Analysing the distribution pattern and group composition of harbour porpoises within the Eastern Scheldt

Minor Research Project

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Abstract

Harbour porpoises are the most common cetacean species living in the coastal waters of the Netherlands. Besides the population in the North Sea, harbour porpoises also occur within the Eastern Scheldt. The Eastern Scheldt is a semi-enclosed tidal bay in the south-western part of the Netherlands. The inflow of freshwater stopped and the tide was muted due to the storm surge barrier and dams that were built after the flood in 1953. In addition, due to these protecting measures, once entered, harbour porpoises are limited to migrate back into the North Sea, which resulted in a year round presence in the Eastern Scheldt with its unique habitat

However, little is known about fine-scale population and group structure of these harbour porpoises. The lack of information is especially concerning because their distribution is structured at a small spatial scale, which can easily be disturbed. Therefore, this research will focus on *"How do harbour porpoises distribute through the Eastern Scheldt and is there a difference in this distribution pattern between individuals?"* and "*What is the group structure and size that occur in the population harbour porpoises within the Eastern Scheldt?".*

Annual counts, to estimate the minimum population harbour porpoises, were carried out by Rugvin Foundation since 2009. During the annual count, approximately 8 boats sailed in line over the Eastern Scheldt and noted each harbour porpoise that was observed. Besides that, boat surveys to observe harbour porpoises were carried out since 2015. During these surveys GPS-coordinates and group size were noted and photo-identification photos were taken from the observed harbour porpoises. The identified individuals, due to the linkage of GPS-coordinates and photo-identification data, were plotted on a map of the Eastern Scheldt. This map was distributed in 4 different zones to analyse the distribution pattern of the harbour porpoises. In addition, group structure was analysed using the combined data of the group size and photo-identified individuals.

During the annual count on 1ste of September, 48 harbour porpoises were observed of which 3 were calves. This indicates an increase of the harbour porpoise population since 2013. In addition, most of the harbour porpoises were observed West of the Zeelandbrug in zone 1 and 3. The preference of this area can indicate higher prey abundance, which can be caused by the tidal streams that have a larger influence on these zones.

The distribution patterns of harbour porpoises differ between the individuals. This can indicate the presence of dominance that results in hierarchy due to a relative small habitat. However, this difference can also be the result of differences in age and sex. In addition, harbour porpoises spend significantly more time in a certain area, which can be caused by prey availability or avoiding behaviour of a dominant individual.

At last, harbour porpoises were observed more in close proximity of each other than solitary. The average group size was 2.96± individuals for groups with an identified individual and 2.34± individuals of all the groups that were spotted during the surveys. This group size can be caused by the predation risks of grey seals or the attraction of individuals to harbour porpoises that are feeding. Besides that, individuals tend to have a preference for the group composition, associating with some individuals more than with others. This can be the result of dominance, sex or age of the harbour porpoise.

Laymen's summary

Antropogene factoren hebben al jaren lang een negatieve invloed op walvisachtige en deze invloeden worden steeds groter. De meest bekende factoren zijn geluidsvervuiling, verstrikking in visnetten en overbevissing. Echter heeft klimaat verandering ook een grote invloed op walvisachtige en met name op soorten met een habitat dichtbij de kust. Door het bouwen van stormvloedkeringen, dammen en sluizen veranderden of verdwijnen delen van het habitat die belangrijke functie voor walvisachtige kunnen hebben.

De stormvloedkering in de Oosterschelde is een van deze maatregel die invloed heeft gehad op de meest voorkomende walvisachtige soort in Nederland, de bruinvis. Het is echter voor vele onbekend dat bruinvissen de meest voorkomende walvisachtige in Nederlandse wateren zijn en zelfs het hele jaar door aanwezig zijn in de Oosterschelde. Daarnaast is weinig bekend over verspreiding en groepsstructuur van deze in de soort, wat de kwetsbaarheid van deze soort vergroot.

Daarom richt deze studie zich op het in kaart brengen van het verspreidingspatroon en de groepsstructuur van de bruinvis populatie in de Oosterschelde. Doormiddel van jaarlijkse tellingen en bootobservaties in combinatie met foto-identificatie van individuele bruinvissen zijn de volgende hoofdvragen onderzocht *"Hoe verspreiden bruinvissen zich door de Oosterschelde en is er een verschil in deze verspreidingspatronen tussen individuen?"* en *"Wat is de groepsstructuur en groepsgrootte van de populatie bruinvissen in de Oosterschelde?".*

Tijdens de jaarlijkse telling op 1 September 2018 zijn er 48 bruinvissen gespot, waarvan 3 kalfjes. In vergelijking met eerdere tellingen is de populatie bruinvissen sinds 2013 toegenomen. Daarnaast werden de meeste bruinvissen gedurende deze tellingen en de bootobservaties waargenomen ten westen van de Zeelandbrug. De verspreiding van bruinvissen word voornamelijk beïnvloed door de aanwezigheid van voedsel.

Echter verschillen de verspreidingspatronen tussen de bruinvissen en hebben niet alle bruinvissen dezelfde voorkeur voor een bepaald gebied waarin ze vaak voorkomen. Dit verschil is waarschijnlijk veroorzaakt door het verschil in geslacht of de leeftijd. Vrouwtjes zijn namelijk in verschillende jaren voornamelijk binnen 1 gebied geobserveerd.

Daarnaast komen bruinvissen in de Oosterschelde vaker in groepen voor dan alleen. De verwachting was echter dat de bruinvissen voornamelijk solitair geobserveerd zouden worden zoals in de Noordzee, aangezien de bruinvissen in de Oosterschelde voornamelijk afkomstig zijn van de bruinvis populatie in de Noordzee. Dit verschil kan veroorzaakt worden door de grijze zeehonden die in een grotere dichtheid aanwezig zijn in de Oosterschelde. Grijze zeehonden jagen namelijk op bruinvissen en een grotere groep kan dan bescherming bieden voor de bruinvis.

De groepsstructuur verschilt daarnaast ook tussen bruinvissen waarbij sommige bruinvissen een voorkeur lijken te hebben om vaker met bepaalde individuen in een groep samen voor te komen. Deze inzichten in zowel de groepsstructuur, grootte en verspreiding van bruinvissen kan uiteindelijk leiden tot beheermaatregelen en restricties waardoor de soort beter beschermd wordt en een gezonde populatie kan ontstaan.

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1. Introduction

One of the smallest cetaceans in the world is the harbour porpoise (*Phocoena phocoena)* (figure 1.1), which is found in the Northern Hemisphere in cold temperate to sub-polar waters (Gaskin 1992; Read 1999). They occur usually in continental shelf waters, which spans estuaries, shallow bays, rivers and tidal channels that are less than 200 m in depth, by which their habitat is largely limited (Bjørge & Tolley 2009). However, some harbour porpoises travel occasionally in deeper offshore waters (Nielsen et al. 2018).

Little is known about the group size and group structure of harbour porpoises and estimations of group sizes differ widely between the populations around the world. The average group size in the North Sea was estimated at 1.14; in contrast with an average of 4.60 in Indre Sognefjord in Norway (Geelhoed et al. 2011; Graner 2003). In British Columbia harbour porpoises occurred typically in groups between 1 to 4 individuals but groups of over 200 individuals were reported as well (Crossman 2012; Hall 2004; 2011).

Figure 1.1 Harbour porpoise (*Phocoena phocoena)* Source: Marprolife

Overall, the global abundance of the harbour porpoises is estimated approximately 700,000 individuals (Angliss & Allen 2009; Bjørge & Tolley 2009; Carretta et al. 2011; Read 1999; Waring et al. 2009). The abundance of the harbour porpoise within the European Atlantic was in 2005 estimated at 385,600 of which approximately 286,500 were estimated in the North Sea (Hammond et al. 2002). However, Camphuysen & Siemensma (2011) hypothesised that two populations exist within the North Sea, but evidence is weak and boundaries are not clear (Camphuysen & Siemensma 2011; Smeenk 2012). In the south-western part of the North Sea, around the coastal waters of the Netherlands, an estimation of 150,000 individuals is given. This number increased within the last decade, which is the result of migration individuals from the north-western North Sea. This migration could be caused by the depletion of the food resources in the Scottish waters (Camphuysen & Siemensma 2011).

