. (2020) showed that there is an opportunity for certain water plants to survive in slight brackish waters (M30) by implementing a relatively simple solution, in their case the exclusion of fish-grazing. Nevertheless, research on possible

additional measures to increase the natural value of nature-friendly banks in a strong brackish water system (M31 waters) is lacking. Therefore it is necessary to find out what problems cause the lacking behind of ecological value and how this could be solved. Another question is, are the ecological legislations for these strong brackish water systems realistic? Or would a different approach for this unique type of water conditions be needed?

1.5 Research question

- The research question for this research is: What is an effective way of maintaining the ecological value of nature-friendly banks in brackish waters?

With the following sub questions:

- Is the WFD assessment realistic for brackish waters?
- What causes the lack of ecological value of nature-friendly banks in brackish waters?
- Which ecological values could be improved?
- How can the ecological value of nature-friendly banks be enhanced?
- How can possible additional measures for enhancing the ecological value of nature-friendly banks in brackish waters be implemented on a larger scale?

2. Theoretical framework

2.1 Assessing the water quality

Part of the Water Framework Directive (WFD) is a fixed monitoring program for assessing the water quality of surface waters (see Figure 3). This program is divided in two parts: the chemical quality and the ecological quality. The chemical quality is based on the concentrations of 45 different substances in the water system. The ecological water quality is divided in the biology part, a physico-chemical part and river basin specific pollutants. The biology and physico-chemical parts consist of a number of quality elements that have to be assessed. At the end, all the assessments are put together to form the overall ecological quality. (Rijksoverheid, 2020a)

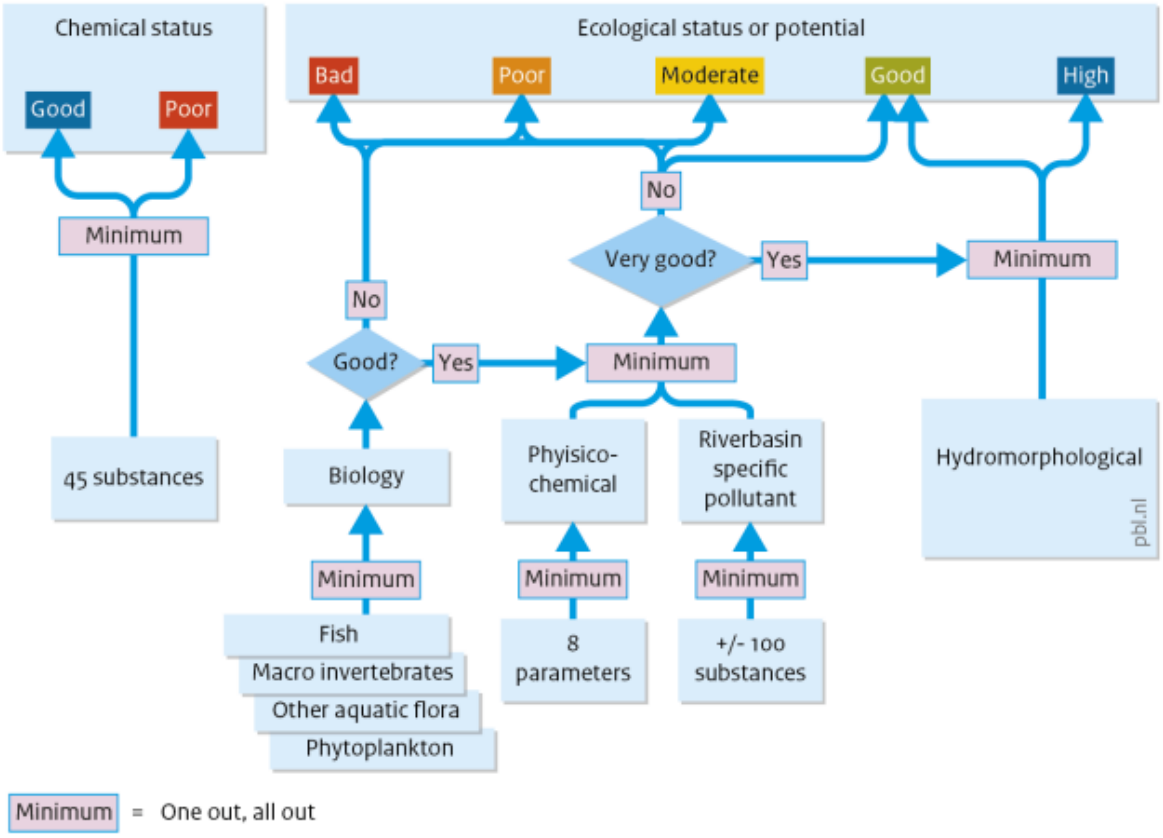

FIGURE 3 A SCHEMATIC OVERVIEW OF THE WATER QUALITY ASSESSMENT ACCORDING TO THE WATER FRAMEWORK DIRECTIVE. (VAN PUIJENBROEK, N.D.)

The rating for the ecological quality can range between “bad” and “high” and is based on either the “Very Good Ecological Potential”, which is based on a natural reference situation or the “Maximum Ecological Potential”, which is based on a reference water system with a sufficient water quality. Beforehand the water systems are divided into different water statuses being “natural”, “artificial” and “heavenly modified”. When the water system is classified as “artificial” or “heavenly modified”, it is impossible to bring it back to its natural state without causing water safety issues and therefore the goal is to reach the “Maximum Ecological Potential”. For the natural waters the goals are based on the “Very Good Ecological Potential”. (Rijksoverheid, 2020a)

Next to the water status, waterbodies are also divided in different water types depending on water flow and salt concentration. As can be seen in Figure 4, the majority of the water system in Zeeland is either M30 (orange line) or M31 (purple line). M30 waters are slightly brackish waters with a salinity between 0.3 – 3 g CL/L, while M31 waters are small slightly brackish to salt waters with a salinity of >3 g CL/L (STOWA, 2018). Both water types are stagnant waters such as ditches or channels.

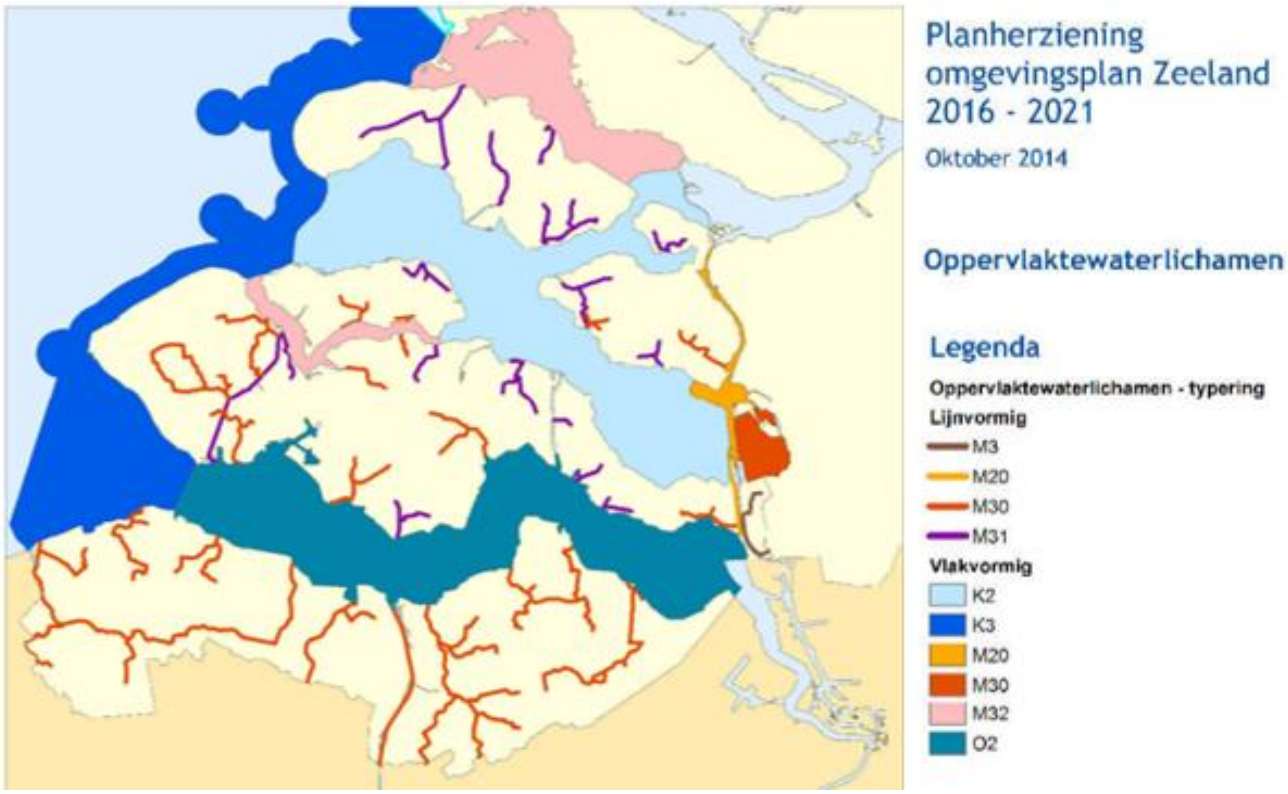

FIGURE 4 OVERVIEW OF THE REGIONAL SURFACE WATERBODIES IN ZEELAND. (PROVINCIE ZEELAND, 2014)

When the water quality assessment results predict that a certain waterbody has a chance of not reaching the WFD goals, an additional monitoring program called “Operational monitoring” should be included. For operational monitoring the measurement frequency of one or more quality elements is being intensified for the specific waterbody. This additional monitoring does not focus on why a certain waterbody may not reach the WFD goals. For finding the cause another additional monitoring program may be chosen, “Monitoring Further Investigation”. (Rijksoverheid, 2018)

Based on the collected data of the monitoring program, a final assessment on the ecological quality and the chemical quality is given for each waterbody. All quality elements are being put together for this final assessment. This process is based on the “one out, all out” principle, meaning that the lowest scoring quality element is determinative for the total score. (Rijksoverheid, 2018)

2.2 River basin management plans

For the WFD, the water system of each EU country is divided into so-called river basin districts. Within the Netherlands there is a number of sub-river basins (See Figure 5). The management area of Water Board Scheldestromen is part of the Scheldt basin. The WFD

obliges Member States to draw up river basin management plans every 6 years. These plans describe the outcomes of the water quality monitoring program including possible measures established for enhancing the water quality within the specific sub-basin area. (Informatiepunt Leefomgeving, n.d.)

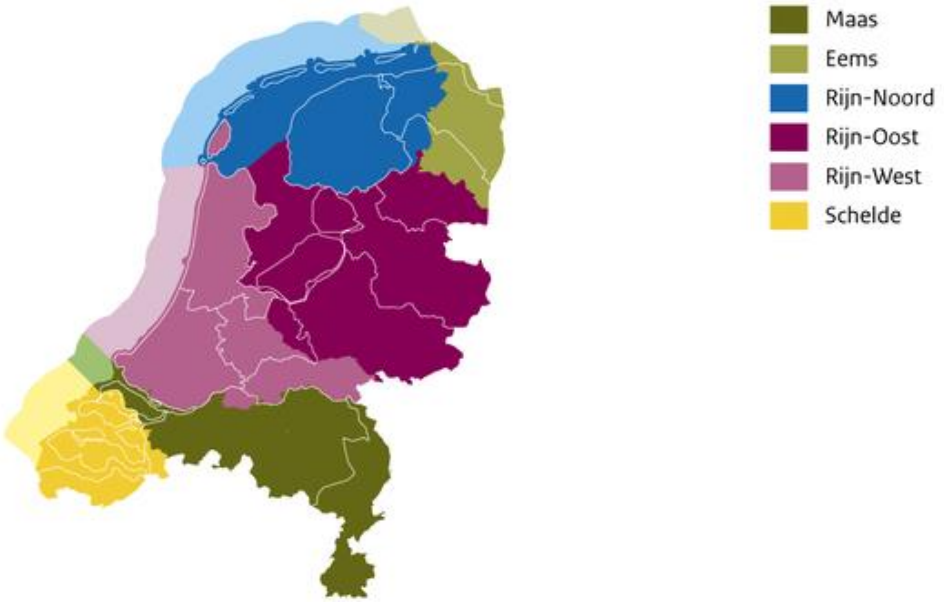

FIGURE 5 SUB-BASIN AREAS WITHIN THE NETHERLANDS ACCORDING TO THE WFD. (RIJKSOVERHEID, 2020B)

2.3 Area analysis

The sub-basin area Scheldt covers an area of 3200 km^2 (within the Netherlands) and consists of 56 surface waterbodies and 5 groundwater bodies. Furthermore, there are 18 Natura2000 areas, 4 shellfish waters, 68 swimming waters and 2 groundwater bodies for human consumption. All these waterbodies are protected by unique laws and regulations as addition to the guidelines of the WFD. (Rijksoverheid, 2009)
In the Scheldt area the majority, 35, of the waterbodies have the status “artificial”. Moreover, 19 waterbodies are assigned with the status “heavenly modified” and 2 waterbodies with the status “natural”. (Rijksoverheid, 2022)
In Figure 6 and 7 the ecological assessments of each quality element for the Scheldt is shown for 2009, 2015 and 2021. On average the scores of the biological quality elements phytoplankton, other aquatic flora and macro fauna decreased, while the quality element fish increased. This can be explained by the increase in constructed fish passages. (Rijksoverheid, 2022)

