The functions of artificial salt marshes for fish

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Preface

In order to complete the Aquatic Ecotechnology bachelor program, on the HZ University of Applied Sciences, I conducted a graduation research. I did this final thesis at Wageningen Marine Research, located in Yerseke. My thesis is a study into the functions of constructed salt marshes for fish, as part of the project *Vissen in Kwelders*. This project consisted of samplings of fish using the managed realignments along the Oosterschelde and Westerschelde.

The goal of this thesis study was to describe the function constructed salt marshes have for different species of fish. A number of field samplings were executed to determine which species of fish are present in the creeks of four salt marshes in Zeeland. Within this study, a comparison was made between fish fauna present in two natural and two constructed salt marshes. In the end, some recommendations for future research on fish using managed realignments are given. This report forms the end product concluding my graduation internship and the bachelor program. Thanks are due to the following people:

Brenda Walles – For the excellent supervision within the company during both of my internships.

Alco Nijssen – For the supervision and feedback on my work from the HZ.

Everybody who was involved in the project or contributed to the field samplings.

And finally, I would like to thank Wageningen Marine Research and all its employees for the opportunity to contribute to this project and the enjoyable internship periods I had.

Daan van Houte

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Abstract

Salt marshes are known to be an important habitat type for numerous species of fish. As fish stocks are pressured around the world, providing them with suitable habitat is very important. Through managed realignments or tidal restoration, intertidal salt marshes are created or restored. Which fish use these measures however, is an understudied subject. In this study, it was investigated which fish use two natural and two constructed salt marshes in the Scheldt estuary (The Netherlands), to understand the functions artificial salt marshes provide for different fish species. Insight in the functions marshes could provide for fish is of importance for coastal managers, to optimize restoration or creation of salt marshes, to better serve fish in their needs.

To assess the fish populations using the marshes and with what purpose, fish was caught, using fyke nets and seine nets. For each species, it was determined which function the natural and constructed salt marshes could provide them, based on their length (age) and life cycle. Sampling of the fish populations took place in two natural marshes: Sint-Annaland and Het Verdronken Land van Saeftinghe, and in two constructed marshes: Rammegors and Perkpolder. All locations were sampled in autumn 2020, by placing six fyke nets, that were retrieved after 24 hours, and fishing a minimum of two transects with the seine net. In spring 2021, additional sampling was executed in Rammegors using the same method. For this location, a seasonal comparison was made as well.

An extensive use by fish was observed for all four marshes. Thirteen species of fish were found to use the salt marshes studied in autumn 2020. These species used the marshes either as feeding ground, nursery ground, or permanent habitat. Locally, specific species like goby (*Pomatoschistus spec*.), eel (*Anguilla anguilla*), and juvenile mullet (*Mugilidae spec.*), were found to reach high numbers. In April 2021, seven species were caught in Rammegors. In May 2021, six species were caught. Seasonal differences observed in Rammegors were the presence or absence of certain species. An example is the high abundance of juvenile European flounder (*Platichthys flesus*) in spring 2021.

The constructed marshes seemed to largely serve fish the same way the natural marshes do, as all species present in the natural marshes were caught in the constructed marshes as well. An exception is the constructed marshes serving juvenile mullet (*Mugilidae spec.*), as this species was much more abundant in the natural marshes. This difference is most likely caused by the level of development of the constructed marshes, causing absence of favourable feeding conditions for mullet. In general, Rammegors seems to serve as a nursery ground for several fish species, whereas Perkpolder functions more as a foraging ground for juvenile fish and estuarine resident species. It was assumed this difference is caused by the differing abiotic conditions and lack of vegetation in Perkpolder.

Additional research is recommended, to get a better understanding of the ‘demands’ fish have to use a salt marsh for a specific purpose. This research could exist of additional sampling, combined with the mapping of vegetation, inundated area and abiotic conditions in the marsh. Another interesting subject that should be studied more extensively are the eel in Rammegors, as this species seems to use this location in high numbers.

Table of contents

1. Introduction

Fish have a high ecological, economical and recreational value as they are important for commercial fisheries, sportfishing and diving. They play a major role in food webs, and fish stocks can be used as water quality measure (Calle et al. 2020, Maes et al. 2005). Despite their high value, fish are globally pressured due to overfishing, pollution and habitat loss. Estuaries are important for fish as they serve as migration corridors for diadromous fish species, provide foraging ground for estuarine residents and act as nursery area for marine juveniles (Blaber 1991, Haedrich 1983). An important foraging and breeding area for fish are salt marshes (Boesch and Turner 1984, Laffaille et al. 2000a).

The position of salt marshes in estuaries, the salinity gradient and whether or not salt marshes are being grazed determines which fish species use salt marshes (Cattrijsse et al. 1994, Hampel et al. 2009, Hostens et al. 1996, Laffaille et al. 2001). Grazing can negatively affect food availability in creeks, as (sheep) grazing limits accumulation of plant detritus, resulting in less favourable conditions for animals like *Orchestia*. These animals form the most important terrestrial prey species for stickleback and common goby (Friese et al. 2018). *Orchestia* was also found in the stomachs of sea bass (*Dicentrarchus labrax*), flounder (*Platichthys flesus*), and other gobies (*P. minutus and P. lazanoi*) (Hampel 2003, Hampel et al. 2005, Laffaille et al. 2000a, Laffaille et al. 2001).

Salt marshes are known to provide several functions for fish. The constant availability of food, cover provided by vegetation, often-warmer water and low currents make salt marshes an interesting nursery ground for fish. Salt marsh creeks in the bay of Mont-Saint-Michel (France) were dominated by juvenile fish such as goby (*Pomatoschistus spp*.), mullets (*Mugilidae spec*.), sea bass (*Dicentrarchus labrax*) and young flatfishes, which use these creeks as nursery ground (Laffaille et al. 2000a). Salt marshes also function as habitat. In the channels of Bull island, Dublin (Ireland) fish catches were dominated by goby, three-spined stickleback and juveniles of mullet and flounder, representing 98.4% of all caught fish (Koutsogiannopoulou and Wilson 2007). These species are estuarine residents (except for mullet), using the marsh as habitat. Furthermore, are salt marshes important foraging grounds for fish. Predatory fish like sea bass (*Dicentrarchus labrax*) and flounder (*Platichthys flesus*) actively use tidal salt marsh creeks as feeding ground. In the Westerschelde estuary (The Netherlands), most individuals of these species were 1 and 2 year olds (Hampel et al. 2005). Juvenile fish and crustaceans find protection from bigger fish within tidal creeks. Stomach content analyses of sea bass and flounder, caught in tidal creeks, revealed a diet of macrobenthic organisms, with no active predation on juvenile fish. The presence of bigger fish does not restrict the use of the salt marsh as a nursery by smaller peers or other species. Also, the low predation pressure does not negatively affect the nursery population within the creeks (Hampel et al. 2005).

Salt marshes are globally declining due to climate change and anthropogenic activities (Boorman 2003, Lo et al. 2017, Luisetti et al. 2011). Loss of salt marshes will affect species which rely on this habitat (Luisetti et al. 2011). Worldwide salt marshes are restored or created (e.g. (Colclough et al. 2005, Ledoux et al. 2005, MacDonald et al. 2020, Pétillon et al. 2014, Rupp-Armstrong and Nicholls 2007). Restoration projects mainly focus on restoring morphological features and monitor the morphological development and development of vegetation, benthic communities, and bird communities. The function of constructed salt marshes for fish is often understudied. Ecological functions of constructed salt marshes are expected to differ from natural salt marshes, especially during the first decade after construction. Over time the amount of food and complexity in constructed salt marshes is expected to increase, facilitating richer foraging grounds and increased vegetation cover for fish. Inundation period is important for fish, as it determines the time fish have to migrate into the creeks and forage during high tide (Wolff et al. 1981). The level of vegetation further dictates the cover available for small or juvenile fish.

- In this study, the functions artificial salt marshes provide for different fish species along the Oosterschelde and Westerschelde estuary were studied. Insight in the functions managed realignments or tidal restoration could provide for fish is of importance for coastal managers, to optimize future measures, to better serve fish in their needs.

2. Method

2.1. Study area

The Oosterschelde and Westerschelde estuaries are located in the southwestern part of the Netherlands. Within these estuaries, fish were caught in two natural and two constructed salt marshes (Figure 1).

Figure 1. Overview map of the study area, showing the two natural (a: Sint-Annaland; d: Het Verdronken land van Saeftinghe) and two constructed (b: Rammegors; c: Perkpolder) salt marshes along the Oosterschelde and Westerschelde estuary (SW Netherlands). Insert maps show the constructed salt marshes four years after construction (http://www.satellietdataportaal.nl).

The Oosterschelde estuary is a tidal bay which is separated from the North Sea by a storm surge barrier (completed in 1986). In addition, a series of compartmentalization dams were constructed in the eastern part of the estuary, isolating the estuary from its river influence. The estuary has an surface area of 351 km^2, existing of tidal flats (114 km^2), salt marshes (ca 4.65 km^2) , rocky shores (dikes), deep gullies and shallow water areas (Jentink 2017, Smaal and Nienhuis 1992). The estuary has a semi-diurnal tide, with an average tidal range of 3.24 meters and currents ranging between 0.2 and 1.5 ms^{-1} (Louters et al. 1998, Troost 2009). There is no salinity gradient. Salinity throughout the estuary is high, generally 30 psu (Smaal and Nienhuis 1992). With the construction of the storm surge barrier, tidal prism, tidal volumes and sediment transport into the system reduced (Ledoux et al. 2005). These changes hamper higher intertidal areas in their development, as little sediment is available and reduced tidal currents are unable to transport sediment to these areas (Jacobse et al. 2006). The now oversized tidal gullies act as sediment sinks, causing increased erosion on tidal flats and salt marshes (Mulder and Louters 1994, van der Werf et al. 2015). Before the construction of the dams and barriers, about 2000 ha of salt marshes occurred in the Oosterschelde. Whereas only 500 ha was left after construction of the dams and barriers (DeltaExpertise n.d.). Most of this loss was caused by the compartmentalization dams, which closed marshes off from tidal influence. Due to increased erosion in the Oosterschelde, an additional 3 ha of salt marsh is lost annually (Geurts van Kessel 2004). Most of the remaining salt marshes are situated in the eastern, more sheltered, part of the Oosterschelde. In total ten areas with salt marsh vegetation occur in the Oosterschelde nowadays (Jentink 2017). These areas are all decreasing in surface area. Only the bigger marshes at Rattekaai, Rumoitschor and Krabbenkreek are expected to be present by 2060 (Jacobse et al. 2006).

The Westerschelde is the tide-dominated estuary of the river Scheldt, with a surface area of 350 km^2, making it one of the biggest estuaries of Europe (Vlaams-Nederlandse Scheldecomissie 2019). The estuary is funnel shaped and about 160 km in length, with a width ranging from 6 km to 100 m (Wang et al. 2002). The Westerschelde contains 82 km^2 tidal flats, 24 km^2 salt marshes and rocky shores in the form of dikes (Smit et al. 1997). The estuary has a semi-diurnal tide, with a tidal range from 3.8 m (Vlissingen) to 5.2 m (Antwerpen) (Wang et al. 2002). A salinity gradient is present throughout the estuary, as it forms an open connection between the North Sea and the river Scheldt. Salinity varies from 10 to 25 or 30 psu (Gerringa et al. 1998). The marine part of the estuary is recognized for its well-developed channel system, existing of one straight flood channel with a meandering ebb channel, surrounded by numerous smaller channels (Wang et al. 2002). During the last four decades, a tidal asymmetry developed, as the estuaries edges were embanked and dredging activities were executed. As a result, the estuary became a narrow system with fixed channels, causing an increased tidal volume and tidal current (Vlaams-Nederlandse Scheldecomissie 2019, Wang et al. 2002). This leads to steeper transition zones, as erosion increased outside the main channels, pressuring salt marshes and tidal flats (Vlaams-Nederlandse Scheldecomissie 2019). In total, 21 marsh areas were present in 1987 (Huiskes 1988). Nearly all salt marshes increased in height, but very little new salt marsh area have developed (Cox et al. 2003).

2.2. Sampling method

To investigate which species of fish use the salt marshes in the Scheldt estuary, field sampling took place in tidal creeks of four salt marshes along the Oosterschelde and Westerschelde estuary.

Field sampling consists of a combination of passive (fyke nets) and active (seine nets) fishing. Both methods were chosen to compensate for the limitations each type of fishing gear has. Fyke nets have relatively large mesh sizes, to prevent clogging with plant material or debris. Consequently, the fyke nets are not suited to catch small or juvenile fish. To be able to catch small and juvenile fish, seine nets (in Dutch: ‘broedzegen’), with a smaller mesh size were used additionally. Both fishing gears and their combination is commonly used to study fish in salt marshes (Kooiman and Ploegaert 2020, Laffaille et al. 2001, Nunn et al. 2016).

Each location was sampled in autumn 2020. Fyke nets were placed in the field and retrieved after two tides, due to time restrictions. Fyke nets were placed such that they would always be in the water. Catches were counted and measured to the millimetre, before releasing the fish back into the creek. Additionally, seine net sampling took place. Furthermore, sampling took place in spring 2021 in Rammegors only. This sampling campaign was combined with environmental DNA (eDNA) sampling of fish in the same area. Results from the eDNA sampling are not part of this study.

2.2.1. Fishing with fyke nets

A fyke net is a bag-like net, held open by plastic hoops (six in this research) (Figure 2). In this study, two sizes of fyke nets were used. Smaller fyke net with an opening 60 cm in diameter and larger nets with a diameter of 85 cm. Inside the net, three funnels are located, preventing fish from swimming back out. On the biggest hoop, forming the opening of the fyke net, two 4-meter-long wings are attached. These wings are equipped with a weighed bottom tendon and a floating top tendon. The function of these wings is to intercept passing fish, guiding them into the net. The cod-end, back end of the fyke net or tail, is closed with a small rope that is tied around the net. The nets have a mesh size of 10 mm half mesh, the cod-end has a mesh size of 5,5 mm half mesh.

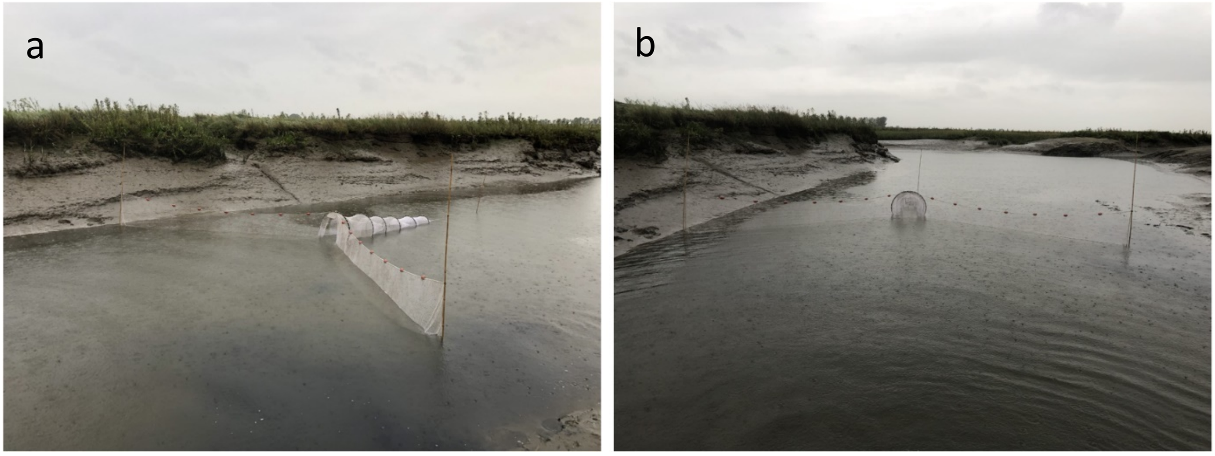

Figure 2. The fyke net as placed in a marsh creek in Sint-Annaland. (a) Side view of the fyke net (60 cm high), (b) View into the opening of the net.