In the Dutch waters and in the Dutch Continental Shelf the recent population was estimated on approximately 30,000 animals in autumn with a density peak of 86,000 animals in March (Geelhoed et al. 2013; Scheidat et al. 2012). Besides that, a second population of harbour porpoises occur in the Eastern Scheldt, a tidal estuary in the province Zeeland in the south western part of the Netherlands (Jansen et al. 2013). Therefore, the harbour porpoise is the most common species of cetaceans that occur in Dutch waters.

Several anthropogenic factors influence the harbour population in the Netherlands negatively. The biggest threat to harbour porpoises are the incidental catches in fishing gear, especially in gill nets (Birkun 2002). Other threats that negatively effect the harbour porpoise population are depletion of the prey due to overfishing, vessel traffic and noise (Birkun 2002; Donovan & Bjørge 1995). Besides that, harbour porpoises will also be exposed to pollution from coastal sources because their near shore distribution. However, not all threats are caused by anthropogenic factors but also by predation by grey seals (*Halichoerus grypus*), which was only discovered recently (Bouveroux et al. 2014; Haelters et al. 2012; McConnell et al. 1999).

The predation of grey seals on harbour porpoises is a cause of death within the Eastern Scheldt (Podt & IJsseldijk 2017). However, not all attacks on harbour porpoises lead to direct mortality, also non-lethal attacks occur (Podt & IJsseldijk 2017). This survival allows a harbour porpoise to learn from the attack so they can adapt their behaviour to prevent a new attack of a grey seal (Leopold et al. 2014). However, this predation threat will impose a significant pressure on the survival rate of the harbour porpoise within the Eastern Scheldt (Podt & IJsseldijk 2017).

In addition on the anthropogenic factors, the consequences of climate changes will impact the harbour porpoise negatively as well. The sea level rise has caused more and higher storm surge floods and coastal inundations, so coastal protection measures were necessary (Hallegatte 2012; Meehl et al. 2005; Rahmstorf 2007). These protection measures can lead to habitat degradation, fragmentation and even habitat loss, which could have consequences for small populations of harbour porpoises due to loss of genetic diversity and the change effects (Jansen et al. 2013). The storm surge barrier in the Eastern Scheldt is such a measure that negatively influences the harbour porpoise population in several ways.

The storm surge barrier in the Eastern Scheldt is a measure that protects the province Zeeland from floods during storms. These flood protection measures changed not only the habitat but also the accessibility of the Eastern Scheldt. Harbour porpoises were used to be common within the area before and during World War II, when the storm surge barrier was not built yet (van Deinse 1945; Viergever 1955). However, there were almost no harbour porpoise observed within the Eastern Scheldt after those barriers were build, until about 10 years ago (Zanderink & Osinga 2010). The harbour porpoises have not only become more abundant but were also present year round. In addition, even mother-calf pairs were observed during the annual surveys that were carried out since 2009 by Rugvin Foundation (Osinga & Zanderink 2015; Rugvin 2015; Zanderink & Osinga 2010). However, the calf production only cannot explain the increasing population within the Eastern Scheldt, so regular influx from animals from the North Sea population must have occurred (figure 1.2) (Jansen et al. 2013).

The harbour porpoises, however, are limited to migrate back into the North Sea because the storm surge barrier is forming a potential impediment, presumably due to high frequent noise whilst tidal currents. It is thought that the Eastern Scheldt works as an ecological trap (van Dam et al. 2017). Another problem the harbour porpoise in the Eastern Scheldt faces is the relatively low fish-biomass in the Eastern Scheldt, which is showing a decreasing trend in contrast with the North Sea (van Dam et al. 2017; Tulp 2015). Between 2010 and 2017 a minimum of 101 individuals stranded within the Eastern Scheldt (Walvistrandingen.nl 2018). Zorgno (2014) suggested that the main reason of harbour porpoise stranding within the Eastern Scheldt and the Voordelta was starvation and emaciation. However, Dam et al. (2017) showed that the harbour porpoises stranded between 2006 and 2015 in the Eastern Scheldt did not differ in terms of their average nutritional condition in comparison with those that stranded along the North Sea shoreline. This would indicate that harbour porpoises in the Eastern Scheldt have adapted their foraging strategies to the prey that occur in the Eastern Scheldt. Some of those prey species are even of better quality, with a higher overall energy density, than the prey species in the North Sea (van Dam et al. 2017; Tulp 2015).

This presumed limited food resource can also be the main reason of population fluctuation observed within the Eastern Scheldt (figure 1.2). However, the reliability of the annual counts and stranding needs to be discussed. The annual count is influenced by the weather and wind conditions. Harbour porpoises are more easily to observe with 0 Beaufort wind than 3 Beaufort wind due to the waves (Rugvin 2018). In addition, not all counts were executed with the same number of boats. All those factors impact the reliability of those counts and the count shows the absolute minimum of the harbour porpoise population within the Eastern Scheldt.

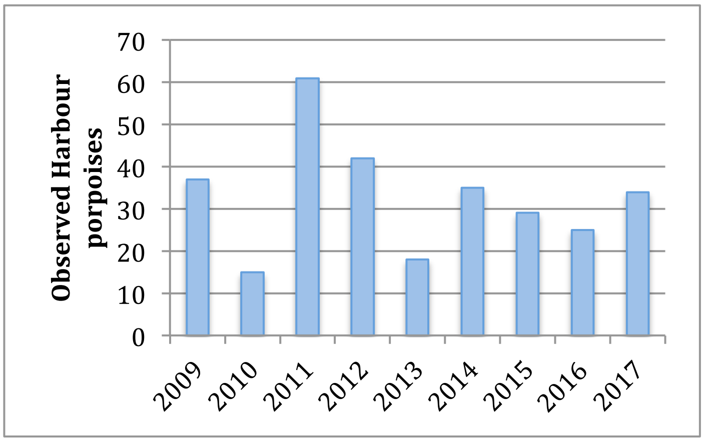

Figure 1.2 Observed individuals within the Eastern Scheldt during the annual Harbour porpoise count executed by Rugvin Foundation.

However, little is known about fine-scale population and group structure of these harbour porpoises. The lack of information is especially concerning because their distribution is structured at a small spatial scale, which can easily be disturbed. Therefore it is important to analyse the habitat, distribution and group structure of harbour porpoises. Therefore, this research will focus on *"How do harbour porpoises distribute through the Eastern Scheldt and is there a difference in this distribution pattern between individuals?"*

Harbour porpoises are small cetaceans and lose relatively high amounts of body heat to their environment due to the large surface-area-to volume ratio, which forced them to maintain high feeding rates (van Dam et al. 2017; Kastelein et al. 1998). In addition, harbour porpoises need to feed 10% of their own body mass each day to survive and their metabolic rates are 2-3 times higher than terrestrial animals, which have the same weight (Elliser et al. 2017; Kanwisher & Ridgway 1983; Kastelein et al. 1998). Due to these factors, harbour porpoises need to feed regularly and they only can survive a short period of time, less than three days, without feeding (MacLeod et al. 2007). Therefore it is expected that harbour porpoises are found throughout the entire Eastern Scheldt and that individuals do not have a preference for a certain area due to the distribution of their prey. In addition, it is expected that harbour porpoises do not avoid a certain feeding area in the Eastern Scheldt due to the presence of grey seals because these areas are too important for feeding. Mothers with calves will have a different distribution pattern and they will stay more in a certain area than harbour porpoises without a calf.

