


Benthic development in and around offshore wind farm Prinses Amalia Wind Park near the Dutch coastal zone before and after construction (2003-2017)

A statistical analysis

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Authors	:	Leewis, L., Klink, A.D., Verduin, E.C.
Review by	:	Prof. Dr. P.M. van Bodegom, Leiden University
E-mail address	:	liesleewis@eurofins.com
Checked by	:	J.J. van Deelen
Signature	:	
Approved by	:	A. de Beauvesère-Storm
Signature	:	
Contact	:	Eurofins Omegam B.V. Eurofins AquaSense H.J.E. Wenkebachweg 120 1114 AD Amsterdam-Duivendrecht Postbus 94685 1090 GR Amsterdam T +31 (0) 20 5976 680 www.aquasense.nl

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1 Samenvatting

Het doel van dit rapport is om de benthische ontwikkeling van de bodemfauna gemeenschap in en rond het offshore Prinses Amalia Wind Park (PAWP) nabij de Nederlandse kustzone te beoordelen. Het huidige rapport richt zich op de ontwikkeling van bodemfauna, 10 jaar na het in gebruik nemen van de PAWP, en daarmee 10 jaar uitsluiting van visserij in het windparkgebied.
Er zijn vergelijkingen gemaakt tussen locaties binnen het windpark (QT) en referentielocaties buiten het windpark (QAW). Deze analyse werd uitgevoerd op basis van de beschikbare gegevens van de basisstudie in 2003, de T5 (2012), T6 (2013) en T10-monitoring in 2017. Trends in fauna gemeenschappen werden geanalyseerd, evenals mogelijke correlaties van milieuomstandigheden (bv. sedimentkenmerken, visserij intensiteit) op de bentische fauna. Gegevens zoals aantal soorten, abundantie en verschillende diversiteitsindices werden statistisch geanalyseerd met univariate methoden. Verschillen in soortensamenstelling werden geanalyseerd met multivariate methoden. Bovendien werden mogelijke correlaties van verschillende abiotische variabelen met benthos onderzocht, wat in eerdere onderzoeken niet werd gedaan.

Er waren duidelijke temporele effecten op de soortensamenstelling van het Prinses Amalia Windpark aanwezig, zowel op de univariate data (zoals het aantal soorten, abundantie en diversiteitsindices) als op de multivariate data (soorten samenstelling). De soortensamenstelling veranderde in de loop van de tijd, zoals bleek uit het vergelijken van de onderzoekslocaties van de verschillende jaren.
Van de geteste variabelen had jaar van monstername de grootste significantie in vergelijking met de andere omgevingsfactoren. Dit suggereert dat er een sterk temporeel effect is op de soortensamenstelling in de data.
Van de omgevingsvariabelen die werden geanalyseerd met multivariate statistiek en multiple regressies, had diepte een correlatie met de soortensamenstelling van de bentische gemeenschap. Het organische stofgehalte en de D50-fractie van het sediment speelden een rol in de diversiteit van de monsters (Margalef-, Shannon Wiener- en Simpson index; behalve voor Pilou evenness).
De visserijintensiteit lijkt geen grote rol te spelen in de samenstelling van de bentische gemeenschap. Wanneer 2003 buiten beschouwing wordt gelaten, heeft de visserij geen effect, zelfs wanneer de visserijintensiteit binnen en buiten het windpark verschilt, vooral in 2017. Bovendien is er nog steeds een verschil in samenstelling van de gemeenschap tussen de bemonsteringsjaren van 2012, 2013 en 2017, die niet kan worden toegeschreven aan visserijintensiteit.
Het lage verklarende vermogen van de multiple regressies, evenals de multivariate analyses, gaven aan dat temporele effecten sterker waren dan de effecten van omgevingsvariabelen en dat andere niet-gemeten variabelen belangrijk kunnen zijn.

Over het algemeen lijkt 2017 een bijzonder jaar te zijn, met grote verschillen ten opzichte van voorgaande jaren, met hoge abundanties en een klein aantal soorten en lage waarden van de diversiteitsindices in 2017. Het is daarom aan te raden om nog een bemonsteringscampagne te doen, aangezien 10 jaar mogelijk niet genoeg is om herstel te zien van de benthische soortengemeenschap na het sluiten van een gebied voor visserij. Analyse van extra omgevingsvariabelen moet worden overwogen, zoals aanvullende sedimentkenmerken en schuifspanning. Bovendien worden aanvullende, verschillende soorten analyses op de gegevens geadviseerd, zoals een trait-analyse, een meta-analyse met inbegrip van andere soortgelijke projecten en het gebruik van de BISI-index. Deze kunnen meer inzicht geven in mechanismen achter herstel na verstoring in verschillende habitattypes en helpen bij het management van natuurbeschermingsdoelen.

2 Summary

The goal of this report is to assess the benthic development of the soft bottom faunal community in and around the offshore Prinses Amalia Wind Park (PAWP) near the Dutch coastal zone. The current report focuses on the development of soft bottom fauna, 10 years after the putting into use of the PAWP, and therewith 10 years of exclusion of fisheries in the wind park area.
Comparisons were made between locations inside the wind park (QT) and reference locations outside the wind park (QAW). This analysis was done on available data from the baseline study in 2003, the T5 (2012), T6 (2013) and T10 monitoring in 2017. Trends in faunal communities were analysed, as well as effects of environmental conditions (i.e. sediment characteristics, fishing intensity) on the benthic fauna. Variables like number of species, abundance and several diversity indices were statistically analysed with univariate methods. Differences in community composition were analysed with multivariate methods. Moreover, possible correlations of several abiotic variables with benthos were investigated, which was not done in earlier research.

Overall, clear temporal effects on the species composition of the Prinses Amalia Wind park were present, both on the univariate data (i.e. number of species, abundance and diversity indices) and on the multivariate data (community composition). The species composition changed over time when comparing the survey sites over the different years.
Of the tested variables, sampling year had the highest significance in comparison to the other environmental factors. This suggests that there is a strong temporal effect on the species composition in the data.
Of the environmental variables that were analysed with multivariate statistics and multiple regressions, depth had a correlation with the species composition of the benthic community. Organic matter content and the D50 fraction of the sediment played a role in the diversity of the samples (Margalef-, Shannon Wiener- and Simpson index; except Pilou evenness).
Fishing intensity does not seem to play a large a role in the composition of the benthic community. When 2003 is left out of the analysis, fishing has no effect, even when fishing intensity differs within and outside the wind park, especially in 2017. Furthermore, there is still a difference in community composition between the sampling years of 2012, 2013 and 2017, which cannot be attributed to fishing intensity.
The low explaining power of the multiple regressions, as well as the multivariate analyses, indicated that temporal effects were overriding effects of environmental variables, and that other non-measured variables may be important.

Overall, 2017 seems to be a peculiar year, with large differences from previous years, with high abundances and low number of species and diversity indices. It is therefore advised to do another sampling campaign, since 10 years might not be enough to capture recovery of the species community after exclusion of fisheries. Analysis of additional environmental variables should be considered, such as additional sediment characteristics and bed shear stress. Additionally, different types of analyses on the data are advised, such as a trait analysis, a meta-analysis including other similar projects and the utilization of the BISI index. These might give more insight in mechanisms behind recovery after disturbance in different habitat types and help in management of nature conservation goals.

3 Introduction

The goal of this report is to assess the benthic development of the soft bottom faunal community in and around the offshore Prinses Amalia Wind Park (PAWP) near the Dutch coastal zone. Other studies on effects of offshore wind parks on soft bottom fauna have focused on the effects after three (Degrear et al., 2012) or five (Bergman et al., 2015) years. The current report focuses on the development of soft bottom fauna, 10 years after the putting into use of the PAWP, and therewith 10 years of exclusion of fisheries in the wind park area.
This investigation is part of WOZEP (a Dutch Governmental Offshore Wind Ecological Program), which is a five-year research program to investigate the gaps in knowledge concerning the ecological effects of offshore wind energy.

In the current report, comparisons were made between locations inside the wind park (QT) and reference locations outside the wind park (QAW). This analysis was done on available data from the baseline study in 2003, the T5 (2012), T6 (2013) and T10 monitoring in 2017. Trends in faunal communities were analysed, as well as effects of environmental conditions (i.e. sediment characteristics, fishing intensity) on the benthic fauna. Data like number of species, abundance and several diversity indices were statistically analysed with univariate methods. Differences in community composition were analysed with multivariate methods. Moreover, correlations of several abiotic variables with benthos were investigated which was not done in earlier research.

4 Methods

A benthos dredge was used in all monitoring campaigns. In the former years, also a boxcorer was used, however for 2017 the decision was made to use only the dredge. Bergman et al. (2015) suggested that a dredge is more suitable than a boxcorer because a larger area is sampled. It gives a higher chance of detecting spatial differences and integrates variation in abundances over a larger area.
The field campaigns in the analysed years were done by different executive parties, which are shown in Table 4-1. Campaigns were always in spring, but differed in the exact period when samples were taken. The same dredge was used in all years for all samples.
Next to dredge samples for analyzing soft bottom fauna, boxcorer samples were used to take sediment samples in order to analyze sediment characteristics. Not only soft bottom fauna, but also fish species were taken into account in the analyses. Some fish species (i.e. sand eels) can be an important food source for porpoises and seabirds and might also be influenced by changes in fishing intensity (Tien et al., 2017). Fishing intensity was another factor that was taken into account in the analyses in this report. This was done by using the data from an analysis of the fishing intensity in and around PAWP (Machiels, 2017).

Table 4-1: Executing organizations

Year	Organization	Sampling period (week number)
2003	Hull University	May (21, 22)
2012	eCoast	March (11)
2013	eCoast	April (14, 15, 17)
2017	Eurofins AquaSense	March (12, 13)

4.1.1 Sampling strategy 2017

In 2017, a different sampling strategy was adopted. Several aspects of the sampling strategy were changed based on a power analysis and literature review on benthos research in the PAWP and OWEZ wind parks (Glorius et al., 2017). A larger number of sampling locations and a focus on the dredge was recommended by Glorius et al. (2017). A boxcorer was only used for determination of sediment characteristics. Median grain size and organic matter content of the sediment were measured by means of laser diffraction (fraction <2mm, after pre treatment by removal of organic matter and carbonates) and loss on ignition (LOI at 550°C), respectively (analyses by Eurofins Analytico). Furthermore, the former reference areas QCN and QSC, which were located approximately 20 km from the QT wind park, were taken out of the sampling campaign. This was done because analysis on the dredge density data showed that these reference area's showed no overlap in species community with PAWP (Lock et al., 2014), and therefore not being proper references. Moreover, the Northern reference area had become unsuitable as a reference due to disturbance from sand extraction (personal communication Maarten de Jong).

In Figure 4-1 the geographical locations of the sampling stations that were used in the current report, are shown for the different survey years. In 2017, the locations of the sampling stations were changed compared to the earlier years. A similar number of locations were sampled within the wind park (QT, in orange). Outside the wind park (QAW, in blue), the number of sampling locations was increased in 2017. These QAW locations are now designated as reference locations, instead of the former reference areas that are mentioned above.
Opposed to a (more or less) regular grid sampling that was done in 2003, 2012 and 2013, the sampling locations were changed in 2017 (both within and outside the wind park). Van Denderen et al. (2014) showed that negative effects of bottom trawl fishing were limited to relatively species rich, deep areas. Hence, more locations were sampled that were in the deeper areas of the wind park, because a different fauna community might be present there. Most of the locations in the wind park were located on the crest of the sand ridge and four samples in the deepest area within PAWP to sample all habitat types (see Figure

4-2**Error! Reference source not found.** for bathymetry). For the reference area, a similar ratio of samples from the tops and troughs was selected. Additionally, locations with assumed differences in fishing intensity were chosen, providing a gradient in fishing intensity, which was also recommended by Glorius et al. 2017.

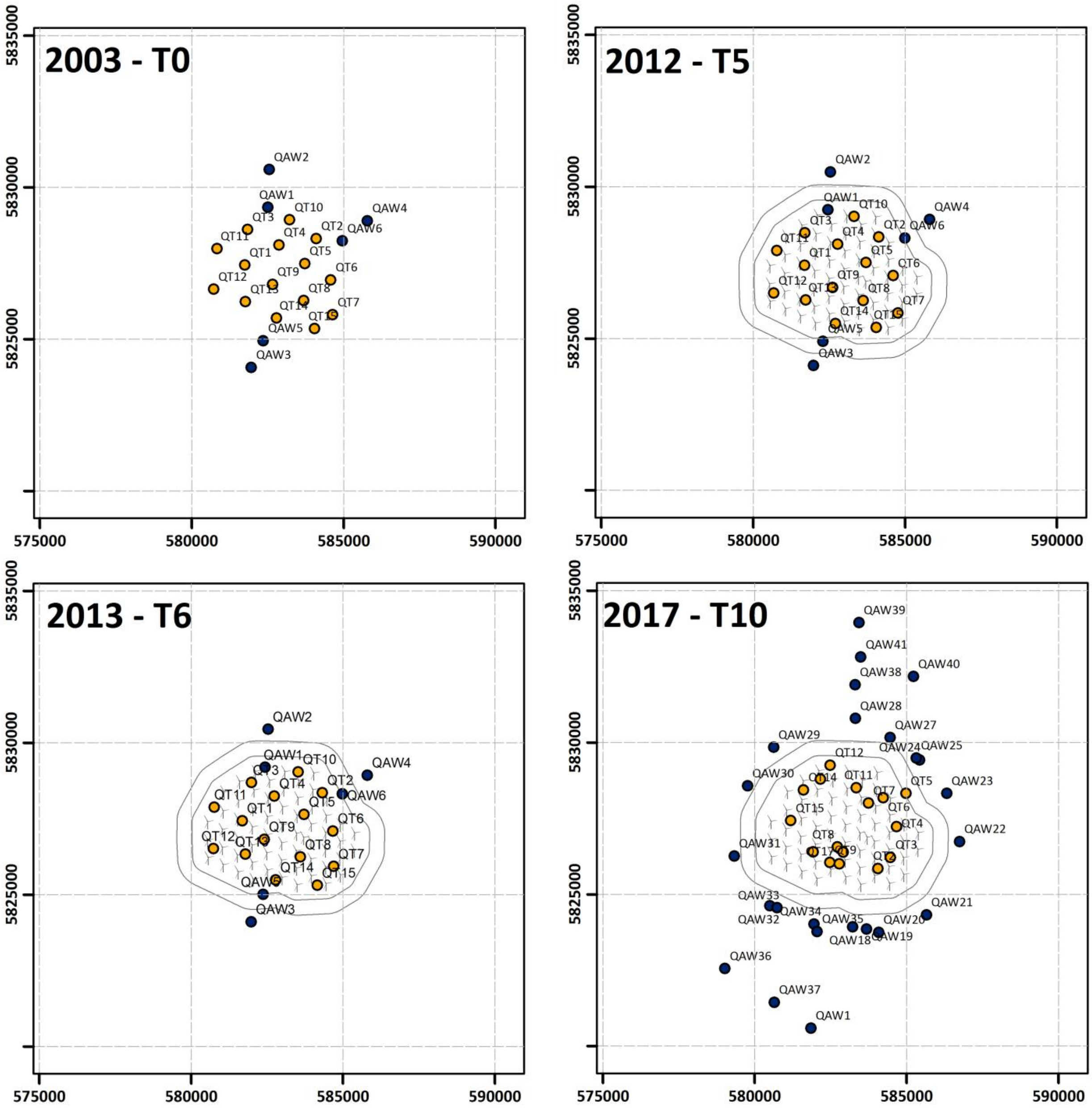

Figure 4-1: All survey sites in 2003, 2012, 2013 and 2017. QT (Orange) are survey stations within the Wind park, the blue stations are the reference stations outside of the wind park (QAW). Shows the survey locations that were sampled each year; top left, T0 – 2003; top right, T5 – 2012; bottom left, T6 – 2013; and bottom left, T10 – 2017.

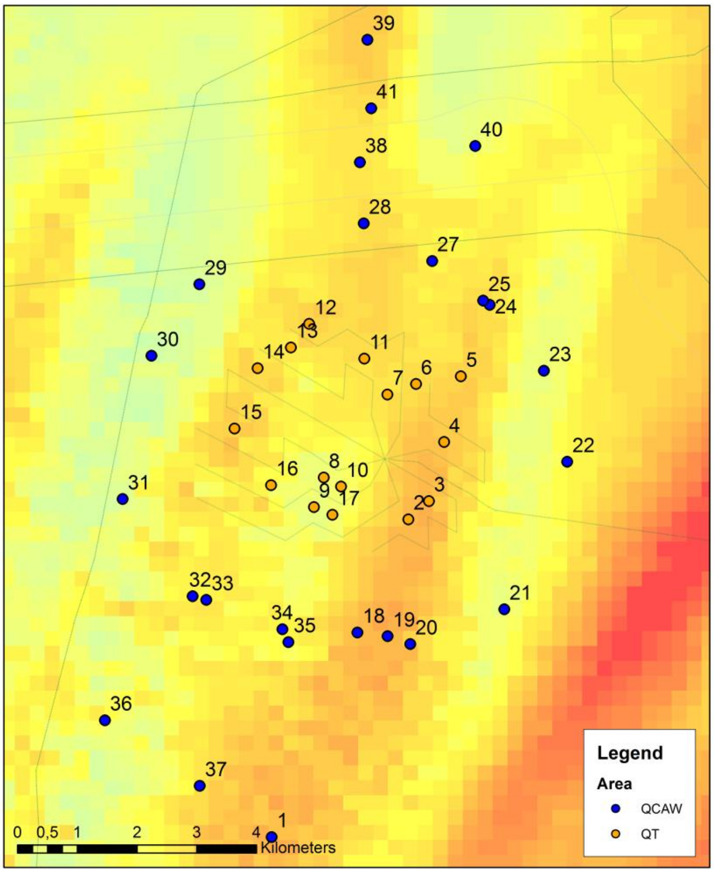

Figure 4-2: Bathymetry of PAWP. Orange locations are QT, blue locations are QAW. Red = 15.1m depth, blue = 26.5 m depth.

4.2 Data preparation

Data of 2003, 2012 and 2013 was obtained from the repository database for WOZEP data, which is managed by Wageningen Marine Research. Data of 2017 was used from the 2017 survey that has been executed by our own laboratory. Before the statistical analysis of the data, several steps needed to be taken in order to prepare the dataset for a proper data analysis. These different steps are explained in the paragraphs below. All data is freely available and will be included in the WOZEP repository database and in the database of the Marine Information and Data Centre (Informatiehuis Marien, IHM).

4.2.1 Location issues 2012/2013

The WMR dredge dataset turned out to have the wrong coordinates for dredge data. Because of this, dredge coordinates were assigned to box core locations, which were not the correct coordinates. The original sample locations of the T-5 and T-6 data were requested from the executive party. The Fieldwork Company supplied the original survey data with the correct dredge locations. All dredge transects were re-analyzed by Eurofins AquaSense in ArcGIS and all transect lines were re-drawn. In this way the lengths were re-calculated and the correctness of the data was checked. It appeared that some transects were longer than the 100 meters that were stated in the WMR dredge dataset which means that the benthos data was translated into abundance/100 m^2 using wrong correction factors. Eurofins AquaSense performed the following steps:

A database was constructed for the total (revised) PAWP dredge data. The dredge lengths were reviewed, the correct coordinates for the start and end points were added, with the addition of the original comments. The biological data from 2013 was revised for the correct dredge lengths. All data was stored in the database.

4.2.2 *Sediment characteristics*

No data of sediment characteristics was available for 2003. Silt contents (2-63 µm) were not reported in 2012 and 2013. In addition, the boxcores were examined for the sediment composition in 2012 and 2013. Some of the corresponding dredge transects were located directly or close to the boxcore sample location. In other cases the dredge transects were located further away, up to 400 meters, from the boxcore locations. In the latter case, those boxcore samples could differ in sediment composition from the sediment at the dredge transect, which would lead to inaccurate sediment composition data. To correct for this effect, the nearest boxcore locations were identified using ArcGis, and were used as reference location for the sediment composition of the dredge transects.