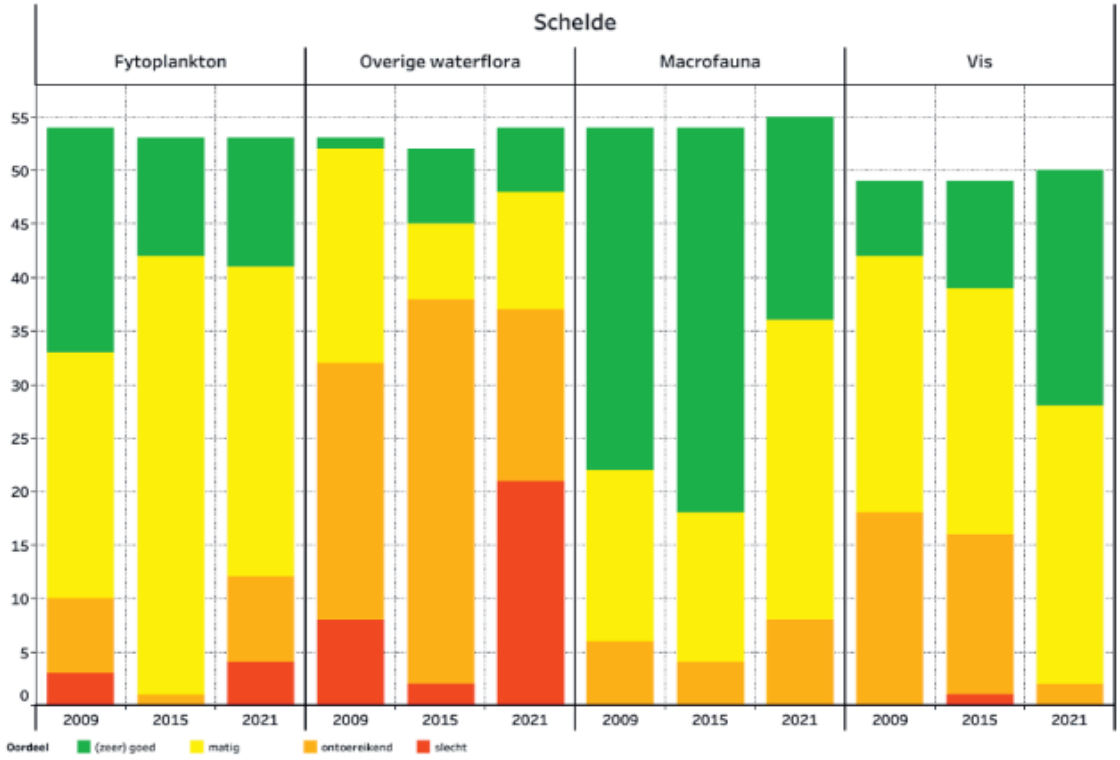

FIGURE 6 WFD SCOES FROM 2009,2015 AND 2021 FOR THE BIOLOGICAL QUALITY ELEMENTS OF THE SCHELDT AREA. (RIJKSOVERHEID, 2022)

The scores of the physico-chemical elements temperature, chloride, total phosphorus and total nitrate decreased when comparing the scores of 2015 and 2021. The other physico-chemical quality elements show an overall increase in score.

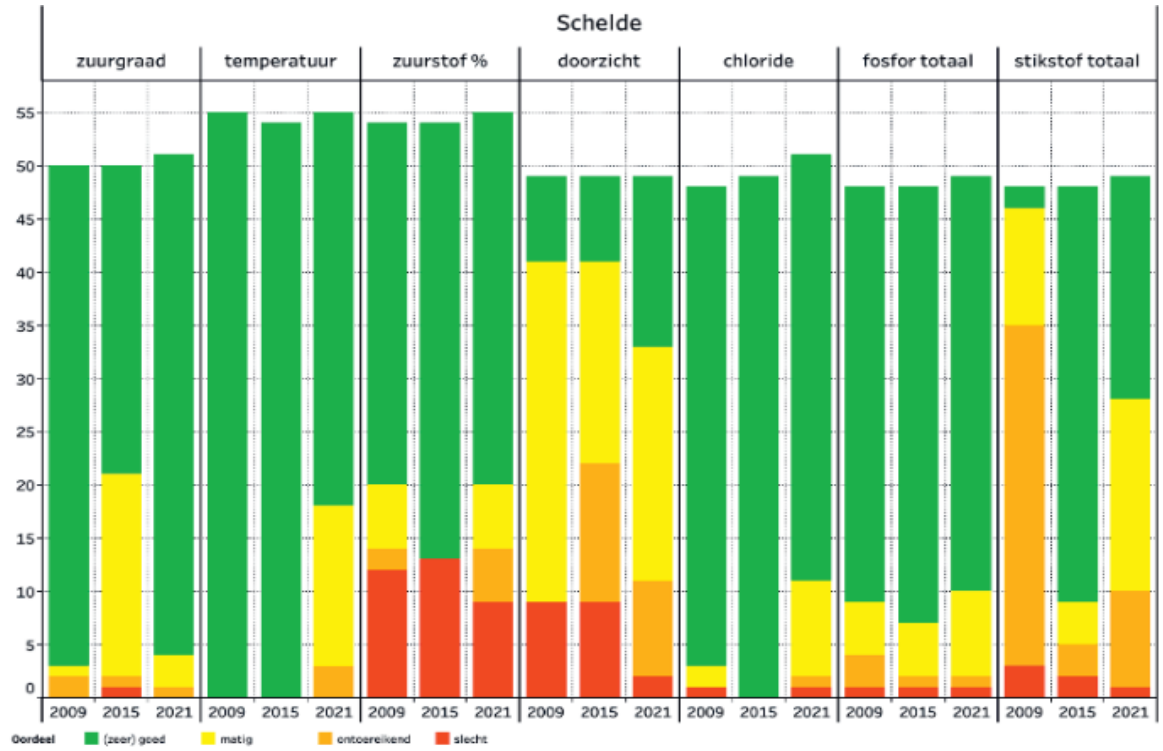

FIGURE 7 WFD SCORES FROM 2009,2015 AND 2021 FOR THE PHYSICO-CHEMICAL QUALITY ELEMENTS OF THE SCHELDT AREA. (RIJKSOVERHEID, 2022)

In Figure 8 the overall water quality of the Netherlands is shown. The water quality of the Scheldt sub-basin area varies between bad and moderate. Only a few waterbodies are assigned with “good” water quality.

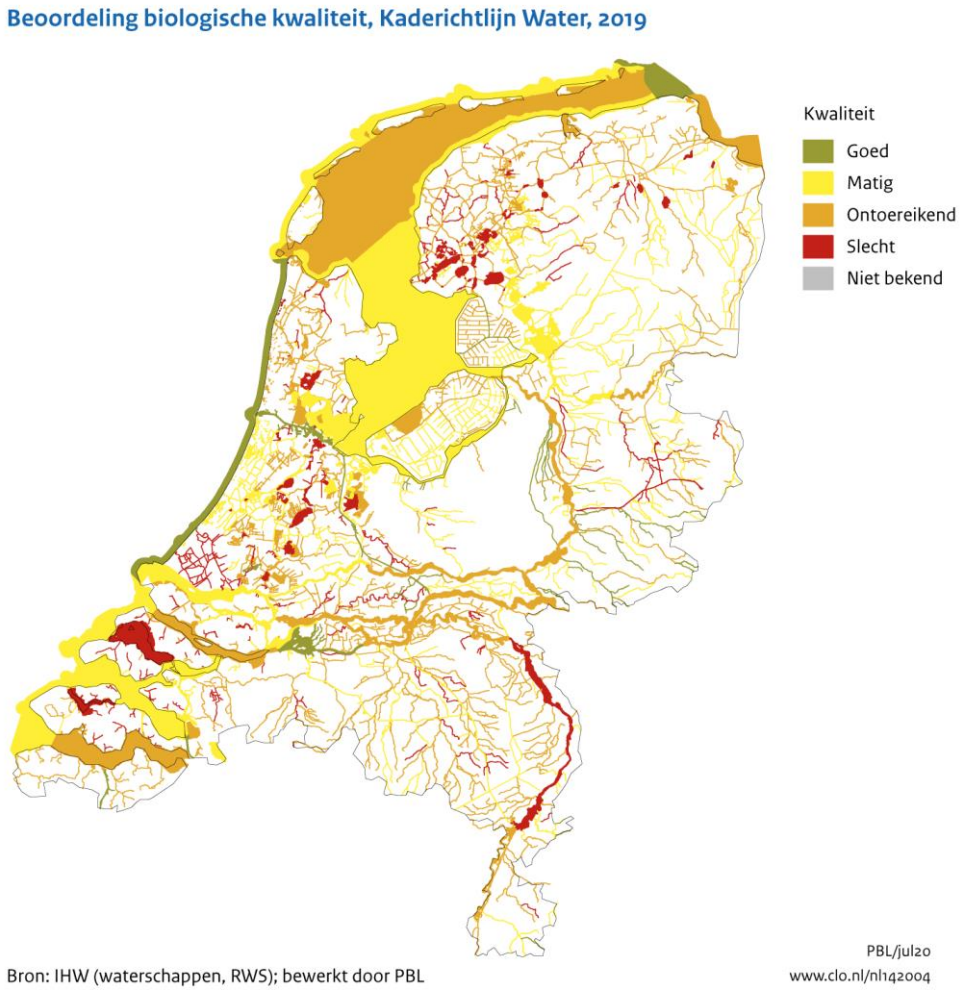

FIGURE 8 ASSESSMENT OF THE BIOLOGICAL QUALITY ACCORDING TO THE WATER FRAMEWORK DIRECTIVE. (IHW, 2019)

2.4 Factors influencing the water quality

In Figure 9 the land-use of the Scheldt sub-basin is shown. The majority of the land, 77%, is for agricultural use. Furthermore, 6% consist of buildings and only 4% is forest and 3% is nature. (Projectgroep IKS, 2004)

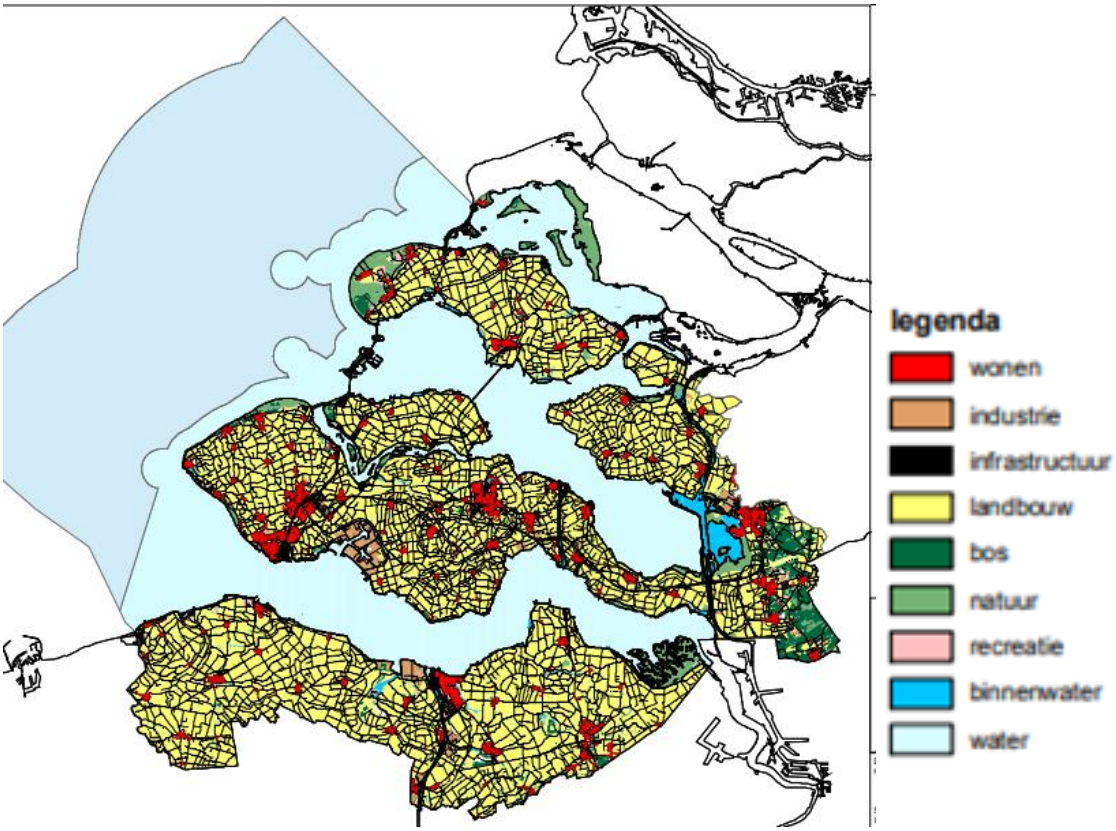

FIGURE 9 MAP WITH ALL TYPES OF LAND-USE WITHIN THE PROVINCE OF ZEELAND, PART OF THE SCHELDT BASIN AREA. (RIJKSOVERHEID, 2004)

Land-use is one of the factors that has a major influence on the water quality. This because the functions of the water system are depending on the land-use. An example, agricultural runoff is one of the main nutrient sources and the biological quality of a waterbody is influenced by the concentrations of nutrients. An excess amount of nutrients can lead to loss in biodiversity. Another influence that is connected to land-use is management and maintenance of the water system. An example is the management of the water level within surface waters. (Rijksoverheid, 2022) For agriculture it is preferred to have a high water level in summer and a low water level in winter. While, for ecology it is preferred to have a high water level in winter and a low water level in summer. (Rijksoverheid, n.d.)