At last, as mentioned earlier, little is know about the group structure and size of harbour porpoises. This leaded to the second focus of this research "*What is the group structure and size of the population harbour porpoises that occur in the Eastern Scheldt?".* It is most likely that the harbour porpoises that occur within the Eastern Scheldt originate from the population harbour porpoises in the North Sea or were born within the Eastern Scheldt. The average group size of the population in the North Sea is 1.14, meaning that harbour porpoises were spotted most of the time solitary (Geelhoed et al. 2011). This leads to the hypothesis that harbour porpoises live most of the times solitary within the Eastern Scheldt.

Little is known about group structure in harbour porpoises and whether harbour porpoises have a preference for certain individuals. The group structure of cetaceans differs a lot between species, but also between populations. Spinner dolphins (*Stenella longirostris*) live in large cohesive groups and these groups change little over time (Karczmarski et al. 2005). In contrast, humpback dolphins (*Sousa chinensis)* in South Africa are not consistent in group size and membership and groups are generally short lasting (Karczmarski 1999; Karczmarski et al. 1999ab). However, the population in Mozambique lives in more stable groups (Guissamulo & Cockcroft 2004).

To analysing distribution patterns, site fidelity, population size and group structure, photo-identification of naturally marked will be used (Irvine et al. 1982; Scott et al. 1990). These natural marks are unique for each individual and recognizable over time (Würsig & Jefferson 1990). Although the photo-identification of harbour porpoises is used only recently because it was thought that they were to small and their dorsal fin was not unique enough (Bakkers & Tuhuteru 2016; Elliser et al. 2017).

2. Methods

2.1 Study area

The Eastern Scheldt is a nature reserve that is located in the province Zeeland in the southwester part of the Netherlands. The Eastern Scheldt is a very diverse nature reserve with salt marshes, mudflats, shallow water and maximum water depths of 48 meters. Besides that, it is a National Park of 35,000 ha and was appointed in 2010 as Natura 2000 area.

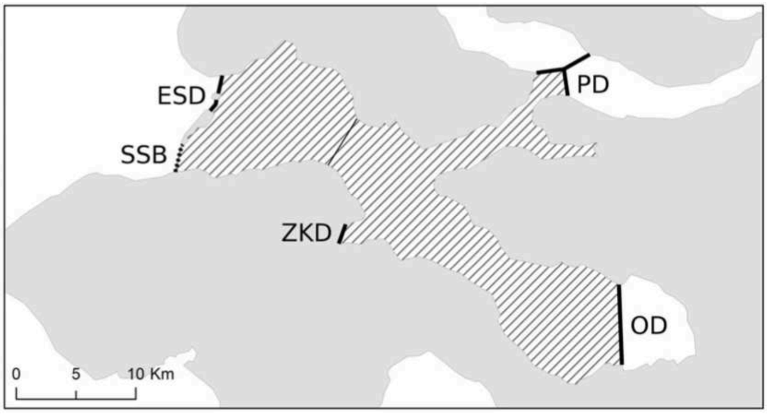

Figure 2.1 The Eastern Scheldt in the southwester part of the Netherlands. Indicated are the Storm Surge Barrier (SSB), Eastern Scheldt Dam (ESD), Philipsdam (PD), Oesterdam (OD) and Zandkreekdam (ZKD). Source (Jansen et al. 2013)

The Eastern Scheldt was part of the former estuary of the river Scheldt and had an open connection to the sea. However, several storm surge constructions and dams were built in the Netherlands after a flood in 1953 were several dyke breaches occurred. Between 1977 and 1987 two large auxiliary compartment dams were built which isolated the estuary from an input of freshwater from the rivers Rhine and Scheldt (figure 2.1) (Stichting deltawerken 2009). This led to a higher salinity and lower nutrient condition within the Eastern Scheldt (Nienhuis & Smaal 1994). Besides that, a storm surge barrier with gates was built between 1979 and 1986 at the entrance of the Eastern Scheldt (figure 2.1). These gates ensure the safeguard of the tidal ecosystem and reduce the risk flooding as well (Nienhuis & Smaal 1994; Stichting deltawerken 2009)

2.2 Fieldwork

My fieldwork was carried out by boat surveys from May until September 2018. When boat surveys were carried out the wind speed did not exceed 3 Beaufort and the visibility was equal or more than 1 km. Each boat survey departed from the port of Kats and the direction and route of the boat survey depended on tidal state, wind- and current direction and weather conditions. At the beginning and end of each boat survey a survey form (Appendix I) was filled in, where weather conditions and time were noted. If the weather changed during the boat survey this was noted as well.

When harbour porpoises were encountered the encounter data sheet (Appendix II) was filled in. The start and end time, GPS location of each encounter, number of individuals, behaviour (foraging, travelling or resting) and weather conditions were noted. Besides that, if possible pictures were taken from the flank and dorsal fin. If seals were encountered during a boat survey, GPS coordinates and the number of individuals were noted on the encounter form. Besides that, if possible the species, common or grey seal, was noted on the encounter form as well.

During the annual count on September 1st 2018, 8 boats were used to sail in line throughout the Eastern Scheldt (Appendix III) to estimate the minimal population size of harbour porpoises. The distances between the boats varied between 650 and 400 meters, depending on the width of the Eastern Scheldt. Each boat contained a minimum of 3 observers, where observer 1 observed the area of 0 to 90°, observer 2 the area of 270 to 0° and observer 3 the area of 270 to 90° compared to the sailing route of the boat. The GPS coordinates were noted every 30 minutes and when a harbour porpoise was encountered time, GPS coordinates, distance from the boat, swimming direction, group size and life phase were noted.

2.3 Photo-identification

Rugvin Foundation took photo-identification pictures on annual base from 2015 and from these photos a photo-identification catalogue was set up. Besides that, opportunistic photos were taken as well between 2007 and 2018 and those pictures were send to Rugvin Foundation. Harbour porpoises were identified due to the shape of their dorsal fin, scars and pigment on their front and back flank (figure 2.2). This catalogue consists of a left and right side of the harbour porpoise and consists of 47 identified individuals. Pictures taken during the boat surveys were compared to the catalogue.

Only opportunistic photos were taken of individuals for photo-identification during the annual count, because the boats could not follow an individual harbour porpoise but had to stay in line with other boats.

However, it needs to be taken into account that not all individuals are equally approachable. Some individuals avoid the boat of which photos were taken and others do not seem to be disturbed by the presence of the boat and even approach the boat. In addition, some individuals are more easy to recognise due to their marks and scars on their body and dorsal fin (Elliser et al. 2017; Hammond 1986; Würsig & Jefferson 1990). Figure 2.2 shows two different individuals from the catalogue, one that is very recognizable due to its scars and the other is more difficult to recognize due to the lack of scars. The likeability of photo-identification is therefore depending on the personality of, and marks on the harbour porpoise. This can influence the results, because only the easy approachable and recognizable individuals were more likely to be included within the analysis.

Figure 2.2 Individual 8 (upper 2 pictures) and individual 5 (lower 2 pictures). Individual 8 has a lot of scars on its dorsal fin and flanks so it is easy to recognise even with pictures of lower quality. Individual 5 does not have these easy recognizable scars and the pictures need to be of high quality to recognize this individual.

2.4 Data analyses

Distribution pattern

All data sheets from the surveys from 3 June 2015 until 31 August 2018 were analysed and the GPS coordinates of the encounters were converted from Degrees"Minutes"Secondes into Degrees"Secondes so the data could be plotted into a geographical map of the study area using the Geographic Information System (QGIS). All the data collected during the surveys and the annual count were plotted into the study area map to provide an overview of were the harbour porpoises occurred within the Eastern Scheldt.

Data of the encounter sheets were combined with the photo-identification catalogue. The opportunistic photos that were provided between 3 August 2007 and 31 August 2018 and contained GPS coordinates were analysed as well. Due to the settings of the taken photos during the surveys it was possible to link the time the picture was taken to an encounter sheet. When the harbour porpoise could be identified with the Photo-ID catalogue, a data point, unique for each individual, was plotted with QGIS. This combined data of the GPS coordinates and the ID of the individuals was used to analyse the distribution pattern of the harbour porpoise on individual bases and the differences of those distribution patterns between individuals.

