Fisheries displacement effects of managed areas: a case study of De Voordelta

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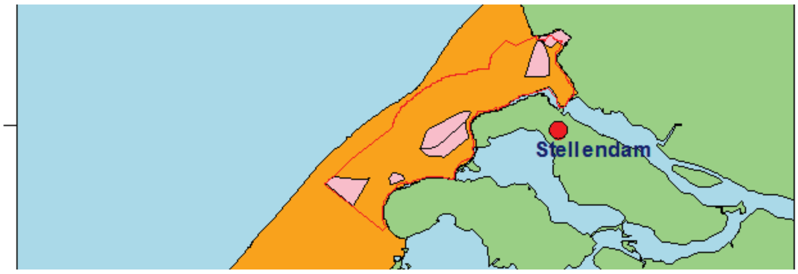

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Summary

In the process of implementing Marine Strategy Framework Directive measures, such as area closure, questions arise on the aspect of displacement of fisheries. Displacement is a relatively new topic to fisheries science, and no studies in the Dutch North sea are available. Because the MSFD measures are not yet implemented, actual displacement in the assigned areas cannot be studied yet. Therefore, displacement in historically closed/managed areas was studied. The Voordelta – specifically the Bottom protection area- was taken as the study area. The aim was to study if displacement could be analysed, and if so, to what extent displacement depends on the type of fisheries.

The research question was whether displacement effects could be identified using VMS and logbook data. In addition it was analysed which elements, such as season or gear used, would be most important for the displacement effect. Displacement effects were analysed focussing on trip distance (expected to increase after the bottom protection area was managed) and Catch Per Unit of Effort (CPUE) (expected to drop as fishermen need to find new suitable fishing grounds).

We conclude that that displacement effects were identified for part of the fishing fleet. The methodology -the combination of VMS and log book data- was able to detect these effects. Important to note is that the managed area used in this study has an area of 300 km^2 and is close to the Dutch coast. All elements that may have an impact on displacement, such as season, fraction of time spent fishing in the managed area and status of area (open or closed for fisheries) showed an effect on displacement.

Trip distance for fishermen from ports further away from the bottom protection area (e.g. Scheveningen) decreased. They instead fished closer to their home port. If the gear type was still allowed to fish in the area (e.g. small trawlers), no effect on trip distance was observed. This study emphasizes the importance of port origin as an important factor to include in displacement studies.

Fleet specifications (port, gear, target species, and share in the potentially managed area) are important variables in whether or not an effect of displacement is to be expected- and how large this effect can be.

To study displacement effects in MSFD context, specifically regarding future closures on the Frisian Front and Central Oystergrounds, it is important to take into account the transition of the fleet segments, ports, differences in value in time and space (season) of the target area and species, and the size of managed areas.

1. Introduction

The implementation of the Marine Strategy Framework Directive (MSDF) is rapidly progressing. In 2015 a programme of measures needs to be defined and reported to Brussels. In this programme, the Frysian Front and Central Oystergrounds are designated as searching areas for spatially explicit fisheries management, targeting the conservation and recovery of biodiversity of the local seafloor fauna.

A result of installing managed areas is displacement of fisheries: fisheries are (partially) banned, and fishermen must fish elsewhere. This displacement of fishing effort may have economic effects, as steaming to the fishing grounds may take longer, new fishing grounds have to be explored or competition for the same resource may increase.

However, little is known about the patterns of displacement of fisheries and the ecological and economic consequences within the context of protecting the Frysian Front (FF) and Central Oystergrounds (CO). To support the development of MSFD measures for these areas, and in particular the role of displacement in potential area closures, IMARES has been commissioned to conduct 3 studies: a literature review on relevant ecological and socio- economic factors related to displacement (report A), a case study on previous closures and displacement in which the actual economic effect is calculated (report B = this report) and interviews with fishermen to evaluate our findings and translate these to the FF and CO situation (included in report A).

2. Assignment

The assignment of the ministry of Economic Affairs was to explore the knowledge of displacement related to closures in the North Sea. This study focusses on the question whether we can show a displacement effect using VMS and logbook data, and if so, which characteristics of the fishery determine the type and extent of the displacement.