4.2.3 *Bathymetry*

Depths were not reported during all monitoring campaigns. The bathymetry data for 2012/2013 were taken from the depth data in the RWS depth map of 2010 and stored for every location in the database.

4.2.4 *Shell length*

Data of shell lengths were missing in the repository WMR benthos dataset for the years 2003, 2012 and 2013. The data was not stored as a single variable per sample, but instead stored for every taxon present in the sample. Therefore, no comparison could be made with the shell lengths that were reported in the 2017 dataset.

4.2.5 *Fishing intensity*

The data of fishing intensity was not directly available at the start of this report. In a parallel study Wageningen Marine Research has done an analysis of the fishing intensity in and around PAWP from 2003 until 2016 (Machiels, 2017). In this study the area was divided in 500m * 500m grid cells. To calculate the fishing frequency, the VMS (Vessel Monitoring System) positions of fishing vessels were projected in this grid. Using a geostatistical interpolation method, a realistic VMS ping density was estimated. The estimated VMS ping density was scaled to a total fishing frequency estimation. The total fished area is estimated using time of fishing, fishing speed and the width of the used gear. Using this area, the total fishing intensity is estimated.

To get an impression of the fishing activity close to the dredge sampling, all VMS registrations are gathered in a spatial and temporal scale and were presented in a table. In a temporal scale two years before the benthic dredge sampling is chosen. In a spatial scale a radius of 2 kilometer around the sampling site is used (Machiels, 2017). In the table all dredging samples are presented and different information is presented: sampling site, sampling date, geographical position, fished surface (km^2), period between the dredge sampling and the last VMS ping and the distance from the VMS ping to the sampling site. This data is linked to the benthic fauna and abiotic factor dataset in order to analyze their statistical relationships.

4.2.6 *Genera and species data*

Before analysis of the species data, the data was corrected for the presence of genera and species in the same sample. This was done to make sure individuals identified on different levels, but likely belonging to the same species, were not over-represented in the number of species for that sample. For instance, if *Ensis* (spec.) as well as *Ensis directus* were identified in the same sample, the number of species in that sample would be two. This was corrected to one species because it is highly likely that the specimens belonging to *Ensis* are actually *Ensis directus*.

For some taxa, the data was also corrected for differences in identification between years, by scaling the species to the genus of the species. This was done so that differences in identifications between years would not have an effect on the analysis of species compositions for the same samples between different years.

Because no data of biomass was available for the sampling year 2003, species biomass was not incorporated in the analyses. All species abundances were scaled to a length of a standard dredge length of 100 m and 1m wide ($n/100m^2$). Both benthos and fish were incorporated in the analyses.

Analysis were done with and without fish species, however, extracting fish species from the data only had minor effects on the results (analyses are not shown in this report). Therefore it was decided to include fish species in all data and analyses.

All species data, environmental data and diversity indices per sampling station of 2017 are in Appendix 2, 3 and 4, respectively.

4.3 Statistical analyses

Data was analysed with both univariate and multivariate methods.

Number of species, abundances and several diversity indices were analysed with univariate methods. One way ANOVA’s were done with the combination year-park as a factor, resulting in eight year-park levels. Post-hoc multiple comparisons with Tukey's honest significance test (Tukey's HSD) were done to obtain significance levels for all individual combinations of year-park. This method was chosen opposed to two-way ANOVA’s, since significant year*park interactions were expected, which make the interpretation of main effects difficult.
To check for normality of the residuals from the ANOVA tests, Shapiro-Wilk Tests were performed. Homogeneity of error variance was checked with residual plots. Data that did not comply with the assumptions of normality and homogeneity of error variance were transformed according to the “Tukey´s Ladder of Powers”. All univariate data was transformed accordingly, except for number of species.
To visualize the results, box plots were created, with labels according to the multiple comparisons, visualizing significant differences between each box plot. This was done by adding a single similar letter above each box that is in a similar (i.e. not statistically different) group of combinations.

To test which environmental variables (fishing intensity, median grain size (D50), organic matter content and depth) were related to the univariate variables, multiple regression was performed. Since D50 and organic matter had no data for 2003, the analyses for these variables are only done over the years 2012, 2013 and 2017. Year of sampling was not included in these analyses, since we wanted to analyze whether differences between years would be explained by differences in environment.
A stepwise selection procedure with Akaike’s Information Criterion (AIC) was used to assess which environmental variables were best fitting the data, obtaining the best regression model. In addition, the significance and R^2 values were obtained, to be able to determine the importance of the environmental variables.

The community composition within and outside PAWP over the four years was analysed with non-Metric Multidimensional Scaling (nMDS) using Bray-Curtis dissimilarity. Data was square-root transformed (as opposed to no transformation), to focus on differences between species (and not on differences in abundances). A series of nMDS plots were constructed from the square root transformed and fourth root transformed data. The two-dimensional ordination with the lowest stress was then selected for further analyses; this was the square root transformed data. A two-way PERMANOVA analysis (Permutational Multivariate Analysis of Similarity) was done on year * wind park (including their interaction) to determine statistical differences in the community composition between the sample groups. Moreover, the “envfit” procedure of r package Vegan was used to correlate the environmental variables to the dissimilarity matrix, to assess which variables were best related to the community composition. Furthermore, for 2017, the significant environmental variables from the envfit procedure were plotted over the nMDS plot with the “ordisurf” procedure.

All analyses were performed with R-project (R Core Team, 2017). See Appendix 1 for a list of used packages in R.

5 Results

5.1 Biotic data

In Table 5-1 the averages of the data are shown. The average abundance for the area adjacent to the wind park (QAW) is much higher compared to the number of individuals per 100 m^2 in the wind park (QT). This is mainly driven by two stations: Station 21 and 22 (26 and 24 meters of depth and a relatively low median sediment grain size of 256 and 262 µm)) in 2017, that have a very high density because of a high presence of *Spisula subtruncata* in both sampling stations. Striking is the relative high number of species of 2013 and low abundance, compared to the relative low number of species and high abundance of the other years. In paragraph 5.3, the data from the table below is statistically analysed on differences between years and area (i.e. QT vs. QAW).

Table 5-1. Averages of numeric variables with the two sample groups (QT and QAW).
The second column shows the average of each variable for the sample group QAW, with the exclusion of samples 21 and 22 from the 2017 dataset in brackets.

	QT	QAW
Species	**19,13**	**18,02 (18,12)**
2003	18,27	18,00
2012	19,73	21,00
2013	22,53	23,00
2017	16,19	16,04 (16,05)
Abundance (n/100 m^2)	**154,13**	**536,81 (267,40)**
2003	110,90	184,20
2012	177,50	213,30
2013	73,55	97,17
2017	248,37	815,80 (351,40)
Shannon-Wiener index	**2,17**	**1,93 (1,98)**
2003	2,34	2,06
2012	2,11	2,19
2013	2,35	2,19
2017	1,90	1,76 (1,85)
Simpson's index	**0,82**	**0,76 (0,78)**
2003	0,86	0,80
2012	0,79	0,84
2013	0,85	0,83
2017	0,78	0,71 (0,74)
Margalef diversity index	**1,94**	**1,70 (1,73)**
2003	1,88	1,74
2012	1,93	2,00
2013	2,47	2,41
2017	1,53	1,44 (1,46)
Pilou's measure of species evenness	**0,74**	**0,67 (0,69)**
2003	0,81	0,73
2012	0,71	0,72
2013	0,76	0,70
2017	0,69	0,64 (0,67)

5.2 Abiotic data

5.2.1 Fishing intensity

Based on the method described in 4.2.5, values for fishing intensity were calculated (Machiels, 2017). Fishing intensity clearly decreased in the wind park after the building of PAWP in 2006 (Figure 5-1). A decrease in fishing intensity outside PAWP can be seen from 2011 onwards.

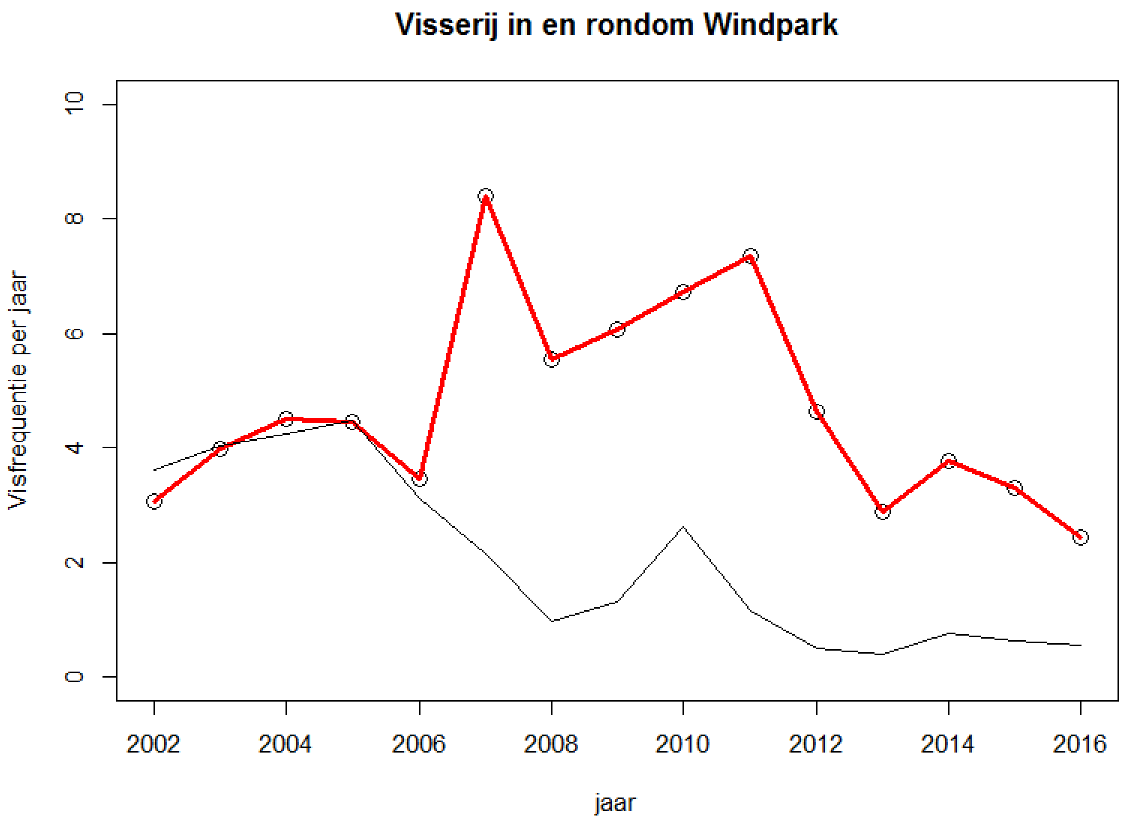

Figure 5-1: Fishing intensity around the sampling locations within and outside PAWP. Grey line: within PAWP, red line: up until 2 km outside PAWP (from: Machiels, 2017).

Figure 5-2 shows the fishing intensity in and around PAWP during several years in a geographical map. From these maps and Figure 5-1 , it becomes clear that in the T0 (2003), there was no difference in fishing intensity within and outside the wind park.

In both figures, fishing intensity is never zero within the wind park. This has to do with the grid of 500 x 500 meter that was used to calculate fishing intensity. These grid cells have an overlap with the borders of PAWP (as can also be seen from Figure 5-2), from which it seems that some fishery took place within the wind park.

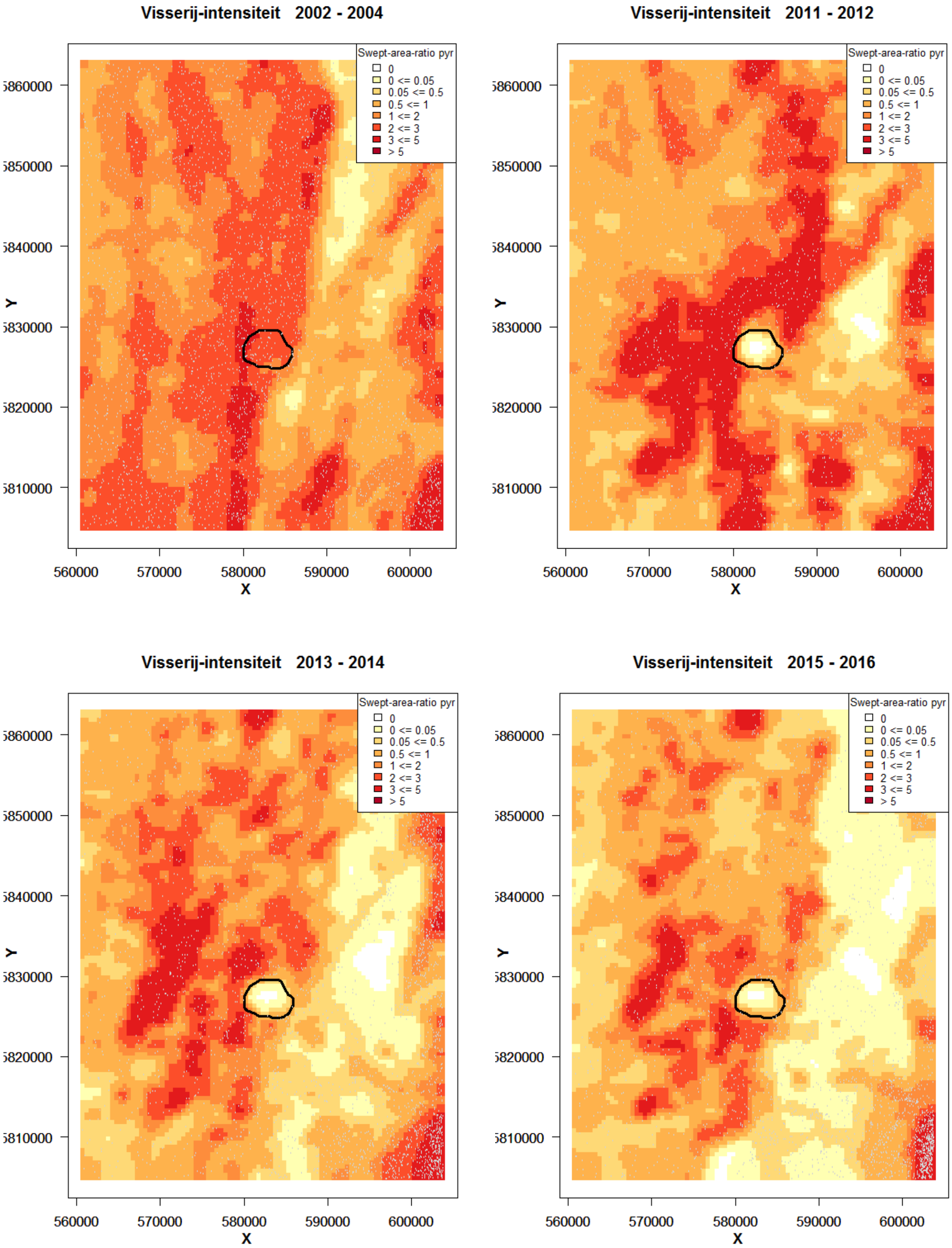

Figure 5-2: Fishing intensity in and around PAWP in the years around sampling. PAWP is within the black circle (from Machiels, 2017).

5.2.2 *Environmental data*

In Table 5-2 the averages of the used environmental data are shown. On average there are no large differences in depth. Striking is the relatively high average organic matter content in 2012 within the wind park (QT). This high average is solely due to a high organic matter content in QT13 (10.3%); without this high value, the average is 0.50%, which is more comparable to the other values. Overall, the organic matter content in 2017 was relatively low compared to the other years. Although there are a few locations with extremely low organic matter content values in 2017, overall the values are still low. The reason for this remains unclear. Median grain size (D50) shows that in all cases, median grain sizes are in the range of medium to coarse sand. Location QT13 in 2012 had a deviating grain size value of 565 µm, which is in contrast to the also high organic matter content. Fishing intensity was highest in 2003, both within (QT) and adjacent (QAW) to the wind park. From 2008 onwards, fishing intensity was much lower especially inside the wind park, which was expected due to the prohibition of fishing activities inside wind parks. In 2017, the intensity was even lower.

Table 5-2. Averages of environmental variables with the two sample groups (QT and QAW).

	QT	QAW
Depth (m)	**22,91**	**23,47**
2003	24,91	24,97
2012	21,85	22,32
2013	21,71	22,08
2017	23,16	23,73
Organic Matter (%)	**0,68**	**0,33**
2003		
2012	1,16	0,54
2013	0,74	0,66
2017	0,17	0,20
D50 (µm)	**287,78**	**299,83**
2003		
2012	290,73	278,17
2013	274,53	285,00
2017	297,44	308,96
Fishing intensity	**1,50**	**1,85**
2003	4,12	4,05
2012	0,85	1,94
2013	0,97	1,99
2017	0,10	1,25

5.3 Univariate analyses

5.3.1 Number of species

Figure 5-3 shows the geographical distribution of the sampling stations and the number of species found in each station. The number of species was clearly lower in several of the stations in 2017, mainly in the QT area.

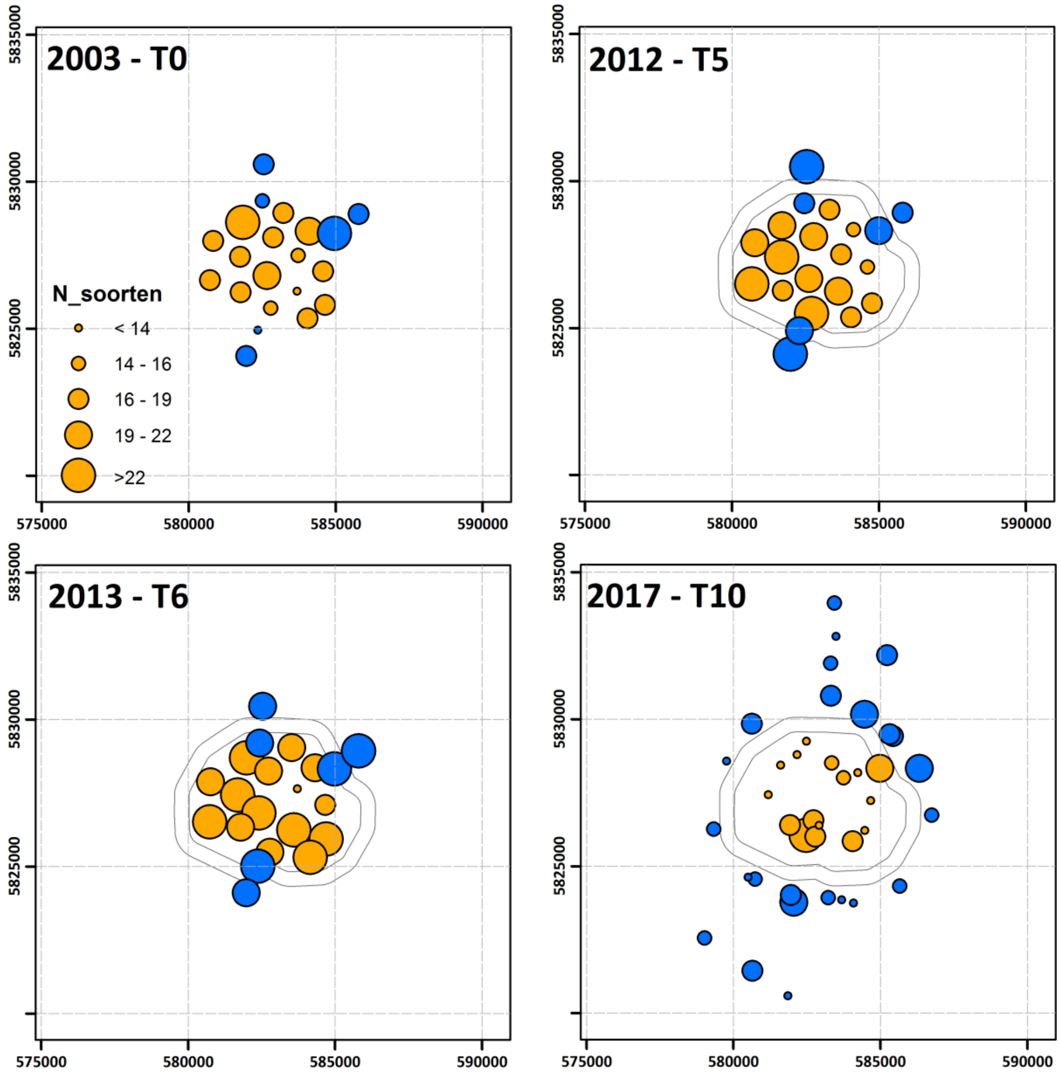

Figure 5-3: Number of species found per year, QT (Orange) are survey stations within the wind park and the blue stations are the reference stations outside of the wind park (QAW).