The fyke nets were placed with the entrance facing both inwards as well as outwards of the marsh creek. This way, both fish migrating into the creek and out of the creek were caught. The nets were not blocking the entire creek, enabling fish to pass the nets. Preferably, nets were placed both in the mouth, as well as deeper in the salt marsh. This way, it may be possible to check if fish migrate into the creeks with the tide, or that they reside in the creeks more permanent. Placement of the fyke nets was done at low-tide, 24 hours later the nets were retrieved, resulting in the nets fishing during two flood periods. To determine the location of the fyke nets, current, water depth and the creek edges were observed. Placement of the nets is always done in a spot with sufficient water depth, even at low tide. This ensures potential fish in the net always remaining in the water.

To place the nets, bamboo sticks or (concrete) rebars were used. First, the wings were placed in a suitable location, fixing them with a stick placed in the sediment. The position of the wings is important, as these intercept the fish passing by. A good location is next to a steep edge, as fish swim along these edges (Figure 2a). To prevent the net floating off the sticks, the net was secured with tie-wraps. The entire net was stretched, placing the hoops backwards. Finally, the whole net was pulled tight by fixing the anchor line at the tail of the net, to a third stick. It is important to place this last stick a little oblique, away from the fyke. This way, the net is unable to slip from the stick as easily.

Each fyke net was labelled with a label stating the organization, number of the fyke net and a telephone number. This labelling was obligated as fishing was executed in protected nature areas. The number of the net was used in processing the catches.

Retrieving the nets was done as follows: first, the sticks fixating the two wings were pulled from the sediment. The wings were cleaned, checking if species linger in the wings and preventing potential debris from floating into the net. After this, the net was lifted hoop by hoop, proceeding backwards. The net was slightly shaken to make sure everything inside the net got into the back section (cod-end). Finally, the cod-end of the net was lifted at once, keeping the end of the tail up. This way, potential failure of the knot closing the net was prevented. The net was then brought onto land, keeping the tail up.

To process the potential catches, all contents of the net were dumped in a big tub. A picture was made from the catch, after which the catches were sorted by species into other containers. All fish were kept in a small layer of water until they were measured, to prevent them from suffocating. The fish were measured one by one, using a measuring board and rounding off downwards on centimetres (In autumn 2020). During the samplings in spring 2021, all catches were measured in millimetres. The length was written down and the fish was returned into the water. European shore crabs (*Carcinus maenas*) were counted and sorted into the groups 0-2 cm carapace, or >2 cm carapace. This division was made to be able to say something about the food-availability for fish and how crabs use the marshes. Other species of crabs were only sorted on species and counted. However, benthos was not part of this study and thus not considered in this report. Potential special catches or unknown species were photographed for further examination.

2.2.2. Fishing with seine nets

Seine nets were used next to the fyke nets. A seine net is a long net (10 metres wide and 2 metres high) with a heavy bottom tendon and a floating upper tendon (Figure 3). This net is pulled through the water in a U-shape. In the back end of the net, the cod-end is located (2,5 mm half mesh), collecting everything in the net. The two wings of the net have a mesh size of 5 mm half mesh. Beside this seine net, a smaller version was used but only in the artificial marsh Perkpolder in the Westerschelde. This net was 3 metres wide and 1,5 metres high. The mesh was 2,5 mm half mesh. While pulling the seine net, the bottom tendon scrapes the creek bed. This causes organisms to come from the bottom, which are then caught in the net. The seine net was used in sampling of the salt marshes, as this net also catches the smaller fish and shrimps that pass through the fyke nets. This way, a more complete image of the presence of juvenile fish and potential benthic prey animals could be obtained.

To use the seine net, two people are needed. One of them crosses the creek, the other remains on the opposite bank. Fishing is always done against the current, as this helps opening the net. Once the net is open and floats in a U-shape, both people start slowly walking. Important is to keep the bottom tendon in contact with the bottom as much as possible. This way, a chosen length of creek

Figure 3. Sampling with the seine net in the back of a creek in Sint-Annaland (Transect 7b).

was fished. At the end of the fished distance, an area on which the net can be pulled ashore is needed. Once the landing area is reached, the person on that side of the creek slows down. The person on the other side then crosses the creek, closing the net. It is important to constantly keep moving, as stopping could cause the fish to escape. The net is pulled onto land with a constant motion and the wings pulled closely together, making sure that the bottom tendon stays on the ground. Preferably, a third person walks behind the seine net, to check for escaping organisms. Once the complete net was on land, the same method was used as with the fyke nets. The net was slightly shaken towards the back, keeping the tail up, gathering all species stuck in the wings in the cod-end. The contents of the net were dumped into a big tub, and the contents were photographed. As a seine net often catches clay and sand, a sieving tub could be used to rinse the catch.

The catch was then put in a white tray, after which the catch was sorted and measured. If big numbers of small fishes were caught, special catches or bigger fish were taken out, after which the catch was evenly divided into subsections. Only one of these sections was completely sorted and measured. Important is to make sure that the factor of division is written down with it. During the samplings in autumn 2020, all species were measured in centimetres, rounding off downwards. During the samplings in spring 2021, all catches were measured on the millimetre. After measuring, all species were released.

2.3. Natural and constructed salt marshes

To increase intertidal habitat, including salt marshes, restoration projects were executed in the Oosterschelde and Westerschelde. In the Oosterschelde, Rammegors, a former sea arm that was closed off by a compartmentalization dam, was reconnected to the tidal influences of the Oosterschelde by an inlet (Elschot et al. 2016). In the Westerschelde a former farmland, Perkpolder, was connected to the Westerschelde, increasing the tidal habitat (Lageweg et al. 2019). For both natural and both constructed salt marshes the function for fish was investigated.

The salt marsh of Sint-Annaland is a natural salt marsh along the Krabbenkreek (Oosterschelde) and one of the biggest marsh areas in the Oosterschelde (Jacobse et al. 2006). This system consists of six main creeks, with numerous smaller creeks, that are flooded twice a day (Figure 4). Because of its sheltered location along the Oosterschelde estuary and the gentle slope in front of the Krabbenkreek, the salt marsh of Sint-Annaland is one of the most stable marshes in the estuary.

A total of six fyke nets was placed in this salt marsh (Figure 4b). The nets were placed with the opening in the direction of the Oosterschelde (3, 4 and 6) and with the opening directed inwards of the creek (1, 2 and 5). Fyke nets 3 and 5 were the smaller nets (60 cm diameter). Fyke nets 1 and 2 were declared invalid, as they came loose from the sticks and tangled. These fyke are not considered in the results. All seine net transects were fished using the big seine net and fishing up-stream, walking further into the system. The transects differed in length (7a = 60m; 7b = 45m; 8b = 150m).

Figure 4. Satellite images of the salt marsh of Sint-Annaland. (a) The area at high tide in September 2020, (b) Overview of the sampling positions in the salt marsh of Sint- Annaland. The red points mark the location of a fyke net, with the corresponding number of the net. The blue points mark the beginning point of a transect fished with the seine net (http://www.satellietdataportaal.nl).

Figure 5. Impression of the salt marsh of Sint-Annaland, Krabbenkreek (Van Houdt 2008).

Nature area Rammegors is a 145-ha constructed salt marsh located along the Oosterschelde estuary. This area was part of the Oosterschelde but in 1972 it was closed-off from the estuary, developing into a freshwater wetland (Walles et al. 2019). This area was reconnected to the Oosterschelde by an inlet in the Krabbenkreekdam, finished in December 2014. The inlet, consisting of three culverts, enables the tide to flow into the nature reserve twice a day (Walles et al. 2019). Between 2014 and 2016, the inlet was mostly closed due to technical difficulties, but since 2016, it is fully functioning (Walles et al. 2019).

Figure 6. Impression of the Rammegors nature area, April 3, 2020 (Paree 2020).

The area is intersected by a creek with two side-creeks. During high tide, water covers about half of the area (Figure 7a). In front of the inlet on the Rammegors side, a dam was constructed ensuring a shallow waterbody of about 14 ha remaining in the area during low tide (Figure 7b). No sedimentation takes place in the area (Walles et al. 2019). Salt tolerant vegetation developed quickly and wading birds use the area (Elschot et al. 2016). Benthic macro-organisms showed a fast colonization of brackish and saltwater species. In 2019, a decline could be seen in brackish species, indicating the transition to a marine environment (Walles et al. 2019). In the past, the Rammegors area was grazed by sheep, cattle and horses (Van der Reest and Van Haperen 1996). At the moment, no maintenance is executed.

Six fyke nets were placed in this location (Figure 7a) with the opening in the direction of the Oosterschelde (2, 4, 5) and with the opening directed inwards (1, 3, 6). Fyke nets 3 and 5 were the smaller nets (60 cm diameter). The same positions and numbers were used during all four samplings in Rammegors. All transects were fished up-stream, walking further into the system. The transects differed in length (7a = 75m; 7b = 30m; 8b = 90m; 9b = 30m). The big seine net was used for all transects.

Figure 7. Satellite images of the Rammegors nature area. (a) Overview of the sampling positions in the Rammegors area. The red points mark the location of a fyke net, with the corresponding number of the net. The blue points mark the beginning point of a transect fished with the seine net, (b) The area at low tide in March 2020 (http://www.satellietdataportaal.nl).

Het Verdronken Land van Saeftinghe (hereafter Saeftinghe), is a natural salt marsh located along the Westerschelde, on the border of the Netherlands and Belgium. With its surface area of 3580 hectare, Saeftinghe is the largest brackish intertidal area of Europe. The area has a characteristic system of creeks, with three main gully's and a large number of smaller creeks and higher areas (Figure 8). The tidal difference in Saeftinghe can vary between 3,5 and 7 metres (Jacobusse and Decleer 2003). The area is for 70% covered with vegetation, the western part being more saline species, the eastern part being mostly reed. This gradient in salinity is caused by the age of the salt marsh. The area's vegetation is maintained through grazing of both cattle and sheep (Lensink et al. 2008).

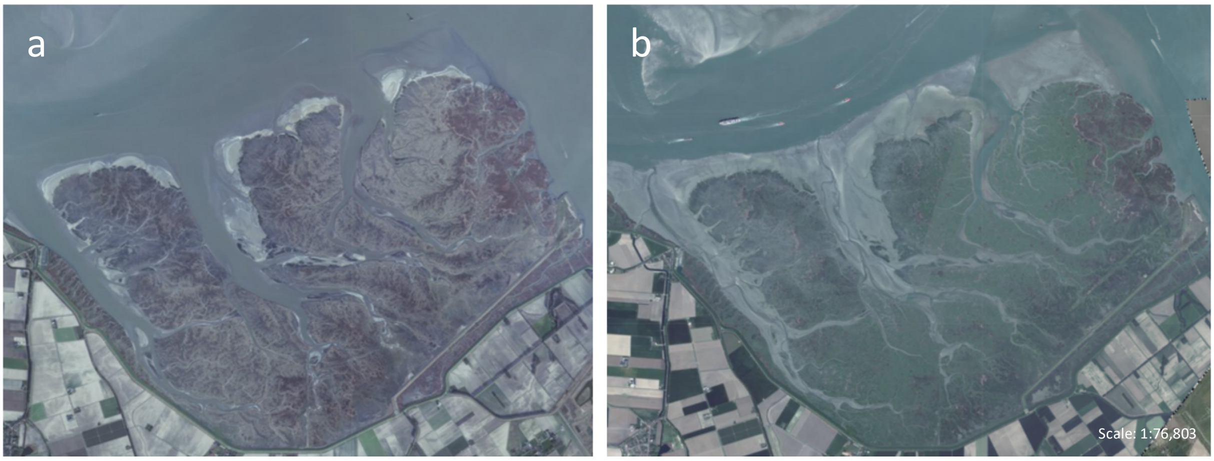

Figure 8. Satellite images of Het Verdronken Land van Saeftinghe. (a) The area during high tide in March 2018, (b) The area during low tide in May 2019 (http://www.satellietdataportaal.nl).

The fyke nets (Figure 9) were placed with the opening in the direction of the Westerschelde (1 & 2) and with the opening directed inwards of the creek (3, 4, 5, 6). Fyke nets 3 and 5 were the smaller nets (60 cm). All seine net transects were fished up-stream, walking further into the system, and using the big seine net. The two transects differed in length (7b = 25m; 8b = 50m).

Figure 9. Overview of the sampling positions in Het Verdronken Land van Saeftinghe. The red points mark the location of a fyke net, with the corresponding number of the net. The blue points mark the beginning point of a transect fished with the seine net.

Perkpolder is a managed realignment along the Westerschelde. A new dike was built around the perimeter of the area, after which the existing dike was breached. The area is since June 2015 connected to the Westerschelde and floods twice a day (Figure 10a) (Lageweg et al. 2019). This adds 75 ha of intertidal nature to the Westerschelde.

Fast sedimentation occurs in the back of the area, while the front near the inlet experiences some erosion (Lageweg et al. 2019, Ysebaert 2016). No vegetation is growing in the area yet, except for some seeded patches of grass (Ysebaert 2016). The benthic macrofauna population developed quickly into a population comparable to natural salt marshes and tidal flats along the Westerschelde (2019) (Lageweg et al. 2019). Because of this, birds are using the area to feed and to rest on the dikes around it (Lageweg et al. 2019, Ysebaert 2016). No maintenance strategy is adopted in this location, as the area is still under development. Currently it is a mudflat, which should develop into an area containing salt marsh vegetation. The area consists of very fine sediment and is completely flooded during high tide (Figure 10a). Little water is present in the area during low tide (Figure 10b, 11).

The six fyke nets used for sampling (Figure 10b) were placed with the opening in the direction of the Westerschelde (3 & 4) and with the opening directed inwards (1, 2, 5, 6). Fyke nets 3 and 6 were the smaller nets (60 cm diameter). All transects fished with the seine net were fished up-stream, walking further into the system. The small seine net was used for all three transects in this location. The transects differed in length (7 = 15m; 8 = 20m; 9 = 25m).