Another influencing factor mentioned in the river basin management plan of the Scheldt 2022-2027 is the influence of climate change on the water quality. One of the consequences of climate change is the increase in water temperature of waterbodies. It is known that a change in water temperature can lead to changes in the biological quality. A decrease in species richness and increase in chloride concentrations have been observed in some ditches and lakes, caused by an increased water temperature. Other consequences of climate change include more extreme weather conditions such as droughts and heavy rainstorms. The consequences are influencing the water system and involved sectors in different ways.

Therefore, more research will be done on the exact influences of climate change on the water system and will then be translated to the WFD goals. (Rijksoverheid, 2022)

2.5 Implementing a nature-friendly bank

A research on the effects of nature-friendly banks by De la Haye et al. (2011) implied that the construction of nature-friendly banks in freshwater systems contributed to a higher ecological value for macrophytes and macro fauna. Furthermore, does the more gradual sloop provide a favorable habitat for water plants. Minor erosion of the bank proofed to be advantageous for the development of macrophytes. In the waterbody itself, an increase in fish population was observed. (De la Haye et al., 2011)

A research from Hoogheemraadschap van Delfland (2019), executed within the management area of Water Board Delfland, also suggested that constructed nature-friendly banks contributed to enhancement of the water quality in freshwater systems. Furthermore, did the more natural banks have a higher diversity of water plants and macro fauna and showed an increase in numbers of fish. (Hoogheemraadschap van Delfland, 2019)

In Zeeland a total of 267 kilometers of nature-friendly banks were constructed between 2000 and 2020 (Provincie Zeeland, 2021). The mentioned researches showed that nature-friendly banks can have a positive influence on the ecological value of the water system. However, it is important to mention that both researches focused on freshwater systems. As already mentioned, the observations by Water Board Scheldestromen do not correspond with this.

2.6 Brackish waters

The observed conditions of the nature-friendly banks in Zeeland (no/limited water plants or dominated by reeds) are not enhancing the ecological value of the water system, meaning that the construction of the more natural banks in brackish waters do not contribute to reaching the WFD objectives. This, however, can be explained by the unique conditions of brackish waters and the subsequent presence of a variety of stressors, making it relatively difficult for species to live in these conditions. One of the stressors being large fluctuations in salt concentrations leading to osmotic and ionic stress. Osmotic stress can cause cell shrinking in higher salt concentrations or falling apart of cells in lower salt concentrations. Ionic stress can lead to toxic effects. Furthermore, does toxicity of ammonia and sulfide also occur in brackish waters. Other stressors are most often turbidity, low oxygen concentrations and excess nutrients. (Arts et al., 2021)

The curve of Remane (1934), Figure 10, shows the relation between species diversity and salt concentration (the curve does not apply for planktonic species). The curve shows that a salinity of about 3 to 10 g Cl/L has the lowest species diversity. As previously described, in Zeeland most waters are either M30 waters or M31 waters. M31 waters are characterized by a salinity of >3 g Cl/L, meaning that in these types of waters, according to the curve of Remane, the lowest species diversity is expected. This corresponds with the aforementioned observations by Water Board Scheldestromen on the limited variety of water plants and subsequent macro fauna species diversity in the system. However, although the species diversity in these systems are limited, there are certain species, such as Zannichelia and

Ruppia, that are able to live in these extreme conditions. Information on the characteristics of type “M31: small brackish to salt waters” including species that are able to live in these waters can be found in Appendix 1.

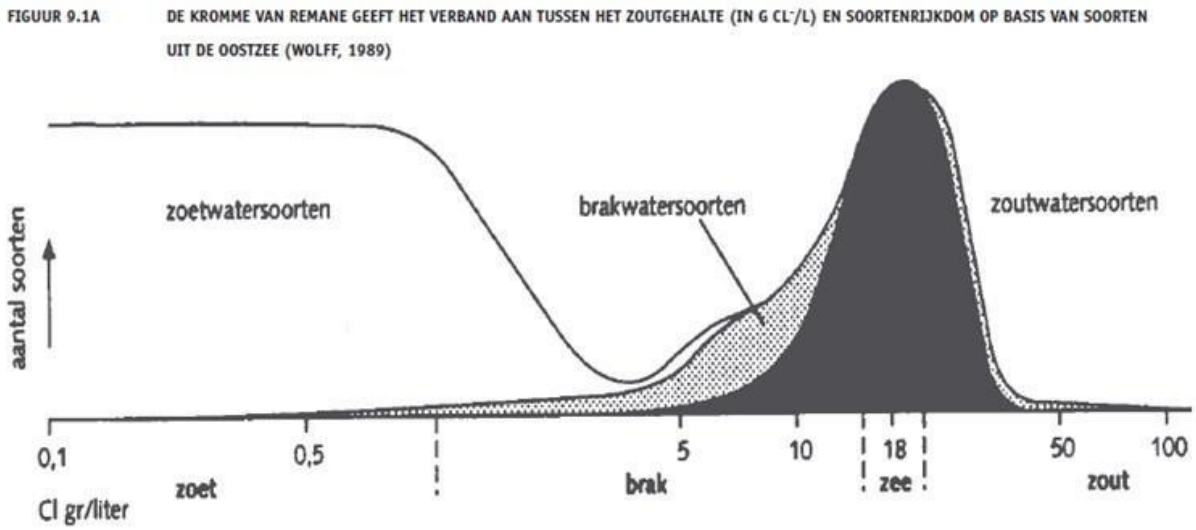

FIGURE 10 THE CURVE OF REMANE (1934), SHOWING THE INFLUENCE OF SALINITY ON SPECIES DIVERSITY. (STOWA, 2018)

2.7 Kennisimpuls brakke wateren

In 2019 “Kennisimpuls brakke wateren” was established with the aim to get a better understanding in the ecological functioning of brackish waters. Based on this knowledge it is aimed to substantiate and improve the WFD goals for brackish waters. Research for the “Kennisimpuls brakke wateren” is focused on distinguishing different types of brackish waters, which environmental factors are driving for brackish waters and the relations between these environmental factors. (Van Geest & Arts, 2019) According to “Kennisimpuls brakke wateren” (2021) and mentioned in the most recent (2022-2027) river basin management plan for the Scheldt, additional research is needed to be able to substantiate a reference for the WFD goals for brackish waters. These improved goals are needed to be able to properly assess the water quality of brackish waters. (Rijksoverheid, 2022)

3. Methodology

3.1 General

The process of implementing a nature-friendly bank consists of a number of steps. For this research, the implementation process is divided into four different components: Assessment WFD, Implementation, Maintenance and Additional measures. These components cover a large part of the implementation process of a nature-friendly bank and demarcate the research in such a way that it fitted within the internship period. The mentioned components of the process are both researched independently and as a total process. The tools used for gathering information on each component are literature research, a survey, interviews and experiments.

3.2 Component analysis

The first step is the individual component analysis. The component analysis is mainly based on literature research. In order to ask specific questions for the interviews and the survey and to be able to substantiate the resulting recommendations, it is important to start with literature research for each component to gather relevant knowledge. Afterwards, the theoretical knowledge will be compared with the results from the interviews and the survey. The gathered knowledge can be found in the “Theoretical framework”.

3.2.1 Assessment WFD

The first component is about how the Water Framework Directive (WFD) assesses the chemical and ecological condition of a WFD waterbody. For this, research was done on how waterbodies are being categorized into specific water types and what the specific conditions of M31 waters are. Moreover, on how the assessment process exactly works and what it is based on. The objective for researching this component is to get a clear view on the procedures of the WFD and whether these are realistic. Another objective is to understand the usefulness of the WFD assessment and whether improvements would be needed.

3.2.2 Implementation

The next component is about the implementation phase of a nature-friendly bank. The component is also about monitoring the value of a nature-friendly bank. Research was done on how nature-friendly banks are being monitored and why . Moreover was focused on what will be done with this monitoring data. Another focus was on how data is being gathered and why. The objectives for this component are to gather relevant information about how the process of implementing a nature-friendly bank works and what objectives are being considered. Furthermore, to understand when nature-friendly banks are being monitored and how this monitoring process works. Another objective is to find out whether processing data on the usefulness of the nature-friendly bank and its influence on the corresponding condition (water quality and biodiversity) of a waterway is being done in a structured way or whether improvement would be needed.

3.2.3 Maintenance

The third component is about the maintenance of nature-friendly banks. Research was done on different types of maintenance in general and whether the maintenance of nature-friendly banks differ with conventional banks. Moreover, was focused on the reasoning for

choosing a specific type of maintenance and how maintenance could contribute to the enhancement of the ecological values of a nature-friendly bank. The objectives for this components are to understand the different types of maintenance in general and when and why each type is being executed. A last objective is to gather knowledge on whether water boards use different ways of maintaining nature-friendly banks and what would be the most effective way of maintenance when considering the ecological values of the nature-friendly banks.

3.2.4 Additional measures

The last component is about additional measures for improving the ecological value of nature-friendly banks. There are a number of measures for improving the condition of a waterway. One of them being the implementation of a nature-friendly bank. However, what if this measure does not work out? As addition, many water boards experiment with relatively simple additional measures that should support the value of a measure, such as a nature-friendly bank. For this component, research was done on what possible measures there already are and to find out whether these measures were effective or not.

An additional part of this component was to experiment with relatively simple solutions that should support the enhancement of the ecological values of nature-friendly banks in brackish waters within the management area of Water Board Scheldestromen. A total of three different experiments were implemented and monitored. The methods for the conducted experiments can be found in Appendix 2. For the experiments, results that could be gathered within the internship period were analyzed and incorporated in this research.

3.3 Survey & interviews

After doing literature research for each component, a survey was created with questions for each component. The survey can be found in Appendix 3 and was send via e-mail to all water boards in the Netherlands and to colleagues from Water Board Scheldestromen. The survey had a more general approach and did not only focus on brackish waters, this because the input from all water boards could be relevant and should therefore be considered. The survey could provide an overview on the experiences that water boards have so far on the use of nature-friendly banks as measure for WFD waterbodies and the practicality of the implementation process. Moreover, could it tell something about possible points of improvement that have to be taken into account. Next to this, could it also enlighten possible solutions to be considered.

Next to the survey experts were interviewed. These interviews concentrated on the effectiveness of nature-friendly banks in brackish waters. The experts provided knowledge on this matter within their field of expertise.

With the survey and the interviews both general and specific data were gathered on the practical experiences of implementing nature-friendly banks in brackish waters. Data collected from the interviews is processed with the use of intelligent verbatim transcription. Moreover, are the interviews also structured by coding the transcriptions.

3.4 Data analysis

After gathering information for each component with the use of literature research, the survey, interviews and experiments, the data was analysed and compared. The comparison between the theoretical approach and the practical approach of implementing a nature-friendly bank was taken into account. These two different ways of gathering knowledge could show whether there is a difference between theory and practice. Moreover, a broad perspective on the topic could increase the value of the research and increases the chance of covering most parts of the implementation process together with its benefits and points of improvement. With the use of this data a number of recommendations could be elaborated and explained. Moreover, could the research questions be answered. The recommendations could support Water Board Scheldestromen in taking next steps for improving the natural value of the water system.

4. Results

As explained in the method a survey and interviews were tools for collecting data. The survey was send via e-mail to employees from all 21 water boards in the Netherlands including Water board Scheldestromen. A total of 14 persons responded to the survey of which 6 persons were from Water board Scheldestromen. The other respondents were employees from Water board Hollands Noorderkwartier, Brabantse Delta, Wetterskyp Fryslân, De Stichtse Rijnlanden, Zuiderzeeland and Hunze en Aa's. This means that data was collected from a total of 7 water boards. The survey questions were divided into the different components: WFD assessment, Implementation, Maintenance and Additional measures. For each of the components a number of questions were developed including multiple choice questions. Next to the multiple choice questions there were also open questions to create the opportunity for respondents to explain their given answers. The survey questions can be found in Appendix 3.

For the interviews an e-mail was send to people that were recommended by a colleague (and in-company supervisor) from Water board Scheldestromen. These people are employees from other water boards that manage brackish waters, ecologists and researchers. The questions for each person were dependent on their specialism, however the components were used as guidance, meaning that he interviews were semi-structured. A total of 3 persons responded and were interviewed. Coded transcriptions of the interviews can be found in the attachment.

4.1 WFD assessment

Below in Figure 11 the average grades of the WFD assessment process can be found. In the survey, questions were asked about the experience and knowledge of the respondents on the process of the WFD assessment; to what extent the assessment is realistic and to what extent the WFD stimulates water boards to take measures for increasing the water quality of a water system.