The box plots in Figure 5-4 show that the number of species found in 2017 is significantly lower than the number of species found in 2013 and 2012. No differences were found between the wind park area (QT) and adjacent waters (QAW) within any year. More species were found in 2013 in the wind park area than in 2003 in the wind park area and in 2017 in both the wind park and adjacent waters.
When we focus on the number of species found on sampling stations inside the wind park, we see that there is a rising trend from 2003 to 2013 in the number of species. However, in 2017 we see a significant drop in the number of species to a similar level that was found in 2003 in the wind park.

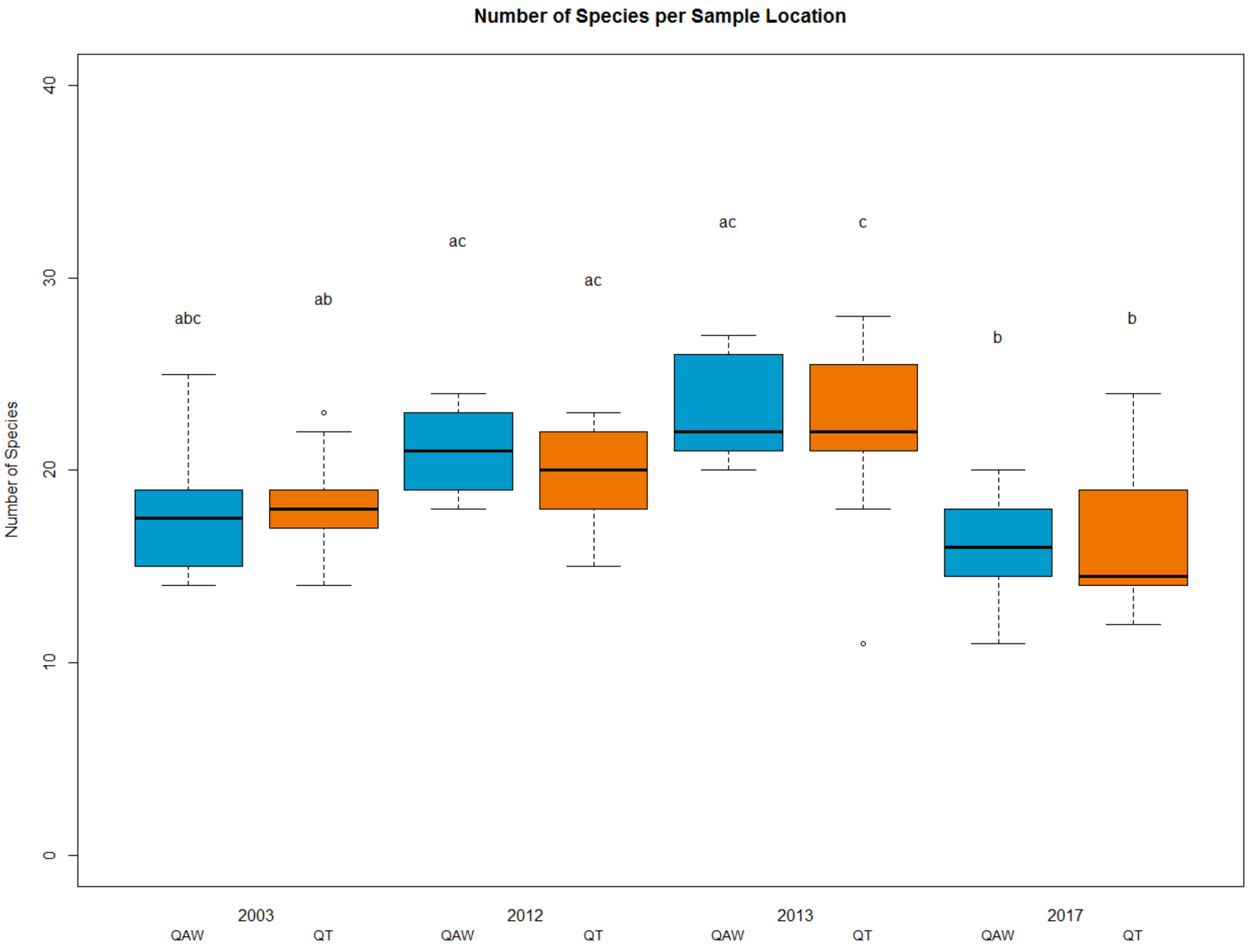

Figure 5-4: Number of species found in the wind park (QT) and adjacent waters (QAW). Similar letters above the individual boxes indicate no significant difference between the different levels of the year-park combinations (QT and QAW), based on Tukey's HSD post-hoc multiple comparisons ($p>0.05$).

The multiple stepwise regression analysis on number of species and the environmental variables and fishing intensity, showed that fishing intensity, median grain size and organic matter were best explaining the number of species. This means that depth had no relationship with the number of species. The selected model was highly significant and the adjusted R-squared of the whole model was 0.2197.

5.3.2 *Abundance*

Abundances seem to vary between years, with relatively low abundances in 2003 and 2013, and higher abundances in 2012 and 2017.

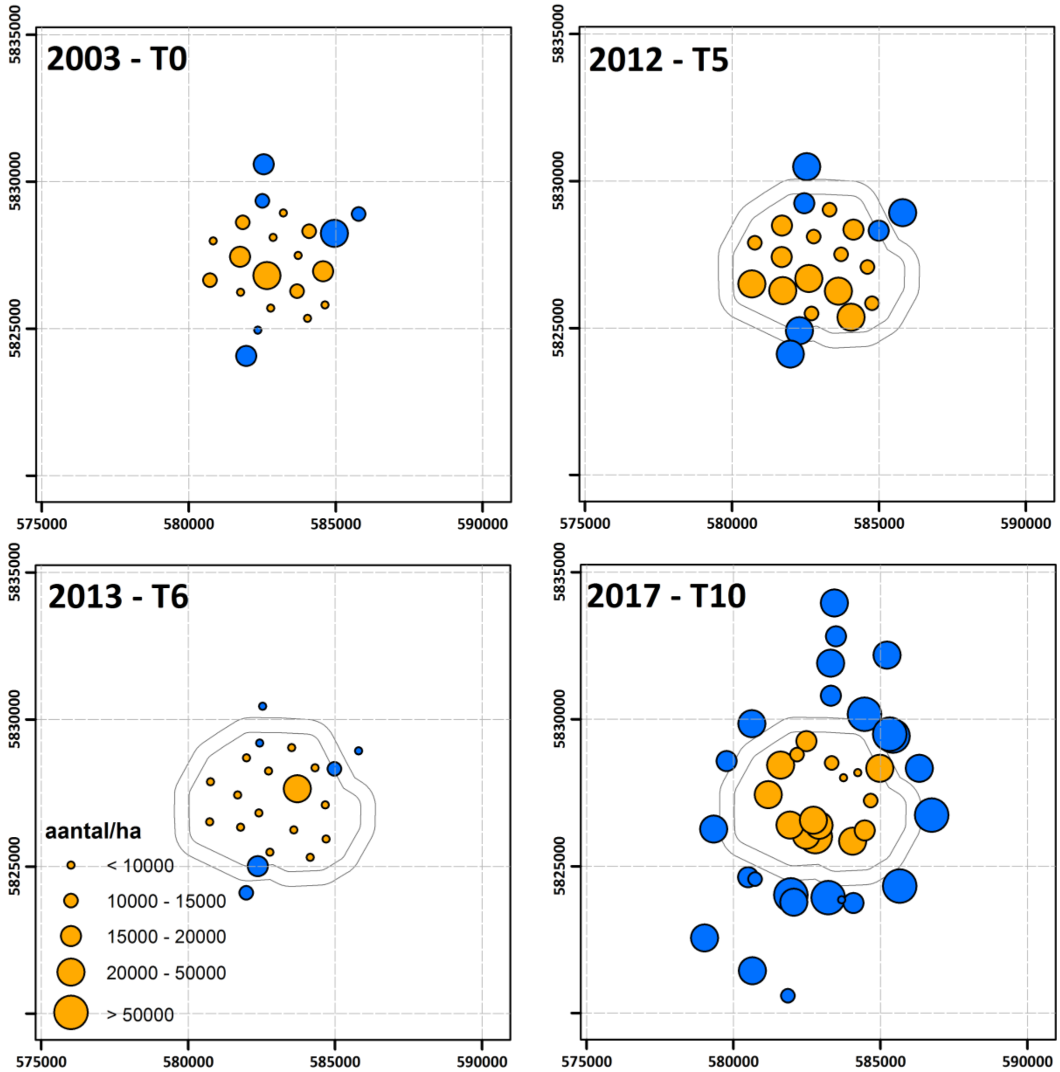

Figure 5-5: Abundance (n/ha) found per year, in QT (Orange) are survey stations within the Wind park, the blue stations are the reference stations outside of the wind park (QAW).

Multiple comparisons with Tukey's HSD showed several significant differences (Figure 5-6), where the stations in the wind park in 2003 have lower abundances than 2012-QAW, 2017-QT and 2017-QAW. 2013-QT showed significantly lower abundances than 2003-QAW, 2012-QAW, 2012-QT, 2017-QAW and 2017-QT, while 2017 seems to have very high abundances compared to the other years. The QAW area in 2017 showed the highest abundances, and was significantly different to all other groups, except for 2012-QAW and 2017-QT. Comparing abundances of the wind park area over the years, we see significantly lower abundances in 2013 and higher abundances in 2017. However, these higher abundances in 2017 are not significantly different than the abundances found in 2012. This can also be seen in when comparing the orange dots in Figure 5-5, 2012 and 2017 plots.

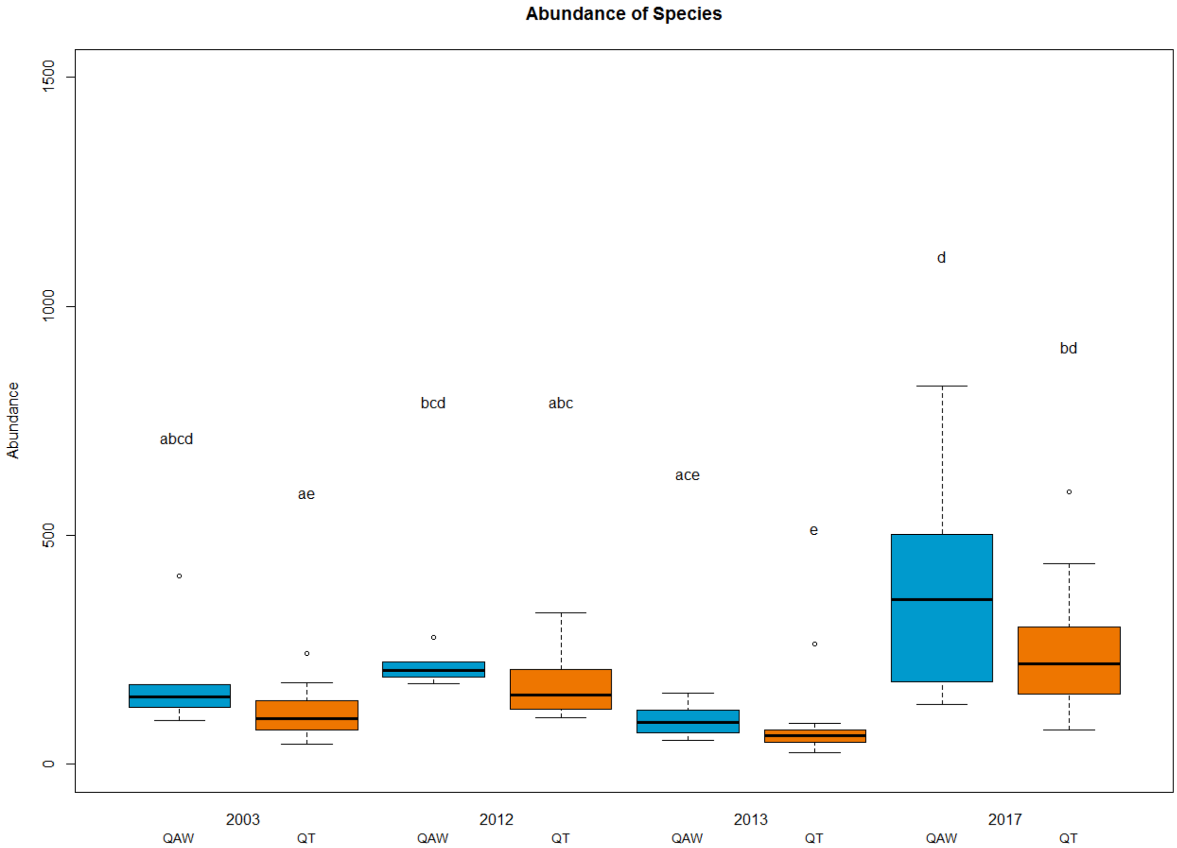

Figure 5-6: Abundance (n/100 m^2) found in the wind park (QT, orange) and adjacent waters (QAW, blue) over the four years. Similar letters above the individual boxes indicate no significant difference between the different levels of the year-park combinations (QT and QAW), based on Tukey's HSD post-hoc multiple comparisons (p>0.05).

The multiple stepwise regression analysis on abundance and the environmental variables fishing intensity, depth, median grain size and organic matter, showed that including all environmental variables would best explain the abundance. The whole model was highly significant and the adjusted R-squared of the whole model was 0.2762.

5.3.3 *Margalef diversity index*

Margalef diversity index shows a similar pattern to the number of species, with low index values in 2017, when compared to the other years.

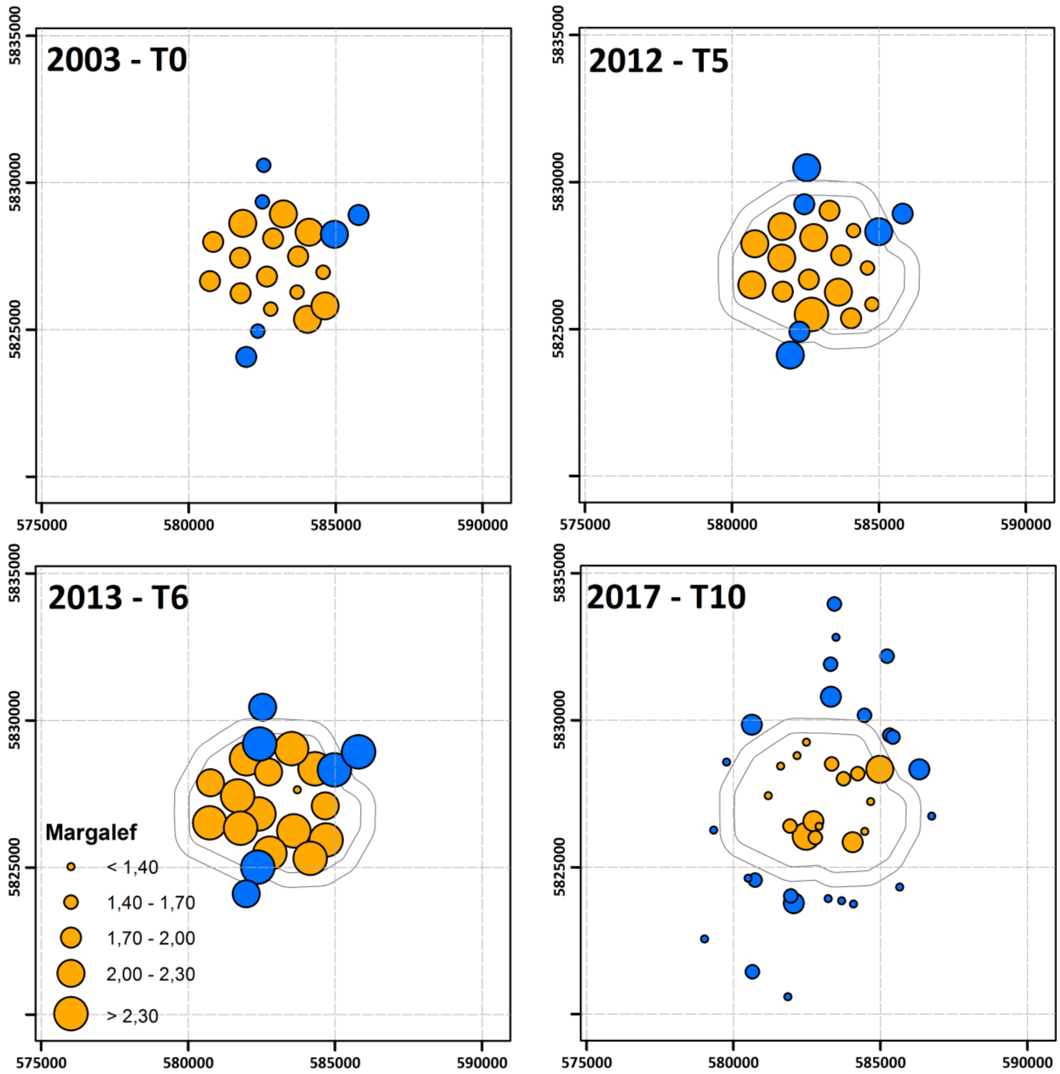

Figure 5-7 Margalef index calculated from the species data in the wind park (QT, orange) and adjacent waters (QAW, blue) over the four years.

Significant differences were found when comparing Margalef diversity index values from samples taken at adjacent waters in 2003 and samples taken from both the wind park area and adjacent waters in 2013 (Figure 5-8). The Margalef diversity index values from both the wind park area and adjacent waters samples in 2017 were significantly lower than all other groups tested, with the exception of adjacent waters in 2003. Margalef diversity index values showed significantly higher values in 2013 the wind park area than in 2012 for the wind park area, and 2003 for both the wind park area and adjacent waters and both groups in 2017. When solely comparing the wind park area index data, we see no difference between the years 2003 and 2012 in Margalef diversity index values. In 2013 there is a significant increase in index values, and in 2017 a significant decrease in index values can be seen.

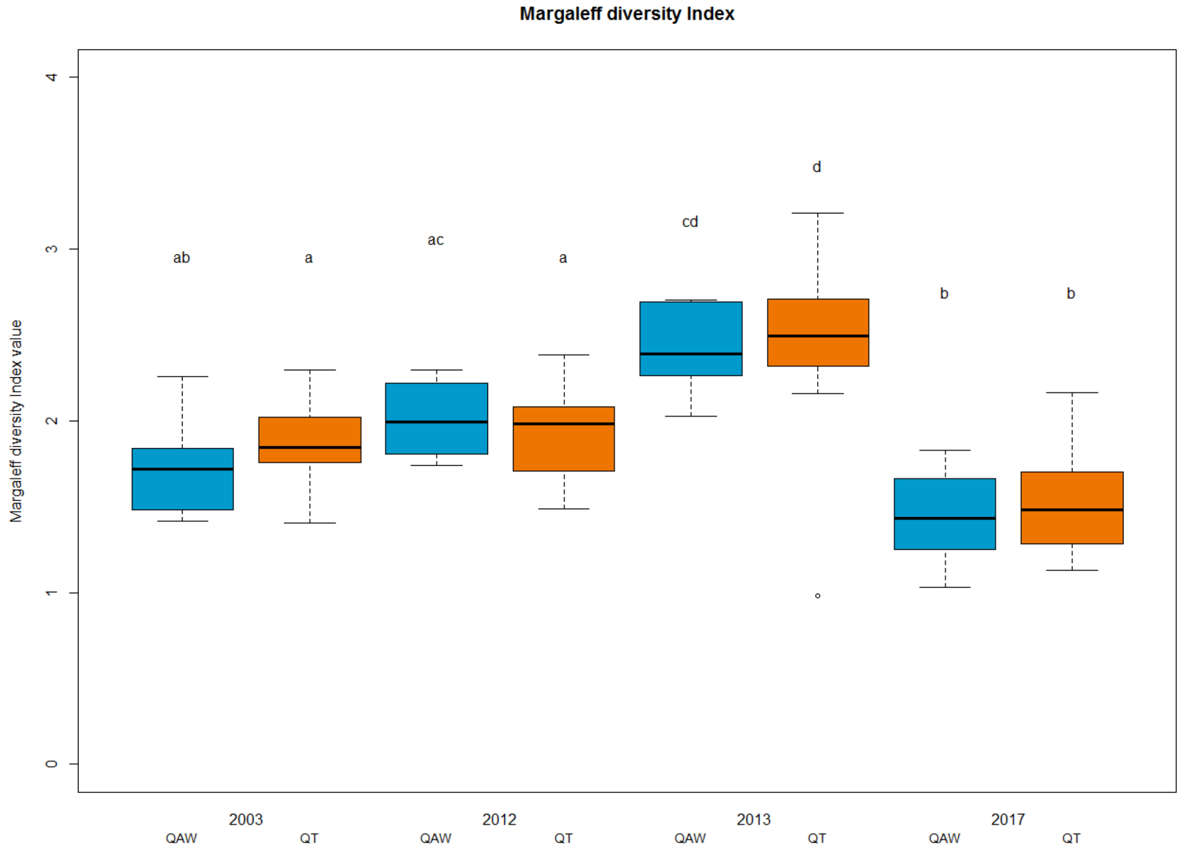

Figure 5-8: Margalef diversity calculated from the species data in the wind park (QT, orange) and adjacent waters (QAW, blue) over the four years. Similar letters above the individual boxes indicate no significant difference between the different levels of the year-park combinations (QT and QAW), based on Tukey's HSD post-hoc multiple comparisons (p>0.05).