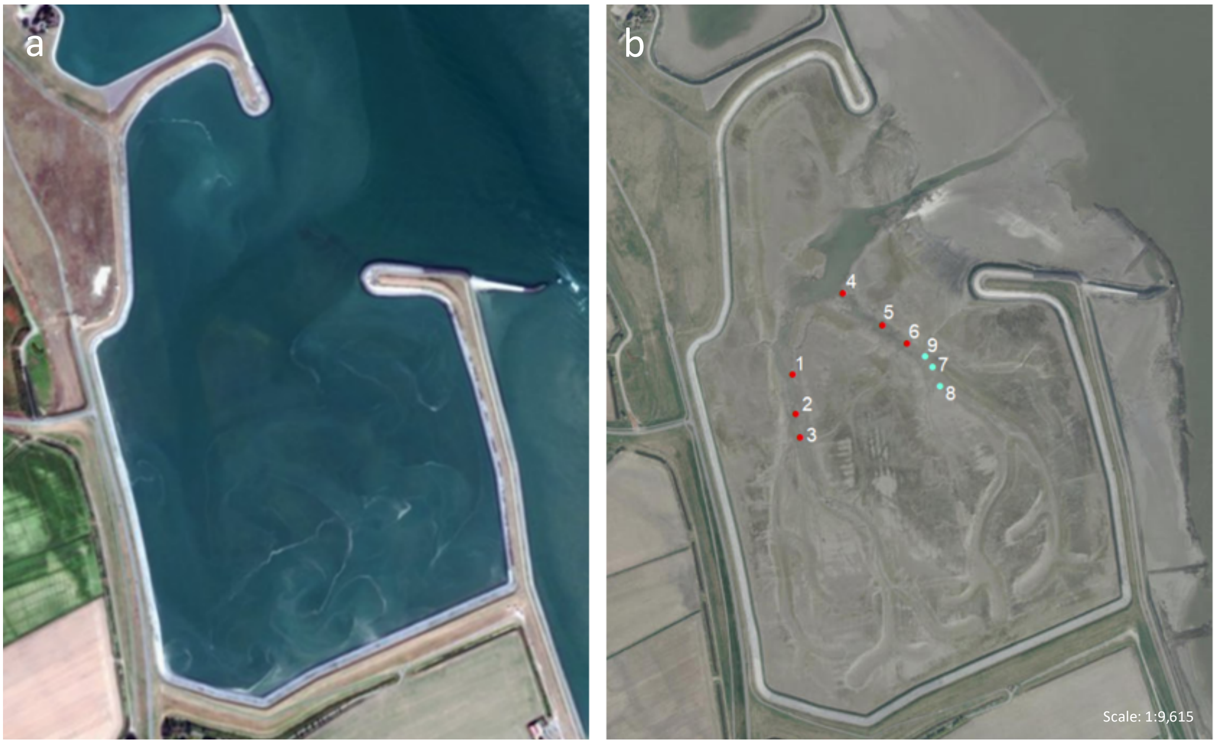

Figure 10. Satellite images of the Perkpolder area. (a) The area at high tide in September 2020, (b) Overview of the sampling positions in the Perkpolder area. The red points mark the location of a fyke net, with the corresponding number of the net. The blue points mark the beginning point of a transect fished with the seine net (http://www.satellietdataportaal.nl).

Figure 11. Aerial photo of the Perkpolder tidal basin at low tide, September 6, 2016 (Paree 2016).

2.4. Data analysis

To answer the research questions in this study, a combination of a literature study and data analysis was used. Literature study was used to gather existing data on the use of salt marshes by fish, and the functions these marshes provide to different species in different life stages of the fish.

In order to be able to say something about the use of the natural and artificial salt marshes by fish in the Oosterschelde and Westerschelde, the data collected in the field was analysed. All data collected in the field were stored in the program Billie and as an Excel-file. The field data, all existing of qualitative data, was further analysed with 'R' software. The results found in this project were compared with each other and against literature, to further formulate conclusions.

Comparisons were only made between the marshes in a single waterbody, and not between the two waterbodies. The demersal fish survey (DFS) shows that fish populations in the two systems differ greatly, making comparison irrelevant (Tulp 2015). The comparisons were based on numbers of individuals per species in the natural or artificial marshes. Lengths of the caught fish give an indication of the life stage of the fish. This was combined with the estuarine guild each species belongs to, to formulate the function the marsh has for that fish species.

For the marsh of Rammegors, a seasonal comparison between autumn 2020 and spring 2021 was made, as multiple samplings were only executed in this location. A length-comparison between April 2021 and May 2021 was made as well, as changes in length could be monitored for species caught in both samplings.

3. Results

In the natural salt marsh of Sint-Annaland, a total of six different fish species were caught during sampling in October 2020 (autumn). The species caught were distributed over four different estuarine guilds: estuarine residents (1), marine juveniles (3), marine seasonal migrants (1), and diadromous migrants (1). The three species: goby (*Pomatoschistus spec.*), sand smelt (*Atherina presbyter*), and sea bass (*Dicentrarchus labrax*) were caught using both fishing methods. The three species: mullet (*Mugilidae spec.*), herring (*Clupea harengus*), and stickleback (*Gasterosteus aculeatus*) were only caught in the seine net. In the fyke net catches, sand smelt was most abundant, followed by goby (Figure 12). In the seine net catches, goby was most abundant, with mullet also forming an identifiable share of the catches (24.0%) (Table 2).

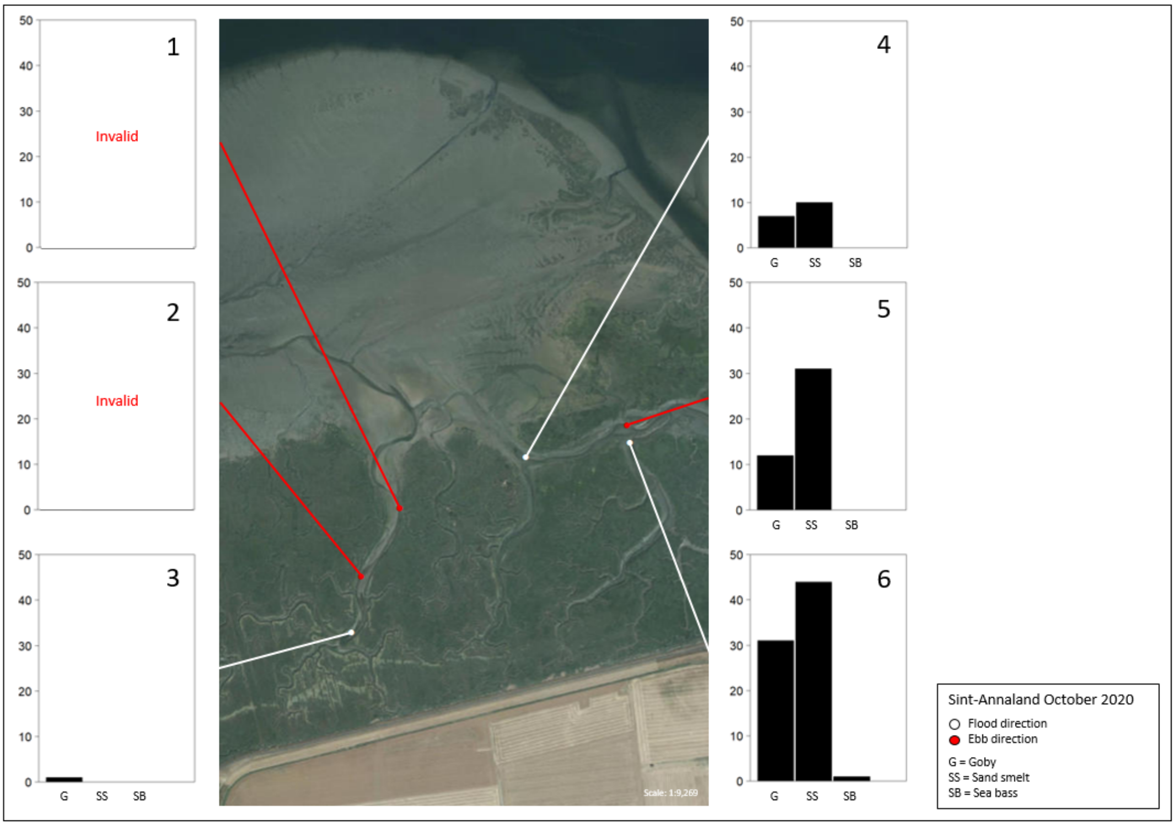

Figure 12. The number of fish caught in the fyke nets in Sint-Annaland during sampling in October 2020. For each net, the number per species is shown. The different coloured points show the direction the fyke net was positioned in; flood direction (white) or ebb direction (red). Fyke nets 1 and 2 were declared invalid, as they came loose from the sticks and tangled.

Goby were caught with lengths between 1 and 5 cm (2 cm was not caught in the fyke nets), with the majority of fish in the fyke nets being 4 cm in length (Figure 13), while the majority was 2 or 3 cm in the seine net catches (79.2%) (Figure 13). Sand smelt were caught in lengths of 6, 7 and 8 cm, with the majority being 7 cm in length (Figure 14). Mullet had lengths ranging from 1 to 4 cm, half of them being only 1 cm (Figure 15). Other species were caught in low numbers with differing lengths: herring (7 cm), sea bass (3, 4 and 8 cm), and stickleback (3 (n=13) and 4 (n=4) cm).

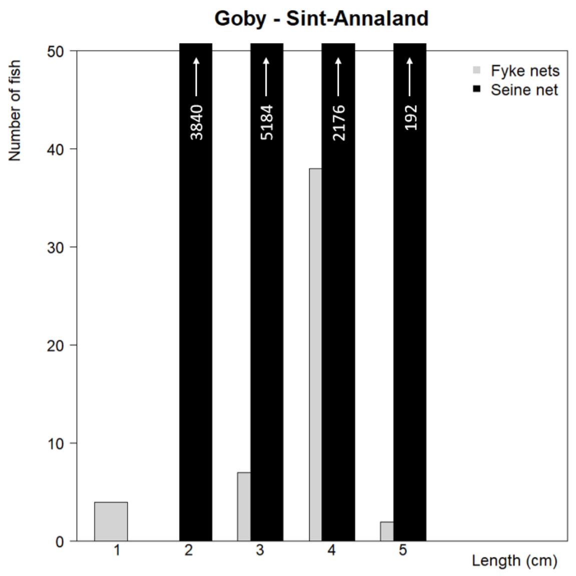

Figure 13. Barplot displaying the lengths of all goby (Pomatoschistus spec.) caught in Sint-Annaland during sampling in October 2020. The catches for both types of fishing gear are shown; Fyke nets (grey) and seine net (black).

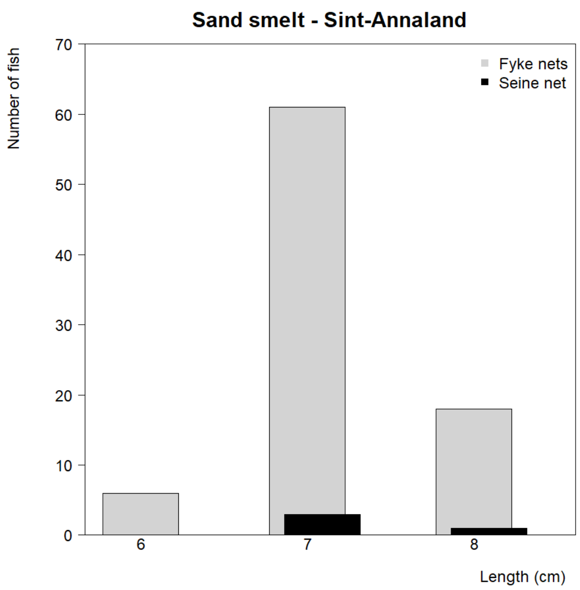

Figure 14. Barplot displaying the lengths of all sand smelt (Atherina presbyter) caught in Sint-Annaland during sampling in October 2020. The catches for both types of fishing gear are shown; Fyke nets (grey) and seine net (black).

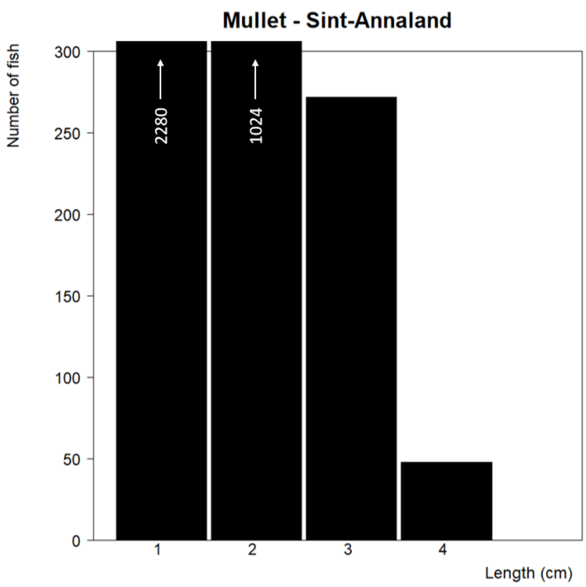

Figure 15. Barplot displaying the lengths of all mullet (Mugilidae spec.) caught in the seine net in Sint-Annaland during sampling in October 2020. No mullet were caught in the fyke nets in this location.

In the constructed salt marsh Rammegors, a total of five fish species was caught in October 2020 (autumn). These species originated out of four different estuarine guilds: marine juveniles (2), marine seasonal migrants (1), diadromous migrants (1), and estuarine residents (1). Most abundant in the fyke net catches were eel (*Anguilla anguilla*) (Figure 16). The number of eels caught in this location (86) is remarkable, as much fewer eel were caught in each of the other three marshes (Table 1). Goby (*Pomatoschistus spec*.) was caught using both fishing methods, even representing 99.1% of all seine net catches (Table 2). Mullet (*Mugilidae spec.*) was also caught using both methods, numbers however were limited. Herring (*Clupea harengus*) and sand smelt (*Atherina presbyter*) were both only caught using the seine net.