The Eastern Scheldt was divided into 4 zones of approximately the same size during high tide, between 5.000 and 6.000 ha (figure 2.3). The presence of sandbanks and depth were not taken into account, because it is assumed that harbour porpoises could be using these areas during high tide. Besides that, these approximately same size zones made it possible to analyse the differences in presence of harbour porpoises between each zone.

These zones were also used to analyse the distribution patters per individual and if there was a difference in distribution patterns between individuals. Besides that, the 4 different zones were also used to analyse the zone preference of the harbour porpoises that were observed during the annual count.

Figure 2.3 The Eastern Scheldt divided in 4 different zones

However, it was not possible to analyse the photo-identification data of harbour porpoise occurrences in the 4 different zones between years (2015 to 2018). Due to the boat capacity in 2015 and 2016, surveys only could be conducted near the harbour of Burghsluis. The surveys in 2017 and 2018 were carried out from a different boat, which could be used to study the entire Eastern Scheldt.

Group composition

A group was defined within this research as "*the number individuals that were present near the boat during an encounter*". During this estimation all individuals were counted and no distinction was made between individuals that performed a different behaviour, which could influence the group size. However, it needs to be taken into account that the group that occur near the boat during an encounter is very dynamic. It is likely that individuals leave and appear during an encounter and therefore the best estimated group size on the encounter sheet was used to determine the average group size. In addition, the group size of a group individuals where photo-ID pictures were taken, was more stable because it was possible to make photo-ID photos, which indicates that the group stayed together for a longer period of time.

Groups with the presence of a calf were not used to estimate the average group size of all surveys. Because the presence of a calf will influence and in most times increase the size of the group. In addition, the average group size during foraging and travelling was estimated as well. This group size was also estimated with surveys where calves were not present. However, to estimate the difference, average group size of groups with the presence of a calf was estimated as well.

As mentioned earlier, the encounter sheet data were linked to the individuals due to similarity of time that the picture was taken and the time on the encounter sheet. This showed whether individuals were observed solitary or in a group during an encounter. Besides that, this linked data showed which identified individuals were present in the group during an encounter. This ensured the number of times an individual was observed solitary or in a group was estimated. At last, it was analysed with which individuals the identified harbour porpoise was present in the group and how many times these combinations occurred.

2.5 Statistical analyses

The data of all surveys and photo-ID from 2007 to 2018 were used to analyse the data statistically. Individuals that were identified 3 times or more and observed with 6 months apart from each other were used to analyse the data statistically. These 6 months apart were necessary because this assured that the individual, when originated from the North Sea, adapted to the conditions within the Eastern Scheldt. This leaded to 24 individuals in total that were used to analyse the distribution pattern and group size statistically. All statistical analysis were carried out by SPSS 22.0.

Annual count

The plotted data provided the number of individuals that were observed in a certain zone in each year from the annual count in the years 2013 to 2018. A One Way Anova was carried out to analyse whether individuals were observed more in a certain zone.

Distribution pattern of the 24 individuals

To analyse whether individual harbour porpoises occurred more often in a certain zone data of the photo-identified harbour porpoise was converted into ordinal data. Per individual the number of sightings within a zone were converted to a percentage of the total number of sightings of that individual. Afterwards data was transformed into 4 equal ordinal categories (table 2.1) and with this data a Friedman test was carried out. A Wilcoxon test was carried out to analyse which zones different significantly from each other.

Table 2.1 The 4 ordinal categories used in the Friedman test

0-25%	**1 Very few sightings**
>25-50%	**2 Few sightings**
>50-75%	**3 Many sightings**
>75-100%	**4 A lot of sightings**

Besides that, a Chi-Square cross tabulation test was carried out to analyse whether the differences of zone preferences was caused by the different individuals. The number of sightings per zone per individual were used as the weighting variable within this analyses. The Fisher's exact test was used within this test because 94.8% of the values had a lower expected value of 5.

Group composition

The data of the number of times that individuals were spotted in a group or solitary were not normally distributed. Besides that, 7 individuals were only seen in groups and not solitary, therefore a log (x+1) transformation was performed instead of log transformation. After this transformation, a paired samples T-Test was performed on the 24 individuals (n=24).

Besides that, a Chi-Square cross tabulation test was carried out to analyse whether the individual caused the differences if an individual was observed in a group or solitary. The number of sightings in a group or solitary per individual was used as the weighting variable within this analysis. The Fisher's exact test was used within this test because 85.4% of the values had a lower expected value of 5

Descriptive statistics were used to analyse if the individuals preferred certain individuals to occur with in a group. Within this group structure analyses only identified individuals were used.

3. Results

3.1 Photo-identification catalogue

The photo identification catalogue now consists of 57 identified individuals, of which new 10 individuals were identified in the field season of 2018. Within the field season of 2018, 28 individuals that were already identified were spotted again, which lead to a total of 38 individuals that occur in the photo identification catalogue.

3.2 Annual count

During the annual count on 1 September 2018, 48 harbour porpoises were counted of which 3 were calves. The average group size during the annual count of 2018 was 1.41± individuals per observation. In 67.7% of the times a harbour porpoise was observed solitary, in 23.5% of the time in a group of 2 and 8.8% of the time in a group of 3 individuals. Figure 3.1 shows the location and group size of the harbour porpoises that were spotted within the Eastern Scheldt

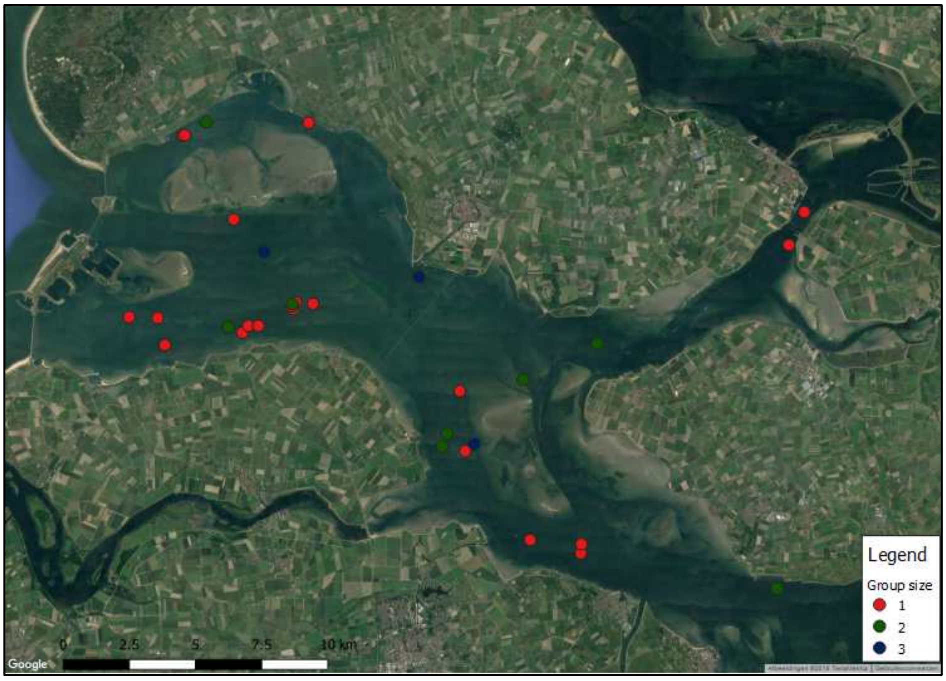

Figure 3.1 Overview of the observed harbour porpoises during the annual count of Rugvin Foundation on 1 September 2018. In total 48 harbour porpoises were counted of which 3 were calves.