The multiple stepwise regression analysis on the Margalef diversity index and the environmental variables fishing intensity, depth, median grain size and organic matter, showed that including all environmental variables would best explain the index values. The model was highly significant and the adjusted R-squared of the whole model was 0.2623.

5.3.4 Shannon Wiener index

The Shannon Wiener index seems to be relatively low in 2017 when compared to the other years. A high Shannon Wiener index is generally an indication for high biodiversity, and a low index for low biodiversity. A low Shannon Wiener index can also indicate an unequal distribution of abundances over the different species, for instance due to a dominant species with very high abundances compared to the other species found on a station. This is for instance the case on stations 21 and 22 in 2017, where *Spisula subtruncata* was present in very high abundances.

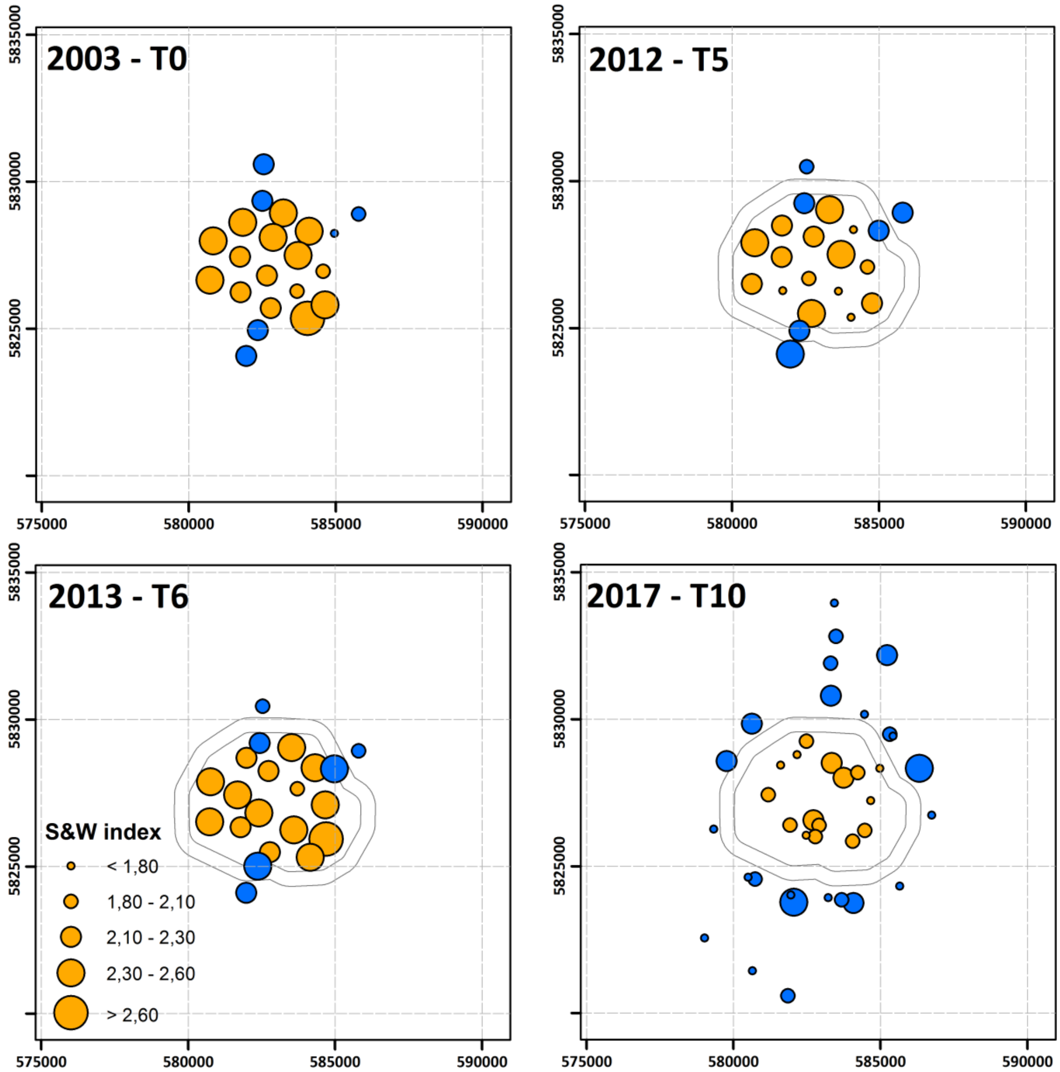

Figure 5-9: Shannon Wiener index calculated from the species data, in QT (Orange) are survey stations within the Wind park, the blue stations are the reference stations outside of the wind park (QAW).

Figure 5-10 shows the box plots for the Shannon Wiener index for all the tested groups. Here we see that the Shannon Wiener index values were significantly lower in the 2017-QAW area compared to 2013-QT, 2012-QT and 2003-QT index values. The index values for 2017-QT sites were significantly lower than 2013-QT, and 2003-QT index values. No significant differences were found between the Shannon Wiener index values of both QT and QAW in 2003, 2012 and 2013. Comparing wind park Shannon Wiener index values over the years, we see a decrease in the index values in 2017. This is also apparent when looking at Figure 5-9, where orange dots are similar in size over 2003, 2012 and 2013, but dots are smaller in the 2017 plot of figure 3-5.

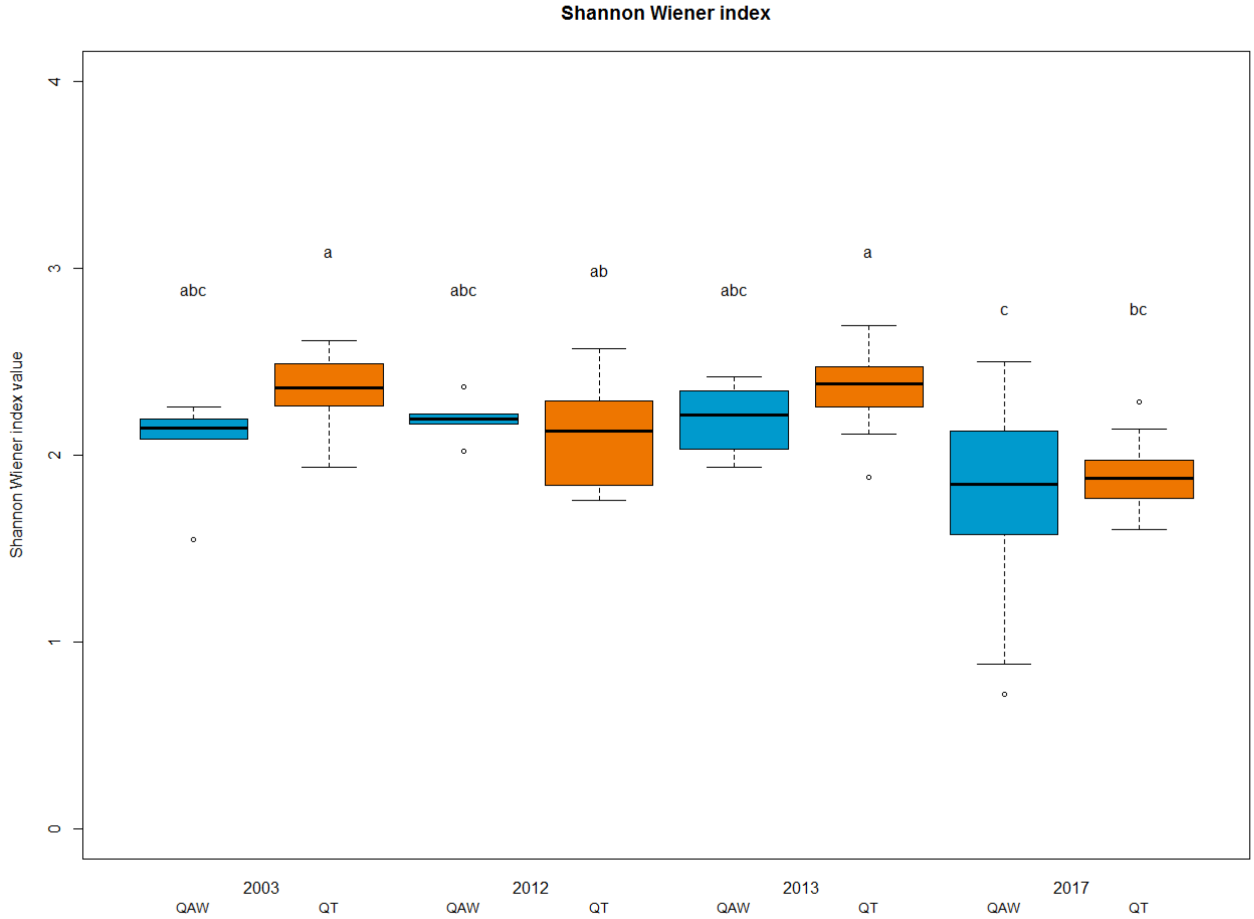

Figure 5-10: Shannon & Wiener index calculated from the species data in the wind park (QT, orange) and adjacent waters (QAW, blue) over the four years. Similar letters above the individual boxes indicate no significant difference between the different levels of the year-park combinations (QT and QAW), based on Tukey's HSD post-hoc multiple comparisons (p>0.05).

The multiple stepwise regression analysis on the Shannon Wiener diversity index and the environmental variables fishing intensity, depth, median grain size and organic matter, showed that including depth, median grain size and organic matter best explained the Shannon Wiener diversity. The selected model was significant and the adjusted R-squared of the whole model was 0.1481.

5.3.5 *Simpson's index*

The used Simpson's index is actually 1- Simpson's index, which represents the probability that two individuals selected randomly from a sample will belong to different species. The index ranges from 0-1 and a higher the value indicates higher diversity.

The two-way ANOVA showed that year was significant ($p<0.001$), but wind park and the interaction were not. The year effect is mainly caused by 2017.

Values from the Simpson's index were significantly higher in 2003-QT sites than in 2012-QT sites and both QT and QAW in 2017. 2012-QT sites did not show significantly different values for the Simpson's index than values from both site-groups in 2017. 2013-QT sites showed significantly higher values for the Simpson's index than 2017-QAW and 2017-QT site values. The wind park data fluctuates over the years, with a decrease in 2012, compared to 2003. In 2013 there is an increase in index values, which is followed by a significant decrease in 2017, to similar values as found in 2012.

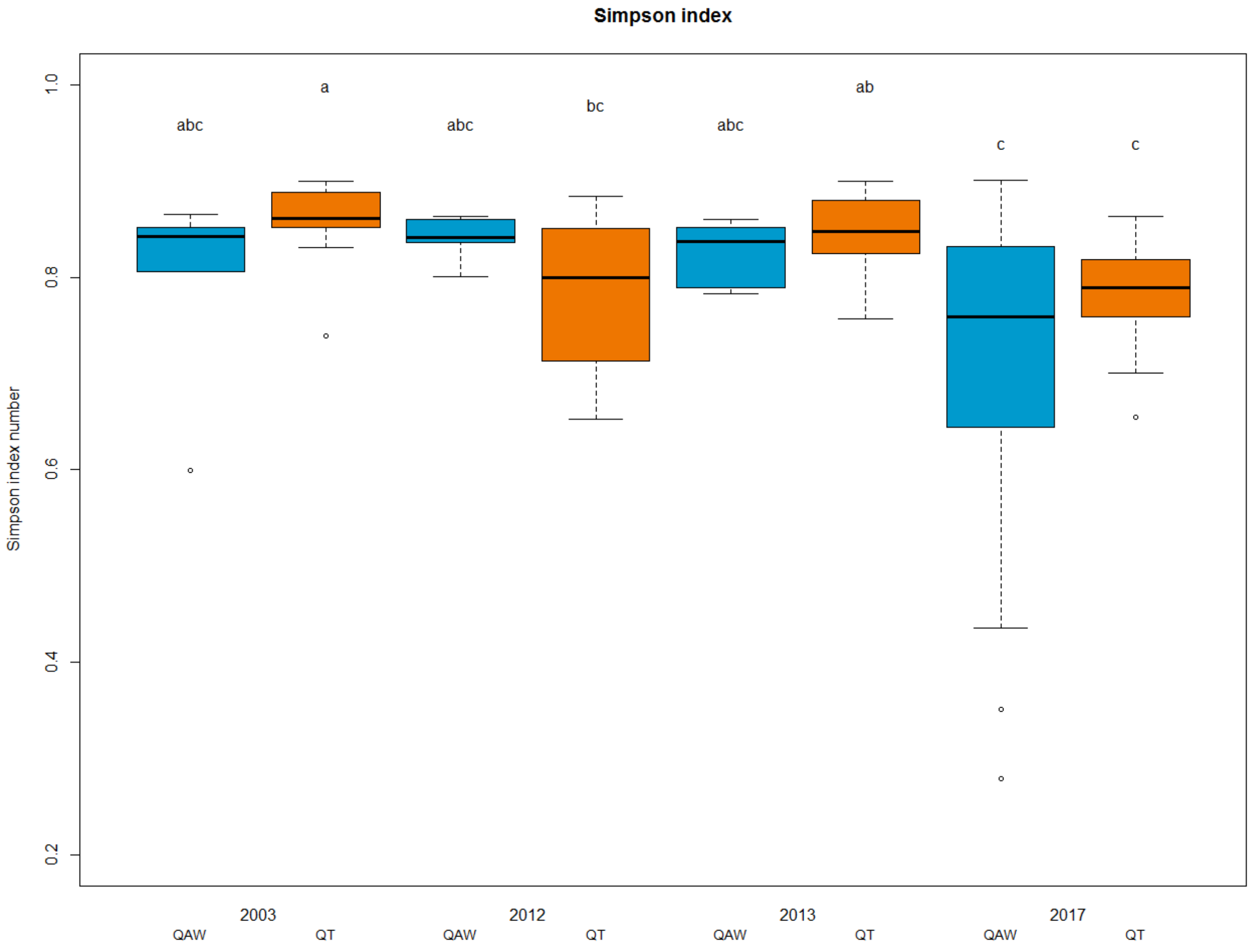

Figure 5-11: Simpson's index calculated from the species data in the wind park (QT, orange) and adjacent waters (QAW, blue) over the four years. Similar letters above the individual boxes indicate no significant difference between the different levels of the year-park combinations (QT and QAW), based on Tukey's HSD post-hoc multiple comparisons ($p>0.05$).

The multiple stepwise regression analysis on the Simpson index and the environmental variables fishing intensity, depth, median grain size and organic matter, showed that including median grain size and organic matter best explained the Simpson diversity. The selected model was significant and the adjusted R-squared of the whole model was 0.0518.

5.3.6 Pilou's evenness index

Pilou´s evenness index ranges from 0 to 1, with low values indicating low evenness, and also possible present dominant species.

The two-way ANOVA was significant for year (p<0.001), nearly significant for wind park (p=0.052) and the interaction was not significant.

The values for the Pilou's Measure of Species Evenness were significantly higher in 2003 wind turbine sites than values in 2012 wind turbine sites, 2013 adjacent waters, and values from both groups in 2017. The other values for the Pilou's Measure of Species Evenness did not show significant diversion from each other in this analysis. When comparing wind park values, a decrease after 2003 can be seen. The index values after 2003 stay relatively constant over the years. In 2013 the index values did not differ from the values in 2003 however.

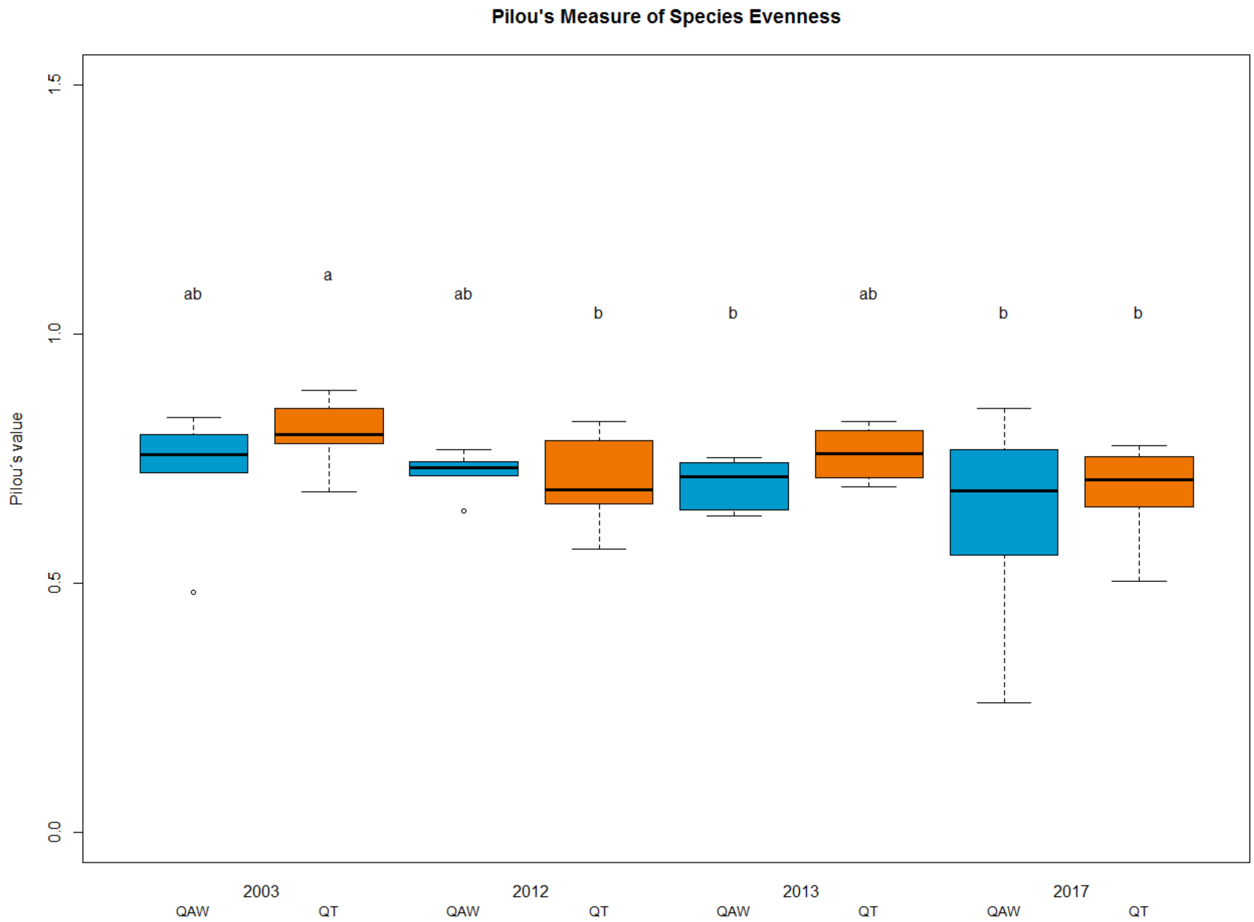

Figure 5-12: Pilou index calculated from the species data in the wind park (QT, orange) and adjacent waters (QAW, blue) over the four years. Similar letters above the individual boxes indicate no significant difference between the different levels of the year-park combinations (QT and QAW), based on Tukey's HSD post-hoc multiple comparisons (p>0.05).