Since the closure of areas on FF and CO is not yet assigned, no data are available to analyse the effect of displacement in this context. A longlist of potential relevant managed areas in the past was drafted in order to select proper areas for a case study. This longlist was evaluated in order to select a proper case study area. This selection is based on the assumptions that the area has to be large enough to cover natural variation in fishing behaviour and is large enough to detect substantial changes in fishing behaviour. The larger the area, the larger the chance that these changes are detectable in data. Furthermore, the area had to be closed/managed for several years in order to include as many data as possible, and the management had to be implemented *after* the implementation of VMS in order to obtain data before closure (hence, the Plaice Box could not be used as case study as VMS data before closure are not available) for that period).

Based on the longlist and criteria the Voordelta fitted best for our data analysis in this case study. The Voordelta was partly closed since 2008 for specific types of bottom trawling fisheries (beam trawl larger than 260 hp) (*Figure 1*). Smaller vessels are still allowed. The specification of the Voordelta are included in appendix A and in the caption of figure 1. .

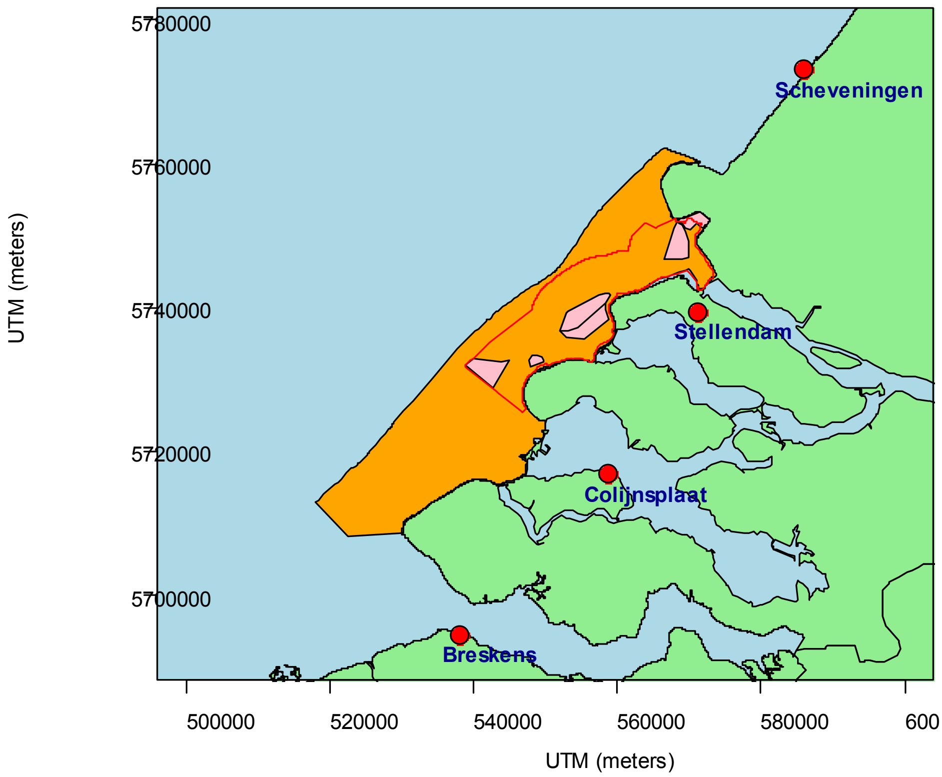
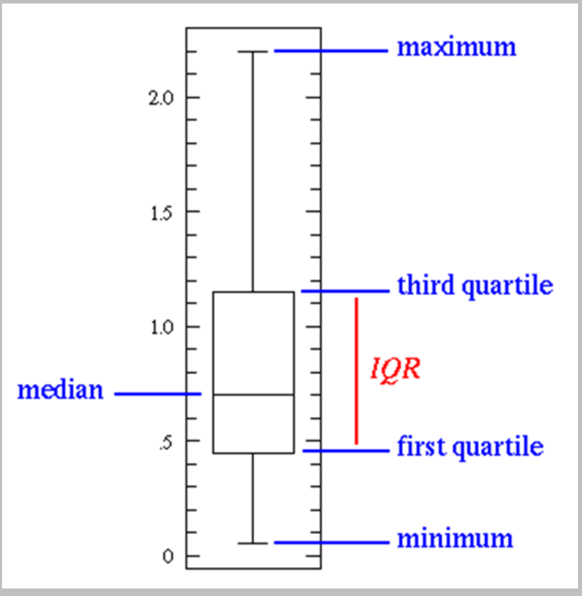