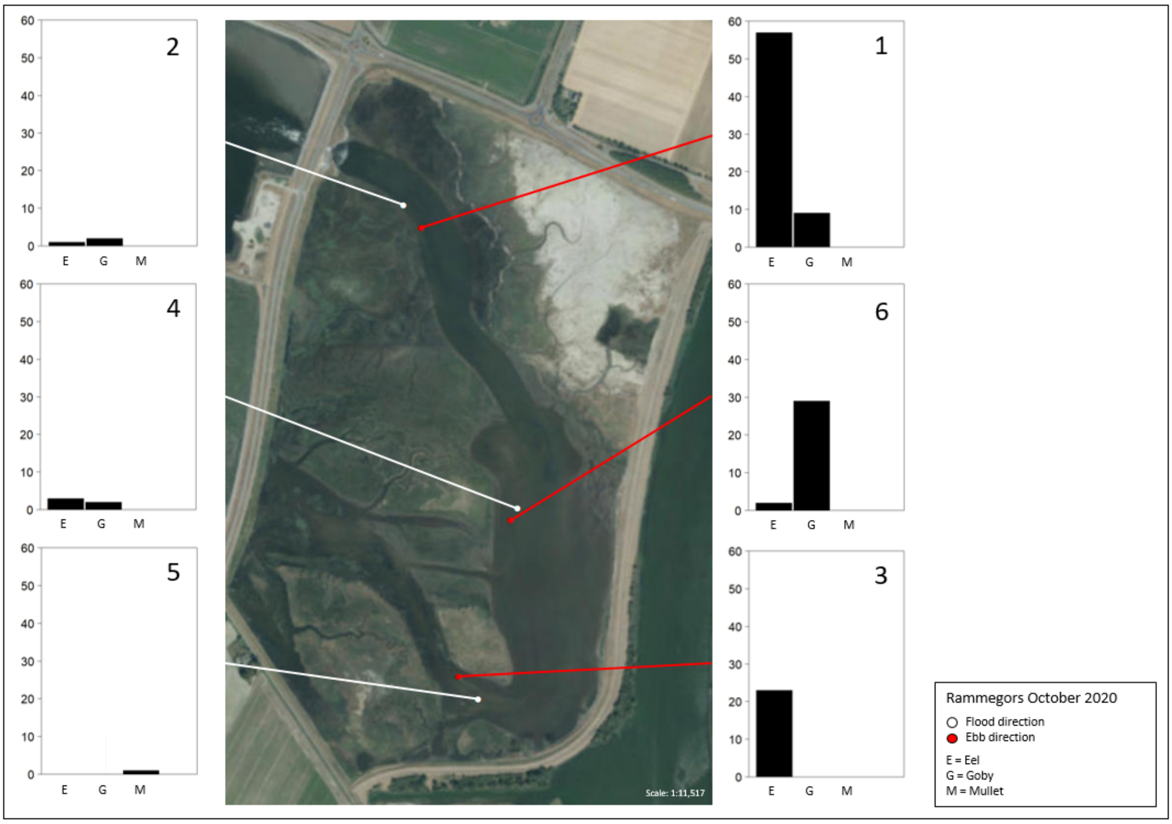

Figure 16. The number of fish caught in the fyke nets in Rammegors during sampling in October 2020. For each net, the number per species is shown. The different coloured points show the direction the fyke net was positioned in; flood direction (white) or ebb direction (red).

The eel caught had lengths ranging from 16 to 63 cm, with the majority being 30 to 40 cm, and a second, smaller peak around 50 cm (Figure 17). Caught goby had a length between 3 and 7 cm with the majority being 4 cm in length in the fyke net catches (Figure 18). In the seine net, goby were caught in lengths varying between 2 and 5 cm, with a majority of them being 3 cm in length (65.0%) (Figure 18). Mullet were caught in lengths ranging from 1 to 5 cm, with the majority being 3 cm. All herring and sand smelt in the catches had lengths between 6 and 8 cm, without a specific length being more present.

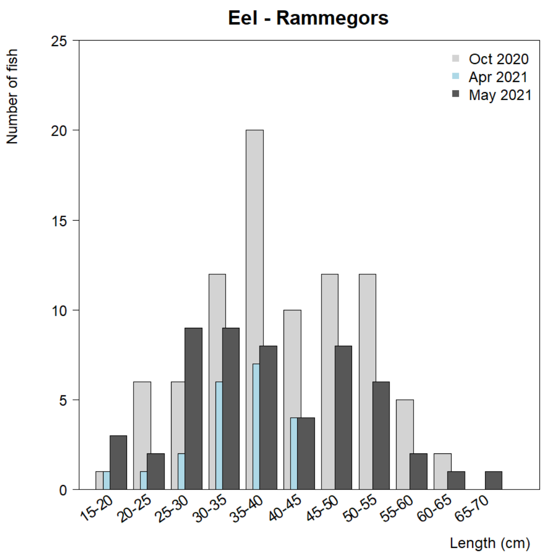

Figure 17. Barplot displaying the lengths (divided in 5-cm groups) of all eel (Anguilla anguilla) caught in the fyke nets in Rammegors, during the three sampling moments in October 2020, April 2021, and May 2021. During all samplings, only one eel was caught using the seine net in May 2021. This eel measured 23 cm.

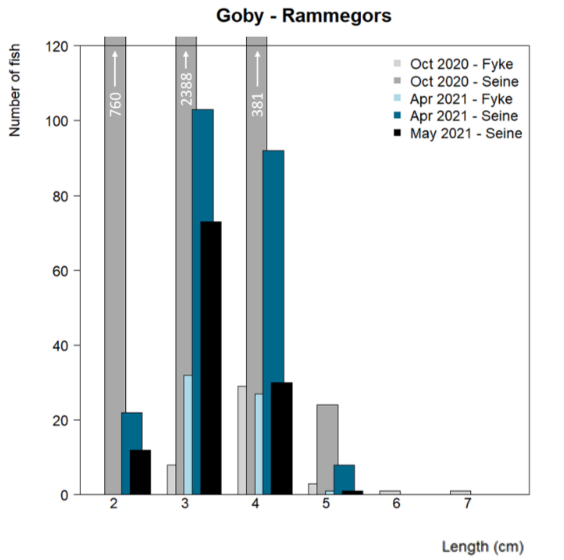

Figure 18. Barplot displaying the lengths of all goby (Pomatoschistus spec.) caught in Rammegors, during all three sampling moments. The catches for both types of fishing gear are shown, as explained in the legend. No gobies were caught in the fyke nets during the sampling in May 2021.

Analyzation of the data collected in Rammegors in April 2021, shows that fish use the area during spring as well (Figure 19). In total, seven species were caught during this spring sampling, with the

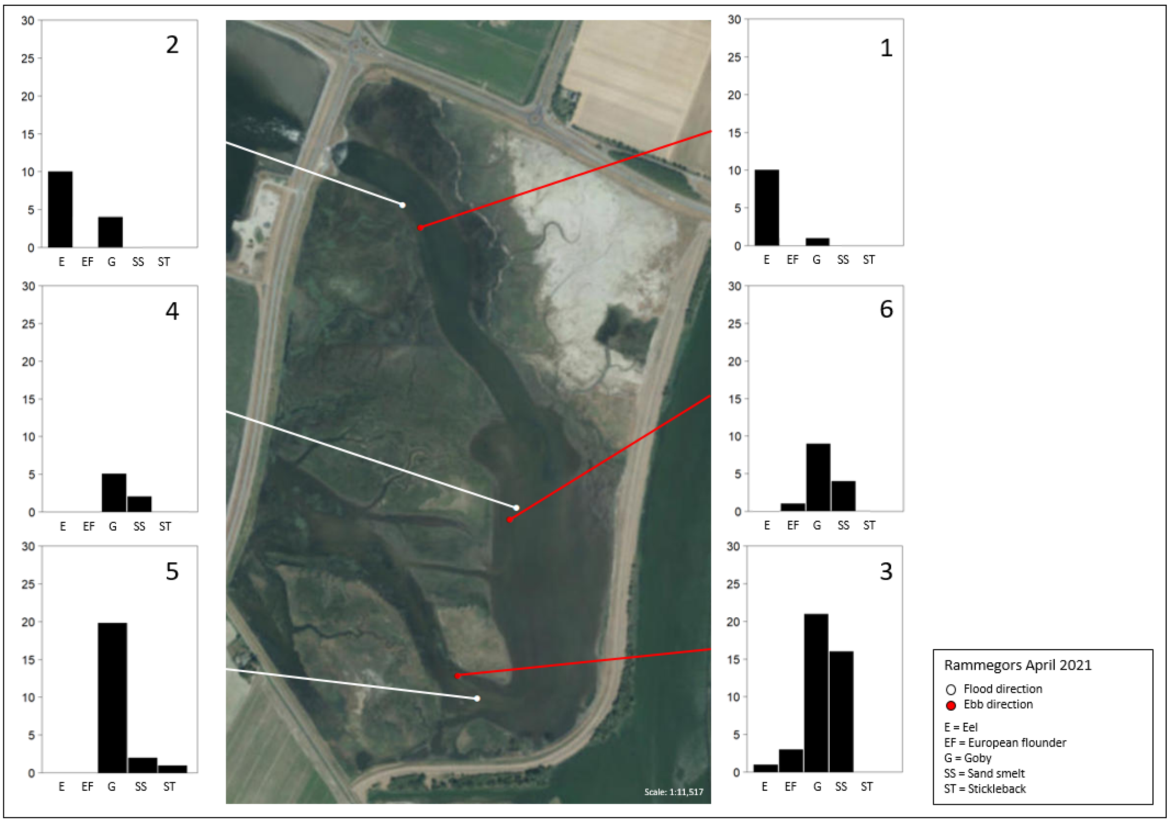

Figure 19. The number of fish caught in the fyke nets in Rammegors during sampling in April 2021. For each net, the number per species is shown. The different coloured points show the direction the fyke net was positioned in; flood direction (white) or ebb direction (red).

total number of fishes being lower than during the sampling in autumn 2020. The species that were caught, originated from four different estuarine guilds: estuarine residents (3), marine juveniles (1), marine seasonal migrants (1), and diadromous migrants (2). Most abundant in the catches of both fishing methods was goby (*Pomatoschistus spec*.) (Figure 19 and table 2). European flounder (*Platichthys flesus*) and sand smelt (*Atherina presbyter*) were caught using both fishing methods as well. Other species caught were eel (*Anguilla anguilla*), sandeel (*Ammodytes tobianus*), stickleback (*Gasterosteus aculeatus*), and European sprat (*Sprattus sprattus*)*.

Goby were caught in lengths between 2 and 5 cm, with the majority being 3 or 4 cm in both types of fishing gear (Figure 18). European flounder (30.2% of the seine catches), was mostly caught in lengths ranging from 2 to 4 cm, with the majority being 3 cm in length (Figure 20). Next to that, a single 1 cm flounder and a single 8 cm flounder were caught (Figure 20). The sprat* was 3 cm in length. Eel were caught in lengths ranging from 15 to 45 cm, with the majority between 30 and 40 cm in length (Figure 17). Sand smelt were 8 to 12 cm, with the majority being 9 cm (Figure 21). The other species, caught in lower numbers, were: sandeel (4 and 6 cm) and stickleback (5 cm).

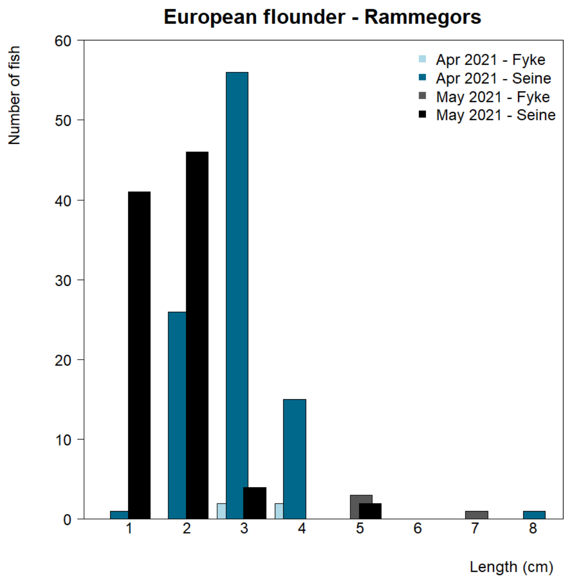

Figure 20. Barplot displaying the lengths of all European flounder (Platichthys flesus) caught in Rammegors during sampling in April and May 2021. The catches for both types of fishing gear are shown. No European flounder were caught in October 2020.

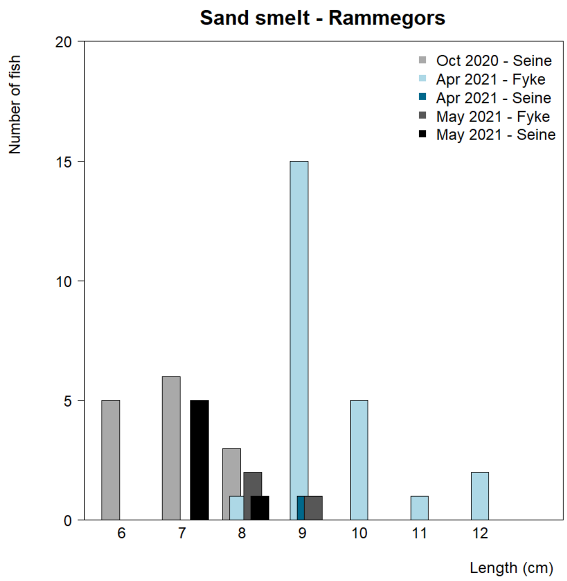

Figure 21. Barplot displaying the lengths of all sand smelt (Atherina presbyter) caught in Rammegors during all three samplings. The catches for both types of fishing gear are shown. Sand smelt were not caught in the fyke nets in October 2020.

During sampling in May 2021 in Rammegors, a total of six fish species was caught, representing four different estuarine guilds: estuarine residents (2), diadromous migrants (1), marine juveniles (1) and marine seasonal migrants (2). Species caught using both fishing methods were eel (*Anguilla anguilla*), European flounder (*Platichthys flesus*), and sand smelt (*Atherina presbyter*). Besides that, three species were caught using the seine net: goby (*Pomatoschistus spec*.), mullet (*Mugilidae spec*.), and European sprat *(Sprattus sprattus*)*. Eel was most abundant in the fyke net catches (Figure 22), goby and European flounder dominated the catches from the seine net (Table 2).

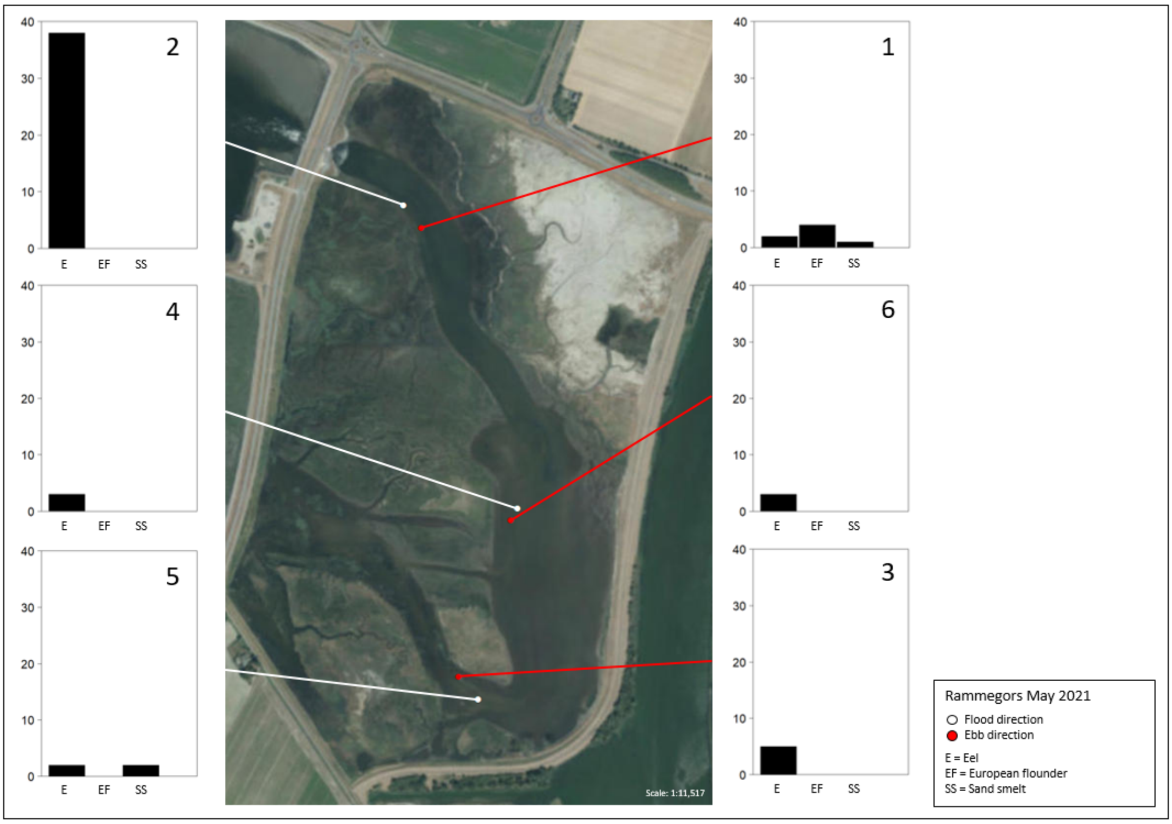

Figure 22. The number of fish caught in the fyke nets in Rammegors during sampling in May 2021. For each net, the number per species is shown. The different coloured points show the direction the fyke net was positioned in; flood direction (white) or ebb direction (red).