There is no significant difference between the zones in the number of harbour porpoises that were observed during the annual counts of 2013 to 2018 (N=6; F=2.92; p>0.05) (Table 3.1). However, most individuals were spotted in zone 1 and 3 in the western part of the Eastern Scheldt (figure 3.2)

Table 3.1 Mean and standard deviation of the 4 zones of the One Way Anova

	Mean	Std. Dev.
Zone 1	9.33	1.751
Zone 2	5.67	4.926
Zone 3	10.83	3.656
Zone 4	5.50	4.231

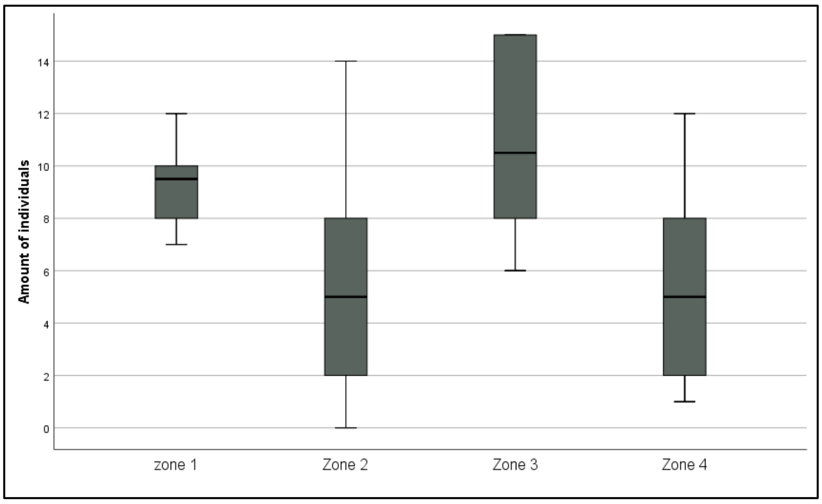

Figure 3.2 The average number of individuals that were spotted in each zone during the annual counts of 2013 to 2018

3.3 Distribution within the Eastern Scheldt

Overall, individual harbour porpoises spend significantly more time in a certain zone compared to the other zones P(N=24; df=3; χ^2=45.0>12.8)=α<0.005. Overall, harbour porpoises were observed significantly more in zone 1 compared to the other 3 zones (p<0.005)(figure 3.3 & figure 3.4). Only individual 28 and 35 were not observed within zone 1, both individuals were only observed in the eastern zones (2 & 4) within the Eastern Scheldt.

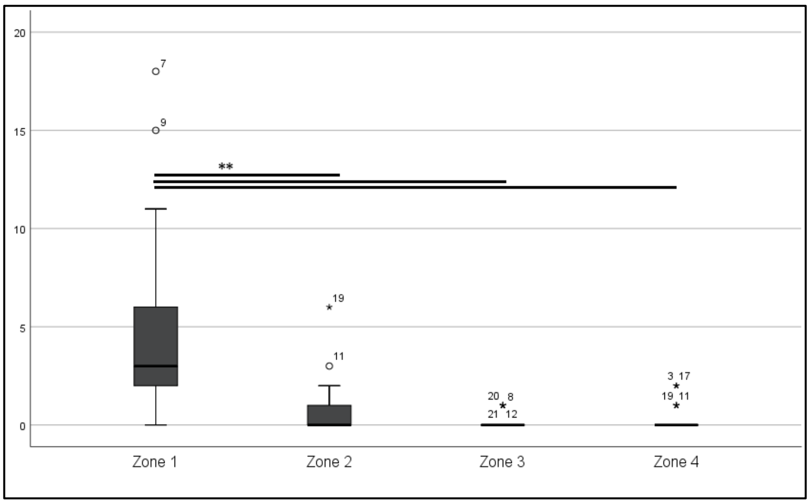

Figure 3.3 The average number of times the individuals was observed within a zone

In addition, the zone preference of harbour porpoises is significantly different between the individuals P(N=142; df=69; χ^2=108.4>104.2)=α<0.005. More than half of the identified individuals were only observed in zone 1 and only individual 9 was observed in all the 4 zones (figure 3.4 & figure 3.5). In addition, only 4 individuals were observed in zone 3. Besides that, as shown in figure 3.4, females tend to prefer a certain zone or area within the Eastern Scheldt.

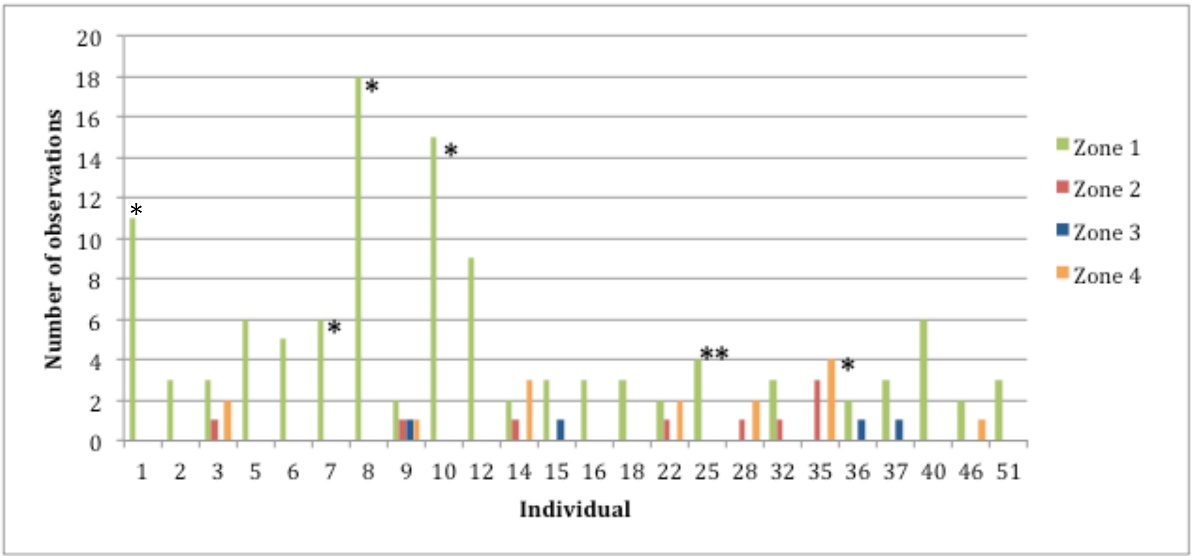

Figure 3.4 The number of observation of the identified individual per zone. * Indicates female individuals ** indicate the offspring of individual 10