Figure 1 Area used in pilot case study. In orange De Voordelta as a protected area. Red line indicates the management area, the sol called "Bottom protection area" in which fisheries with beam trawl (larger than 260 hp) is prohibited. Within this zone the resting areas (pink) are situated= closed areas. Green indicates land, blue indicates water. Ports relevant in this study are plotted.

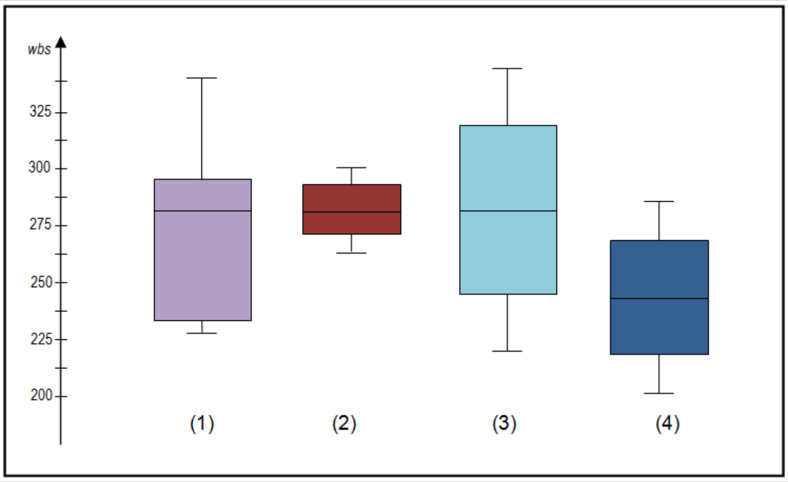
This study explores the economic effects of designating management areas in the Voordelta. The catch per unit effort (CPUE), expressed as the landed value of fish per day at sea, is used as the major indicator of economic consequences. A lower CPUE indicates a decrease in fishing efficiency due to e.g. lack of information of newly explored fishing grounds or a lack of good fishing grounds. Besides this, CPUE will also decrease if steaming distances increase and vice versa. The effect of closing the bottom protection area for some fisheries in the Voordelta on this CPUE is studied for a selection of relevant metiers[1] and ports. It is studied how big this effect is and whether it is affected by the share the vessels had in the area (prior to the closure). For this purpose, the CPUE of fishing trips prior to the management and after were compared, taking season and share in the management area into account. As there is a lot of variability between trips, the results are given using boxplots, that show this variability in a summarized way.

HOW TO READ A BOXPLOT

Boxplots are presentations used to show the distribution of a data. In the left figure, the various definitions are presented: Median, Quartiles, Minimum whisker, Maximum whisker. It displays the full range of data variation (from min to max), and the likely range of variation (IQR).
. Some examples are presented in the second figure.



[1] A métier is defined as a fishing activity which is characterised by one catching gear and a group of target species, operating in a given area during a given season, within which each boat's effort exerts a similar exploitation pattern on a particular species or group of species, i.e. the species composition and size distribution in catches taken by any vessel working in a particular métier will be approximately the same. A métier is indicative of where and how boats work, not of the port or original or landing (*nsrac.org/wp-content/.../wp05_wd2007115_The_**metier**_concept.pdf*).



The box plot is comparatively tall – see examples (1) and (3). This suggests data are relatively variable. The box plot is comparatively short – see example (2). This suggests that data are not that variable

- One box plot is much higher or lower than another – compare (3) and (4) – This suggests a difference between groups.
- The 4 sections of the box plot are uneven in size – See example (1). This means that many trips have similar CPUE at certain parts of the scale, but in other parts of the scale trips are more variable in their CPUE. The long upper whisker in the example means that CPUE are varied amongst the most positive quartile group, and very similar for the least positive quartile group.

Same median, different distribution – See examples (1), (2), and (3). The medians (which generally will be close to the average) are all at the same level. However the box plots in these examples show very different distributions of data (e.g. CPUE).