Eel caught during the sampling in May 2021 had lengths ranging between 15 and 70 cm, with the majority being around 30 cm in length (Figure 17). Goby were caught in lengths between 2 and 5 cm, with the majority being 3 cm (62.9 %) (Figure 18). In the seine net, European flounder were caught in lengths between 1 and 5 cm, without 4 cm being present and the majority being 1 or 2 cm (Figure 20). In the fyke net catches, four European flounder were present, being 5 (n=3) and 7 cm in length. Sand smelt caught had lengths of 7 (n=5), 8 (n=3) and 9 cm (Figure 21). European sprat* was caught in a length of 3 cm (n=3). The single mullet that was caught had a length of 29 mm.

In the natural marsh of Saeftinghe, ten species were caught. The species represented five different estuarine guilds: diadromous migrants (2), estuarine residents (3), freshwater adventitious (2), marine juveniles (2) and marine seasonal migrants (1). Goby (*Pomatoschistus spec.*) and mullet (*Mugilidae spec.*) were caught using both fishing methods. Sea bass (*Dicentrarchus labrax*), eel (*Anguilla anguilla*), European flounder (*Platichthys flesus*), perch (*Perca fluviatilis*), and white bream (*Blicca bjoerkna*) were only caught using the fyke nets. Sand smelt (*Atherina presbyter*), sandeel (*Ammodytes tobianus*), and stickleback (*Gasterosteus aculeatus*) were only caught in the seine net.

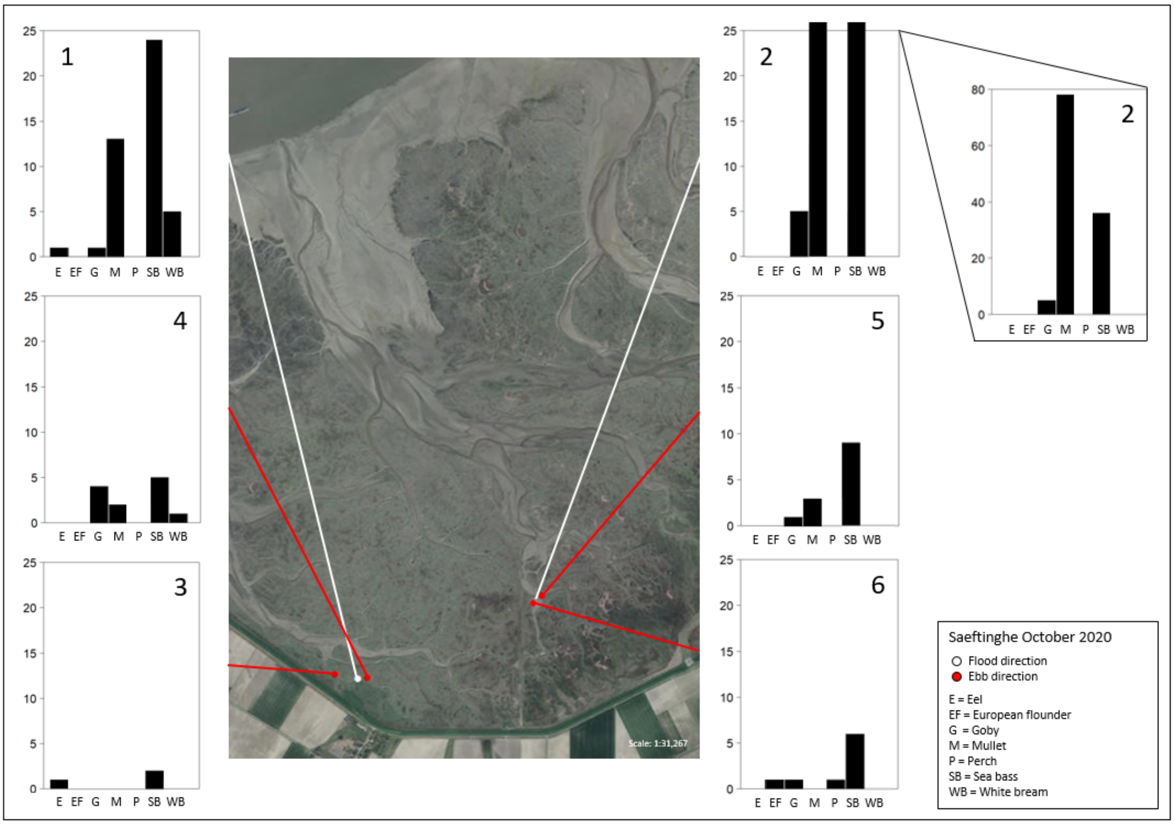

Figure 23. The number of fish caught in the fyke nets in Het Verdronken Land van Saeftinghe during sampling in October 2020. For each net, the number per species is shown. The different coloured points show the direction the fyke net was positioned in; flood direction (white) or ebb direction (red). An additional insert for fyke net 2 shows the catches from this net in a fitting scale.

In the fyke net catches, mullet and sea bass were most abundant (Figure 23). Most abundant in the seine net catches were goby and mullet (Table 2). Analyzation of the lengths shows that a majority of the sea bass caught had a length between 20 and 30 cm (64.6%) (Figure 25). In the fishing methods combined, both mullet and goby were caught in lengths between 2 and 5 cm, with the majority around 3 and 4 cm (Figure 26, figure 27). Grazing marks of bigger, adult mullet were observed during fieldwork, but these fish were not caught (Figure 24). Other species were caught in low numbers with differing lengths: eel (53 and 55 cm), European flounder (5 cm), perch (9 cm), white bream (7 (n=5) and 8 cm), sand smelt (7 and 9 cm), sandeel (5 (n=2), 6 (n=2) and 7 (n=2) cm), and stickleback (4 cm).

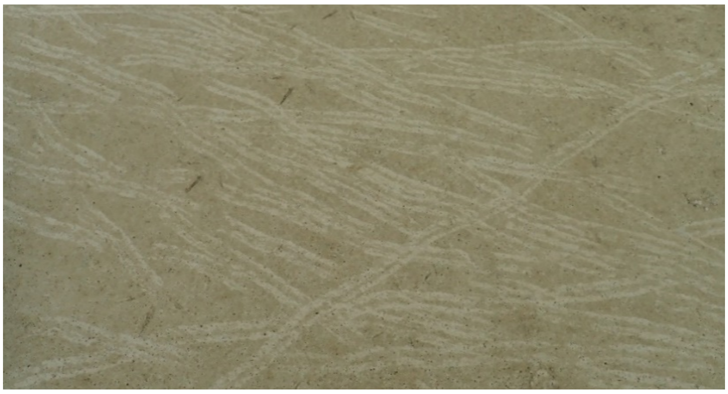

Figure 24. Grazing marks of adult mullet near the location of fyke net 5, photo taken during fieldwork in Saeftinghe on October 13th, 2020.

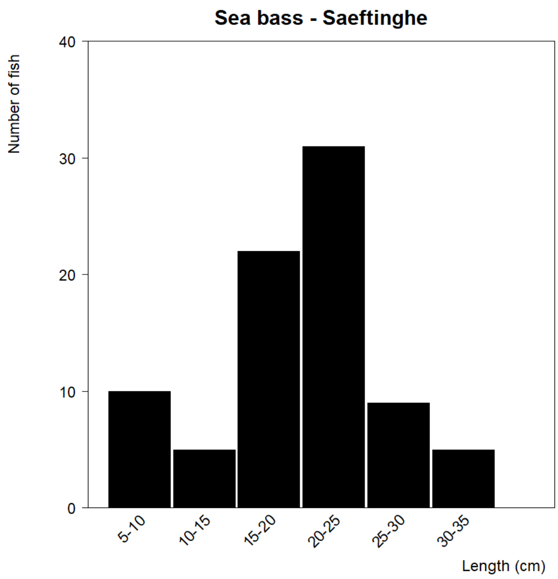

Figure 25. Barplot displaying the lengths of all sea bass (Dicentrarchus labrax) caught with the fyke nets in Saeftinghe during the sampling in October 2020, divided in 5cm-groups. No sea bass were caught using the seine net in this location.

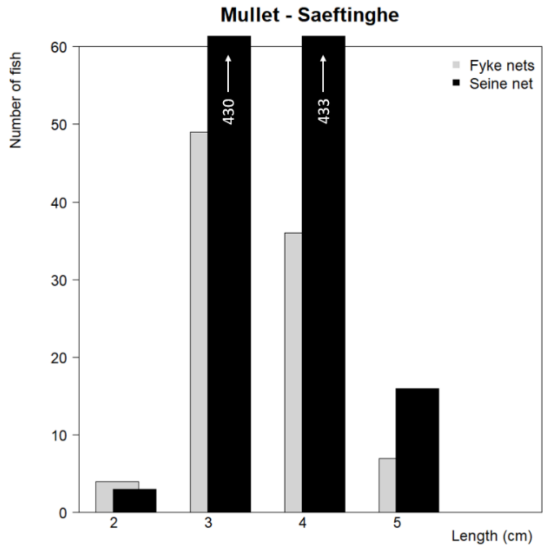

Figure 26. Barplot displaying the lengths of all mullet (Mugilidae spec.) caught in Saeftinghe during sampling in October 2020. The catches for both types of fishing gear are shown; Fyke nets (grey) and seine net (black).

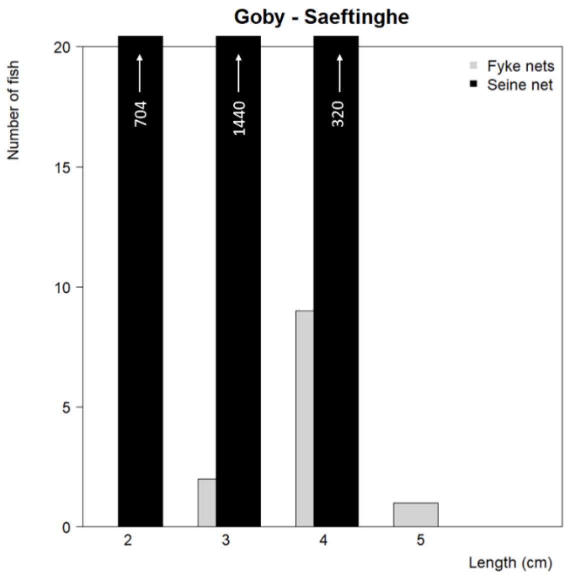

Figure 27. Barplot displaying the lengths of all goby (Pomatoschistus spec.) caught in Saeftinghe during sampling in October 2020. The catches for both types of fishing gear are shown; Fyke nets (grey) and seine net (black).

Eight species of fish were caught in the Perkpolder area during sampling in September 2020, distributed over three estuarine guilds: diadromous migrants (1), estuarine residents (4), marine juveniles (2), and marine seasonal migrants (1). Species caught in the fyke nets were goby (*Pomatoschistus spec*.), sea bass (*Dicentrarchus labrax*), eel (*Anguilla anguilla*), European flounder (*Platichthys flesus*), greater pipefish (*Syngnathus acus*), and Nilsson's pipefish (*Syngnathus rostellatus*) (Figure 28). In the seine net, only seven fish were caught, being five mullet (*Mugilidae spec*.) and two sand smelt (*Atherina presbyter*) (Table 2).

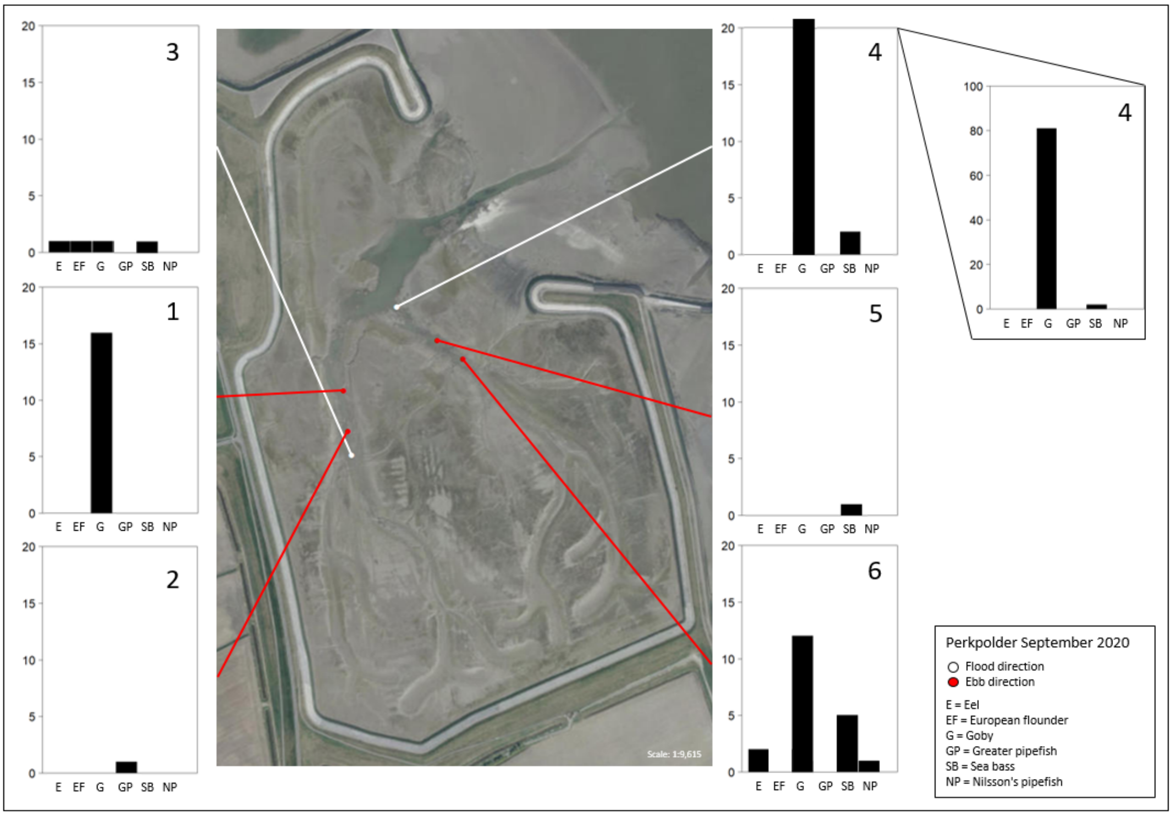

Figure 28. The number of fish caught in the fyke nets in Perkpolder during sampling in September 2020. For each net, the number per species is shown. The different coloured points show the direction the fyke net was positioned in; flood direction (white) or ebb direction (red). An additional insert of fyke net 4 shows the catches from this net in a fitting scale.