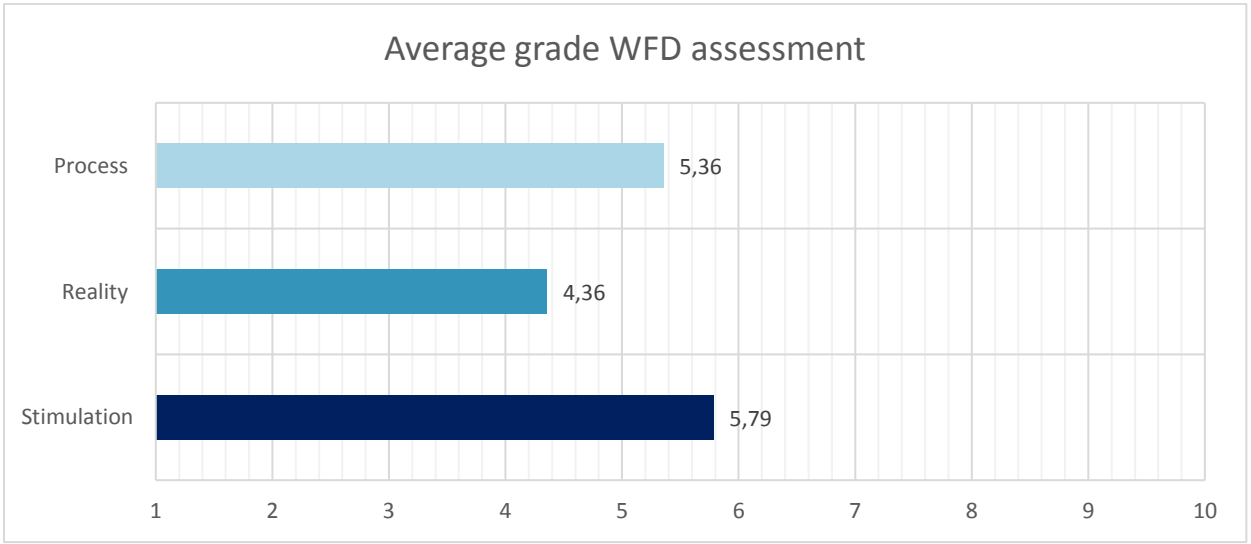

Figure 11 Average grade WFD assessment based on the outcomes of the survey, n=14

The majority of the respondents, 50% gave the process a grade of 5 or lower. 21% gave the process a 6 and 29% gave the process a grade above 6. The average grade of the process is a 5,36.
On the question whether the WFD assessment gave a realistic image of the actual water quality a lower average grade of 4,36 was given. A total of 71,4% of the respondents gave the reality of the WFD assessment a 5 or lower, 14,3% of the respondents gave the reality a 6 and 14,3% gave the reality a grade above 6.
Another question asked in the survey focused on whether the WFD gave enough encouragement for water boards to increase the water quality of the water system in their management area. The answer to this was quite divided. On average the stimulation got a grade 5,79. Of the respondents 42,9% graded the stimulation under 5, 21,4% gave a 6 and 35,7% filled in a grade above 6.

Both interviewee N and S (See Interview 1 and 2 in the Attachment) experienced the WFD assessment as unrealistic and explained that the process had guidelines that were too strict. This because interviewee N said that “every situation is unique. You can have a good ecological quality, while the WFD condition assessment scores poor or insufficient for any reason.” Interviewee S also mentioned the complexity of the WFD assessment that makes it difficult: “The WFD has become quite complex in the Netherlands, meaning that there are so many different chemical substances that have to be assessed. You also have the biology part with the different parameters and everything together has to be expressed in one colour meaning its reached or not.”

In the survey was also asked what the WFD could do to stimulate parties for executing measures to increase the water quality. A total of 28,6% of the respondents mentioned that there should be more cooperation between involved parties, also within the government. Furthermore, did 57,1% of the responds explain that the effectiveness of implemented measures should be made visible. The “one out, all out” principle does not show this.

4.2 Implementation

For this component, the outcomes were categorized per water board, since it is assumed that within a water board the process of implementing a nature-friendly bank happens in a uniform way. This means that averages were taken based on 7 water boards. Similar graphs where the data is analysed per person can be found in Appendix 4.

Figure 12 shows the responds from the survey on reasons for implementing a nature-friendly bank, multiple answers could be chosen. All water boards consider implementing nature-friendly banks for reaching the WFD goals. Moreover, other important reasons seem to be for a higher biodiversity and for increasing the biological water quality. Reasons with the lowest score, 28,6%, are increasing the recreational value and shore protection. 42,9% mentioned other reasons for implementing nature-friendly banks. Other reasons included costs, realisation of ecological connection zones and creating extra water retention area.

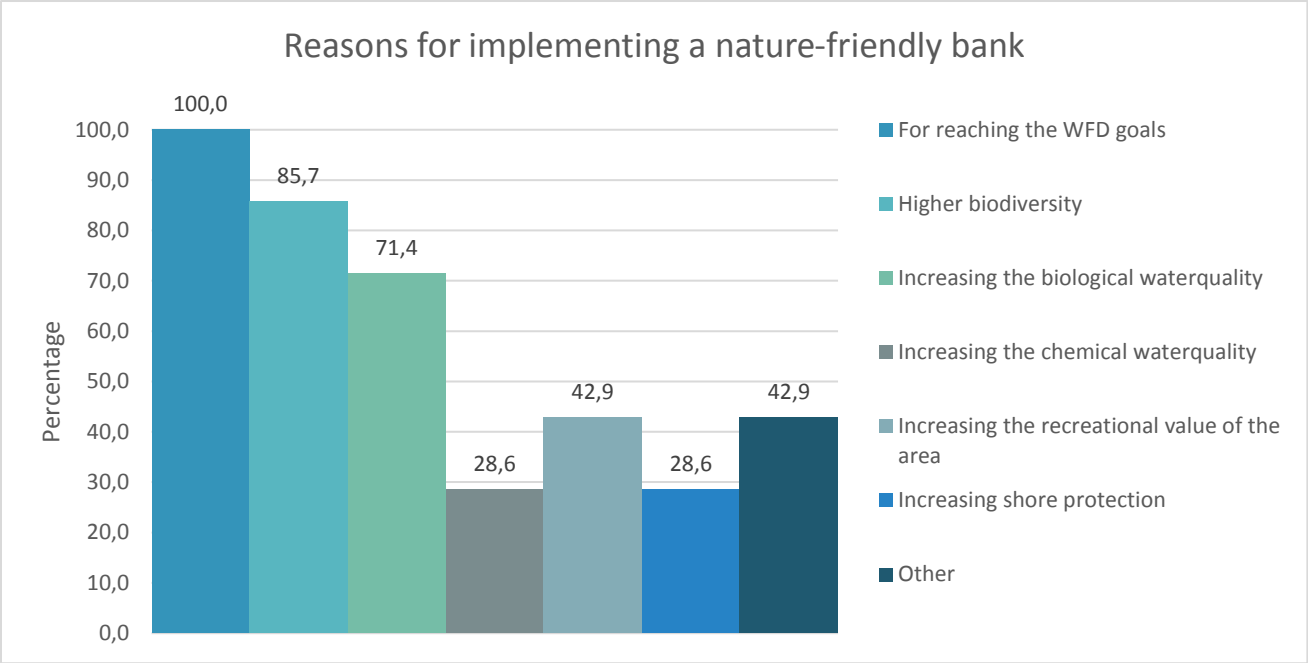

FIGURE 12 RESPONDS FROM THE SURVEY ON REASONS FOR IMPLEMENTING A NATURE-FRIENDLY BAN K. BASED ON THE AVERAGE ANSWERS PER WATER BOARD, N=7.

The next graph shows the aspects considered when implementing a nature-friendly bank. For this question multiple answers could be chosen. All water boards that responded on the survey include the aspect “land acquisition” in their implementation process. The majority of the water boards, 71,4%, also considered the other mentioned aspects. Additional measures were only included by 28,6% of the water boards that responded.

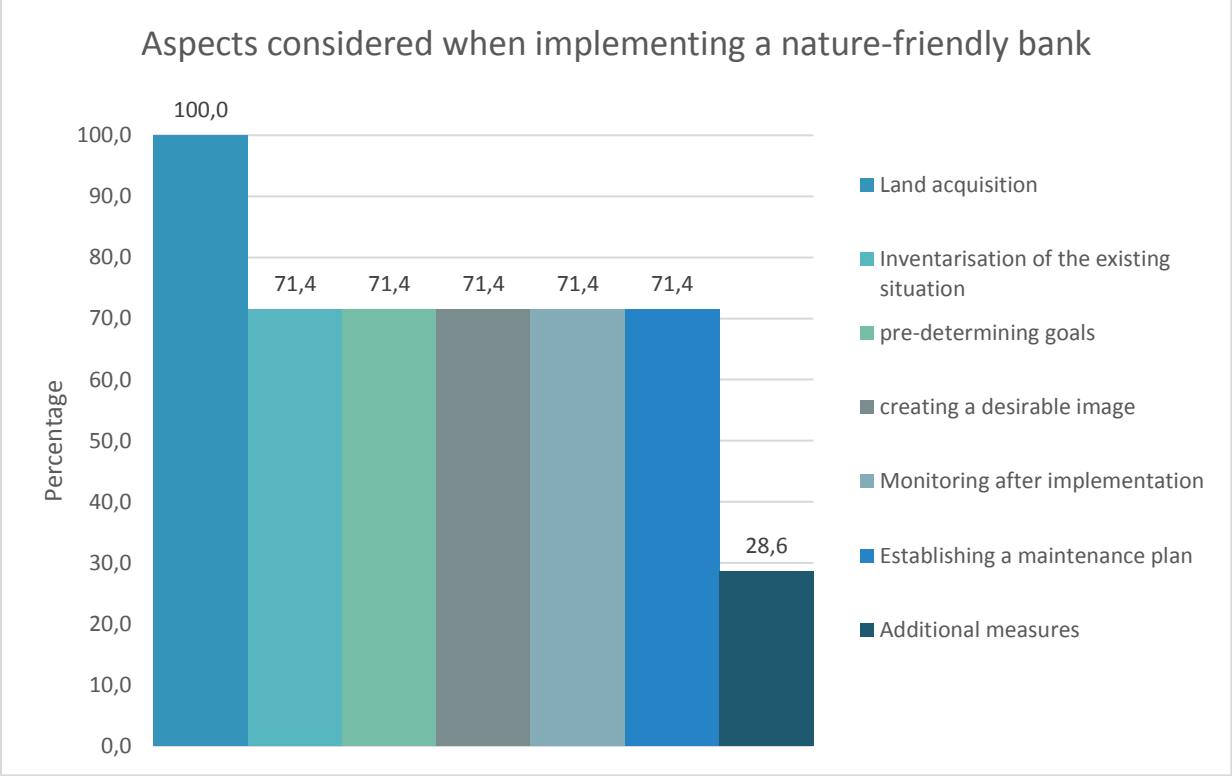

FIGURE 13 RESPONDS FROM THE SURVEY ON ASPECTS CONSIDERED WHEN IMPLEMENTING A NATURE-FRIENDLY BANK. BASED ON THE AVERAGE ANSWERS PER WATER BOARD, N=7.

Another question asked in the survey was whether the respondents experienced a difference between the theoretical implementation process of a nature-friendly bank and the practical process. All water boards that responded experienced (almost) no difference between theory and practice. The majority of the water boards however mentioned that changes in the process are considered when it turns out that these additions are more effective in practice.

Figure 14 shows replies on measures taken when a nature-friendly bank does not give the desired result. For this, multiple answers could be chosen. The majority of the water boards that responded chose “adjustment in maintenance”. Moreover did 57,1% of the water boards consider doing nothing and additional research. Almost half of the water boards, 42,9%, mentioned implementation of additional measures and only 28,6% of the water boards chose extra monitoring and observation.

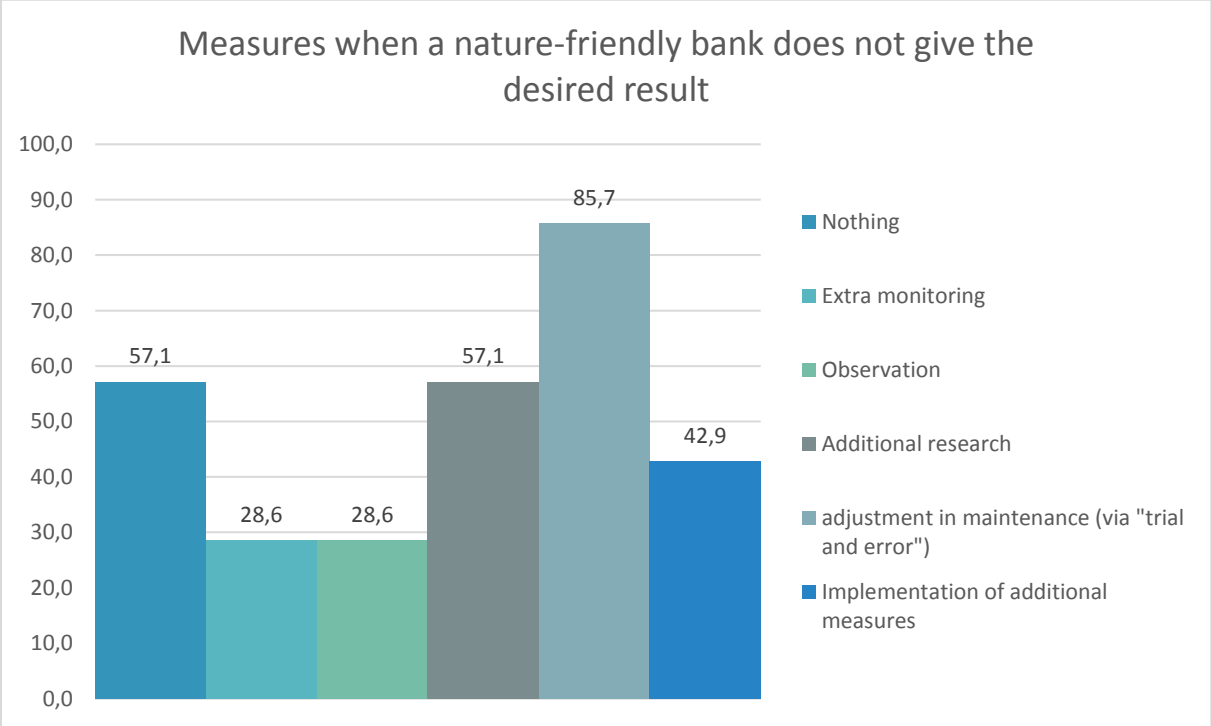

Figure 14 Responds from the survey on what measures would be taken when a nature-friendly bank does not give the desired result. Based on the average answers per water board, N=7.