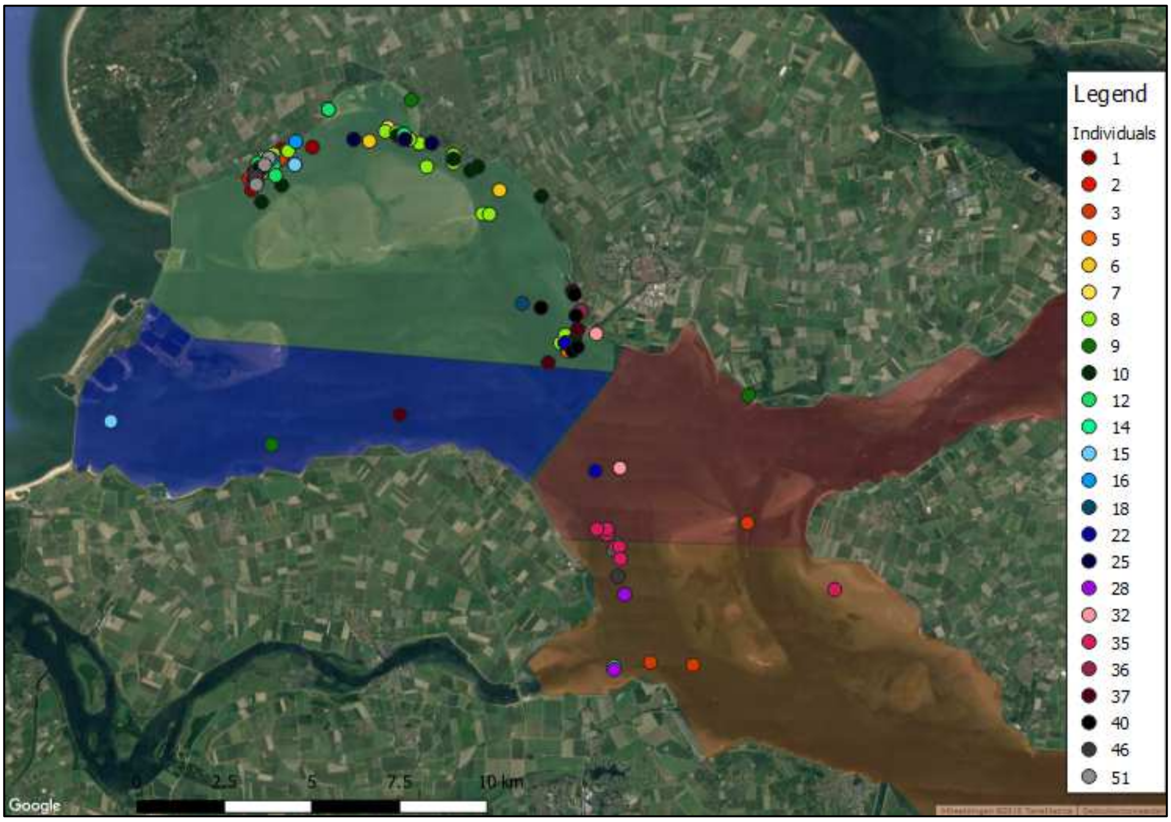

Figure 3.5 Overview of the distribution patterns of the identified individuals within the 4 different zones in the Eastern Scheldt.

3.4 Group composition

The 24 individual harbour porpoises were observed significantly more in groups than solitary (df=23; p<0.05) (figure 3.6). However, there is no significant difference in group- or solitary preference between the individuals P(N=147; df=23; χ^2=31.7<35.2)=α>0.05. The average group size of those 24 harbour porpoises within the Eastern Scheldt when observed in a group was 2.96± individuals. In contrast, the average group size of all surveys of a group without a calf (2015 to 2018) was 2.34± individuals. When a calf was present, the average group size was 4.07± individuals. At last, group size without the presence of a calf was 2.31± individuals during foraging and 2.33± individuals during travelling.

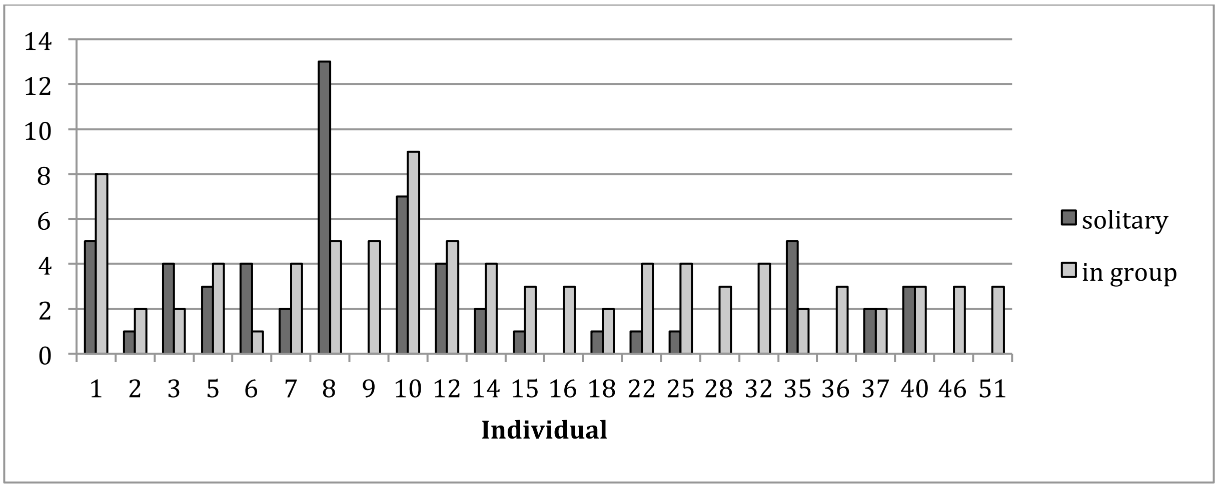

Figure 3.6 The number of times an individual was spotted solitary or in a group.

In addition, there is a difference in the number of identified individuals that harbour porpoises were observed with during a group encounter (figure 3.7). Most identified individuals were spotted 0, once or twice with other identified individuals within the same group (Appendix VI). However, individual 1 was observed three times with individual 10 and 15. This could indicate a preference for certain individuals when harbour porpoises occur in a group.

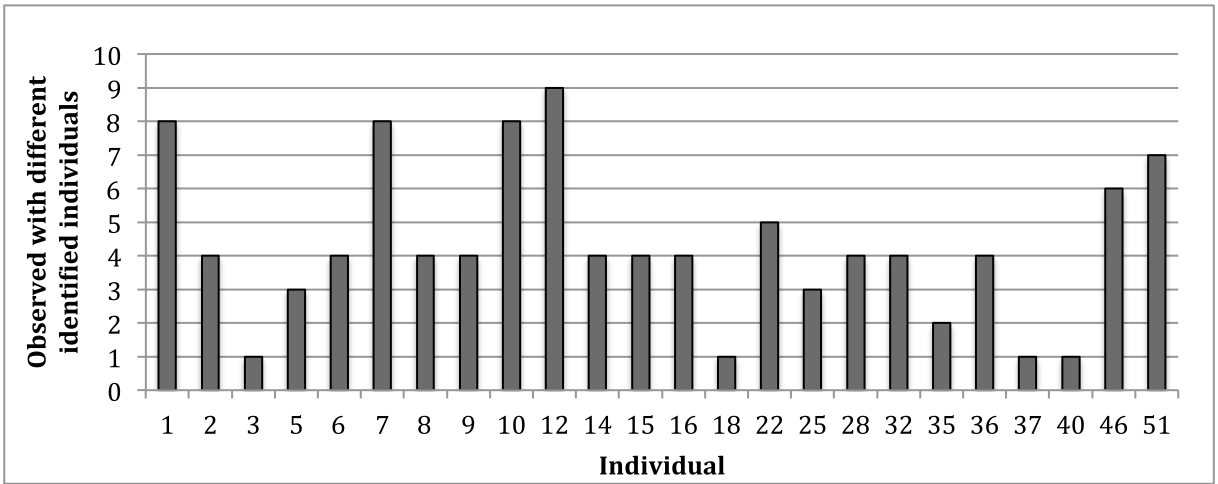

Figure 3.7 The number of different identified individuals that an individual was spotted with when it occurred in a group

4. Discussion & Conclusion

In The Eastern Scheldt, which is a unique marine environment due to the storm surge barrier and closure of the freshwater supply from the rivers (Nienhuis & Smaal 1994; Stichting deltawerken 2009), lives a population of harbour porpoises. This research focused on "*What is the group structure and size of the population harbour porpoises that occur in the Eastern Scheldt?*" and "*What is the group structure and size of the population harbour porpoises that occur in the Eastern Scheldt?*". The harbour porpoises occur in the relatively small habitat within the Eastern Scheldt and most likely originate from the North Sea population. Therefore distribution patterns, group size and group structure were compared first to studies on the population in the North Sea.

The population in the Eastern Scheldt increased to at least 48 individuals in 2018, when compared to the annual counts of 2013 to 2017. However, the effort during the annual count of 2017 was lower and the weather conditions in 2016 were not optimal (Rugvin 2018). Especially poor weather conditions are known to influence the ability to observe harbour porpoises (Hammond et al. 2002; IJsseldijk et al. 2015; Teilmann 2003). Therefore it is difficult to be certain of an actual increase of population size in 2018, when compared to 2016 and 2017. However, in 2014 and 2015 the weather conditions were good and the count was carried out on 8 boots (Rugvin 2018). During these counts, 35 and 29 individuals were observed and this indicates a certain increase of the population since 2014, which indicates a healthy and restoring population.