Most abundant was goby, which were caught in lengths varying between 2 and 7 cm, with the majority being 3 and 4 cm (Figure 29). Remarkable is the presence of bigger gobies, in lengths of 6 and 7 cm (17.5%). Sea bass were caught in two different length classes: 5-10 cm (n=7) and 25-30 cm (n=2). The other species were caught in differing lengths: eel (31, 55 and 80 cm), European flounder (24 cm), greater pipefish (26 cm), Nilsson's pipefish (14 cm), mullet (3 and 4 cm), and sand smelt (9 cm (n=2)). Although not caught in high numbers, numerous juvenile gobies were seen in tidal pools in the area.

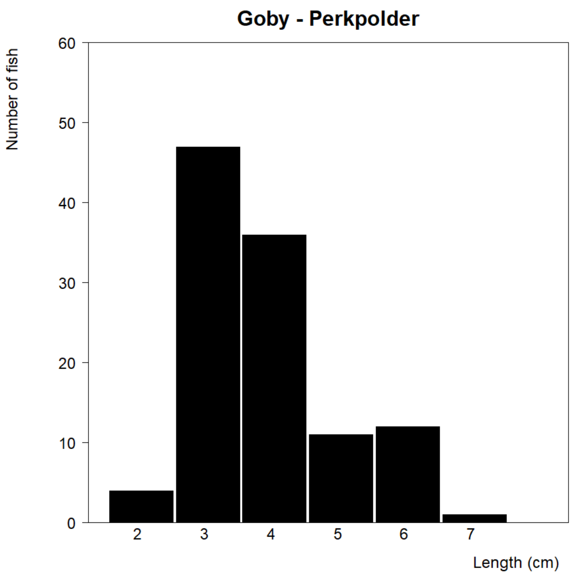

Figure 29. Barplot displaying the lengths of all goby caught in the fyke nets in Perkpolder during the sampling in autumn 2020. No gobies were caught using the seine net in this location.

Table 1. Species caught in the fyke nets during the field samplings. For each study site and sampling moment, the number per species, the total number of fishes caught, and the number of species present are shown. The number of fyke nets represented in the data is shown as well.

Species/Taxon	**Sint-Annaland**	**Rammegors**			**Saeftinghe**	**Perkpolder**
	Oct 2020	**Oct 2020**	**Apr 2021**	**May 2021**	**Oct 2020**	**Sep 2020**
Number of fyke nets	*(n = 4)*	*(n = 6)*	*(n = 6)*	*(n = 6)*	*(n = 6)*	*(n = 6)*
Anguilla anguilla		86	21	53	2	3
Atherina presbyter	85		24	3		
Blicca bjoerkna					6	
Dicentrarchus labrax	1				71	9
Gasterosteus aculeatus			1			
Mugilidae spec.		1			57	
Perca fluviatilis					1	
Platichthys flesus			4	4	1	1
Pomatoschistus spec.	51	43	60		12	70
Syngnathus acus						1
Syngnathus rostellatus						1
Total	137	130	110	60	150	85
Number of species	3	3	5	3	7	6

Table 2. Species caught with the seine net during the field samplings. For each study site and sampling moment, the number per species, the total number of fishes caught, and the number of species present are shown. The number of transects and the total fished distance represented in the data are shown as well. Numbers presented are partially based on factors of division, as subsamples were taken of the catches.

Species/Taxon	**Sint-Annaland**	**Rammegors**			**Saeftinghe**	**Perkpolder**
	Oct 2020	**Oct 2020**	**Apr 2021**	**May 2021**	**Oct 2020**	**Sep 2020**
Number of transects	*n = 4*	*n = 4*	*n = 3*	*n = 3*	*n = 2*	*n = 3*
Total fished distance	*255 m*	*225 m*	*90 m*	*113 m*	*75 m*	*60 m*
Ammodytes tobianus			2		6	
Anguilla anguilla				1		
Atherina presbyter	4	14	1	6	2	2
Clupea harengus	1	8				
Dicentrarchus labrax	1					
Gasterosteus aculeatus	17				1	
Mugilidae spec.	3624	10		1	882	5
Platichthys flesus			99	93		
Pomatoschistus spec.	11392	3553	225	116	2464	
*Sprattus sprattus**			1	3		
Total	15039	3585	328	217	3355	7
Number of species	6	4	5	6	5	2

*Based on determination in the field, further determination will provide a definitive species.

4. Discussion

Samplings executed in the four salt marshes studied in this research, showed that thirteen species of fish, coming from twelve different families, used the marsh creeks in autumn 2020. Among these species, five estuarine guilds were represented: diadromous migrants (2), estuarine residents (5), marine juveniles (3), marine seasonal migrants (1) and freshwater adventitious (2). In the sampling in Rammegors in April 2021, a total of seven species was caught, all of which were caught in at least one of the four marshes during the previous sampling, except for European sprat (*Sprattus sprattus*)*. In May 2021, six species were caught during the sampling in Rammegors. All species present in the natural marshes were also caught in the artificial marshes, indicating the constructed marshes being developed enough to serve different species of fish in their needs. A description of the expected function of the marshes for each species is given below.

Eel (*Anguilla anguilla*) was caught most in the Rammegors area but were also caught in both marshes along the Westerschelde. In Rammegors, eel were caught in a big variety of lengths (Figure 17). The majority of eel caught was around 35 cm in length, indicating these eel being 5 to 7 years old (Tesch 1999). More importantly, this length indicates male eels reaching sexual maturity (30–45 cm), which is non-dependent on the eels age (Müller 1975, Vøllestad and Jonsson 1986). This indicates the majority of eel caught probably being almost sexually mature males (silver eel) and younger females (Figure 17). The group around 50 cm probably are older females (Figure 17), that have not become silver eel yet, as females take longer to become sexually mature (54–61 cm) (Hoestlandt 1991). This group is expected to exist of female eel only, as male eel migrate away before they reach this length, resulting in eel above 50 cm being practically always female (Personal communication 2021, Reeze et al. n.d.). However, growth, maturation and sexuality in eel are highly dependent on environmental influences (Personal communication 2021, Tesch 1999). Fewer and smaller eels were caught in Rammegors in April 2021. In May 2021, again more eels were caught, following the same length distribution as in October 2020 (Figure 17). Eels migrate mostly between September and November (Reeze et al. n.d.), which could indicate the eel caught in autumn 2020 were migrating and used the salt marshes as foraging ground. This presumption is strengthened as silver eel were caught in Rammegors during this sampling. It is also possible eels use salt marshes as their permanent foraging area or habitat, as lengths show non-sexually mature fish extensively using the marshes. Especially Rammegors forms a suitable habitat for eel, because of the soft sediment, permanent waterbody, vegetation coverage, and sufficient food sources (Elschot et al. 2016, ICES/EIFAC 2004). Finally, factors attracting eel are present too: freshwater seepage and a lot of degrading organic material (Walles et al. 2019). Further research on the eel in Rammegors is needed to draw a solid conclusion on the function this salt marsh has for eel.

European flounder (*Platichthys flesus*) was only caught in the marshes along the Westerschelde in autumn 2020 (Table 1 & 2). During these samplings, both adult as well as juvenile flounder were caught. Flounder is known to use salt marshes as foraging and nursery ground (Hampel et al. 2005, Kroon 2009, Reeze et al. n.d.). The relatively low number of flounder could been caused by the sampling moment, as flounder migrates to deeper water during the colder months (Kroon 2009, Muus et al. 1999). European flounder are known to spend their juvenile life stage in nursery areas along the coast, and reside in shallow coastal water between February and July (Muus et al. 1999, Reeze et al. n.d.). During the samplings in Rammegors in April and May 2021, European flounder was very abundant in the catches, in lengths between 1 and 8 cm (Figure 20). These lengths indicate the fish being juveniles (Kroon 2009, Muus et al. 1999), indicating flounder do use this salt marsh as a nursery site during spring.

Goby (*Pomatoschistus spec*.) were caught in all four marshes (Table 1 and 2). For all marshes, most caught were gobies with a length of 3 or 4 cm. This length indicates the fish being about 1 year old and reaching sexual maturity (Doornbos and Twisk 1987), but all lengths were present in the catches. The presence of this wide length distribution indicates gobies using the salt marshes as their habitat in all life stages, which also corresponds with the estuarine guild they belong to; estuarine resident. The length of an age 1+ juvenile being most present can be explained by the high mortality rate in goby after their first spawn. It would be interesting to see how the average length of the gobies develops over the year, as gobies grow faster under warmer conditions and spawn in summer (Calle et al. 2020, Doornbos and Twisk 1987). Remarkable is the fact that bigger gobies (6+ cm) were caught in the two constructed marshes in autumn 2020, but not in the natural marshes. No explanation could be found for this.

Herring (*Clupea harengus*) was caught in the two marshes along the Oosterschelde in autumn 2020. The length of all herring present in the catches was 7 or 8 cm, which indicates the fish being younger than 1 year (Brevé et al. 2007). Herring are known to use shallow coastal waters as a habitat during their juvenile life stage (Calle et al. 2020), indicating the marshes serving as a nursery ground.

Mullet (*Mugilidae spec*.) were caught in lengths between 1 and 5 cm in all four marshes. This length indicates the fish being in the beginning of their juvenile life stage (Richter 1995). In Saeftinghe, grazing marks of adult mullet were seen as well (Figure 24). Salt marshes are known to serve as a nursery area and feeding ground for mullet (Calle et al. 2020, Gandolfi 1991). The presence of juvenile mullet in all marshes, and even mullet in their larval life stage in Sint-Annaland (<25 mm) (Figure 15), indicates the studied marshes indeed serve as a nursery area. Although present in all four marshes, mullet abundance was significantly less in the constructed salt marshes compared to the natural marshes (Table 2). It was assumed this lower abundance is caused by a lack of suitable food or feeding grounds, as (juvenile) mullet mostly feed on diatoms and detritus on more solid substrate (as sand) (Leijzer and van Emmerik 2006, Mohr 1988). It is conceivable that these feeding conditions are not present in volumes able to support big numbers of juvenile mullets, due to the constructed marshes being relatively young and consisting of soft sediments.

Sandeel (*Ammodytes tobianus*) were caught in Saeftinghe in October 2020 and in Rammegors in April 2021. Sandeel catches ranged from 4 to 7 centimetres, which is half of their full-grown size. No literature is available on the age-length ratio. Sandeel are present in both the Oosterschelde and Westerschelde in big numbers (Calle et al. 2020). In other studies, all length-classes of sandeel were caught in these waterbodies, indicating sandeel using the estuaries as there permanent habitat (Calle et al. 2020). As sandeel also belong to the estuarine resident guild, it was assumed these fish use the salt marshes as part of their permanent habitat.

Sand smelt (A*therina presbyter*) was caught in all marshes and during all samplings. Lengths ranged from 6 to 9 cm in autumn 2020, and from 7 to 12 cm in Rammegors in spring 2021. The different lengths indicate all sand smelt caught in autumn 2020 being about 1 year old, which is the end of their juvenile stage and almost becoming sexually mature (Lorenzo and Pajuelo 1999). For spring 2021, lengths indicate the different fish all being between 1 and 3 years old (Lorenzo and Pajuelo 1999). Sand smelt are known to use estuaries and tidal plains to spawn (Calle et al. 2020). The fact that mostly juvenile fish or young adults were caught, could indicate that these fish use the salt marshes as a nursery ground in their juvenile life stage. The presence of bigger sand smelt (age 2+ or 3+) in Rammegors in spring 2021, indicating adult fish use the salt marsh as well.

Sea bass (*Dicentrarchus labrax*) were mostly caught in the Westerschelde (Table 1 & 2). In Sint-Annaland, two juvenile sea bass were caught as well. No sea bass were caught in Rammegors during all three samplings. All sea bass caught had a length below 35 cm, and thus being in their juvenile life stage (Pawson and Pickett 1987). These lengths indicate that the majority of sea bass were between 2 and 4 years old (Pawson and Pickett 1987). The juvenile life stage of sea bass last four to seven years (ICES 2013), of which sea bass are known to spend the first four or five year in nursery areas along the coast (Kroon 2007). Sea bass use salt marshes as foraging ground and nursery area during these first 4 to 5 years of their life (Hampel et al. 2005, Kroon 2007, Laffaille et al. 2000a). After this, sea bass start migrating as adult fish and use salt marshes as a foraging ground in the summer period (Kroon 2007). No adult fish were caught in the samplings, most likely because of them migrating to deeper water during autumn.

Stickleback (*Gasterosteus aculeatus*) were caught in Sint-Annaland and Saeftinghe in the sampling in autumn 2020. In April 2021, a single stickleback was caught in Rammegors as well. All stickleback caught had a length of 3 to 5 cm. At this length, a stickleback living in marine conditions is between 0,5 and 1 year old, which means the fish are sexually mature (Snyder 1991). The mature stickleback live most of their live in shallow coastal waters like salt marshes (Calle et al. 2020, Reeze et al. n.d.). This indicates the fish caught in this study probably use the marshes as their permanent habitat.

Greater pipefish (*Syngnathus acus*) and Nilsson's pipefish (*Syngnathus rostellatus*) were both caught in Perkpolder. These fish being estuarine residents and both adults indicate them probably using Perkpolder as feeding ground or permanent habitat. Both species are widely abundant in the Oosterschelde and Westerschelde (Calle et al. 2020), making it presumably salt marshes form an extension of their habitat.

Perch (*Perca fluviatilis*) and white bream (*Blicca bjoerkna*), both freshwater species, were caught in Saeftinghe in autumn 2020. Both species are relative salt-tolerant, but do not withstand higher salinities (Calle et al. 2020, Voorhamm and Van Emmerik 2011). This indicates the water in Saeftinghe being relatively low in salinity, which is expected as Saeftinghe lays in the brackish part of the Westerschelde. The other marshes that were studied are to saline for these species. These species most likely use Saeftinghe as foraging ground, as they are both opportunistic feeders (Calle et al. 2020, Voorhamm and Van Emmerik 2011), or ended up there by accident. The fish using the salt marsh as their permanent habitat is unlikely, as an increase in salinity could be lethal.

European sprat (*Sprattus sprattus*)** was caught in its larval life stage in Rammegors in April and May 2021. The fish being in its larval life stage indicates the marsh serving as a nursery ground. However, as numbers were very limited and no juveniles or adult fish of this species were caught, importance is most likely limited.