When asking whether there were any points of improvement for a certain water board on the implementation process, 46,2% of the respondents mentioned that their water board lacked having a clear management and maintenance plan.

4.3 Maintenance

In the survey a question was asked on how nature-friendly banks are being maintained. This was an open question and answers were explained differently. Of the respondents 42,9% explained that their water board did little to no maintenance. This means that the nature-friendly banks were only being mowed every 8 or 10 years together with the dredging activities. 57,1% of the responds mentioned that nature-friendly banks needed customized maintenance. Meaning that the way of maintaining nature-friendly banks was area-

dependent. Respondents also mentioned phased mowing for maintaining the natural value of the nature-friendly bank.

4.4 Additional measures

The experiments mentioned in the method could not be implemented within the internship period to provide results. Reasons for this are loss of time due to inefficient communication between the involved parties including the contractor and the inefficiency of the commissioning process. It was also assumed that the relatively short internship period could not provide sufficient results. Therefore, there are no results available on the experiments.

5. Discussion

5.1 Data analysis

Within the research period there was a relatively short time frame (one month) available for collecting data from the survey and interviews. There were several responds from people explaining that these people had no time or were on holiday. It is recommended to implement a sufficient amount of time for people to react on the survey and interviews and collect the data.

Results from the components “implementation” and “maintenance” were analyzed a little different, the data was categorized per water board instead of per respondent. This because it is assumed that the implementation and maintenance of a nature-friendly bank within one water board would be the same. However, when looking at the same graphs analyzed per person (See Appendix 4) there are some notable differences. The differences could be explained by the way in which a person interpreted the survey questions or differences in experiences or opinions. A last reason could be the lack of communication or having different approaches within a certain water board.

5.2 WFD

5.2.1 Assessment

The results showed that the majority of the respondents experienced the WFD assessment as unrealistic and complex. Moreover was mentioned that the assessment, because of the “one out, all out” principle, does not show improvement of results from implementing measures for enhancing the water quality. In the most recent Dutch river basin management plan 2022-2027 the “one out, all out” principle was also discussed: “One out all out” has many objections from outside, also in the scientific literature” (Rijksoverheid, 2022). The document mentioned an alternative assessment method based on the most sensitive quality element. Figure 15 shows the difference in water quality scores when looking at the most sensitive biological quality element compared to the conventional WFD assessment. The chosen quality element for brackish waters is macro fauna and for ditches and canals water plants were chosen as most sensitive quality element. As can be seen, the water quality increases fundamentally. (Rijksoverheid, 2022)

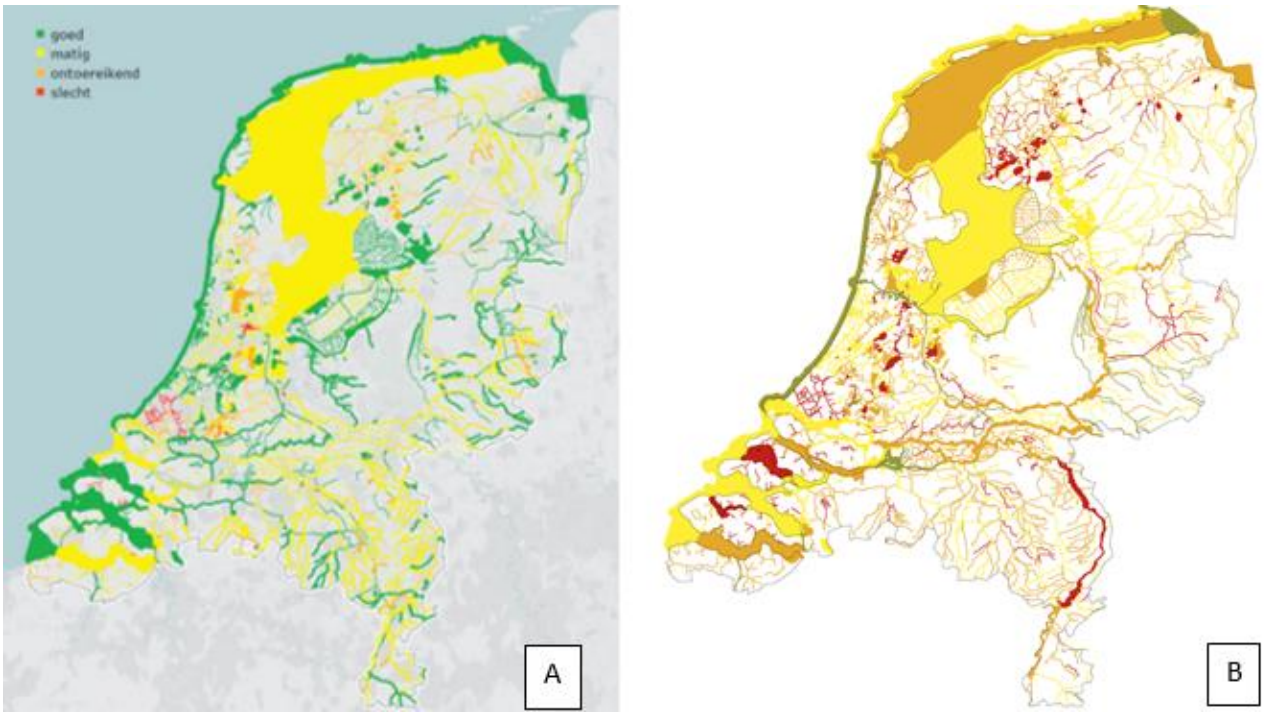

FIGURE 15A WATER QUALITY ASSESSMENT SCORE BASED ON THE MOST SENSITIVE BIOLOGICAL QUALITY ELEMENT (MARCORFAUNA FOR BRACKISH WATERS AND WATER PLANTS FOR DITCHES AND CANALS) (RIJKSOVERHEID, 2022) AND 14B IS THE WATER QUALITY ASSESSMENT SCORE BASED ON THE CURRENT WFD ASSESSMENT (IHW, 2019).

Data from the survey also depicted the preference of actually seeing an increase in water quality when taking measures. If a different water quality assessment shows the effectiveness of certain measures, water boards would be more motivated to take action. It would be recommended to create a water quality assessment that does not focus on only one end score, but takes into consideration the dynamics, complexity, uniqueness and influencing factors of a water system.

5.2.2 A national problem

Until 2027 Member states have the legal obligation to measure the water quality according to the WFD assessment and focus on reaching the established WFD goals. However, it is expected that the Netherlands will not reach all WFD goals before 2027 (H2O, 2022). Although the majority of the respondents experienced the WFD assessment as unrealistic, it is quite complex to establish a new method for assessing the water quality, since it also has to be approved by the European Union. Nevertheless, it is still important to focus on increasing the water quality, also if the way of assessing the water quality would change.

The water quality of the Dutch water system is a much larger problem than only for the water boards. Nature-friendly banks could enhance the score, but to a minimum especially because of the poor water quality, interviewee S (See interview 2 in the Attachment) mentioned this as well. Therefore it is also recommended to have more cooperation between involved parties concerning the water quality. Cooperation within the government, but also cooperation with parties that have a major influence on the water quality such as farmers. Water boards are not the only parties responsible for the water quality and by creating the opportunity for all involved parties to cooperate, effective measures could be taken on a large scale. Moreover, does this cooperation create the opportunity for

exchanging knowledge and working together on finding solutions on the shared matter. (STOWA, 2022)

5.2.3 Brackish water systems

The high number of stressors present in brackish waters together with the artificiality of the water system in Zeeland, the limited amount of species that are able to live in brackish conditions and the lack of a referential image make it difficult to take measures for improving the quality elements of these waterbodies and therefore improving the WFD scores. Therefore, it is recommended for Water Board Scheldestromen until 2027 to focus on waterbodies within their management area that have potential for increasing the water quality and establish a fitting action plan including specific measures for each chosen waterbody to implement between 2022 and 2027. When focussing on improving the water quality and wanting to reach the WFD goals this approach would be most effective and efficient. For brackish waterbodies with low potential it is recommended to focus on increasing the ecological value of the system and less on reaching the WFD goals. This because Van Geest, Arts & Van Dijk (2022) concluded that the salt fluctuations present in brackish waters are unnatural. Moreover, for the development of a brackish water system with a good ecological quality the excess nutrients in the water system are also a major limiting factor now. This means that without cooperation between involved parties and measures for increasing the water quality drastically, it would be ineffective to focus on these type of waters for reaching the WFD goals.

5.3 Implementation

The results of the survey showed that all water boards that responded had “reaching the WFD goals” as one of the reasons for implementing a nature-friendly bank. This means that the legal obligation of the WFD urges water boards to implement certain measures. It is however important to take into account to what extent implementing a nature-friendly bank can be successful in a certain area. It would be a waste of investment if nature-friendly banks would only be implemented for the WFD because of the legal obligation while the measure turns out unsuccessful.

Interviewee G (See Interview 3 in the Attachment) mentioned the importance of doing a chemical or biological analysis for finding the exact cause of a certain problem before implementing measures such as a nature-friendly bank. Finding the cause of a problem, for example lack of water plants, can contribute in the effectiveness of a certain measure. For example, a chemical analyses includes measuring the concentrations of certain substances.

The results on aspects considered when implementing a nature-friendly bank showed that 71,4% of the water boards that responded consider 6 of the 7 aspects. However, the majority of the respondents mentioned that more attention should be given to management and maintenance of the nature-friendly banks within their water board. Therefore it is recommended to establish a clear management plan with guidelines on when and how a nature-friendly bank can be implemented and what aspects have to be taken into account to guarantee success of the measure. According to Langbroek et al. (2021) the success of a nature-friendly bank is dependent on a variety of factors including available space, management, maintenance, monitoring and evaluation of the measure. The more available

space, the more possibilities there are such as creating pools or a secondary channel. These additions could increase the natural value in terms of biodiversity. A research by Torenbeek (2021) mentioned that, next to the design of a bank, other factors also play an important role in the biodiversity of macrophytes and macro fauna which is the chemical and ecological water quality.

5.4 Maintenance

Results from the survey showed that nature-friendly banks are either maintained once every 8 to 10 years or maintenance is based on customization and therefore area-dependent. The majority of the respondents also mentioned that their water board lacks having a maintenance plan for nature-friendly banks. Furthermore, was mentioned that more attention should be given to maintenance in the form of guidance and investment. Moreover, did the respondents address the benefit of phased mowing, which means that the banks are being partly mowed. For example, one side of the water system is being mowed and the other side is not. Both interviewee N and S (see interview 1 and 2 in the Attachment) stated that phased mowing could be beneficial for the biodiversity of the water system.

One respondent from the survey explained that maintenance would only be needed to prevent desiccation of the bank. Moreover, is maintenance needed for protecting the functioning of the water system. It is important to find some sort of balance between both. On the one side should the nature-friendly banks have limited to no disturbance for nature. On the other side is it important to protect the functioning of the water system. An article by Langbroek, Tempelman & Roodzand (2021) explained that when there would be no maintenance, the waterway could become obstructed and the water quality could decrease. Therefore the article mentioned the importance of monitoring and evaluation.

An article by Visser & De Kwaadsteniet (2014) states the importance of having a clear maintenance plan for protecting and/or enhancing the natural value of a nature-friendly bank. Therefore, it is recommended to establish a maintenance plan together with ecologists, employees carrying out the maintenance and the water board managing the specific water system. This document should consist guidelines for maintaining a nature-friendly bank exactly explaining when to take action and how. Furthermore, should there be a plan the campaign for the monitoring and evaluation process.

5.5 Additional measures

The proposed experiments were not implemented within the internship period and therefore no results could be analysed. The experiments will be implemented and monitored after the research period. It is advised to communicate effectively about the plan the campaign and keep involved parties updated as much as possible. This will increase the time efficiency and prevent miscommunication. It is also important to do the experiments on a small scale first to keep it feasible. When the results of the experiments proof the effectiveness of a certain measure, measures could be taken on a larger scale.