The increasing population cannot only be caused by the birth of calves within the Eastern Scheldt because approximately 3 or 4 calves were observed during the annual count and surveys each year. When the population only would increase due to the birth of calves, the calf survival rate need to be 100% to sustain the population increase that occurred between 2015 and 2018, which is very unlikely (Read & Gaskin 1990; Woodley & Read 1991). Therefore, it is assumed that juvenile and adult harbour porpoises migrated into the Eastern Scheldt from the North Sea. It is hypothesized that the harbour porpoises that pass the storm surge barrier cannot travel back into the North Sea, due to the noise barrier that is created by the tides within the storm surge barrier (van Dam et al. 2017; Jansen et al. 2013). This means that those harbour porpoises need to adapt to the new prey and environment conditions, especially because the prey density is 10% lower within the Eastern Scheldt compared to the North Sea (van Dam et al. 2017; Leopold 2018). When harbour porpoises cannot adapt to these new conditions they will die in a short period of time due to starvation (IJsseldijk et al. 2015; Leopold 2018). However, when harbour porpoises adapt to those new conditions, it is most likely that they live for years within the Eastern Scheldt and even produce offspring (Leopold 2018). For instance, an individual was observed since 2007 for almost every year until 2017 (Bakkers & Tuhuteru 2016). In addition, individual 10, which was identified in 2007 was spotted in 2011 with a calf within the Eastern Scheldt. This calf was later on identified as individual 25 and observed until 2015 several times solitary. This shows that when harbour porpoises adapt to catching different prey, this habitat can support the food requirements of a harbour porpoise for a many years and they even can produce offspring.

During the annual count, harbour porpoises in the Eastern Scheldt were mainly observed in zone 1 and 3, West of the Zeelandbrug. In addition, during the surveys most individuals were also observed in zone 1. The distribution of harbour porpoises will be influenced by, and depending on prey availability and prey density. Especially due to the unfavourable body weight to body ratio of harbour porpoises it is likely that they remain within close desistance of food sources (IJsseldijk et al. 2015; Kastelein & van Battum

1990; Koopman 1998; McLellan et al. 2002). De Boois & van Asch (2013) found a higher fish biomass West of the Zeelandbrug, which provides a more favourable habitat for harbour porpoises. Besides that, the tides from the North Sea have more impact on this western area, because this area is closest to the storm surge barrier and North Sea. The distribution and behaviour of marine mammals is mainly influenced by tides (Jones et al. 2003; IJsseldijk et al. 2015). Especially because, oceanographic drivers can increase the primary production, which in turn will attracts small consumers (Johnston et al. 2005; St. John et al. 1992; St John & Pond 1992). This results in localized patches of food for marine predators such as harbour porpoises.

There is a difference in distribution pattern between individual harbour porpoises, as seen this shows the presence of individual variability (Elliser et al. 2017; Read & Westgate 1997). In total, the gender of 5 identified individuals females were estimated due to the presences of a calf. Of these 5 individuals, 4 were only observed in zone 1 and the other female individual was observed in zone 2 and 4. However, duration of presences within the Eastern Scheldt does not influence the zone preference. For instance, individual 10 and 40 were both observed only in zone 1 for over 9 years. In contrast, individual 3, 14 and 22 were observed in zone 1, 2 and 4 for over 7 years. Therefore it is more likely that these differences between individuals were caused by differences between sex and age classes (Benjamins et al. 2015). Especially adult females are more stable and tend to be more reside at certain locations, in contrast with immature porpoises who roam over larger areas (Graner 2003).

Another factor that could cause the differences in zone preference could be a hierarchy within the population of harbour porpoises (Shane et al. 1986). Hierarchy is a well known phenomenon in captive population of dolphins, but little is known about hierarchy in populations of wild dolphins and porpoises (McBride & Hebb 1948; Tavolga 1966). Dominance has especially been displayed between the large adult males from different capture locations, which indicates that dominance relationships were long-established within a population (Mcbride & Kritzler 1951; Wood 1977). The Eastern Scheldt is in some degree a captive area, which could ensure the dominance that is expressed in hierarchy between individuals. This hierarchy could lead to the differences in zone preference between individuals, with the most dominant harbour porpoises in the most productive areas (Norris & Dohl 1979).

It was hypothesized that harbour porpoises that occur in the Eastern Scheldt originate from the North Sea population. The average group size of the population in the North Sea was 1.14; which indicates that these harbour porpoises mainly occur solitary (Geelhoed et al. 2011). In contrast, the average group size within the Eastern Scheldt that consists an identified individual was 2.96; of all encounters during the surveys without the presence of a calf 2.34 and with the presence of a calf 4.07. The difference between these group sizes is often related to predation (Elliser et al. 2017; Johnson & Norris 1986). It is expected that individuals are observed more often within groups when predation risk is higher because a larger group size reduces the predation risk (Würsig 1986). Especially calves are vulnerable for predation, which results in a larger group sizes when a mother-calf pair occur within a group (Geelhoed et al. 2011). In addition, the predator density of grey seals within the Eastern Scheldt is higher than within the North Sea. Besides that, a higher average group size is also shown when harbour porpoises were fishing for prey (Elliser et al. 2017; Graner 2003; Würsig 1986). This could indicate that fishing in the Eastern Scheldt requires a larger group or attract additional porpoises to the group. However, the difference between the group size of foraging (2.31) and travelling (2.33) harbour porpoises was minimal within the Eastern Scheldt.

During an encounter group size was estimated by counting all individuals that were near the boat and no distinction was made between individuals showing the same behaviour and individuals that passed by. In contrast, Wells et al. (1980) distinguished groups into primary and secondary groups, where primary groups were smaller units of cetaceans engaged in similar activities and were associated closely. Whereas secondary groups were temporary aggregations of the primary groups. These distinctions between primary and secondary groups were not made during the encounters, which could influence the results of the group size.

Some individuals were spotted more often with certain individuals and this can indicate a preference for group composition. This can also be caused by the dominance, which is mentioned above, between individuals. Bottlenose dolphins show a similar pattern, where researches found a frequently changes group composition but certain associations between specific individuals appeared to be repeated more often or be more persistent (Irvine et al. 1981; Shane 1980; Shane et al. 1986; Wursig 1978; Würsig & Würsig 1977). This social system can also depend on the time, where some individuals of the population only be together at a certain time (Karczmarski et al. 2005).

All together, it seems that the Eastern Scheldt with his small, unique habitat has his own population of harbour porpoises that probably is stable or even is growing. This population has is own characteristics with a group size of 2.96 and 2.34; which is larger than of the population harbour porpoises within the North Sea (1.14) from which they origin, and of preferential individual associations. This shows the behaviour flexibility of the harbour porpoises to predator density and food availability.

5. Recommendations

It is important to create a more random survey direction to analyse the distribution patterns of harbour porpoises. At the moment survey direction mostly depend on the likeability of observing a harbour porpoise at a certain "hotspot". This will influence the data that is collected because only harbour porpoises that are observed on this route are analysed. The data is therefore at the moment not representative for the entire Eastern Scheldt. To gain more reliable data it is recommend to use different routes that cover the entire Eastern Scheldt. These different routes need to be used randomly so the routes are observed at different times and tidal states creating a more reliable dataset.

In addition, the previous survey routes were not noted, which makes it more difficult to analyse the routes and which parts of the Eastern Scheldt were observed. It is therefore useful to note every 15 to 30 minutes the GPS coordinates of the boat. This can lead to a more robust conclusion of certain zones when no harbour porpoises are observed during boat surveys. Especially, because at the moment there is no certainty whether harbour porpoises were not spotted at a certain area or that boat surveys were not conducted to this area of the Eastern Scheldt. Besides that, this will give also more information about the harbour porpoises when observed for a longer period of time. Because at the moment only begin and end GPS coordinates of an encounter are noted.

Besides that, little is known about harbour porpoises travelling through the storm surge barrier and it is only hypothesized that harbour porpoises are trapped within the Eastern Scheldt. It would therefore be interesting to conduct surveys from the storm surge barrier. This would provide more information about how often en if harbour porpoises actually travel through the storm surge barrier.