Distribution of species throughout an individual salt marsh does not present notable differences, except for eel in Rammegors and Goby in Perkpolder both being captured mostly around the deeper areas in the marsh (Figure 16, 19, 22, and 28). During sampling, slight differences between the seine net transects in Sint-Annaland were observed, with stickleback (*Gasterosteus aculeatus*) being caught only in the back of the marsh, while juvenile sea bass (*Dicentrarchus labrax*) were only caught in the front. This is most likely caused by the difference in function for these fish species, as stickleback reside in the area more permanent. The shifted distribution between the two creeks in Sint-Annaland can be explained as two of the nets were declared invalid, and number 3 was doubtful as well. The difference in number of species caught in the different marshes (Table 1) can be explained by the differences between the two waterbodies, as results from the Demersal Fish Survey (DFS) show that the populations of fish in the Oosterschelde and Westerschelde differ greatly (Tulp 2015).

Differences in function between the two constructed marshes were dedicated to the abiotic conditions in the two salt marshes. Rammegors seems to serve as a nursery ground for a number of fish species, whereas Perkpolder functions more as a foraging ground for juvenile fish and estuarine resident species. It was assumed this difference is caused by a difference in development of the marsh. Rammegors is covered with vegetation and a permanent body of water is present, while Perkpolder almost completely drains during low tide and lacks in vegetation. This assumption was made, as vegetation and cover provided are known to be important for fish to use a salt marsh as nursery ground (Cattrijsse and Hampel 2006, Friese et al. 2018, Laffaille et al. 2000a, Laffaille et al. 2000b).

Comparison of the samplings in autumn 2020 and spring 2021 for Rammegors, shows a difference in both total number of fish as well as the number of species (Table 1 & 2). Species caught in both seasons were goby (*Pomatoschistus spec.*), sand smelt (*Atherina presbyter*) and eel (*Anguilla anguilla*). The biggest difference in number of fish between autumn and spring is caused by the number of gobies being significantly less. It was assumed this difference is caused by goby spawning during summer, causing high numbers in autumn. In April 2021, the number of eels was remarkably less compared to the other two samplings (Table 1). No explanation could be found for this difference. The difference in abundance of juvenile European flounder (*Platichthys flesus*) can be explained by their migratory cycle, as explained previously. Other species being present or not is dedicated to the seasons, although additional research is needed to state this with certainty.

** Based on determination in the field, further determination will provide a definitive species.

5. Conclusion

The two artificial salt marshes along the Oosterschelde and Westerschelde serve as a permanent habitat, nursery ground and foraging area dependant on the species of fish. Both areas seem developed enough to serve the different fish species present in the natural reference sites in their specific needs. An exception on this is the mullet (*Mugilidae spec*.), as this species was significantly less abundant in the artificial marshes compared to the natural marshes. This lower abundance indicates something is missing for this species in the artificial marshes, most likely being favourable feeding conditions. A difference in function that can be observed between the two constructed marshes is the function as a nursery ground. Rammegors seems to serve as a nursery ground for several fish species. Perkpolder functions more as a foraging ground for juvenile fish and estuarine resident species. It is assumed this difference is caused by a difference in development of the marsh.

In the natural marsh of Sint-Annaland, located along the Oosterschelde, a total of six fish species was caught during the sampling in autumn 2020. The species that were caught were: goby, herring, mullet, sand smelt, sea bass and stickleback. Together, these six species represent four different estuarine guilds: estuarine residents (1), marine juveniles (3), marine seasonal migrants (1) and diadromous migrants (1).

In the natural marsh of Saeftinghe, located along the Westerschelde, ten different fish species were caught in autumn 2020. The species that were caught were: goby, mullet, eel, sand smelt, sandeel, sea bass, stickleback, European flounder, perch and white bream. These species originate from five different estuarine guilds: estuarine residents (3), marine juveniles (2), marine seasonal migrants (1), diadromous migrants (2) and freshwater adventitious (2).

In the constructed salt marsh Rammegors (Oosterschelde), a total of five fish species was caught during the sampling in autumn 2020: eel, goby, mullet, sand smelt, and herring. In April 2021, six species of fish were present in the catches: eel, European flounder, goby, sand smelt, stickleback, and sandeel. Finally, a number of six fish species was caught in May 2021: eel, European flounder, sand smelt, goby, mullet, and European sprat. Altogether, the nine species caught over both seasons represent four different estuarine guilds: estuarine residents (3), marine juveniles (2), marine seasonal migrants (2) and diadromous migrants (2).

In the constructed salt marsh Perkpolder, located along the Westerschelde, eight fish species were caught during the sampling in autumn 2020. These species were: eel, European flounder, goby, greater pipefish, Nilsson’s pipefish, sea bass, mullet and sand smelt. These species originate from four different estuarine guilds: estuarine residents (4), marine juveniles (2), marine seasonal migrants (1) and diadromous migrants (1).

A difference that was observed between the natural and constructed salt marshes is the function as nursery area. Perkpolder seems to be not developed enough to serve as a nursery ground for all species using Saeftinghe for this purpose. It was assumed this is due to the low-lying character of Perkpolder and the lack of vegetation in the area. Juvenile fish that were caught in Perkpolder are expected to migrate in and out of the area, following the tide. An exception is goby, this species was seen being abundant in tidal pools at low tide. Rammegors seems to largely serve fish the same way Sint-Annaland does.

For goby, a difference in lengths was observed between the natural and constructed marshes. In both constructed marshes, gobies were caught with 6+ cm lengths during the sampling in autumn 2020. This size gobies were not caught in the natural marshes. No explanation could be found for this observation.

Juvenile mullet seems to use the constructed marshes significantly less then they use the natural marshes. A potential explanation could be feeding conditions being less favourable in the younger, constructed marshes. Additional research needs to be done to state this with confidence.

Multiple differences in fish fauna were observed between the spring and autumn sampling in Rammegors. In autumn 2020, mullet and herring were caught, which were not present in spring 2021. In the samplings in spring 2021, European flounder, stickleback and sandeel were caught, that were not caught in the previous sampling. An important difference is the number of gobies being significantly less in spring 2021 compared to autumn 2020. No explanation could be found for this difference. Finally, average lengths of eel that were caught differed between the samplings. In both October 2020 and May 2021, eel were caught up to 65 - 70 cm in length. In April 2021, all eels were smaller than 45 cm. An explanation for these bigger fish being absent cannot be given.

6. Recommendations

This research has shown that fish use the four salt marshes that were studied along the Oosterschelde and Westerschelde. Additional research is recommended, to get a better understanding of the ecological role salt marshes play for the different species of fish. Adding the monitoring of fish use to the monitoring program of projects will contribute in understanding the development of an area. An advice would be to combine more extensive and more frequent sampling of fish with an analyzation of the conditions within specific salt marshes. When the level of vegetation, volume of water at low tide, possible food sources and sediment types in different salt marshes are mapped, a more complete image and understanding of the function salt marshes have for fish could be obtained. Expanding research with the use of transmitters could provide more insight in the function marshes have for certain species, and how these are distributed within the area, as for instance an endangered species as eel.

When the conditions and level of development in a marsh are mapped more thoroughly, this could be used to describe the 'demands' fish have for using a salt marsh. Long term, this could help coastal managers in designing future managed realignment projects, potentially providing pressured fish stocks with new suitable habitat. Understanding which species use the (artificial) salt marshes and for which purpose, which is the result of this study, provides a useful foundation for future research on this subject.

The different questions and recommendations that came forward as a result of this study are:

- Research on the differing conditions in the different salt marshes, by mapping vegetation, inundated area at both high and low tide, sediment types and available food sources.
- Executing more frequent and more complete monitoring of fish using managed realignment projects. An idea would be to monitor new artificial salt marshes from the beginning and maybe do so multiple times a year. This way, knowledge on the development of fish use would be obtained. When monitoring only once a year, recommendation would be to do this at the end of summer or early autumn, as this is the period species using the salt marshes as a nursery ground have just spawned and species using the marsh as a foraging ground as adult sea bass or flounder have not migrated to deeper water yet.
- Equipping fish with transmitters. What is the function of a marsh for certain species and how do they use it? Are they swimming in and out or do they remain in the marsh creeks? Very interesting for this subject would be the eel in Rammegors. This area seems very important to eel, but it would be interesting to know if these fish use the area as their permanent habitat, only feed there or use this as part of their migration.
- For fish using the salt marshes as a foraging ground, what do they eat in the tidal creeks? This could be determined by the examination of stomach contents.

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Appendices

Appendix A: Glossary

Anadromous species: Species living in sea that migrate to spawn in freshwater (Kooiman and Ploegaert 2020).

Catadromous species: Species living in freshwater that migrate to spawn in sea (Kooiman and Ploegaert 2020).

Diadromous species: Species migrating between fresh and salt water (Kooiman and Ploegaert 2020).

Euryhaline: (An aquatic organism) capable of surviving in a wide range of salinities (McCormick et al. 2013).

Eurythermal organism: An organism capable of acclimatizing their physiological processes to a wide range of environmental temperatures over a number of different timescales (Logan and Somero 2010).

Managed realignment: The deliberate process of realigning river, estuary or coastal flood defences (Nunn et al. 2016).

Appendix B: Theoretical framework

B – I : The ecological value of salt marshes

Salt marshes can be defined as an intertidal area with fine sediments that were transported by water, stabilized by vegetation (Boorman 1995). Such a marsh can develop in a place where the inundation time is shorter than the time exposed to air, where enough sediment and seeds are present and where water velocities are low enough for sediment to settle down (Boorman 2003). A salt marsh is a type of marine ecosystem, located in estuaries, that forms the transition from the sea to land (Veiga et al. 2006). They form an intertidal and sheltered ecosystem, characterised by an extensive system of creeks, in which terrestrial, freshwater and marine habitats exists side by side (Koutsogiannopoulou and Wilson 2007).

The big amount of primary production in salt marshes supports the development of first-generation consumers, mostly consisting of benthic organisms as amphipods, shrimps and ragworms (Figure 1), as these organisms profit from the dead organic material and stability of the soil. These organisms form an important source of food for fish, making the salt marsh an interesting feeding ground for a number of fish species.

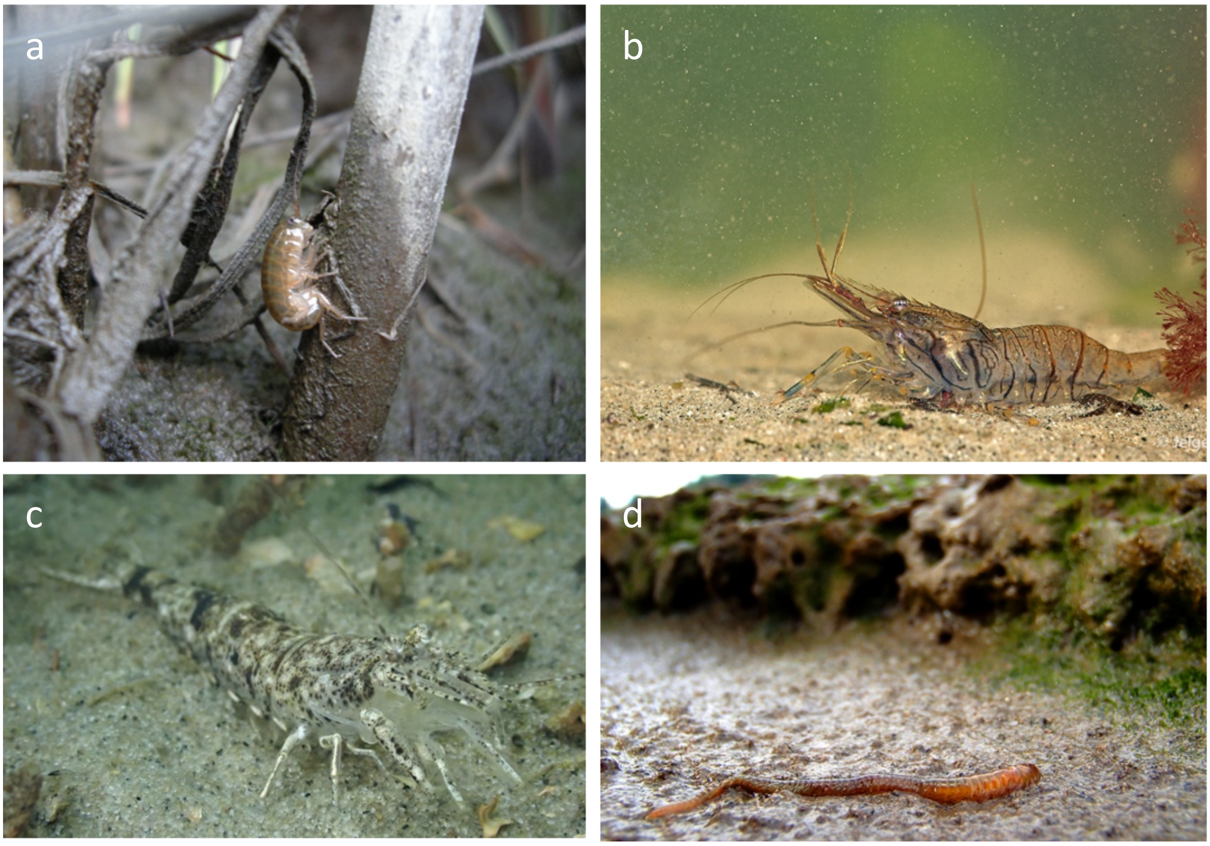

Figure 1. Common benthic animals in a salt marsh. (a) Marine amphipod, Amphipoda (Manayunkia 2017), (b) Common prawn, Palaemon serratus (Herder n.d.), (c) Brown shrimp, Crangon Crangon (Leloux 2019), (d) Ragworm, Nereidae (Van Belzen n.d.)

Salt marsh creeks are under tidal influence and drained during ebbtide. As such, fish are limited to high-tide to move in and feed in the creeks (Green et al. 2009). For fish, this can be quite dangerous, as failure in this migration could cause the fish to die, due to desiccation, bird predation or a shortage of oxygen. However, densities of benthic prey animals (Figure 1) can be so high in these creeks, that moving in during high-tide and moving back out during ebb-tide is a profitable feeding strategy for fish (Wolff et al. 1981).

Salt marshes also are an interesting nursery ground for fish. In previous studies, it was found that tidal creeks where dominated by 0, 1+ and 2+ - group fish. European marsh creeks are dominated by goby (*Pomatoschistus spp*.), mullets (*Mugilidae spec.)*, sea bass (*Dicentrarchus labrax)* and flatfishes (Figure 2) (Hampel et al. 2005, Laffaille et al. 2000a).