During the internship other samples were taken and analysed from structures that were already present in the water. This to see to what extent structures in the water may

influence aquatic ecology. Samples were taken from rocks, a tree trunk and a sample was taken between the reeds, see Figure 16.

Figure 16 Pictures of the structures that were sampled in Ouwerkerk.

The samples were taken in Ouwerkerk near the transition of the Koningin Julianastraat and the Oostweg. The waterbody has a chloride concentration of 5710 mg/l and is a M31 waterbody. Moreover is the location one of the WFD measuring points.

The samples were analysed in the lab under supervision of one of the hydro-biology analysts from Water Board Scheldestromen. The samples were first put in a large bin with water and around 30 individuals per different species were being picked and put in a bottle with ethanol. Then each species was put under the microscope and identified. This aligns with the working method from "Handboek Hydrobiologie" (Bijkerk et al., 2014). Table 1 shows the species that were found for each sample. Mainly amphipods, snails and common pill-bugs were found in the samples. These species are quite common in this waterway. No new species were found.

Sample	Species found in the sample
Reeds	Lekanosphaera hookeri
	Gammarus zaddachi
	Gammarus duebeni
Rocks	Lekanosphaera hookeri
	Gammarus zaddachi
	Jaera spec juvenile
	Potamopyrgus antipodarum
Tree trunk	Lekanosphaera hookeri
	Gammarus zaddachi
	Gammarus duebeni
	Gammarus juvenile

Table 1 List of species found per sample.

It was observed that on the tree trunk there was a higher biomass of each species compared to the stones. This could be explained by the difference in surface area. The tree trunk

consisted of different cracks in which the species could hide, while the stones had a flat surface. The sample of the reeds showed that reeds can also be of added value to ecology. Therefore showing that a nature-friendly bank dominated by reeds is an addition to the natural value of the water system. This however, cannot be seen back in the WFD assessment.

In short, based on the samples taken, providing structures underwater with as much surface area as possible could increase the biomass of present species, however may not contribute in creating a higher biodiversity in brackish water. It is important to mention that no concrete conclusions can be drawn on these results, however it proofs that species make use of structures under water.

Although the water quality may be an important factor for the success of a nature-friendly bank, mainly in a brackish water system, it could be useful to experiment with additional measures. For example, interviewee N (see interview 1 in the Attachment) explained that when water plants do not grow on their own in a certain area, transplanting these plants will not be successful. However, Interviewee G (See interview 3 in the Attachment) mentioned that brackish water plants may not grow on their own due to the limited dispersion, therefore it could be useful to do research where transplantation of water plants is involved and see whether these give any results. It could be useful to do such an experiment to gather results on this matter. Also because too little is known about the conditions in which brackish water plants are able to survive and what exactly causes the absence of brackish water plants in a certain water system. Moreover, are these kind of experiments relatively cheap and therefore worth the try.

Interviewee S (See interview 2 in the Attachment) mentioned the addition of pools or lenses next to a nature-friendly bank. These pools are not connected to the waterbody and therefore only store rainwater and some seepage. Within the management area of Water Board Noorderkwartier these pools have already been implemented. Interviewee S (See interview 2 in the Attachment) explained that the additional pools or lenses provide habitat for other species, because the water in the pool has a lower salt concentration and can dry up in the summer. These different conditions make it a suitable habitat for other species compared to the adjacent nature-friendly bank. (Langbroek, Tempelman & Roodzand, 2021) This is a way of creating heterogeneity in a bank design. Interviewee G (See Interview 3 in the Attachment) mentioned the importance of heterogeneity for increasing the natural value of a bank. A research by Verhofstad et al. (2021) also mentioned the importance of creating heterogeneity within a nature-friendly bank to increase the connectivity between the water zone and the riparian zone. By creating different water depths, the natural value of the nature-friendly bank could also positively affect the ecological quality of the water system. This then could enhance the WFD assessment score.

6. Conclusion

The complexity of the WFD, the increasing national challenge of reaching the WFD goals together with the large number of stressors in brackish waters make it difficult to implement an effective measure for increasing the natural value of the system. According to Van Geest et al. (2022) the most often too high nutrient concentrations in the water and the unnatural salt fluctuations are important factors for causing the relatively low ecological value of brackish waters. The water quality is a national matter and therefore it is important to take action on national scale for improving the water quality. Cooperation between involved parties and within the government can be a useful approach for coming up with measures on a larger scale concerning the water quality. Therefore, for Water Board Scheldestromen it is recommended until 2027 to establish an action plan focussing on waterbodies with potential for reaching the WFD goals. it would be most efficient and effective to invest in waterbodies that have opportunities for improving the water quality. Mainly because drastically increasing the water quality cannot be done by the Water Board itself, but requires cooperation on a national scale.

For brackish water systems with limited to no potential for improving the water quality (for the WFD) it would be recommended to conduct a chemical and biological analyses before implementing any (additional) measure, such as a nature-friendly bank, to find the exact problems causing the lack of opportunities. Based on the outcomes of the analyses appropriate measures can be taken for locally increasing the ecological value of the water system.

Implementing additional measures, e.g. extra structures underwater, on a local scale could provide valuable information on the possibilities of a specific water system. The established experiments could not be implemented during the research period. It is however recommended to implement these measures and see to what extent the provision of underwater structure could enhance the ecological value in brackish waters. It is also recommended to research the possibilities of transplanting water plants in the system. This because, the limited dispersion of brackish water plants could be the cause for the absence of water plants. A last recommendation is to focus on creating heterogeneity within a bank. This could create different conditions and therefore different habitats for species to live.

7. Recommendations

7.1 Management & maintenance plan

The effectiveness of a nature-friendly bank, whether in brackish water or not, is dependent on the water quality, available space, management, maintenance, monitoring and evaluation of the measure (Langbroek et al., 2021). The majority of the respondents mentioned the lack of having a clear management and maintenance plan (m&m plan) . Establishing an m&m plan can be time consuming dependent on the situation, however could be of added value for increasing the effectiveness of a certain measure. An example is the “Location approach” for nature-friendly banks from Sollie et al. (2011). This report also shows the importance of having a well-thought plan for improving the effectiveness of implementing a nature-friendly bank. This document could be used as inspiration when working on the m&m plan.

Due to the large amounts of impacts on the natural value of a brackish waterbody, having a m&m plan is recommended for finding possibilities that increase the ecological value of the system locally. Creating an m&m plan could be relevant when wanting to implement a measure in a water system such as for example a nature-friendly bank. It could also be relevant when it is observed that a certain water system lacks ecological value due to for example the absence of water plants and the cause of this is unknown. A last situation could be for mapping the possibilities of a water system. When establishing a m&m plan it is recommended to consider the following steps:

1. Determining goals
2. Chemical/biological analyses
3. Mapping possibilities
4. Theory to practice
5. Monitoring
6. Maintenance
7. Documentation & Feedback

First it is important to determine goals for a specific area. These pre-determined goals will function as guidance during the process. Additionally a preferred image could be established.
After determining the aims of the plan it is recommended to conduct a biological or chemical analyses to find out what problems may intercept from achieving the pre-determined goals. An analyses could be in the form of observations, chemical/biological measurements or data analyses. This analyses can provide valuable information considering the problems within the area that have to be kept in mind and can support in coming up with relevant measures for achieving the goal. Having a clear view on the expectations and the possibilities of a water system can support in the decision-making process as well. Furthermore, could it prevent unnecessary costs.
Then a suitable measure, dependent on the possibilities of the specific water system, can be chosen. The next step is to translate this chosen measure into a concrete action plan. For this it is important to consider practical factors such as costs, materials needed and more. Basically, everything needed to put the plan into practice.

After successfully implementing the chosen measure it is recommended to monitor the effect of the measure. A possible recommendation is to establish a standard monitoring document containing a step-by-step plan for how to monitor the implementation of a new measure to improve ecological values. Including monitoring as a tool could provide valuable information on the effectiveness of the measure and considerate action could be taken when the results show a decrease in value. This may require more work and investment at the beginning, however it decreases the chance of having to implement an additional measure because of the lack of effectiveness, which may be more expensive. Moreover, based on monitoring observations a suitable maintenance plan can be established. For nature-friendly banks it is recommended to have as little maintenance as possible to prevent disturbance. Phased mowing could also be an option for example.
A last recommendation for the m&m plan would be to organize all documentation regarding the management or maintenance within one document. This document should then be shared with all concerning parties. This is recommended for increasing the cooperation between different departments. Additionally the plan should be discussed and reflected upon among involved parties. Any feedback given can be processed in the plan.

7.2 Additional measures

The experiments mentioned in the method could not be implemented within the research period. However, it is still recommended to implement the experiments (See Appendix 2 for the working protocols). The outcomes of the experiments could provide valuable information on possible effective measures for improving the ecological value of brackish waters.
It is recommended, when focussing on the design of a nature-friendly bank, to create heterogeneity within a bank. Increasing the heterogeneity of a bank needs investment and may increase the difficulty for maintaining it. It does however provide different habitats and could therefore increase the biodiversity of the water system. It is advised to do research on an effective and heterogenic bank design that is also feasible. The outcomes of the experiments mentioned before can be taken into account. An example could be to add different structures to the design of the bank. Verhofstad et al. (2021) mentioned the importance of the connectivity between the water zone and the riparian zone. This can increase the influence of the nature-friendly bank on the ecological water quality.

Both a chemical analyses and experimenting with additional measures in brackish waters could lead to valuable information and is therefore recommended. A chemical analyses could give a better understanding of the brackish water system and explain the cause of a certain problem, such as the lack of water plants. Additional measures could increase the biomass of available species in the water system and therefore increase the natural value of the system. Experimenting with additional measures, e.g. the proposed measures (see Appendix 2), could also provide information on how the water system works and what measures would be effective. It is however important to keep in mind the dynamic, unique and complex character of brackish water systems.

References

Altenburg, W., Arts, G., Baretta-Bekker, J. G., Van den Berg, M. S., Van den Broek, T., Buskens, R., Bijkerk, R., Coops, H. C., Van Dam, H., Van Ee, G., Evers, C. H. M., Franken, R., Higler, B., Ietswaart, T., Jaarsma, N., De Jong, D. J., Joosten, A. M. T., Klinge, M., Knoben, R. A. E., Walvoort, D. (2020, June). *Referenties en maatlatten voor natuurlijke watertypen voor de Kaderrichtlijn Water 2021–2027* (No. 2018–49). STOWA. https://www.stowa.nl/sites/default/files/assets/PUBLICATIES/Publicaties%202018/STOWA%202018-49%20Maatlatten%20-%202020v4.pdf

Arts, G. H. P., Van Geest, G. J., & Van Dijk, G. (2021, January). *Factsheet Brakke wateren*. STOWA. https://www.stowa.nl/deltafacts/waterkwaliteit/kennisimpuls-waterkwaliteit/brakke-wateren

Bijkerk, R., Beers, M., Bonhof, G., Brans, B., Buskens, R., Coops, H., Van Dam, H., Fockens, K., Kampen, J., Van Maanen, B., Mertens, A., Moeleker, M., Nieuwenhuis, R., Pilon, J., Pot, R., Spier, J., Swarte, M., Van Tongeren, O., Torenbeek, R.., Van Maanen, B. (2014). *Handboek hydrobiologie*. STOWA.

De la Haye, M. A. A., Verduin, E. C., Everaert, G., Goethals, P., Pauwels, I., & Blom, C. (2011, April). *Scoren met natuurvriendelijke oevers* (275711 GM-1032497/MDH). Grontmij. https://edepot.wur.nl/183641#:~:text=In%20dit%20door%20Agentschap%20NL,ten%20te%20geven%20voor%20toekomstige

De la Haye, M., Verduin, E., Blom, C., & Everaert, G. (2011). Zijn natuurvriendelijke oevers effectief voor de KRW? *H2O*, *25*, 42–44. https://edepot.wur.nl/339207#:~:text=Zijn%20natuurvriendelijke%20oevers%20effectief%20voor%20de%20KrW%3F,-Michelle%20de%20la&text=De%20aanleg%20van%20natuurvriendelijke%20oevers,echter%20niet%20eerder%20statistisch%20onderbouwd

Dorpsbelang Goutum. (2019, May). *Nvooerdefeart2* [Drawing and Picture]. Goutum. https://www.goutum.info/2019/05/10/oer-de-feart-krijgt-een-natuurvriendelijke-oever/

European Commission. (2012, November). *Implementation of the Water Framework Directive (2000/60/EC) River Basin Management Plans*. https://www.eumonitor.eu/9353000/1/j9vvik7m1c3gyxp/vj4mtdb6pgxv

H2O. (2022, April 20). *Minister: 'Stevige uitdaging om alle KRW-maatregelen tijdig uit te voeren.'* Retrieved June 1, 2022, from https://www.h2owaternetwerk.nl/h2o-actueel/minister-stevige-uitdaging-om-krw-maatregelen-tijdig-uit-te-voeren

Hoogheemraadschap van Delfland. (2019, October). *Evaluatie effectiviteit Natuurvriendelijke oevers* (No. 1425126). https://www.hhdelfland.nl/publish/library/43/rapport-evaluatie_effectiviteit_nvos_delfland_def_-v3.pdf

IHW. (2019, July 20). *Beoordeling biologische kwaliteit, Kaderrichtlijn Water, 2019* [Illustration]. Rijksoverheid. https://www.clo.nl/indicatoren/nl1420-krw-biologische-kwaliteit-oppervlaktewater

Informatiepunt Leefomgeving. (n.d.). *Stroomgebiedbeheerplannen*. Retrieved April 2022, from https://iplo.nl/thema/water/oppervlaktewater/kaderrichtlijn-water/stroomgebiedbeheerplannen/

Kennisimpuls Waterkwaliteit. (2021). *Brakke wateren: hoe zout kan het worden? | Kennisimpuls Waterkwaliteit*. Retrieved March 2022, from https://www.kennisimpulswaterkwaliteit.nl/nl/themas/brakke-wateren-hoe-zout-kan-het-worden

Langbroek, W., Tempelman, D., & Roodzand, S. (2021). De meerwaarde van natuurvriendelijke oevers in Noord-Holland. *H2O, Online*. https://www.h2owaternetwerk.nl/vakartikelen/de-meerwaarde-van-natuurvriendelijke-oevers-in-noord-holland

Ministerie van Infrastructuur en Waterstaat. (2022, May 24). *Uitvoering Kaderrichtlijn Water*. Rijkswaterstaat. Retrieved March 2022, from https://www.rijkswaterstaat.nl/water/wetten-regels-en-vergunningen/natuur-en-milieuwetten/kaderrichtlijn-water

Projectgroep IKS. (2004). *Karakterisering stroomgebied Schelde*.