At last, it would be interesting to continue noting the presences of harbour and grey seals. Especially because grey seals predate on harbour porpoises and can influence the distribution pattern of the harbour porpoises. It was not possible to analyse the impact of the grey seals within this study because only 1 encounter of a grey seal occurred during the surveys conducted in 2018.

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Appendix

Appendix I Survey Data Sheet

Date (dd/mm/yy): …………/…………./………… **Survey number:**

Surveyors & vessel	General remarks

Departure information	Return information
Start time:	End time:
Start location:	End location:
Start GPS:	End GPS:
51…………………………3…………………………	51…………………………3…………………………
Start weather:	End weather:
H F	H F
Beaufort (sea state): 0 1 2 3 4 5	Beaufort (sea state): 0 1 2 3 4 5
Cloud coverage: ……….%	Cloud coverage: ……….%
Tidal state: high falling low rising	Tidal state: high falling low rising

Optional change in weather during survey	
Time (hh:mm):	Time (hh:mm):
Weather:	Weather:
H F	H F
Beaufort (sea state): 0 1 2 3 4 5	Beaufort (sea state): 0 1 2 3 4 5
Cloud coverage: ……….%	Cloud coverage: ……….%
Tidal state: high falling low rising	Tidal state: high falling low rising

Appendix II Encounter Data Sheet

Date (dd/mm/yy): …………/…………./………… **Encounter number:**

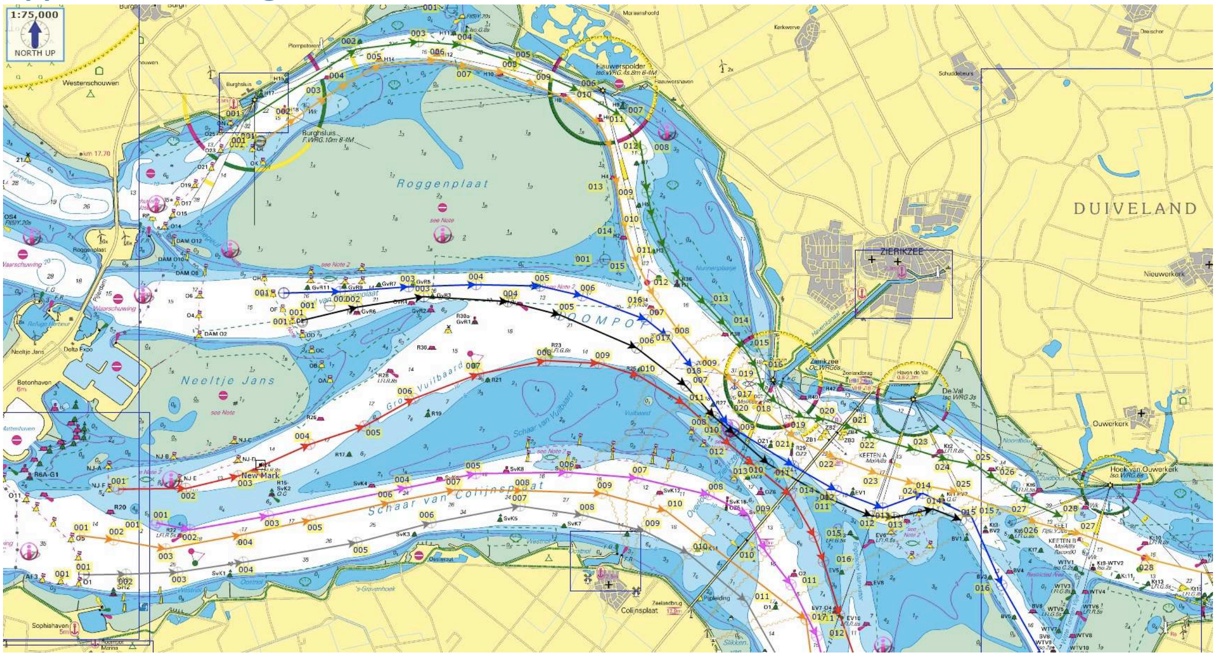
Start encounter information	End encounter information
Start time (hh:mm):	End time (hh:mm):
Start GPS:	End GPS:
51………………………..3………………………..	51………………………..3………………………..

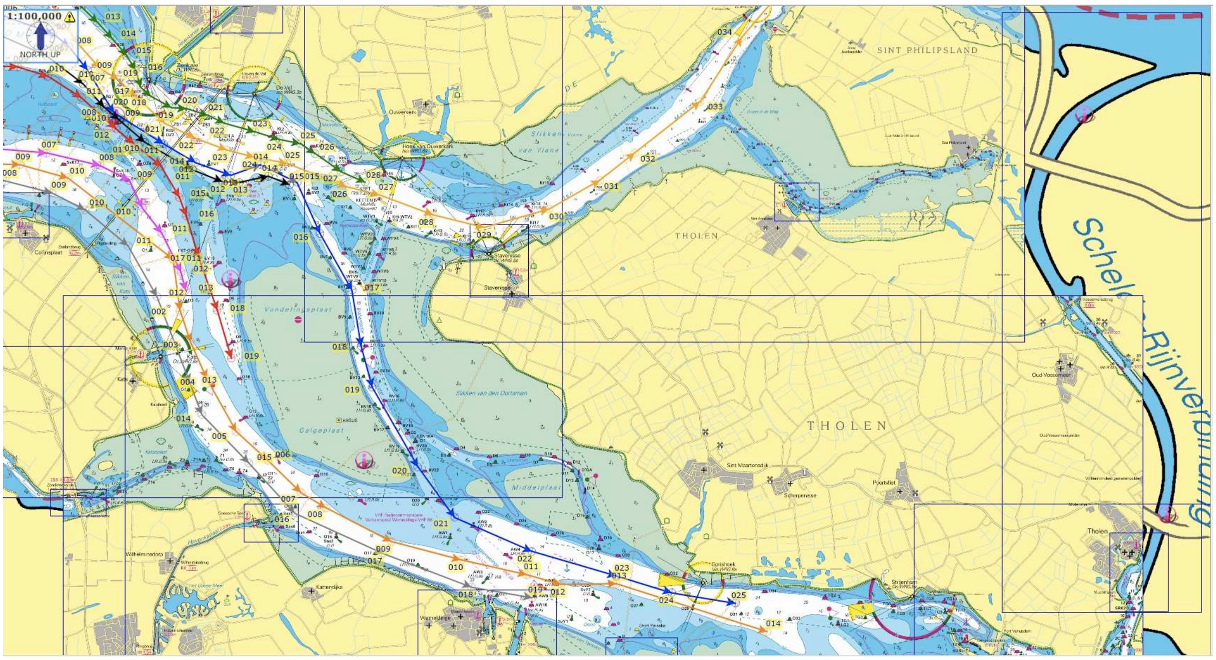
Weather during the encounter	
 H F	Cloud coverage: ……….%
Beaufort (sea state): 0 1 2 3 4 5	Tidal state: high falling low rising

Estimated group size			Primary behaviour	Secondary behaviour
Min.	Max.	Best	Foraging / travelling / resting / other:	Foraging / travelling / resting / other:

Remarks (e.g. calf present, group structure, heading, ID photo success)

Appendix III Sailing route annual count





Appendix IV Group combination

The number of times that individuals were observed together within the same group.

	1	2	3	5	6	7	8	9	10	12	14	15	16	18	22	25	28	32	35	36	37	40	46	51
1						2			3			3	2							1		1	1	1
2			1						1	1						1								
3		1																						
5							2	1							1									
6						1				1													1	1
7	2				1				1	1		2	1										1	1
8				2				2		1														
9				1			2			1	1													
10	3	1				1				2		2	1	1		4								
12		1			1	1	1	1	2							1							1	1
14								1							1		1		2					
15	3					2			2				1											
16	2					1			1			1												
18									1															
22				1							1						1	1					1	
25		1							4	1														
28											1				1			1	1					
32															1		1			1				1
35											2						1							
36	1																	1			1			1
37																				1				
40	1																							
46	1				1	1				1					1									1
51	1				1	1				1								1		1			1	