The multiple stepwise regression analysis on Pilou's evenness index and the environmental variables fishing intensity, depth, median grain size and organic matter, showed that including depth and organic matter best explained Pilou's index values. The whole model was not significant and the adjusted R-squared of the whole model was 0.009.

5.4 Multivariate analyses

The nMDS in Figure 5-133 shows that there is a clear distinction in community composition between the years, mainly for 2003 and 2017. 2012 and 2013 largely overlap, with 2013-QAW more overlapping 2012-QAW than 2012-QT. In 2017, locations QAW19, QAW21 and QAW22 were outside the 95% confidence interval ellipse, and can therefore be considered outliers. QAW21 and QAW22 had the highest total abundances (with QAW21 a fourfold higher than QAW22) due to the abundance of *Spisula subtruncata*, while QAW19 had the second lowest abundance in 2017, after QT6. Also QT5 in 2013 can be considered an outlier, also because of having very high abundances of several species (e.g. *Callionymus*, *Ophiura ophiura*, *Liocarcinus holsatus*).
PERMANOVA showed that both year and wind park had a significant effect (p=0.001 for both factors), confirming the visual results of the nMDS.

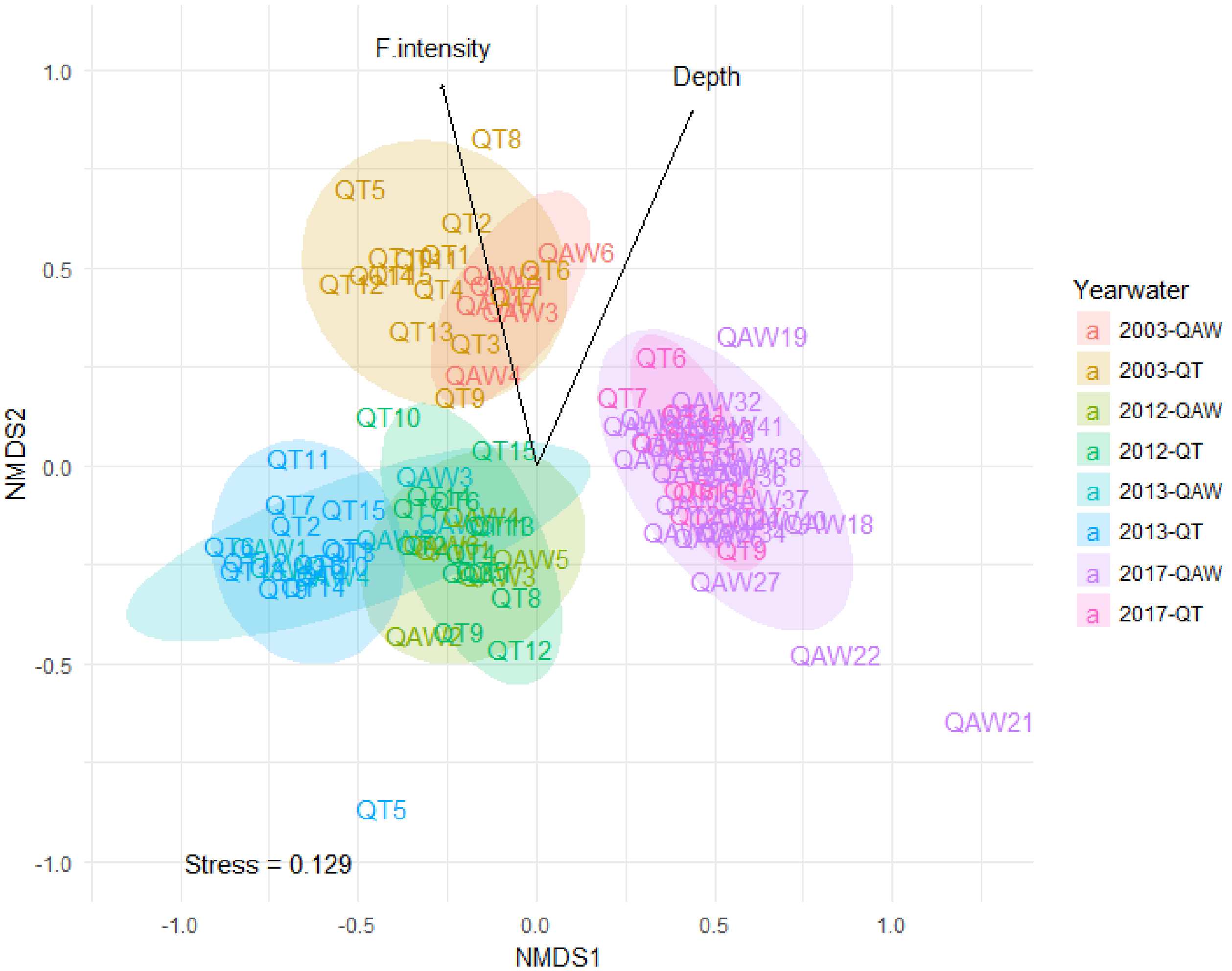

Figure 5-13: nMDS (non-metric multidimensional scaling) based on Bray-Curtis resemblance matrix of square root transformed soft bottom faunal densities for the four years. 95% confidence interval ellipses are shown for each year and wind park location (QT= turbine site; QAW= adjacent waters). Arrows are significantly correlated environmental variables from the envfit procedure.

The envfit procedure (Table 5-3) revealed that the community composition was significantly correlated with all variables that were analysed. Since Month was highly correlated with Year (r=-0.89, p<0.001), the correlation of this variable with the community composition can be considered an artifact. However, Depth and Fishing intensity were also significantly correlated with de community composition, although r^2 was considerably lower than that of Year.

Table 5-3: R outputs from the envfit function, which fits variables onto the nMDS ordination of the species composition. The full dataset was used. Shown are the 2 nMDS coordinates (X-Y axis), correlation coefficient values (r^2) and p-value of the tested variables.

Variable	NMDS1	NMDS2	r^2	P
Year	0.48387	-0.87514	0.6676	0.001^{***}
Depth	0.43911	0.89843	0.1956	0.001^{***}
Fishing intensity	-0.26588	0.96401	0.3937	0.001^{***}

Figure 5-14 shows the nMDS plot of with the exclusion of data from 2003, to include the environmental variables Organic Matter and D50. The figure shows that both organic matter and D50 have a significant correlation (p= 0.048; p=0.009, resp.) with the species composition. This can also be seen in the outputs from the envfit function in Table 5-4.

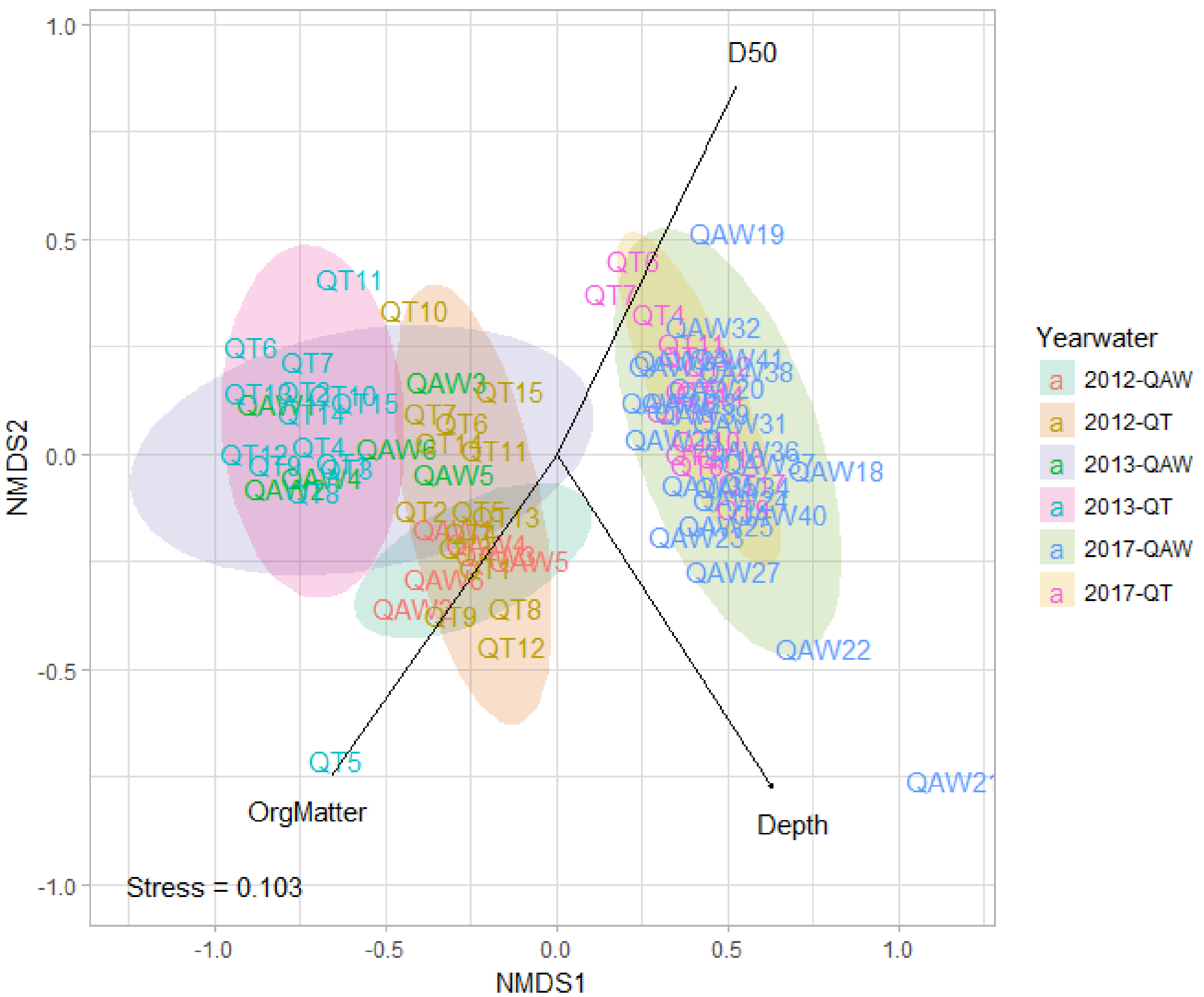

Figure 5-14: nMDS (non-metric multidimensional scaling) based on Bray-Curtis resemblance matrix of square root transformed soft bottom faunal densities for the four years. 95% confidence interval ellipses are shown for each year and wind park location (QT= turbine site; QAW= adjacent waters). Arrows are significantly correlated environmental variables from the envfit procedure.

Table 5-4: R outputs from the envfit function, which fits variables onto the nMDS ordination of the species composition. Data from 2003 was excluded in this analysis. Shown are the 2 nMDS coordinates (X-Y axis), correlation coefficient values (r^2) and statistical power of the tested variables.

Variable	NMDS1	NMDS2	r^2	P
Year	0.81250	0.58296	0.8051	0.001***
Depth	0.62972	-0.77682	0.3110	0.001***
Fishing intensity	-0.72478	0.68899	0.0110	0.617
OrgMatter	-0.66004	-0.75123	0.0627	0.048*
D50	0.52376	0.85187	0.1252	0.009**

Figure 5-15 shows the nMDS plot of the data excluding adjacent waters locations. A clear temporal effect can be seen. No ellipses overlap each other, which indicates a clear difference in species composition over the years. This is also evident by the 'year' arrow which shows a strong correlation (r^2 = 0.73; p = 0.001) between the data and the variable year, which can also be seen in Table 5-6.

Depth and fishing intensity also show significant correlation (p=0.001 for both) with the data as shown by the arrows and in Table 5-5, with fishing intensity having the highest influence (r^2 = 0.57), next to year. Fishing intensity is, however, highly correlated with the data from the year 2003, which was the last year fishing was permitted in the area.

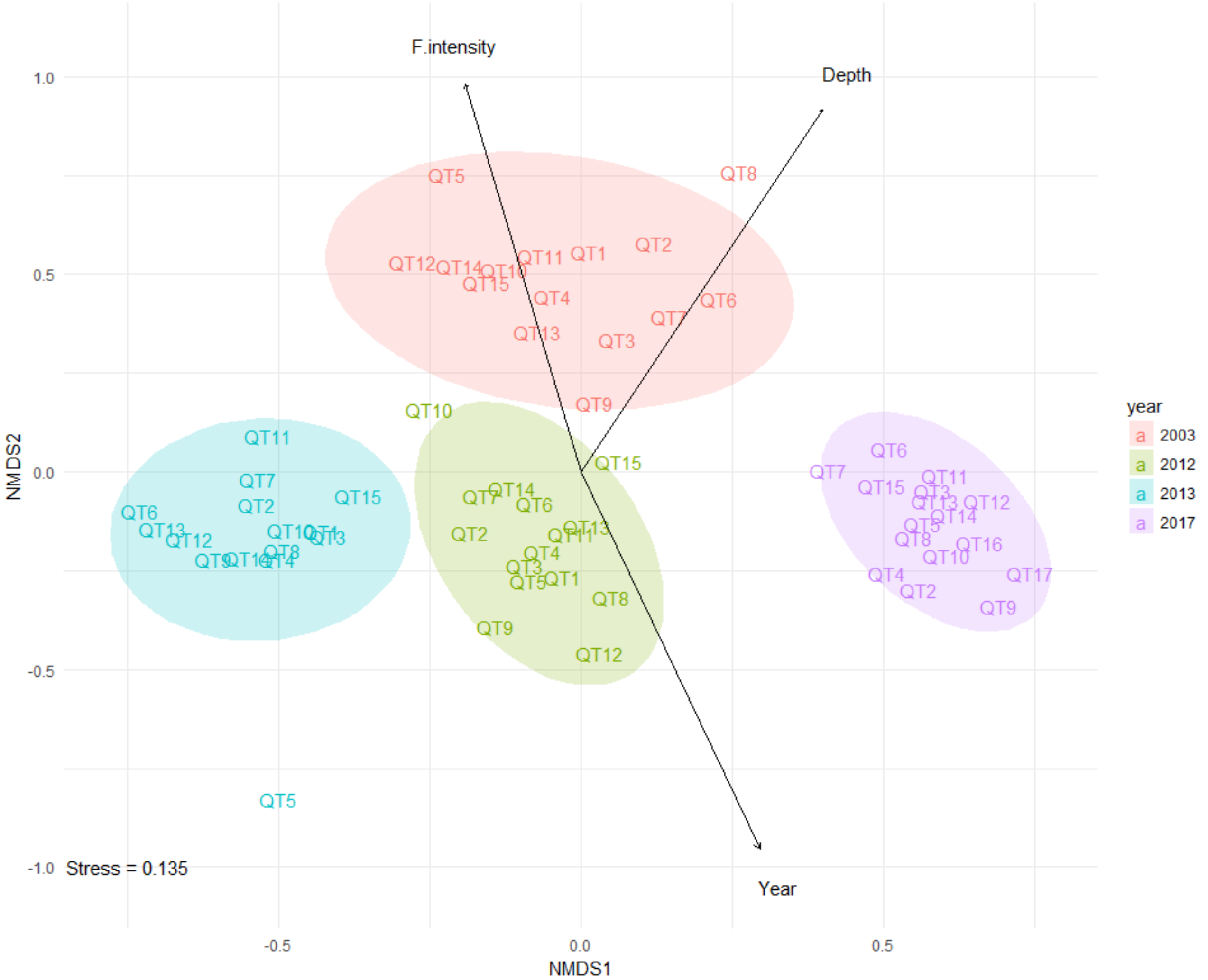

Figure 5-15: nMDS (non-metric multidimensional scaling) based on Bray-Curtis resemblance matrix of square root transformed soft bottom faunal densities for the four years. 95% confidence interval ellipses are shown for each year. Only wind park location (QT= turbine site) were used in this nMDS analysis. Arrows show significantly correlated variables from the envfit procedure.

Table 5-5: R outputs from the envfit function, which fits variables onto an ordination using species composition data collected from wind turbine sites (QT). Comparing nMDS outputs of species composition data from samples collected in different years (2003, 2012, 2013 and 2017). Shown are the 2 nMDS coordinates (X-Y axis), correlation coefficient values (r^2) and statistical power of the tested variables.

Variable	NMDS1	NMDS2	r^2	P
Year	0.29558	-0.95532	0.7330	0.001***
Depth	0.40038	0.91635	0.3034	0.001***
Fishing intensity	-0.19157	0.98148	0.5662	0.001***

Table 5-6 shows the envfit results with data exclusion of the QAW and 2003 data. It shows that year and depth still have significant correlation (p=0.001; p=0.005, resp.) with the community composition of wind park samples. However, organic matter, D50 and fishing intensity do not significantly correlate with the community composition (p = 0.52, p = 0.26; p = 0.18, resp.).

Table 5-6: R outputs from the envfit function, which fits variables onto an ordination, using species composition data from wind turbine sites (QT) and data from three years (2012, 2013 and 2017). Data from 2003 was excluded in this analysis to include the variables Organic matter (OrgMatter) and D50 (grain size). Shown are the 2 nMDS coordinates (X-Y axis), correlation coefficient values (r^2) and statistical power of the tested variables.

Variable	NMDS1	NMDS2	r^2	P
Year	0.87213	-0.48928	0.6852	0.001***
Depth	0.59793	0.80155	0.2345	0.005**
OrgMatter	-0.54019	0.84154	0.0376	0.516
D50	0.88098	-0.47316	0.0570	0.262
Fishing intensity	-0.71320	-0.70096	0.0825	0.181

5.4.1 Zooming in on 2017

In Figure 5-16 the nMDS plot for the year 2017 can be seen. There is no distinct separation between QT end QAW, as was also seen in the quick scan of the 2017 data (Leewis & Klink, 2017).