Provincie Zeeland. (2021, September). *Regionaal Waterprogramma 2022–2027 Provincie Zeeland*. https://www.zeeland.nl/sites/default/files/2021-09/Regionaal%20Waterprogramma%20Provincie%20Zeeland%202022-2027.pdf

Rijksoverheid. (n.d.). *Peilbeheer*. Helpdesk water. Retrieved April 2022, from https://www.helpdeskwater.nl/onderwerpen/water-ruimte/ecologie/meren/ingreep-fysica/peilbeheer/

Rijksoverheid. (2004, August 24). *Kaart 2 Ruimtegebruik* [Map]. Helpdeskwater. https://www.helpdeskwater.nl/publish/pages/131153/02-ruimtegebruik211004.pdf

Rijksoverheid. (2009, December). *Stroomgebiedbeheerplan Schelde 2009–2015*. ministerie van Verkeer en Waterstaat; ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer; ministerie van Landbouw, Natuur en Voedselkwaliteit. https://www.helpdeskwater.nl/publish/pages/131518/sgbpschelde2009-2015.pdf

Rijksoverheid. (2018). *Werkprogramma KRW voor SGBP 2022–2027*. Helpdesk water. Retrieved April 2022, from https://www.helpdeskwater.nl/onderwerpen/wetgeving-beleid/kaderrichtlijn-water/publicaties-krw/werkprogramma-krw/

Rijksoverheid. (2020a). *Europese Kaderrichtlijn Water | Compendium voor de Leefomgeving*. Retrieved April 2022, from https://www.clo.nl/indicatoren/nl1412-kaderrichtlijn-water

Rijksoverheid. (2020b, July 30). *Deelstroomgebieden Kaderrichtlijn Water* [Illustration]. Rijksoverheid. https://www.clo.nl/indicatoren/nl1412-kaderrichtlijn-water

Rijksoverheid. (2022, March). *Stroomgebiedbeheerplannen Rijn, Maas, Schelde en Eems 2022–2027*. Ministerie van Infrastructuur en Waterstaat. https://www.helpdeskwater.nl/publish/pages/198518/stroomgebiedbeheerplannen-rijn-maas-schelde-en-eems-2022-2027_1.pdf

Sollie, S., Brouwer, E., & De Kwaadsteniet, P. (2011, September). *Handreiking natuurvriendelijke oevers een standplaats benadering* (No. 2011–19). STOWA. https://www.stowa.nl/sites/default/files/assets/PUBLICATIES/Publicaties%202011/STOWA%202011-19.pdf

STOWA. (2018). *Referenties en Maatlatten voor natuurlijke watertypen voor de kaderrichtlijn water 2021–2027* (No. 2018–49). https://www.stowa.nl/sites/default/files/assets/PUBLICATIES/Publicaties%202018/STOWA%202018-49%20Maatlatten%20-%202020v4.pdf

STOWA. (2022, April 5). *Samenwerking om KRW-doelen te halen moet op de schop*. Retrieved June 1, 2022, from https://www.stowa.nl/nieuws/samenwerking-om-krw-doelen-te-halen-moet-op-de-schop

Thieffry, P. (n.d.). *Framework of water policy*. ERA - Academy of European Law. Retrieved March 2022, from https://www.era-comm.eu/EU_water_law/part_3/index.html

Torenbeek, R. (2021). *Ecologische effectiviteit duurzame oevers. Statistisch onderzoek naar effecten op vegetatie en macrofauna*. Waterschap Zuiderzeeland. https://api1.ibabs.eu/publicdownload.aspx?site=zuiderzeeland&id=100122936

Van Dijk, G., Postma, J., De Senerpont Domis, L. N., Veldhuis, M., Teurlincx, S., Grutters, B. M. C., Schutter, M., Dubbeldam, M., Gremmen, T., Graafland, J., & Smolders, A. J. P. (2020, December). *Stuurfactoren voor ondergedoken waterplanten in een omgeving onder hoge menselijke druk. Een studie naar de effecten van herbivorie, bodemwoeling, saliniteit, turbiditeit en waterbodemeigenschappen op ondergedoken waterplanten op Goeree Overflakkee* (RP-17.101.20.16). Waterschap Hollandse Delta.

Van Geest, G. J., & Arts, G. (2019, January). *Projectplan Kennisimpuls Brakke Wateren 2020* (No. 11204924–000-ZWS-0003WS). Deltares. https://www.kennisimpulswaterkwaliteit.nl/sites/default/files/2020-02/Projectplan%20KIWK%20Brakke%20Wateren%202020%20WEBSITE.pdf

Van Geest, G. J., Arts, G. H. P., & Van Dijk, G. (2022, February). *Systeemkennis Brakke Wateren* (No. 1566–7197). STOWA.

Van Puijenbroek, P. (n.d.). *Assessment quality surface waters according to the Water Framework Directive* [Scheme]. https://www.iwa-network.org/filemanager-uploads/WQ_Compendium/Cases/The%20WFD%20in%20Netherlands.pdf

Verhofstad, M. J. J. M., Peeters, E. T. H. M., Herder, J., & Van Zuidam, J. P. (2021). Een natuurvriendelijke oever houdt niet op bij de waterlijn. *H2O : tijdschrift voor watervoorziening en afvalwaterbehandeling*, (juni), 24-27. https://edepot.wur.nl/549365

Visser, E., & De Kwaadsteniet, P. (2014). Beheer en onderhoud de sleutel voor succesvolle natuurvriendelijke oevers? *H2O*, *1407–05*. https://www.h2owaternetwerk.nl/images/2014/1407/1407-05_onderhoudNVO.pdf

Waterschap Scheldestromen. (2021a, February 11). *Natuurvriendelijke oevers*. Retrieved March 2022, from https://scheldestromen.nl/natuurvriendelijke-oevers

Waterschap Scheldestromen. (2021b, June). *Waterschapsbeheerprogramma 2022–2027*. https://scheldestromen.nl/sites/scheldestromen.nl/files/eindrapport%20ontwerp%20WBP.pdf

Appendices

Appendix 1: Characteristics M31 waterbodies

Below a description can be found on the characteristics of M31 waterbodies according to Altenburg et al. (2020). More information including the boundaries for each WFD assessment class can be found in the referred document.

(Hydro)morphology

M31 waters have a salinity of >3 g Cl/l and a surface area of <5 km2. These waterbodies are stagnant with a moderately high to high, fairly constant to strongly fluctuating chloride concentration. The waterbed consists of sand, clay or peat.
The hydrology is dependent on brackish seepage, rainfall and/or floods. Evaporation in summer does also play a part in this.

Chemistry

Salt stratification is a common process in brackish water types. In deeper waters temperature and oxygen stratification could also occur. The water is basic till eutrophic and sulfate and phosphate concentrations are high. The vegetation in these waters is limited by nitrogen.

Biology

The salt concentration is the leading factor in the relatively low species diversity. The high nutrient richness is less important for the species diversity. The species richness is lower in strongly brackish waters compared to slightly brackish waters. Tolerant freshwater species disappeared and the diversity of macrophytes is limited. The light climate in bigger, deeper waters can be limited due to the high abundance of sludge. Deeper than 2 meters, no water plants are present. Algae are the most important primary producers at the surface. The algae population consists of brackish water species and, dependent on the distance to the sea, also more saltwater species than freshwater species. The biomass is dependent on the available nutrients, light climate and the residence time of the water.

The more brackish the water, the more fluctuations in nutrient concentrations and chlorophyll concentrations. Summer averages of chlorophyll can reach up to 70 mg/l. Phytoplankton is dominated by diatoms and green algae.

Vegetation in brackish waters has a limited species diversity and consists of characteristic, submerged water plants such as *Ruppia maritima,* R. cirrhosa and Zannichellia *palustris ssp. pedicellata.* Floating leaf plants and emergent species are absent in these waters. Because of the extreme brackish conditions in these relatively big waterbodies, there are limited to no freshwater species present.

Above 2 gCl/L the amount of insects in the macro fauna decreases. Limited species of bugs and water beetles are only present in slightly brackish waters. Characteristic species are the *Sigara stagnalis*, and *Chironomus gr. salinarius.* Furthermore, the amount of crustaceans,

mollusks and worms are increasing. Characteristic species are *Palaemonetes varians, Idotea chelipes, Nereis diversicolor* and *Cerastoderma glaucum.*
In slightly brackish waters there are mainly freshwater fish species present. With increasing chloride concentrations more and more of these fish species disappear. Characteristic brackish fish species are *Pomatoschistus microps, Anguilla Anguilla, Gasterosteus aculeatus, Osmerus eperlanus* and *Platichthys flesus*. Isolated brackish waters have a fish stock without migrating species. The fish biomass in brackish waters if most often low.

Appendix 2: Protocols additional experiments

Below, protocols can be found with an explanation of each experiment conducted in the management area of Water Board Scheldestromen. The description for each experiment consists of an explanation on the objectives, the method and a list of materials.

1. Structures

The first experiment is about the addition of different structures underwater. Structures such as rocks, branches and shells could be beneficial for aquatic life because the added structures could function as hiding area, breeding area or attachment substrate. These functions would normally be fulfilled by water plants, however in most brackish waters there is a lack of water plants, therefore also lacking underwater structure. This then also explains the absence of a number of other organisms.

The goal of this experiment is to research whether the addition of structures underwater in brackish waters could improve the ecological values. Another goal is to see whether there is a difference in ecological value between the different structures and to see which one is most effective.

List of materials

- Basalt split rocks
- Basalt blocks
- Branches 10 – 30 cm
- Shells
- Netting
- Tie-Wraps
- pliers
- 5x gabion
- 10x ground pins
- Notebook
- Pen
- Labels
- GoPro
- Materials for species determination

Method

First the chosen project location will be analysed. With the use of recent data on the water quality and the monitored species a prediction could be made on possible outcomes of the experiment.
The next step is to implement the structures in the water. A total of 5 gabions will be placed in the water, with between each gabion a distance of 2 meters. The gabions will be secured to the ground with ground pins and labelled accordingly. The gabions have the following content:

Gabion 1: Empty, functions as blanc
Gabion 2: Basalt split rocks

Gabion 3: Basalt blocks
Gabion 4: Branches 10 – 30 cm
Gabion 5: Shells

Dependent on the possibilities, the gabions will stay in the water for at least 2 months, preferably longer. Monitoring will occur weekly during this period. The process of monitoring consists of writing down notable observations. Moreover, will be checked whether any damage occurred to the gabions. Lastly, pictures will be taken and possibly a GoPro will be put in the water as addition to the monitoring data. By filming the gabions, it is possible to see whether for example fish make use of the structures. Inserting a GoPro will however only be useful if the water clarity is sufficient.
After the monitoring phase, samples will be taken from the structures and species on the samples will be identified in the lab.

2. Recycling a tree

This experiment is about the implementation of a tree in the water system. A fallen tree or a tree that needs to be cut down, could be used for this experiment. It could also be the case that a tree accidentally fell in a waterbody and that has been decided to keep the tree in the water. In rivers this is a common additional measure for enhancing the natural value of the water system. This because the tree creates possibilities for different species to use as attachment substrate, hiding area or breeding area. This is similar to the addition of structures in the water. The experiment is relatively simple and feasible to implement. It is however not yet properly tested in stagnant brackish waters and that is why it could be interesting to test whether this additional measure will give similar results as it does in a river. Therefore the goal of this experiment is to find out whether the introduction of a tree in a brackish water system could contribute to the ecological value of the system.

List of materials

- A tree
- Transport facilitation for a tree
- Notebook
- Pen
- Materials for species determination

Method

First it is important to analyze the water quality and species diversity of the project location. Based on this analyses, possible outcomes of the experiment could be predicted. The next step is to implement the tree in the water and start the monitoring phase. For this experiment, the monitoring will be for at least two months, depending on the possibilities. Within this period, weekly observations will be done looking at possible damages and species that make use of the tree. All observations will be noted. Additionally, photos will be taken from the tree.