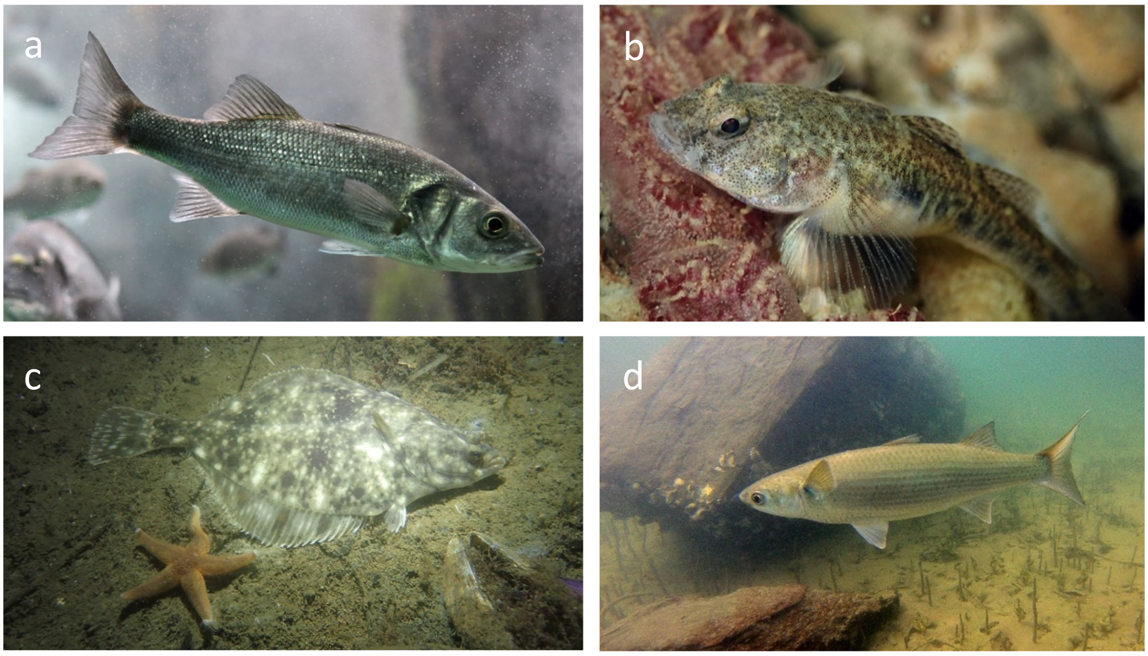

Figure 2. Fish species commonly caught during other studies on fish use of European salt marshes. (a) Sea bass, Dicentrarchus labrax (Citron 2012), (b) Sand goby, Pomatoschistus minutus (Vlierhuis 2016), (c) Flounder, Platichtys flesus, (Baum 2019), (d) Grey mullet, Chelon labrosus (Grace 2015).

For birds, salt marshes are an interesting feeding area as well. Lots of bird species benefit from the benthic organisms living in the sediment, as this forms the core of their diet. Next to that, more fish-eating birds profit from the fishes migrating into the creeks. When fish start migrating out of the creeks, they can end up being trapped in shallow water, forming an easy prey for birds (Wolff et al. 1981). This way, salt marshes help supporting the entire estuarine food web.

B – II: Loss of salt marshes

Salt marshes all over the world are disappearing as result of heavy pressure caused by climate change and anthropogenic activities (Boorman 2003, Lo et al. 2017, Luisetti et al. 2011). Salt marshes are being used for the collection of food by humans for decades. However, with the global rise of agriculture, people started using salt marshes as agricultural ground and for cattle to graze on. To do so, the salt marsh was 'claimed' from the sea. A dike is constructed around the salt marsh, closing it off from the sea and tidal influence. This way, large areas of the world's natural salt marshes have been lost (Boorman 2003, Chmura et al. 2012).

Erosion forms a big problem for the salt marshes that still exist. In salt marshes with established vegetation, soil particles are kept in place, making the salt marsh a rather stable environment. However, disturbance of the marsh edge during extreme weather events can cause an eroding cliff to develop. The edge of the marsh develops into a steep, vertical cliff (Figure 3). A cliff forming the edge of the marsh makes it extra vulnerable for erosion, as the sediment is unprotected and exposed to currents and waves (Koppel et al. 2005). Once a cliff has developed, erosion can happen in a fast pace. The rate of erosion is often increased by human activities. Shipping, dredging and construction of projects like the storm surge barrier can cause sand demand (in Dutch: 'zandhonger') and increased erosion (Adam 2002, Allen 2000). Recovery of the marsh can take a long time, as pioneer plants must regrow in front of the marsh, protecting the cliff from waves and currents (Figure 3a). When water velocities are too high, regrowth of the vegetation is sometimes impossible, causing permanent loss of the salt marsh in that area (Allen 2000).

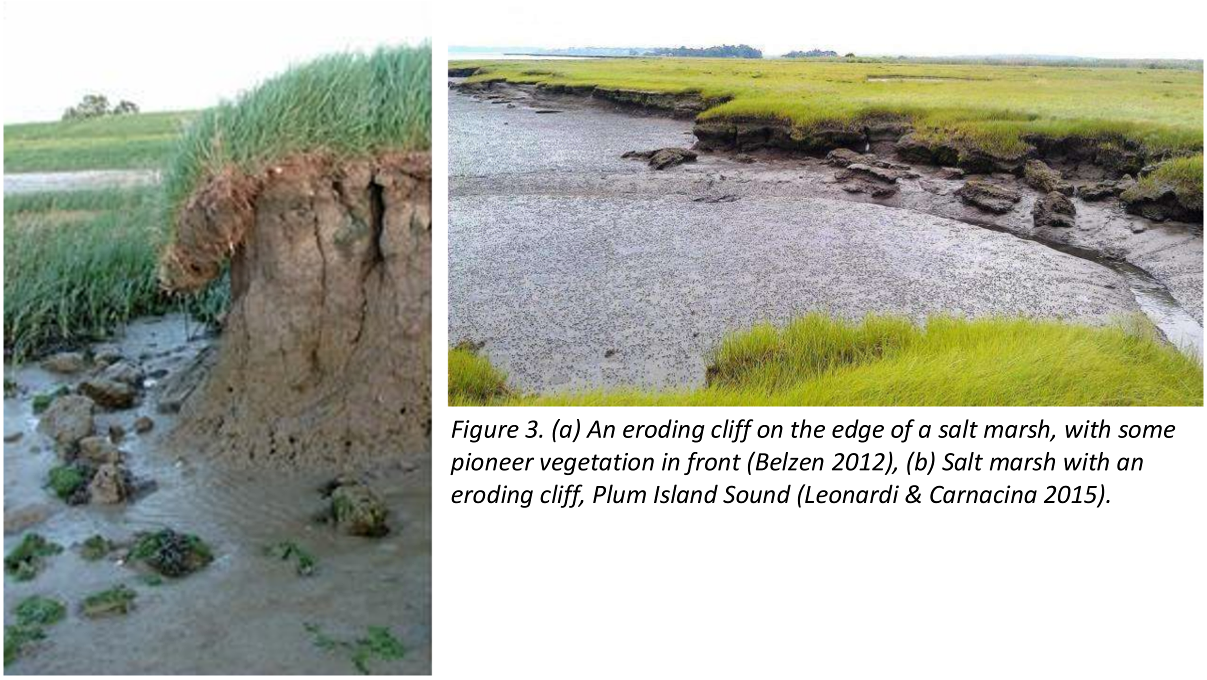

Figure 3. (a) An eroding cliff on the edge of a salt marsh, with some pioneer vegetation in front (Belzen 2012), (b) Salt marsh with an eroding cliff, Plum Island Sound (Leonardi & Carnacina 2015).

The presence of dikes together with sea level rise causes a phenomenon called 'coastal squeeze'. This term is commonly used in the United Kingdom to describe the loss of coastal habitats in front of sea defences (Pontee 2013). Under influence of sea level rise, the seaward edge of salt marshes is eroded. Without the presence of a seawall, a marsh would migrate more inland, as the eroded sediment is deposited on the landward edge of the marsh. This process would continue till a new equilibrium is reached, in which the height of the marsh matches the average sea level (Boorman 2003, Morgan et al. 2009). Sea defences however, prevent this landward migration. As a result, salt marshes are 'squeezed' in a narrowing zone, eventually disappearing (Doody 2013, Pontee 2013).

Not only sea level rise is a problem caused by climate change. With climate change, temperatures increase and weather conditions become more extreme, pressuring salt marshes. The increased global temperature causes changes in salt marsh vegetation. This decreases biodiversity in the marshes. Extreme weather conditions are a problem for salt marshes as well. Longer and heavier periods of drought or storm increase erosion and the loss in vegetation. This all adds to salt marshes disappearing.

Another problem for salt marshes is the increased amount of industry and agriculture, as this increased pollution. Chemicals from industry and agriculture can negatively influence the salt marshes flora and fauna (Boorman 2003). The same applies to oil spills. As shipping and industry increased, oil spills became more common. In smaller estuaries, small oil spills are even reported to happen on a daily basis (Boorman 2003). These oil spills can have devastating effects on flora and fauna in salt marshes.

B – III: Fish guilds

Fish species use salt marshes for different purposes during their life stages, depending on their species-specific ecology. Examples are their lifecycle, habitat preferences and migration strategy. Based on ecological preferences, fish species can be placed in a specific estuarian guild. These guilds can be used to facilitate the analysation of the fish sampling data, describing the ecological role of salt marshes for different species.

In table 1, an overview can be seen of the different estuarian guilds. The common fish species per estuarine fish guild can be found in appendix C. The eventual composition of fish species or guilds found at a specific location within the estuary is influenced by physical and chemical characteristics, which can differ from day to day.

Table 1. Overview of the estuarian guilds (Elliott and Dewailly 1995, Kooiman and Ploegaert 2020).

Abbreviation	Guild	Characteristic
CA	Diadromous migrant species	Species migrating between fresh and salt water. These species use estuaries as a migration route between their spawning and nursery areas and often use the estuary during their juvenile stadium. Within the diadromous species, a distinction can be made between anadromous (migrating from sea to spawn in freshwater) and catadromous (migrating from freshwater to spawn in sea) species.
ER	Estuarine resident species	Species spending their entire life cycle in estuaries. These species often are highly tolerant to fluctuations in salinity.
MJ	Marine juvenile migrant species	Marine species using estuaries as nursery area during their juvenile stadium.
MS	Marine seasonal migrant species	Marine species using estuaries during a specific season, mostly in their adult stadium.
MA	Marine adventitious visitors	Marine species that do not use estuaries for a specific purpose, but irregularly visit.
FW	Freshwater adventitious species	Species living in freshwater, which use the freshwater tidal zone. Depending on their salt tolerance sometimes found in brackish zones.

Appendix C: Fish species per fish guild

Table 2. Common estuarine fish species classified per estuarian guild (De Leeuw and Backx 2001).

Abbreviation	Guild	Species
CA	Diadromous migrant species	Sturgeon, Allis shad, Twaite shad, Eel, Whitefish, Stickleback, River lamprey, Thin-lipped grey mullet, Smelt, Sea lamprey, Salmon, Sea trout
ER	Estuarine resident species	Hooknose, Sandeel, Transparent goby, Big-scale sand-smelt, Houting, Black goby, Seahorse, Sea-snail, Bull-rout, Worm Pipefish, Butterfish, Flounder, Common goby, Sandgoby, Tadpole-fish, Fifteen-spined stickleback, Greater pipefish, Nilsson's pipefish, Broadnosed pipefish, Viviparous blenny
MJ	Marine juvenile migrant species	Sand smelt, Herring, Sea bass, Cod, Dab, Whiting, Red seabream, Plaice, Pollack, Turbot, Brill, Rose fish, Sole, Black seabream, Tub gurnard, Pouting
MS	Marine seasonal migrant species	Garfish, Thick-lipped grey mullet, Five-bearded rockling, Lumpsucker, Stingray, Anchovy, Grey gurnard, Golden grey mullet, Pilchard, European sprat
MA	Marine adventitious visitors	Wolffish, Greater sandeel, Raitt's sandeel, Meagre, Scaldfish, Red gurnard, Triggerfish, Bogue, Ray's bream, Solenette, Dragonet, reticulated dragonet, Rudderfish, Basking shark, Northern rockling, Conger, Goldsinny wrasse, Sea scorpion, Snake pipefish, Three-bearded rockling, Tope, Long rough dab, Halibut, Ballan wrasse, Porbeagle, Opah, Montagu's seasnail, Anglerfish, Pearlsides, Haddock, Hake, Blue whiting, Lemon sole, Sunfish, Ling, Red mullet, Starry smooth-hound, Smooth hound, Coalfish, Lozano's goby, Painted goby, Skate, thornback ray, Mackerel, Atlantic saury, Lesser spotted dogfish, Bull Huss, Norway redfish, Sand sole, Spurdog, Angelshark, Pompano, Greater weever, Scad, Poor cod, Topknot, John dory
FW	Freshwater adventitious species	Bream, Bleak, Asp, Barbel, White bream, Goldfish, Gibel carp, Crucian carp, Nose carp, Bullhead, Grass carp, Carp, Pike, Gudgeon, Ruffe, Pumpkinseed, Chub, Ide, Dace, Tubenosed goby, Rainbow trout, Perch, Topmouth gudgeon, Ten-spined stickleback, Roach, Brown trout, Rudd, Wels, Pike perch, Tench, Vimba

Appendix D: Sampling dates and locations

Table 3. Sampling dates and locations.

Date	Location	Activity
23/09/2020	Perkpolder	Placing fyke nets and fishing with the seine net
24/09/2020	Perkpolder	Retrieving fyke nets and processing potential catches
01/10/2020	Sint-Annaland	Placing fyke nets and fishing with the seine net
02/10/2020	Sint-Annaland	Retrieving fyke nets and processing potential catches
05/10/2020	Rammegors	Placing fyke nets and fishing with the seine net
06/10/2020	Rammegors	Retrieving fyke nets and processing potential catches
12/10/2020	Saeftinghe	Placing fyke nets and fishing with the seine net
13/10/2020	Saeftinghe	Retrieving fyke nets and processing potential catches
19/04/2021	Rammegors	Placing fyke nets and fishing with the seine net
20/04/2021	Rammegors	Retrieving fyke nets and processing potential catches
17/05/2021	Rammegors	Placing fyke nets and fishing with the seine net
18/05/2021	Rammegors	Retrieving fyke nets and processing potential catches
14/06/2021***	Rammegors	Placing fyke nets and fishing with the seine net
15/06/2021	Rammegors	Retrieving fyke nets and processing potential catches

*** This final sampling is not included in this study, as sampling will be executed after the graduation period

Appendix E: Photos of the catches

Figure 4. European flounder caught in a fyke net in Perkpolder in September 2020.

Figure 5. Sea bass (Dicentrarchus labrax) caught in a fyke net in Perkpolder in September 2020.

Figure 6. Sea bass (Dicentrarchus labrax) (Top) and mullet (Mugilidae spec.) (Bottom) caught in the seine net in Sint-Annaland in October 2020.

Figure 7. Eel (Anguilla anguilla) caught in a fyke net in Rammegors in October 2020.

*Figure 8. Juvenile European sprat (Sprattus sprattus)**** caught in the seine net in Rammegors in May 2020.*

Figure 9. Eel (Anguilla anguilla) caught in a fyke net in Rammegors in May 2020.

**** Based on determination in the field, further determination will provide a definitive species.

Figure 10. White bream (Blicca bjoerkna) caught in a fyke net in Het Verdronken Land van Saeftinghe in October 2020.

Figure 11. European flounder (Platichthys flesus) (Top), sea bass (Dicentrarchus labrax) (Middle) and Perch (Perca fluviatilis) (Bottom) caught in the same fyke net in Het Verdronken Land van Saeftinghe in October 2020.