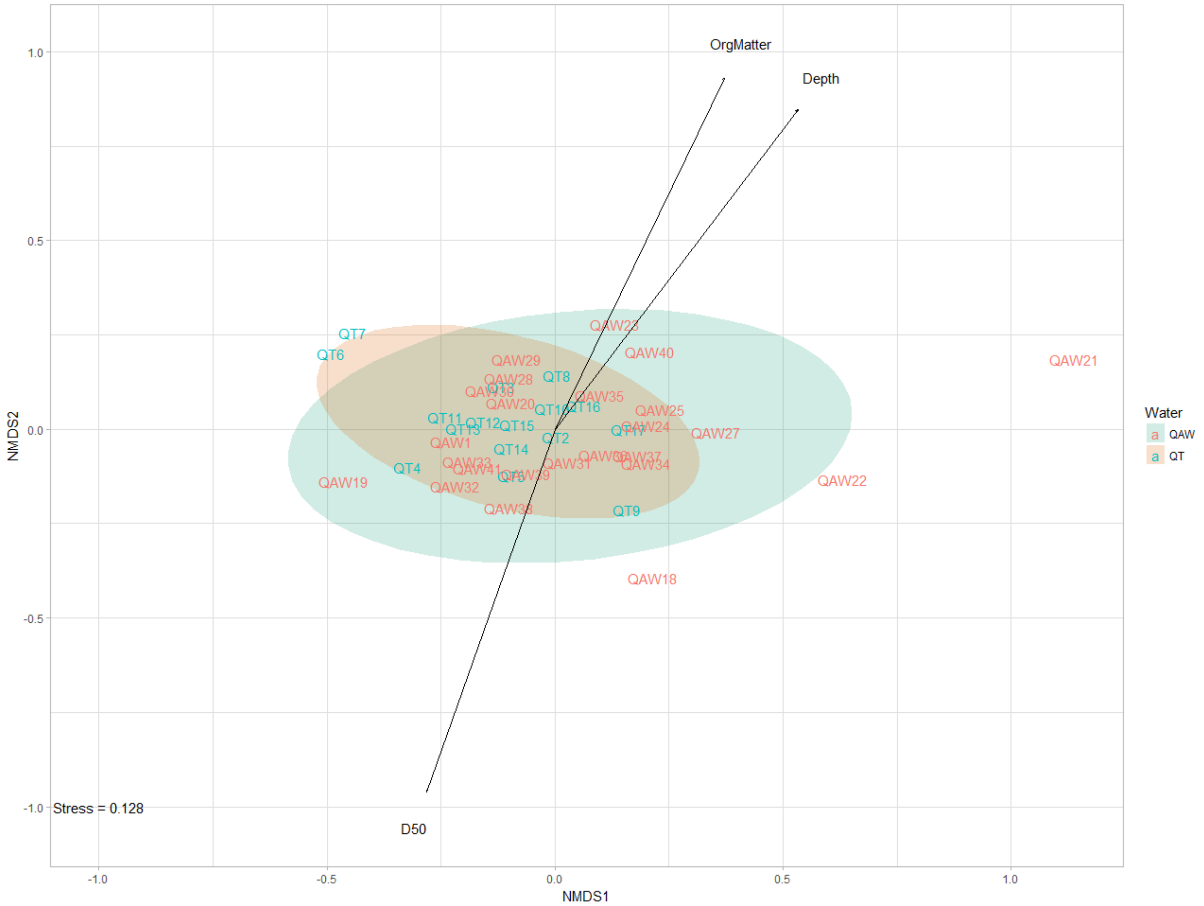

Figure 5-16: nMDS (non-metric multidimensional scaling) based on Bray-Curtis resemblance matrix of square root transformed soft bottom faunal densities for 2017. 95% confidence interval ellipses are shown for each year. Arrows show significantly correlated variables from the envfit procedure.

When the envfit procedure was run on the 2017 data alone (Table 5-7), it becomes clear that depth, organic matter content and sediment grain size (D50) al all significantly related to the species composition. Depth had the strongest relation with the species composition in 2017 (r^2=0.35).

Table 5-7: R outputs from the envfit function, which fits variables onto an ordination, using species composition data from 2017. Shown are the 2 nMDS coordinates (X-Y axis), correlation coefficient values (r^2) and statistical power of the tested variables.

Variable	NMDS1	NMDS2	r^2	P
Depth	0.53237	0.84651	0.3503	0.001***
OrgMatter	0.37112	0.92858	0.2678	0.001***
D50	-0.28116	-0.95966	0.2312	0.004**
Fishing intensity	-0.02826	-0.99960	0.0310	0.497

In the plots below, the significant variables from the envfit procedure are plotted over the nMDS plots. This shows the contour map of the environmental variables over the plotted sampling locations.
Figure 5-17 shows a decreasing depth from the top-right to the bottom-left of the plot. The two outliers QAW21 and QAW22 seem to be in the deeper parts of the sampled area, with low median grain sizes and high organic matter contents. A similar pattern is present in Figure 5-18. Sediment grain size (D50, Figure 5-19) shows a somewhat different pattern, where smaller grain sizes were present in the top right part and upper part of the graph.

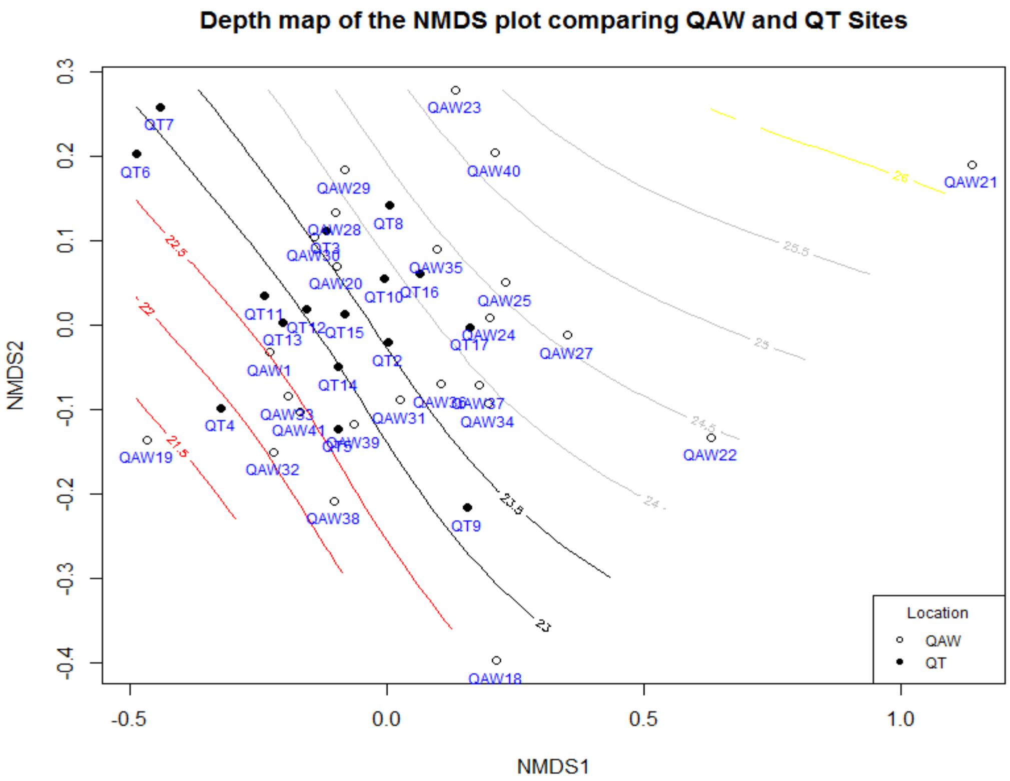

Figure 5-17: nMDS (non-metric multidimensional scaling) based on Bray-Curtis resemblance matrix of square root transformed soft bottom faunal densities for 2017. The variable “depth” is plotted as a smooth surface over the nMDS ordination using the ordisurf function.

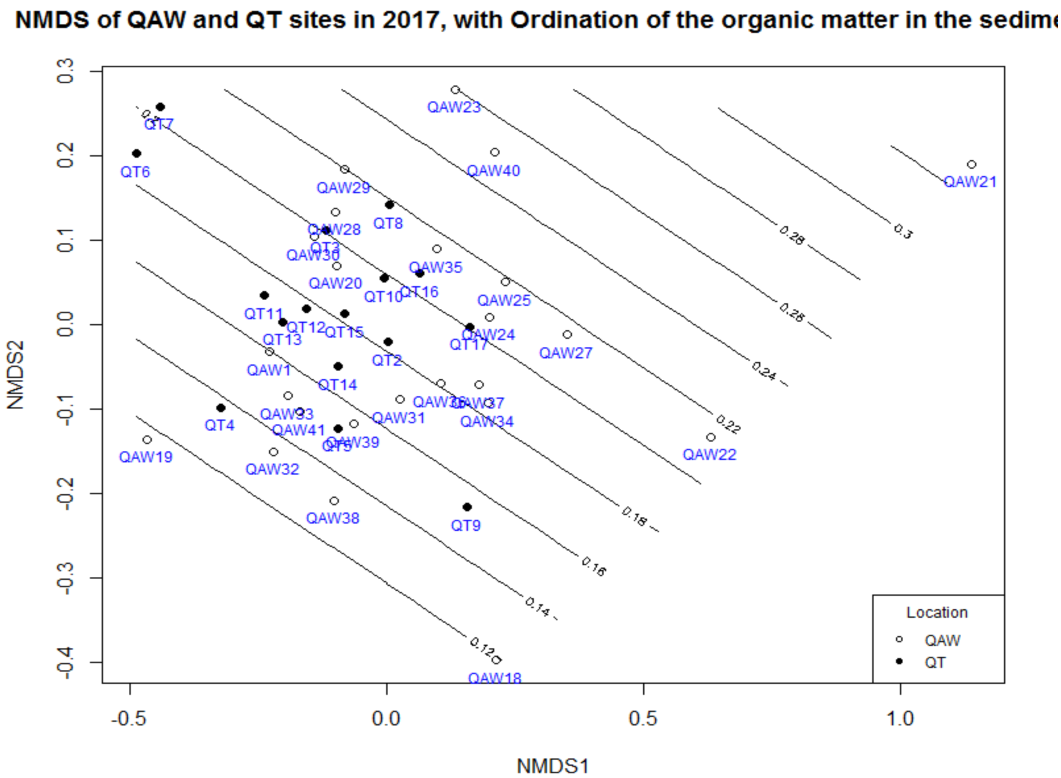

Figure 5-18: nMDS (non-metric multidimensional scaling) based on Bray-Curtis resemblance matrix of square root transformed soft bottom faunal densities for 2017. The variable “organic matter” is plotted as a smooth surface over the nMDS ordination using the ordisurf function.

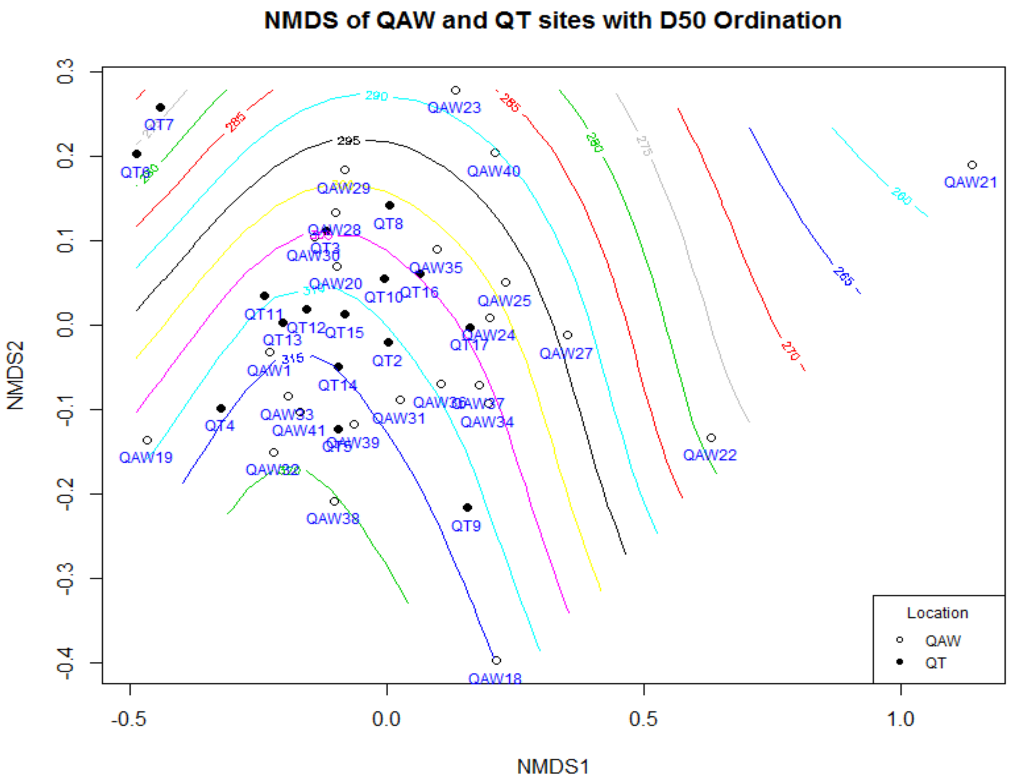

Figure 5-19: nMDS (non-metric multidimensional scaling) based on Bray-Curtis resemblance matrix of square root transformed soft bottom faunal densities for 2017. The variable “D50” is plotted as a smooth surface over the nMDS ordination using the ordisurf function.

In general, sampling locations with larger abundances (see Figure 5-20) seem to be more on the right (top) side of the nMDS plot. This coincides partly with deeper waters, smaller grain sizes and higher organic matter content of the sediment.

Multiple regressions on the data of 2017 also showed the importance of depth for the parameter “abundance”, “number of species” and “Margalef diversity index”. There, depth was the only variable selected from the stepwise multiple regression procedures, which was significant in all cases ($p<0.05$). However, much unmeasured variance is left, since R^2 values indicated were 0.11, 0.21 and 0.12, respectively.

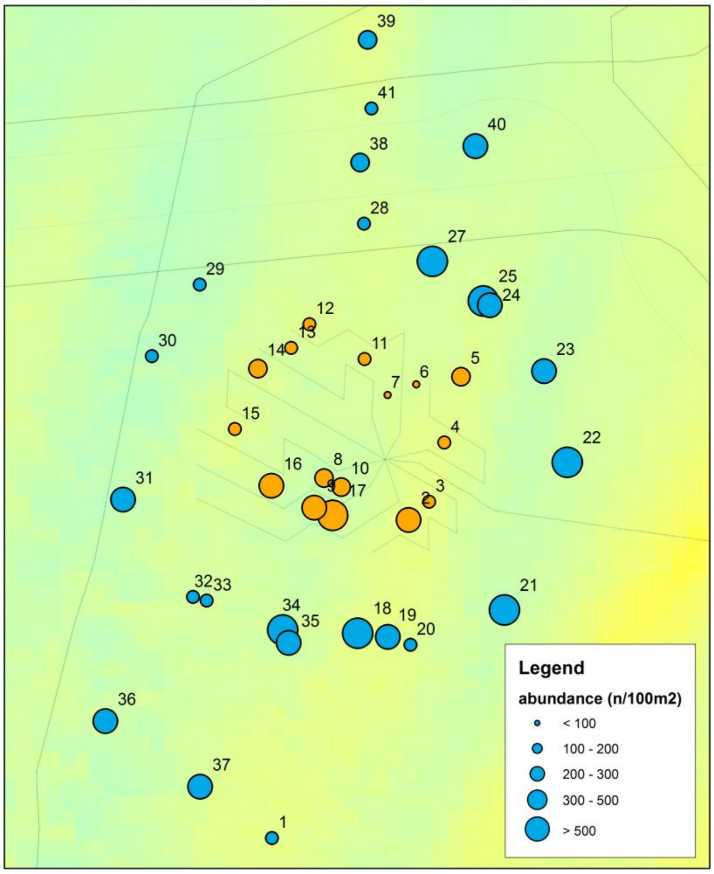

Figure 5-20: Benthic fauna abundance (n/100 m^2) found in the wind park (yellow) and outside the wind park (blue) (from: Leewis & Klink, 2017).

6 Discussion

In this study we analysed the soft bottom faunal communities from the Prinses Amalia Wind park (PAWP). The main goal of this report was to assess differences in faunal communities between PAWP and reference locations. The main comparisons were made between sampling years (2003, 2012, 2013 and 2017) and locations inside the wind park (QT) and the reference locations, adjacent waters (QAW). The adjacent waters were located to the outer regions and outside the wind park.

Univariate analyses

Looking at the results from the univariate analyses there was a clear temporal effect on the average number of species per sampling location, species abundances and most of the indexes that were analysed. The most notable differences in the analyses were the differences of the 2017 data with the other years that were analyzed. Abundances were much higher in 2017, even without outliers, and number of species and diversity indices were much lower than previous years.

The variation in the data was a lot higher for data collected in 2017 than data collected in the other years, mainly for the adjacent waters (QAW), and for the abundance and Shannon Wiener index. Some of this might be explained when looking at the samples that were taken that year. The locations of the sampling stations were very similar in the years 2003, 2012 and 2013. However, the locations of the sampling stations in 2017 did not correspond as well as the other years do. With the introduction of extra sampling stations in the adjacent waters in 2017, the possibility of less similar stations has increased, adding to the extra variation. Despite this, the large differences in 2017 compared to the other years, seem to be largely due to temporal variation, which could be attributed to a number of reasons, like weather and temperature.

The general pattern in diversity for Shannon Wiener and Simpson is comparable. Similar to the Shannon Wiener index, the low index value for 2017-QAW was mainly caused by the stations 21 and 22, but also 18 and 34 had low index values. Also Pilou´s evenness index shows a similar pattern, although a little less explicit. The patterns in these indices seem to be mainly driven by abundance, which shows similar effects. Margalef diversity index seems to follow the patterns of number of species. Overall, the differences in the univariate data seem to be driven by the year 2017, with a relatively low number of species and high abundances.

The high abundances of *Spisula subtruncata* in the sampling stations 21 and 22 are in line with the ever so high stock increase of this species in 2017, as reported by Troost et al. (2017). They also reported a very high stock increase of *Ensis directus*, and also *Donax vittatus*, *Lutratia lutraria* showed high increases when compared to 2016.

In the multiple regressions, year was not included as a variable, since we wanted to see which environmental variables other than year, would explain the variance in the data. The multiple regressions indicated that for most univariate data, median grain size (D50) and organic matter content were important in explaining the data. Also depth was included in the model several times. Similar results were found in de Jong et al. (2015), where fine to medium fine sand and high organic matter values harboured highest species richness and biomass. The inclusion of fishing intensity in the regression models for number of species, abundance and Margalef were most likely mainly driven by the high fishing intensities in 2003. However, entirely excluding 2003 from the species data, resulted in the exclusion of fishing intensity in the final regression model. This is an indication that the moderate fishing intensities in the adjacent waters (QAW) in the other years (2012, 2013 and 2017) did not have a large influence on the data.

Overall, the explaining power (i.e. R^2) of the environmental variables that were tested, was very low. This indicates that there are other variables explaining the variance in the data, like year, again indicating large temporal effects. However also other variables may be important, like modeled bed shear stress (De Jong et al., 2015), and the sediment characteristics sorting and skewness (Leewis et al., 2012).

Multivariate analyses
The shown nMDS plots give a view on the temporal change in faunal composition of the Prinses Amalia wind park. The 95% ellipses show that each sampling year is located around different coordinates and some overlap between years is shown. Samples taken in 2003 consist of a different community than samples taken in 2012 and 2013. This is shown by the overlap in ellipses of those samples, which indicates a higher similarity in faunal densities and species composition between samples taken in 2012 and 2013 years. This can be explained by the time difference of only one year between those samples. Samples taken in 2017 consist of a different community compared to samples taken in all other years. Overall, a clear temporal effect can be observed. The envfit procedure confirms this with having the highest r^2 values for year for all analyses. All together the plots show the change of the faunal community over time.

When looking at the nMDS consisting of samples taken in the wind park alone (Figure 5-15), it becomes clear that the composition of the faunal communities changes over time with 2003 and 2013 being more closely related than the other years. This gives rise to the image that the faunal communities found in the wind park shifted between 2012 and 2013 to a state which resembled the community found in 2003. Afterwards, it shifted to a new composition as is shown by the samples taken in 2017. However, it must be taken into account that that the sampling locations changed in 2017, which might partly explain some of the differences in faunal community found in the 2017 samples.

Next to year, depth of the samples shows significant correlation with the nMDS outputs with relatively high r^2 values compared to median grain size and organic matter. The significance of depth can be interpreted by different species of species assemblages that can be found at different depths. This could be seen for three different *Spisula* species that we present in different parts of the wind park and adjacent area in 2017 (Leewis & Klink, 2017). However, the influence of depth on the species composition is not clear at this point and needs to be further investigated.
The intensity of fishing that was done at the wind park also shows a significant correlation with the communities of fauna found. Fishing within the wind park was prohibited after 2008, with the completion of the building. This is evident by the strong correlation between the faunal community found in 2003 and the direction of the arrows in Figure 5-13 and Figure 5-15. When 2003, the year with the highest fishing intensity, was excluded from the analysis, fishing intensity was no longer significantly related to the community composition.
Different unmeasured factors might be of influence on the species composition at the wind park that are now explained by the intensity of fishing. Therefore we can only speculate on the effects of the prohibition of fishing on the species composition.

There were also differences between the wind park sampling stations and the adjacent waters sampling stations, both in univariate and in the multivariate analyses. However, the community compositions within the different years are still partly overlapping in the nMDS. Here, the group with the least number of sampling stations seems to lie within the group with the largest number of sampling stations, with more variation in the latter case. This suggests that with adding more stations, the chance of finding a more differing community composition will rise. This is in line with the generalities of the species area curve, where more species will be found with increasing sampling effort, up to a certain threshold.