After the monitoring phase samples will be taken and present species will be identified. Based on the results could be concluded to what extent the tree increases the natural value of the water system.

3. Exclosures

The third experiment is about researching the possibilities for enhancing the growth of submerged water plants. The focus for this will be on taking away at least one stressor. This experiment is based on a research by Van Dijk et al. (2020) with the title “stuurfactoren voor ondergedoken waterplanten in een omgeving onder hoge menselijke druk”. The mentioned research did a similar experiment in slightly brackish water and freshwater. In that research the stressor “fish grazing” was taken away and gave submerged water plants the ability to grow. The results showed that, even without transplanting water plants, the plants were able to grow in the water. The objective for this experiment is to see whether the results from this experiment will be similar to the results from Van Dijk et al. (2020). the difference however is that this experiment will be executed in a strongly brackish water system (M31) instead of a slightly brackish water system (M30). Another objective is to see whether transplantation of plants is needed when the stressor “fish grazing” is taken away or whether the plants grow on their own.

List of materials

- 4x Gabion
- Mesh
- Pliers
- Tie-wraps
- *Zannichellia palustris* and/or *Ruppia maritima* plants
- Notebook
- Pen
- 8x ground pin
- Materials for species determination

Method

The first step is analysis of the current situation. This included gathering information on the water quality and the species diversity of the project location. This knowledge will be used to find out the possibilities and to be able to predict the outcomes of the experiment.
The next step is to execute the experiment. A total of 4 gabions will be placed in the water of which 2 will have transplanted water plants and two will be empty. A distance of 2 meters between each gabion is considered. Two gabions will be wrapped with mesh, of which one of them will have transplanted water plants and one of them will be empty. The water plants used are common brackish water species that are able to grow in strong brackish water conditions such as *Zannichellia palustris* and *Ruppia maritima*.

The gabions will be in the water for at least two months and will be monitored weekly. This monitoring includes observations on plant growth, possible damage and taking photos if possible. After the monitoring period samples will be taken and species will be identified in the lab.

Based on the collected data, conclusions can be made on whether fish grazing is a limiting factor for the growth of submerged water plants in strong brackish waters. Moreover, could be concluded whether transplantation of water plants is a successful measure or not.

Appendix 3: Survey

The questions that were used for the survey are listed below. Originally, the survey was in Dutch, so the questions are translated. The survey was sent to all water boards in the Netherlands as well as among colleagues from Water Board Scheldestromen.

General information

1. What is your name? (You can also write down “anonymous”)

……

2. Which water board do you work for?

……

3. What is your function within the water board?

……

4. Which types of surface waters are present within the management area of the water board that you work for? (multiple answers possible)

☐ Fresh
☐ brackish
☐ Salt
☐ Flowing water
☐ Stagnant water

5. Would you be open for an interview? (if you could provide relevant information for my research)

☐ Yes
☐ No

Assessment WFD

6. What do you think of the process of the WFD assessment (clarity, achievability, reliability etc.)?

Very unsatisfied	1	2	3	4	5	6	7	8	9	10	Very satisfied
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

7. Do you think that the outcomes of the WFD assessment provide a realistic image of the actual condition of a waterbody? (“one out, all out” principal)

Not realistic	1	2	3	4	5	6	7	8	9	10	Very realistic
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

8. Do you think that the WFD provides enough encouragement to stimulate the implementation of additional measures for improving the water quality?

1	2	3	4	5	6	7	8	9	10
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

9. According to your opinion, how could the WFD stimulate involved parties in taking additional measures to improve the water quality?

……

10. Possible justification on the answers given for the component "WFD assessment"

……

Implementation

11. What is main reason for the water board to implement nature friendly banks? (multiple answers possible)

☐ For achieving the WFD goals
☐ For more biodiversity
☐ For improving the biological water quality
☐ For improving the chemical water quality through the purifying function
☐ For improving the recreational value
☐ For a better bank defense
☐ Other

12. Which aspects are being considered when implementing a nature-friendly bank within the management area of the water board? (multiple answers possible)
    ☐ space/land acquisition
    ☐ Assessment of the situation as it is now
    ☐ Pre-determining goals (Why this place? What do I want to achieve? etc.)
    ☐ Determining a desired situation
    ☐ Monitoring after implementation
    ☐ Establishing a maintenance plan
    ☐ Additional measures (when the desired results are not achieved)

13. Does the theoretical approach correspond with the practical approach of implementing a nature-friendly bank?

☐ Yes, the theoretical approach is exactly the same as the practical approach
☐ Yes, Only possible modifications are made done when some theoretical aspects would not work in practice

- ☐ No, there is a theoretical implementation plan, however in practice the nature-friendly banks are being implemented in a different way
- ☐ Other

14. What measures are being taken by the water board when the nature-friendly bank does not give the desired result? (multiple answers possible)

- ☐ Nothing
- ☐ Extra monitoring
- ☐ Observation
- ☐ Additional research
- ☐ Modifications on the maintenance (with “trial and error”)
- ☐ Implementation of additional measures
- ☐ Other

15. Are there any points of improvement on the implementation plan of the water board? Explain

……

16. Possible justification on the answers given for the component “implementation”

……

Maintenance

17. How are nature-friendly banks being maintained within the management area of the water board? explain the method, period, frequency and goal

……

18. What are the pros and cons of this way of maintaining nature-friendly banks?

……

19. Possible justification on the answers given for the component “maintenance”

……

Additional measures

20. Has there been experimented with possible additional measures for improving the ecological function of nature-friendly banks within the management area of the water board? Name the measures

……

21. Were these measures effective? Explain

……

22. Possible justification on the answers given for the component “additional measures”

……

Appendix 4: Additional results

Below, additional graphs can be found based on results from the conducted survey.

Figure 17 shows the results from the survey on reasons for implementing a nature-friendly bank. The results are based on the average answers per respondent.

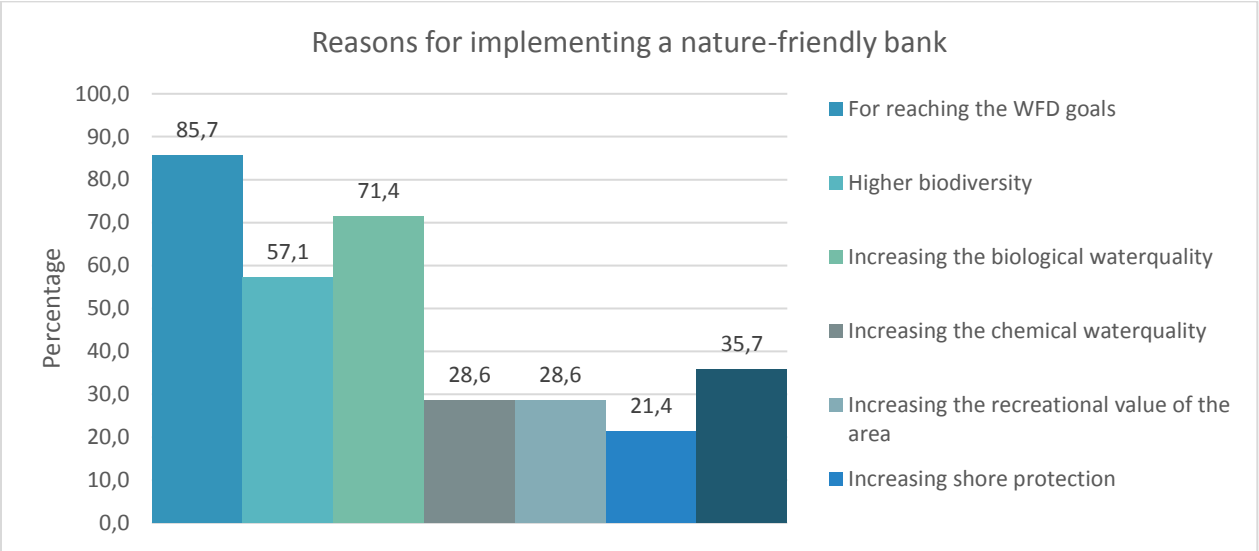

FIGURE 17 RESPONDS FROM THE SURVEY ON REASONS FOR IMPLEMENTING A NATURE-FRIENDLY BANK. BASED ON THE AVERAGE ANSWERS PER RESPONDENT, N=14

Figure 18 shows the results from the survey on aspects considered when implementing a nature-friendly bank. The results are based on the average answers per respondent.

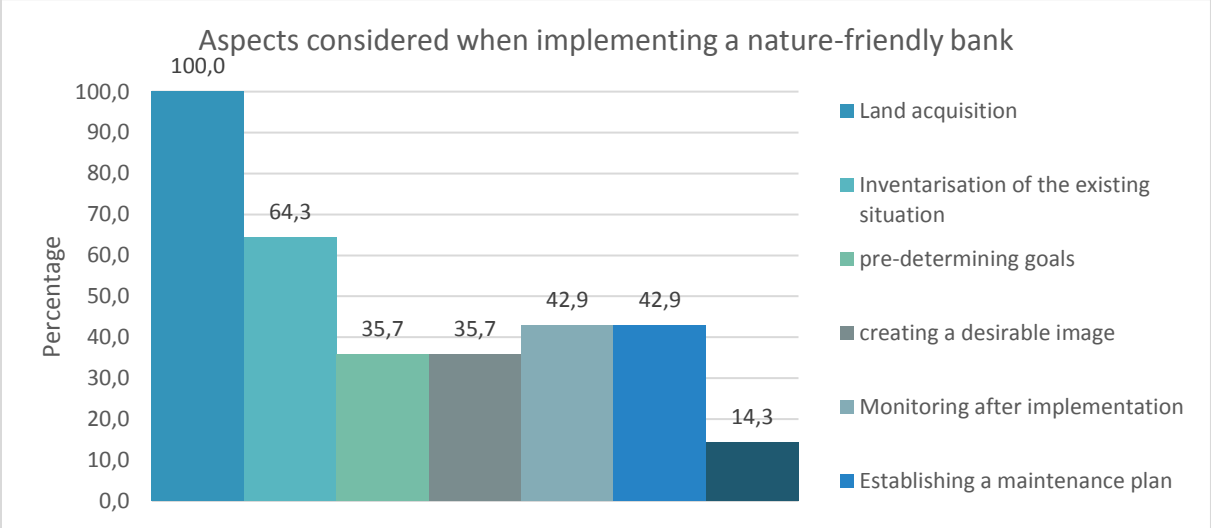

FIGURE 18 RESPONDS FROM THE SURVEY ASPECTS CONSIDERED WHEN IMPLEMENTING A NATURE-FRIENDLY BANK. BASED ON THE AVERAGE ANSWERS PER RESPONDENT, N=14

Figure 19 shows the answers given on measures when a nature-friendly bank does not give the desired result. The results are based on the average answers per respondent.

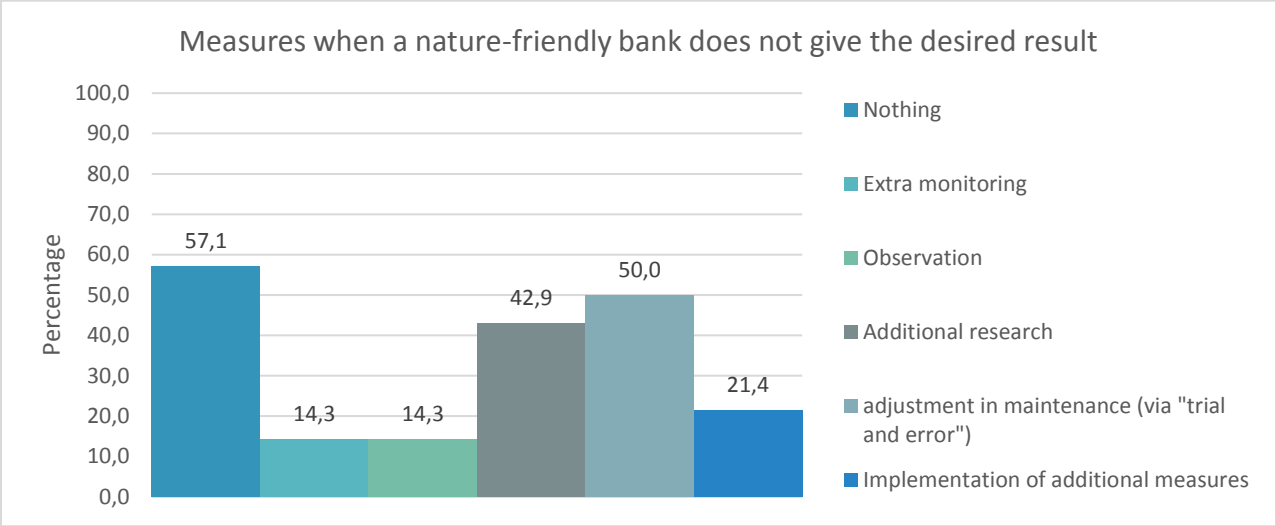

FIGURE 19 RESPONDS FROM THE SURVEY ON MEASURES TAKEN WHEN A NATURE-FRIENDLY BANK DOES NOT GIVE THE DESIRED RESULT.. BASED ON THE AVERAGE ANSWERS PER RESPONDENT, N=14