Sampling design
The sampling design of the Princess Amalia Wind park had changed over time. In 2003, 2012 and 2013 two larger reference areas located North and South of the wind park were present. However, it is highly questionable whether these areas can be considered as valid references. Therefore, the design was changed in 2017 to adding more reference sampling stations to the adjacent waters area (QAW). Although this ensures for a more valid reference area, since environmental conditions are likely to be more similar to the wind park area (QT) than the former references, this makes comparisons between the old and the new reference areas not possible. Therefore the former reference areas were not taken into account during this analysis. However, the adjacent water sampling stations are now unbalanced in number (6 in the former years, 23 in

2017). Next to the implications for the species area curve mentioned before, this can have some statistical implications when comparing the QAW area of the former years with 2017. However, the data in the univariate analyses was transformed in most cases to meet up with the assumptions of the statistical tests, so this should make the implications small. Moreover, ANOVA's are relatively robust for unequal sample sizes.

7 Conclusions

Overall, clear temporal effects on the species composition of the Princes Amalia Wind park were present, both on the univariate data (i.e. number of species, abundance and diversity indices) and on the multivariate data (community composition). The species composition changed over time when comparing the survey sites over the different years.
Of the tested variables, year had the highest significance in comparison to the other environmental factors. This suggests that there is a strong temporal effect on the species composition in the data. In the nMDS, the year 2003 in clearly different from the other years, and this coincides with the high fishing intensities of 2003. Although in the analyses fishing intensity seems to have a role in the composition of the benthic community, it is not possible to prove a causal relationship between fishing intensity and the community composition. Moreover, when 2003 is left out of the analysis, fishing has no effect, even when fishing intensity differs within and outside the wind park, especially in 2017 (with more sampling locations present). Furthermore, there is still a difference in community composition between the sampling years of 2012, 2013 and 2017, which cannot be attributed to fishing intensity.
Of the other environmental variables that were analysed, depth had a correlation with the species composition of the benthic community. Organic matter content and the D50 fraction of the sediment play a role in the diversity of the samples (except Pilou evenness).

At this point we can only speculate on what causes the clear temporal effects. For instance, year to year fluctuations in temperature, climatic conditions, storm events or a combination, could be the driving forces behind these effects on species compositions. However, random drift could also be at the root of the differences found in species compositions at different times in the wind park and adjacent waters. Large natural fluctuations are a well known phenomenon in marine waters and also in the North Sea, as is also shown by van Loon & Walvoort (2018).
Overall, 2017 seems to be a rather peculiar year, with large differences from previous years. This becomes especially clear from the univariate data, with high abundances and low number of species and diversity. Furthermore, one can question whether 10 years after the construction of a wind park is enough to capture recovery of the species community. Therefore it is advisable to do another sampling campaign, for instance after 3 years. This would however require the wind parks to stay closed for seabed disturbing types of fisheries, in order to be able to tell anything about the recovery of benthos and effects of bottom trawl fishing on benthos. In a new sampling campaign, the measurement and analysis of additional environmental variables should be considered, such as additional sediment characteristics and bed shear stress. The latter may be an important variable related to (bottom) dynamics, which might be a very important factor in the recovery of bottom fauna after disturbance.
The current data were analyses on a species level. An extra dimension in the analysis may be added when the data is analysed based on species traits (Glorius et al., 2016). These may give a description of the functioning of the ecosystem and insights in the mechanisms behind recovery. Moreover, a meta-analysis of other similar projects where bottom disturbance is limited, may give important insights in recovery of bottom fauna. Possible differences in recovery between habitat types may become clear from this, and it may give important insights for the management of nature conservation goals. Also the newly developed Benthic Indicator Species Index (BISI) (Wijnhoven & Bos, 2017) may be of help in comparing the current dataset with data from the whole coastal zone.

8 References

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Appendix 1

Used Packages in R-projects

Packages	Usage
ggplot2	**Plotting NMDS in R**
AICcmodavg	**AIC model selectie**
base	This package contains the basic functions which let R function as a language: arithmetic, input/output, basic programming support, etc. Its contents are available through inheritance from any environment.
car	Companion to Applied Regression
cowplot	The cowplot package is a simple add-on to ggplot2.
data.table	Fast aggregation of large data
gplots	Various R Programming Tools for Plotting Data
gridExtra	Miscellaneous Functions for "Grid" Graphics
gtools	Various R Programming Tools
lme4	**Linear Mixed-Effects Models using 'Eigen' and S4: Linear model**
MASS	Support Functions and Datasets for Venables and Ripley's MASS
Matrix	Matrix: Sparse and Dense Matrix Classes and Methods
Minqa	minqa: Derivative-free optimization algorithms by quadratic approximation
multcomp	multcomp: Simultaneous Inference in General Parametric Models: Simultaneous tests and confidence intervals for general linear hypotheses in parametric models, including linear, generalized linear, linear mixed effects, and survival models. The package includes demos reproducing analyzes presented in the book "Multiple Comparisons Using R" (Bretz, Hothorn, Westfall, 2010, CRC Press).
multcompView	multcompView: Visualizations of Paired Comparisons: Convert a logical vector or a vector of p-values or a correlation, difference, or distance matrix into a display identifying the pairs for which the differences were not significantly different. Designed for use in conjunction with the output of functions like TukeyHSD, dist{stats}, simint, simtest, csimint, csimtest{multcomp}, friedmanmc, kruskalmc{pgirmess}.
mvnormtest	mvnormtest: Normality test for multivariate variables: Generalization of shapiro-wilk test for multivariate variables.
mvtnorm	mvtnorm: Multivariate Normal and t Distributions: Computes multivariate normal and t probabilities, quantiles, random deviates and densities.
nloptr	nloptr is an R interface to NLopt. NLopt is a free/open-source library for nonlinear optimization, providing a common interface for a number of different free optimization routines available online as well as original implementations of various other algorithms
plyr	Tools for Splitting, Applying and Combining Data
rcompanion	Functions to Support Extension Education Program Evaluation
sciplot	Barplot of the mean and standard error (or other summary statistics) of a response variable for one-way or higher experimental designs.
splines	Regression Spline Functions and Classes
stats	**The R Stats Package: Multiple regressions and ANOVA's e.d.**
survival	Contains the core survival analysis routines, including definition of Surv objects, Kaplan-Meier and Aalen-Johansen (multi-state) curves, Cox models, and parametric accelerated failure time models.
vegan	**Ordination methods, diversity analysis and other functions for community and vegetation ecologists: metaMDS, running NMDS analyses**

Appendix 2

Species abundances per sampling station in ind/ha for 2017

Species	2017_QAW1	2017_QT2	2017_QT3	2017_QT4	2017_QT5	2017_QT6	2017_QT7
Abra alba							
Abra prismatica							
Achaeus cranchii							
Acotylea							
Agonus cataphractus							
Alcyonidium							
Alcyonidium albidum							
Alcyonidium condylocinereum							
Ammodytes spec	102,04	99,01			450,45	102,04	408,16
Anthozoa							
Aphia minuta							
Arnoglossus laterna							
Asterias rubens							
Astropecten irregularis							
Balanus crenatus							
Bathyporeia elegans							
Bathyporeia guilliamsoniana							
Branchiostoma lanceolatum							
Buglossidium luteum		99,01		252,09	90,09	102,04	102,04
Callionymus spec							
Cancer pagurus							
Carcinus maenas							
Cerebratulus							
Chamelea spec	1020,4	3663,37	217,4	840,31	540,54	204,08	306,12
Ciliata mustela							
Corystes cassivelaunus							
Crangon allmanni							
Crangon crangon	102,04	198,02		168,06	90,09		
Crepidula fornicata							
Diastylis bradyi							
Diogenes pugilator					90,09		
Donax vittatus	3367,33	4653,47	4782,64	4705,88	10450,44	1938,76	1938,76
Ebalia tumefacta							
Echiichthys vipera					90,09		
Echinocardium spec	102,04	792,08	1521,78	168,06	270,27	2346,92	2755,08
Ensis directus	918,36	1881,19	543,5	84,03	270,27		102,04
Ensis ensis		99,01	108,7	84,03	90,09		
Ensis magnus			108,7				
Eteone longa							
Eunereis longissima							
Euspira catena		99,01	108,7	84,03	90,09	102,04	102,04
Euspira nitida	102,04	99,01	217,4		180,18		
Eutrigla gurnardus							
Fabulina fabula							
Gastrosaccus spinifer							
Glycinde nordmanni							
Gymnammodytes semisquamatus							
Hippomedon denticulatus							
Hydractinia echinata							
Hypereteone foliosa							
Hyperoplus lanceolatus		198,02			90,09		
Lanice conchilega							
Limanda limanda							

Species	2017_QAW1	2017_QT2	2017_QT3	2017_QT4	2017_QT5	2017_QT6	2017_QT7
Lineus bilineatus							
Liocarcinus							
Liocarcinus holsatus	102,04	495,05			180,18	102,04	
Liocarcinus marmoreus							
Liocarcinus navigator							
Liocarcinus vernalis							
Lutraria spec					90,09		
Macomangulus tenuis							
Macropodia rostrata							
Mactra stultorum							
Magelona mirabilis							
Malmgrenia							
Metridium dianthus							
Metridium senile							
Myoxocephalus scorpius							
Mysida							
Mytilus edulis							
Nassarius reticulatus		99,01		84,03		102,04	
Necora puber							
Nemertea							
Nephtys spec	510,2	396,04	760,87		540,54	102,04	408,16
Nereididae							
Ophelia spec	3265,3	1881,19	4239,15	2184,87	2432,43	714,28	816,33
Ophiocten affinis							
Ophiura albida							
Ophiura ophiura	2755,09	3267,33	978,28	756,29	1081,08	408,16	816,32
Ophiura spec							
Paguridae spec							102,04
Pestarella tyrrhena							
Phaxas pellucidus							
Philocheras trispinosus							
Pholis gunnellus							
Phyllodoce groenlandica							
Phyllodoce lineata							
Phyllodoce maculata							
Pinnotheres pisum							
Pisidia longicornis							
Platichthys flesus					90,09		
Pleuronectes platessa							
Polychaeta							
Pomatoschistus spec							102,04
Processa spec		99,01					102,04
Sacculina carcini							
Sagartia troglodytes							
Sagartiogeton undatus							
Scolelepis spec							
Scoloplos armiger							
Sigalion mathildae							
Solea solea		99,01			90,09		102,04
Spio							
Spisula spec	918,36	12079,22	5000,02	2352,92	3333,33	1224,48	1020,4
Sprattus sprattus							
Striarca lactea							
Syngnathus rostellatus							
Taurulus bubalis							
Tellimya ferruginosa							
Tellina fabula							
Thia scutellata	204,08		217,4	168,06	90,09	204,08	

Species	2017_QAW1	2017_QT2	2017_QT3	2017_QT4	2017_QT5	2017_QT6	2017_QT7
Trachurus trachurus							
Travisia forbesii							
Tubularia indivisa						102,04	

Species	2017_QT8	2017_QT9	2017_QT10	2017_QT11	2017_QT12	2017_QT13	2017_QT14
Abra alba	100						
Abra prismatica							95,24
Achaeus cranchii							
Acotylea							
Agonus cataphractus							
Alcyonidium							
Alcyonidium albidum							
Alcyonidium condylocinereum							
Ammodytes spec	100	97,09		194,18		200	285,72
Anthozoa							
Aphia minuta							
Arnoglossus laterna		97,09					
Asterias rubens		194,18					
Astropecten irregularis							
Balanus crenatus							
Bathyporeia elegans	100	97,09					
Bathyporeia guilliamsoniana							
Branchiostoma lanceolatum							
Buglossidium luteum	100	194,18	98,04			200	95,24
Callionymus spec							
Cancer pagurus		97,09					
Carcinus maenas							
Cerebratulus							
Chamelea spec	1100	776,71	1666,68	1456,33	934,6	400	857,15
Ciliata mustela							
Corystes cassivelaunus		97,09					
Crangon allmanni							
Crangon crangon				97,09			95,24
Crepidula fornicata							
Diastylis bradyi							
Diogenes pugilator							
Donax vittatus	3200	22524,28	6764,71	3786,41	4112,17	5400	9142,88
Ebalia tumefacta							
Echiichthys vipera							
Echinocardium spec	4300	2135,97	2745,12	679,62	467,3	400	476,2
Ensis directus	1600	776,71	1568,64	1067,97	560,76	400	666,67
Ensis ensis	200	97,09	98,04				
Ensis magnus							
Eteone longa							
Eunereis longissima							
Euspira catena	200	97,09	196,08	194,18	186,92	100	
Euspira nitida	1100		196,08	97,09		100	
Eutrigla gurnardus							
Fabulina fabula							
Gastrosaccus spinifer							
Glycinde nordmanni							
Gymnammodytes semisquamatus							
Hippomedon denticulatus							
Hydractinia echinata							
Hypereteone foliosa							
Hyperoplus lanceolatus							
Lanice conchilega							
Limanda limanda							
Lineus bilineatus							
Liocarcinus							
Liocarcinus holsatus	300	388,36		291,27	186,92	100	380,96
Liocarcinus marmoreus							
Liocarcinus navigator							

Species	2017_QT8	2017_QT9	2017_QT10	2017_QT11	2017_QT12	2017_QT13	2017_QT14
Liocarcinus vernalis				97,09			
Lutraria spec							
Macomangulus tenuis							
Macropodia rostrata							
Mactra stultorum							
Magelona mirabilis							
Malmgrenia							
Metridium dianthus							
Metridium senile		194,17					
Myoxocephalus scorpius							
Mysida							
Mytilus edulis							
Nassarius reticulatus	300			194,18	93,46		
Necora puber		194,18					
Nemertea							
Nephtys spec	400		294,12	97,09	280,37	200	380,95
Nereididae							
Ophelia spec	3200	3592,24	6568,63	388,36	4579,46	1400	4476,21
Ophiocten affinis							
Ophiura albida							
Ophiura ophiura	1500	1456,31	2156,87	970,87	1121,52	700	1142,86
Ophiura spec							
Paguridae spec		97,09					
Pestarella tyrrhena							
Phaxas pellucidus							
Philocheras trispinosus							
Pholis gunnellus		97,09					
Phyllodoce groenlandica							
Phyllodoce lineata							
Phyllodoce maculata							
Pinnotheres pisum							
Pisidia longicornis		194,18	98,04				
Platichthys flesus							
Pleuronectes platessa							
Polychaeta							
Pomatoschistus spec							
Processa spec	300						
Sacculina carcini							
Sagartia troglodytes							
Sagartiogeton undatus		97,09					
Scolelepis spec							
Scoloplos armiger							
Sigalion mathildae							
Solea solea							
Spio							
Spisula spec	6100	7378,66	5196,1	2135,92	3551,44	4800	5238,1
Sprattus sprattus							
Striarca lactea							
Syngnathus rostellatus							
Taurulus bubalis							
Tellimya ferruginosa							
Tellina fabula							
Thia scutellata	600	97,09	294,12	194,18	373,84	100	190,48
Trachurus trachurus							
Travisia forbesii							
Tubularia indivisa							

Species	2017_QT15	2017_QT16	2017_QT17	2017_QAW18	2017_QAW19	2017_QAW20
Abra alba						
Abra prismatica						
Achaeus cranchii						
Acotylea						101,01
Agonus cataphractus						
Alcyonidium						
Alcyonidium albidum						
Alcyonidium condylocinereum						
Ammodytes spec	103,09	582,54	833,31	6063,82	796	
Anthozoa						
Aphia minuta						
Arnoglossus laterna						
Asterias rubens						
Astropecten irregularis						
Balanus crenatus						
Bathyporeia elegans						
Bathyporeia guilliamsoniana						
Branchiostoma lanceolatum						
Buglossidium luteum	103,09	97,09	277,77			
Callionymus spec		97,09				
Cancer pagurus						
Carcinus maenas						
Cerebratulus						
Chamelea spec	412,36	1165,06	1481,47	2021,27	895,5	2525,25
Ciliata mustela						
Corystes cassivelaunus	103,09		92,59			
Crangon allmanni						
Crangon crangon				106,38		
Crepidula fornicata						
Diastylis bradyi						
Diogenes pugilator					99,5	
Donax vittatus	6391,77	14757,29	20277,79	74893,64	3781,07	3434,34
Ebalia tumefacta						
Echiichthys vipera						
Echinocardium spec	1134	7572,82	2407,36	212,76	49,75	707,07
Ensis directus	824,74	679,63	1851,86	319,14	248,75	2323,23
Ensis ensis	103,09			106,38		101,01
Ensis magnus						
Eteone longa						
Eunereis longissima						
Euspira catena		291,27	648,14	212,76	49,75	101,01
Euspira nitida		194,18	185,18	425,54		
Eutrigla gurnardus						
Fabulina fabula						
Gastrosaccus spinifer				106,38		
Glycinde nordmanni						
Gymnammodytes semisquamatus						
Hippomedon denticulatus						
Hydractinia echinata						
Hypereteone foliosa						
Hyperoplus lanceolatus			185,18			
Lanice conchilega						
Limanda limanda						
Lineus bilineatus						
Liocarcinus						
Liocarcinus holsatus	515,45	291,27	185,18	319,14	149,25	
Liocarcinus marmoreus						
Liocarcinus navigator						

Species	2017_QT15	2017_QT16	2017_QT17	2017_QAW18	2017_QAW19	2017_QAW20
Liocarcinus vernalis						
Lutraria spec			185,19			
Macomangulus tenuis						
Macropodia rostrata						
Mactra stultorum			92,59			
Magelona mirabilis						
Malmgrenia						
Metridium dianthus						
Metridium senile						
Myoxocephalus scorpius						
Mysida						
Mytilus edulis						
Nassarius reticulatus				106,38	49,75	101,01
Necora puber						
Nemertea						
Nephtys spec	412,37	388,35	370,37			606,06
Nereididae						
Ophelia spec	2371,13	7572,81	7592,58	1702,13	796,01	2929,29
Ophiocten affinis						
Ophiura albida						
Ophiura ophiura	1443,3	1262,15	2037,05	4042,55	845,75	1717,17
Ophiura spec						
Paguridae spec						
Pestarella tyrrhena						
Phaxas pellucidus						
Philocheras trispinosus						
Pholis gunnellus						
Phyllodoce groenlandica						
Phyllodoce lineata						
Phyllodoce maculata						
Pinnotheres pisum						
Pisidia longicornis						
Platichthys flesus						
Pleuronectes platessa						
Polychaeta						
Pomatoschistus spec						
Processa spec		97,09	185,18	106,38		
Sacculina carcini						
Sagartia troglodytes						
Sagartiogeton undatus						
Scolelepis spec						
Scoloplos armiger						
Sigalion mathildae						
Solea solea		194,18				
Spio						
Spisula spec	5670,11	3883,52	11944,43	2765,94	945,25	3636,36
Sprattus sprattus						
Striarca lactea						
Syngnathus rostellatus						
Taurulus bubalis						
Tellimya ferruginosa						
Tellina fabula						
Thia scutellata	721,64	679,61	277,77			606,06
Trachurus trachurus						
Travisia forbesii						
Tubularia indivisa						

Species	2017_QAW21	2017_QAW22	2017_QAW23	2017_QAW24	2017_QAW25	2017_QAW27
Abra alba						
Abra prismatica						
Achaeus cranchii						
Acotylea						
Agonus cataphractus						
Alcyonidium						
Alcyonidium albidum						
Alcyonidium condylocinereum						
Ammodytes spec			476,2			297,03
Anthozoa						
Aphia minuta						
Arnoglossus laterna						
Asterias rubens			95,24		100	
Astropecten irregularis						
Balanus crenatus						
Bathyporeia elegans						
Bathyporeia guilliamsoniana						
Branchiostoma lanceolatum						
Buglossidium luteum						198,02
Callionymus spec						
Cancer pagurus						
Carcinus maenas						
Cerebratulus						
Chamelea spec	2019,22	1846,16	857,16	1818,18	1200	891,09
Ciliata mustela						
Corystes cassivelaunus						
Crangon allmanni						
Crangon crangon			95,24		100	99,01
Crepidula fornicata						
Diastylis bradyi						
Diogenes pugilator	288,46		190,48	101,01	200	
Donax vittatus	42692,33	38153,85	3523,82	28282,8	20800	30099,03
Ebalia tumefacta						
Echiichthys vipera						
Echinocardium spec	7211,5	461,53	2666,71	2525,25	5200	29009,93
Ensis directus	3749,99		1142,87	2323,23	3500	3663,37
Ensis ensis		76,92	380,96	909,09	700	1089,11
Ensis magnus						
Eteone longa						
Eunereis longissima						
Euspira catena	6057,66	692,29	1619,06	1515,15	1100	
Euspira nitida	7500	2000	4285,71	202,02	900	1188,12
Eutrigla gurnardus						
Fabulina fabula						
Gastrosaccus spinifer						
Glycinde nordmanni						
Gymnammodytes semisquamatus						
Hippomedon denticulatus						
Hydractinia echinata						
Hypereteone foliosa						
Hyperoplus lanceolatus						99,01
Lanice conchilega						
Limanda limanda						
Lineus bilineatus						
Liocarcinus						
Liocarcinus holsatus	288,46	153,84	285,72	101,01	400	396,04
Liocarcinus marmoreus						
Liocarcinus navigator						

Species	2017_QAW21	2017_QAW22	2017_QAW23	2017_QAW24	2017_QAW25	2017_QAW27
Liocarcinus vernalis		76,92	95,24			
Lutraria spec	288,46					
Macomangulus tenuis						
Macropodia rostrata						
Mactra stultorum					200	297,03
Magelona mirabilis						
Malmgrenia						
Metridium dianthus						
Metridium senile						
Myoxocephalus scorpius						
Mysida						
Mytilus edulis						99,01
Nassarius reticulatus	12115,37	384,61	5333,36	202,02		
Necora puber						
Nemertea				101,01		
Nephtys spec	3173,08	384,62	1714,29	404,04	900	99,01
Nereididae						
Ophelia spec	1153,84	1999,99	2095,23	2121,21	2400	2970,3
Ophiocten affinis						
Ophiura albida						
Ophiura ophiura	2307,69	4846,16	4190,48	2929,29	2200	2772,28
Ophiura spec						
Paguridae spec		76,92	95,24	101,01		
Pestarella tyrrhena						
Phaxas pellucidus						
Philocheras trispinosus						
Pholis gunnellus						
Phyllodoce groenlandica						
Phyllodoce lineata						
Phyllodoce maculata						
Pinnotheres pisum						
Pisidia longicornis						
Platichthys flesus						
Pleuronectes platessa						
Polychaeta						99,01
Pomatoschistus spec		76,92				
Processa spec				101,01	200	
Sacculina carcini						
Sagartia troglodytes						
Sagartiogeton undatus						
Scolelepis spec					100	
Scoloplos armiger						
Sigalion mathildae						99,01
Solea solea				101,01		
Spio						
Spisula spec	683076,93	132923,08	3714,29	6666,66	9900	5346,54
Sprattus sprattus						
Striarca lactea						
Syngnathus rostellatus						
Taurulus bubalis						
Tellimya ferruginosa						
Tellina fabula	34326,92					
Thia scutellata	1153,84	76,92	571,44	202,02	500	297,03
Trachurus trachurus						
Travisia forbesii						
Tubularia indivisa						

Species	2017_QAW28	2017_QAW29	2017_QAW30	2017_QAW31	2017_QAW32	2017_QAW33
Abra alba						
Abra prismatica						
Achaeus cranchii						
Acotylea						
Agonus cataphractus						
Alcyonidium						
Alcyonidium albidum						
Alcyonidium condylocinereum						
Ammodytes spec	98,04	109,89	107,53	291,27	212,76	392,16
Anthozoa						
Aphia minuta						
Arnoglossus laterna						
Asterias rubens						
Astropecten irregularis				97,09		
Balanus crenatus						
Bathyporeia elegans						
Bathyporeia guilliamsoniana						
Branchiostoma lanceolatum						
Buglossidium luteum		109,89				
Callionymus spec						
Cancer pagurus						
Carcinus maenas						
Cerebratulus						
Chamelea spec	392,16	109,89	537,65	1747,55	2021,26	882,36
Ciliata mustela						
Corystes cassivelaunus						
Crangon allmanni						
Crangon crangon		219,78		97,09	106,38	98,04
Crepidula fornicata						
Diastylis bradyi						
Diogenes pugilator						
Donax vittatus	5686,29	6593,4	3870,95	20388,34	6382,98	5882,37
Ebalia tumefacta						
Echiichthys vipera						
Echinocardium spec	1274,52	3296,7	1397,89	1262,17	319,14	98,04
Ensis directus	882,36	1538,46	2150,54	776,71	106,38	784,32
Ensis ensis	392,16		645,18		106,38	
Ensis magnus						
Eteone longa						
Eunereis longissima						
Euspira catena	294,12	109,89		97,09		
Euspira nitida	294,12	219,78	107,53			98,04
Eutrigla gurnardus						
Fabulina fabula						
Gastrosaccus spinifer						
Glycinde nordmanni						
Gymnammodytes semisquamatus						
Hippomedon denticulatus						
Hydractinia echinata						
Hypereteone foliosa						
Hyperoplus lanceolatus						196,08
Lanice conchilega						
Limanda limanda	98,04					
Lineus bilineatus						
Liocarcinus						
Liocarcinus holsatus	98,04	109,89	322,59	291,27		98,04
Liocarcinus marmoreus						
Liocarcinus navigator						

Species	2017_QAW28	2017_QAW29	2017_QAW30	2017_QAW31	2017_QAW32	2017_QAW33
Liocarcinus vernalis						98,04
Lutraria spec						
Macomangulus tenuis						
Macropodia rostrata						
Mactra stultorum						
Magelona mirabilis						
Malmgrenia						
Metridium dianthus						
Metridium senile						
Myoxocephalus scorpius						
Mysida						
Mytilus edulis						
Nassarius reticulatus						98,04
Necora puber						
Nemertea	98,04					
Nephtys spec	1176,47	1208,79	645,16	97,09	319,15	196,08
Nereididae						
Ophelia spec	3823,54	1648,35	1505,38	3980,6	1489,36	1666,67
Ophiocten affinis						
Ophiura albida						
Ophiura ophiura	882,36	1208,79	1505,38	2135,92	531,92	2156,87
Ophiura spec						
Paguridae spec						
Pestarella tyrrhena						
Phaxas pellucidus		109,89	107,53			
Philocheras trispinosus						
Pholis gunnellus						
Phyllodoce groenlandica						
Phyllodoce lineata						
Phyllodoce maculata				97,09		
Pinnotheres pisum						
Pisidia longicornis						
Platichthys flesus						
Pleuronectes platessa						
Polychaeta						
Pomatoschistus spec						
Processa spec	98,04	659,34				
Sacculina carcini						
Sagartia troglodytes						
Sagartiogeton undatus						
Scolelepis spec	98,04	219,78				
Scoloplos armiger						
Sigalion mathildae						
Solea solea						
Spio						
Spisula spec	1960,8	3296,7	1827,95	2912,63	4787,22	1764,72
Sprattus sprattus						
Striarca lactea						
Syngnathus rostellatus						
Taurulus bubalis						
Tellimya ferruginosa						
Tellina fabula						
Thia scutellata	294,12	659,34	537,65	582,52		196,08
Trachurus trachurus						
Travisia forbesii						
Tubularia indivisa						

Species	2017_QAW34	2017_QAW35	2017_QAW36	2017_QAW37	2017_QAW38	2017_QAW39
Abra alba						
Abra prismatica						
Achaeus cranchii						
Acotylea						
Agonus cataphractus						
Alcyonidium						
Alcyonidium albidum						
Alcyonidium condylocinereum						
Ammodytes spec		104,17	421,04		192,3	707,07
Anthozoa						
Aphia minuta						
Arnoglossus laterna						
Asterias rubens						
Astropecten irregularis						
Balanus crenatus						
Bathyporeia elegans						
Bathyporeia guilliamsoniana						
Branchiostoma lanceolatum						
Buglossidium luteum		208,34				202,02
Callionymus spec						
Cancer pagurus						
Carcinus maenas				100		
Cerebratulus						
Chamelea spec	2407,4	3125,02	2526,31	3000	673,05	808,08
Ciliata mustela						
Corystes cassivelaunus		104,17				
Crangon allmanni						
Crangon crangon						101,01
Crepidula fornicata						
Diastylis bradyi						
Diogenes pugilator		312,5	105,26	200	96,15	101,01
Donax vittatus	41481,47	7291,68	28000,02	24000	9038,47	9292,92
Ebalia tumefacta						
Echiichthys vipera				100		
Echinocardium spec	2037,01	2395,89	1157,87	1000	288,45	303,03
Ensis directus	2314,81	4270,84	2631,59	3300	192,3	303,03
Ensis ensis	277,77	312,51	315,78	200		101,01
Ensis magnus						
Eteone longa						
Eunereis longissima						
Euspira catena	185,18	416,68		100		101,01
Euspira nitida	92,59	1041,67	315,78	200	384,61	
Eutrigla gurnardus						
Fabulina fabula						
Gastrosaccus spinifer						
Glycinde nordmanni						
Gymnammodytes semisquamatus						
Hippomedon denticulatus						
Hydractinia echinata						
Hypereteone foliosa						
Hyperoplus lanceolatus	185,18					
Lanice conchilega						
Limanda limanda					96,15	
Lineus bilineatus						
Liocarcinus						
Liocarcinus holsatus	370,36	208,34	526,3	300	673,07	101,01
Liocarcinus marmoreus						
Liocarcinus navigator						

Species	2017_QAW34	2017_QAW35	2017_QAW36	2017_QAW37	2017_QAW38	2017_QAW39
Liocarcinus vernalis	92,59			100		
Lutraria spec		104,17				
Macomangulus tenuis						
Macropodia rostrata						
Mactra stultorum	92,59					
Magelona mirabilis						
Malmgrenia						
Metridium dianthus						
Metridium senile						
Myoxocephalus scorpius						
Mysida						
Mytilus edulis						
Nassarius reticulatus			105,26		288,45	
Necora puber						
Nemertea						
Nephtys spec	185,19	416,67	1052,63	500	288,46	505,05
Nereididae						
Ophelia spec	2962,96	3020,84	2105,25	9400	2211,54	2424,24
Ophiocten affinis						
Ophiura albida						
Ophiura ophiura	2685,19	3229,16	2000	2800	2403,84	2727,27
Ophiura spec						
Paguridae spec	92,59					
Pestarella tyrrhena						
Phaxas pellucidus				100		101,01
Philocheras trispinosus						
Pholis gunnellus						
Phyllodoce groenlandica						
Phyllodoce lineata						
Phyllodoce maculata						
Pinnotheres pisum						
Pisidia longicornis						
Platichthys flesus						
Pleuronectes platessa						
Polychaeta						
Pomatoschistus spec						
Processa spec		208,34				
Sacculina carcini						
Sagartia troglodytes						
Sagartiogeton undatus						
Scolelepis spec						
Scoloplos armiger						
Sigalion mathildae						
Solea solea		208,34				
Spio						
Spisula spec	2500,01	5208,38	3473,67	2300	2788,45	7070,7
Sprattus sprattus						
Striarca lactea						
Syngnathus rostellatus						
Taurulus bubalis						
Tellimya ferruginosa						
Tellina fabula					865,38	
Thia scutellata	185,18	625	105,26	500		
Trachurus trachurus						
Travisia forbesii						
Tubularia indivisa						

Species	2017_QAW40	2017_QAW41
Abra alba		
Abra prismatica		
Achaeus cranchii		
Acotylea		
Agonus cataphractus		
Alcyonidium		
Alcyonidium albidum		
Alcyonidium condylocinereum		
Ammodytes spec	105,26	1111,11
Anthozoa		
Aphia minuta		
Arnoglossus laterna		
Asterias rubens		
Astropecten irregularis		
Balanus crenatus		
Bathyporeia elegans		
Bathyporeia guilliamsoniana		
Branchiostoma lanceolatum		
Buglossidium luteum		
Callionymus spec		
Cancer pagurus		
Carcinus maenas		
Cerebratulus		
Chamelea spec	1052,61	1616,16
Ciliata mustela		
Corystes cassivelaunus	105,26	
Crangon allmanni		
Crangon crangon		
Crepidula fornicata		
Diastylis bradyi		
Diogenes pugilator	105,26	
Donax vittatus	11052,62	6060,6
Ebalia tumefacta		
Echiichthys vipera		
Echinocardium spec	2736,81	101,01
Ensis directus	526,31	707,07
Ensis ensis		
Ensis magnus		
Eteone longa		
Eunereis longissima		
Euspira catena	2210,52	
Euspira nitida	1578,95	101,01
Eutrigla gurnardus		
Fabulina fabula		
Gastrosaccus spinifer		
Glycinde nordmanni		
Gymnammodytes semisquamatus		
Hippomedon denticulatus		
Hydractinia echinata		
Hypereteone foliosa		
Hyperoplus lanceolatus		
Lanice conchilega		
Limanda limanda		
Lineus bilineatus		
Liocarcinus		
Liocarcinus holsatus	526,3	202,02
Liocarcinus marmoreus		
Liocarcinus navigator		

Species	2017_QAW40	2017_QAW41
Liocarcinus vernalis		
Lutraria spec		
Macomangulus tenuis		
Macropodia rostrata		
Mactra stultorum		
Magelona mirabilis		
Malmgrenia		
Metridium dianthus		
Metridium senile		
Myoxocephalus scorpius		
Mysida		
Mytilus edulis		
Nassarius reticulatus	1894,73	
Necora puber		
Nemertea		
Nephtys spec	947,37	303,03
Nereididae		
Ophelia spec	3894,73	1515,15
Ophiocten affinis		
Ophiura albida		
Ophiura ophiura	7052,64	1818,18
Ophiura spec		
Paguridae spec		
Pestarella tyrrhena		
Phaxas pellucidus		
Philocheras trispinosus		
Pholis gunnellus		
Phyllodoce groenlandica		
Phyllodoce lineata		
Phyllodoce maculata		
Pinnotheres pisum		
Pisidia longicornis		
Platichthys flesus		
Pleuronectes platessa		
Polychaeta		
Pomatoschistus spec		
Processa spec		
Sacculina carcini		
Sagartia troglodytes		
Sagartiogeton undatus		
Scolelepis spec		
Scoloplos armiger		
Sigalion mathildae		
Solea solea		
Spio		
Spisula spec	5157,89	3030,3
Sprattus sprattus		
Striarca lactea		
Syngnathus rostellatus		
Taurulus bubalis		
Tellimya ferruginosa		
Tellina fabula	4526,32	
Thia scutellata	210,52	
Trachurus trachurus		
Travisia forbesii		
Tubularia indivisa		

Appendix 3

Environmental variables and fishing intensity values for 2017

Location	Depth (m NAP)	Organic Matter (%)	D50 (µm)	Fishing intensity
2017_QAW1	21	0,033	346	1,257
2017_QT2	22	0,1197	312	0,015
2017_QT3	21	0,1697	311	0,01
2017_QT4	21	0,147	284	0,041
2017_QT5	22	0,12	300	0,117
2017_QT6	22	0,1236	244	0,1
2017_QT7	23	0,1881	263	0,029
2017_QT8	25	0,1687	299	0,002
2017_QT9	26	0,1816	304	0,02
2017_QT10	26	0,1296	261	0,011
2017_QT11	23	0,213	290	0,343
2017_QT12	23	0,2216	319	0,4
2017_QT13	23,5	0,075	336	0,196
2017_QT14	22	0,0307	341	0,101
2017_QT15	22	0,1651	321	0,078
2017_QT16	24	0,4232	295	0,051
2017_QT17	25	0,1843	279	0,051
2017_QAW18	21,9	0,0883	325	0,754
2017_QAW19	21,4	0,1892	330	0,632
2017_QAW20	21,37	0,2023	338	0,606
2017_QAW21	26	0,322	256	0,313
2017_QAW22	24	0,1963	262	0,509
2017_QAW23	26,55	0,2832	317	0,133
2017_QAW24	23,5	0,1843	296	0,186
2017_QAW25	24	0,2318	282	0,186
2017_QAW27	24,5	0,1854	305	0,428
2017_QAW28	22,17	0,2219	316	0,795
2017_QAW29	26,95	0,2351	285	1,796
2017_QAW30	27,54	0,2914	292	2,908
2017_QAW31	26	0,1913	306	1,739
2017_QAW32	22,48	0,2037	331	2,361
2017_QAW33	22	0,0041	341	1,565
2017_QAW34	24,88	0,1136	318	1,023
2017_QAW35	25,03	0,4127	316	1,342
2017_QAW36	23,84	0,1837	340	6,565
2017_QAW37	23	0,2166	330	1,74
2017_QAW38	22,1	0,175	304	1,044
2017_QAW39	21,93	0,3123	296	0,946
2017_QAW40	24,83	0,2845	268	0,337
2017_QAW41	22,43	0,057	315	0,908

Appendix 4

Number of species, abundance and diversity indices for 2017

Location	Number of Species	Abundance (ind/100m²)	Margalef diversity	Pilou evenness	Shannon Wiener	Simpson index
2017_QAW1	13	130,36	1,262	0,7598	1,949	0,82
2017_QT2	19	309,06	1,744	0,6554	1,93	0,7822
2017_QT3	13	160,16	1,219	0,729	1,87	0,8016
2017_QT4	13	169,98	1,278	0,6865	1,761	0,7619
2017_QT5	22	255,3	2,113	0,5739	1,774	0,7008
2017_QT6	14	75,48	1,452	0,7445	1,965	0,8072
2017_QT7	15	89,2	1,534	0,777	2,104	0,8314
2017_QT8	19	249	1,779	0,7756	2,284	0,8629
2017_QT9	24	437,69	2,165	0,5038	1,601	0,6543
2017_QT10	14	291,7	1,27	0,7492	1,977	0,8289
2017_QT11	16	128,69	1,598	0,7712	2,138	0,8319
2017_QT12	12	190,32	1,133	0,7576	1,882	0,8025
2017_QT13	14	146	1,357	0,6508	1,718	0,7371
2017_QT14	14	260,35	1,292	0,6662	1,758	0,7575
2017_QT15	14	192,09	1,311	0,7303	1,927	0,7968
2017_QT16	17	423,3	1,511	0,654	1,853	0,7777
2017_QT17	19	595,54	1,66	0,6197	1,825	0,7594
2017_QAW18	16	826,26	1,311	0,3176	0,8805	0,3507
2017_QAW19	12	351,75	1,213	0,7292	1,812	0,7616
2017_QAW20	13	185,13	1,219	0,8252	2,117	0,861
2017_QAW21	16	8732,88	1,103	0,2605	0,7222	0,2791
2017_QAW22	16	3115,5	1,237	0,3194	0,8855	0,4355
2017_QAW23	20	368,55	1,824	0,8343	2,499	0,9011
2017_QAW24	19	496,98	1,661	0,5623	1,656	0,6593
2017_QAW25	19	506	1,662	0,6606	1,945	0,7712
2017_QAW27	20	806,99	1,685	0,5434	1,628	0,7108
2017_QAW28	18	186,66	1,736	0,7399	2,139	0,8261
2017_QAW29	18	177,45	1,705	0,7497	2,167	0,8382
2017_QAW30	14	132,06	1,349	0,8499	2,243	0,8671
2017_QAW31	15	369,77	1,339	0,5632	1,525	0,6293
2017_QAW32	11	144,76	1,031	0,6765	1,622	0,7373
2017_QAW33	16	153	1,563	0,7012	1,944	0,7833
2017_QAW34	17	678,24	1,458	0,4304	1,22	0,4799
2017_QAW35	20	302,4	1,827	0,7752	2,322	0,8739
2017_QAW36	15	404,7	1,307	0,5517	1,494	0,5917
2017_QAW37	18	485	1,577	0,5785	1,672	0,6991
2017_QAW38	15	222,52	1,41	0,6925	1,875	0,7562
2017_QAW39	16	244,53	1,482	0,6365	1,765	0,7569
2017_QAW40	17	394,25	1,497	0,8027	2,274	0,8663
2017_QAW41	11	162,36	1,029	0,7806	1,872	0,7959