It therefor important to consider the pattern of the whole distribution of responses in a box plot, and not only the median.

This case study will indicate whether displacement effects can be determined based on available data using CPUE as main indicator. This study thus shows if, and how displacement effects can be studies, and how this effect for a case study area has been. Expected and unexpected results can be used to define and discuss steering conditions including new hypotheses for other study areas such as Frisian Front and Central Oysterground closures.

3. Materials and Methods

Selection and preparation of data

Since the 1st of January 2005 all fishing vessels larger than 15 meters are equipped with VMS, while VMS was introduced on-board of vessels larger than 12 meters since the 1st of January 2012. A VMS transponder sends approximately every 2 hours a signal to a satellite providing information on the vessel's ID, position, time and date, direction and speed. Hence, VMS is a useful data source to study the distribution of the fishing fleet both in time and space. The Dutch ministry of Economic Affairs is tasked with the collection of VMS data of all Dutch fishing vessels. VMS data of foreign vessels are not included in this case study. In this study, data from 2004-2014 are included.

As VMS does not contain any information on the activities of the vessel, e.g. regarding fishing gear, catch composition, departure harbour or vessel dimensions, for many fisheries related studies, VMS is coupled to fisheries logbooks. These logbooks report per fishing trip (approx. 4 – 5 days) when fishermen leave harbour, what gear has been used to fish, their catch composition and a rough estimate of the location of the catches for each 24 hour period. Both VMS and logbook data report on the fishing vessel ID, which allows for the coupling of the two datasets and study fisheries distribution at higher spatial and temporal scales.

A summary of the process to pre-process, analyse VMS- and logbook data, combine these datasets and link gear specific effort to the pipelines is given below. A more detailed description on the processing and assumptions made during this process can be found in Hintzen et al. (2013)

<u>Data pre-processing:</u>

- VMS and logbook data are received from the Ministry of Economic Affairs and stored in a local database at IMARES.
- VMS records are considered invalid and therefore removed from the analyses if they:
    - are duplicates or pseudo-duplicates (indication of malfunctioning of VMS device)
    - identify an invalid geographical position
    - are located in a harbour
    - are located on land
    - are associated with vessel speeds > 20 knots
- Logbook records are removed from the analyses when they:
    - are duplicates
    - have arrival date-times before departure date-times
    - overlap with other trips

<u>Link VMS and logbook data:</u>

- VMS and logbook datasets are linked using the unique vessel identifier and date-time stamp in both datasets available. In other words, records in the VMS dataset that fall within the departure-arrival timeframe of a trip described in the logbook are assigned the unique trip number from the logbook record which allows matching both datasets

<u>Define fishing activity:</u>

- Speed recordings obtained from VMS data are used to create frequency plots of these speeds, where along the horizontal axis the speed in knots is given and the vertical axis denotes the number of times that speed was recorded. In general, 3 peaks can be distinguished in such a frequency plot. A peak near 0 knots, associated with being in harbour/floating, a peak around the average fishing speed and a peak around the average steaming speed. These analyses are performed separately per gear type for two kW classes (<= 225kW and > 225kW), if relevant for the gear type and if sufficient data is available, as these vessel types show different fishing behaviour and are allowed to fish in different regions. Speeds corresponding with being at harbour/floating were discarded from the dataset.

- According to the method described above, a number of VMS records can be associated with fishing activity, depending on the gear used by the vessel. In general, vessel speeds between 1.5 and 8 knots are characterized as fishing. For small beam trawlers the selected range was approximately 2-7 knots. For large trawlers the range was approximately 4-8 knots.

For the analysis a consistent part of the fleet must be selected. It was decided to select ships based on their home port and fishing gear used. It is assumed here that ships that fish with the same gear type from the same home port will behave similarly. A home port was attributed to each fishing vessel based on the most common departure and landing harbour as listed in the logbook data. The combination of a gear-type and a home-port is considered one subgroup which is analysed separately from other subgroups.

Home ports and gear types of ships that have the highest share (fraction of their fishing activity) inside the management area (Bottom protection area) are selected for further analyses. This share is based on the fraction of landed value caught inside the management area (based on "fishing" VMS records).

CPUE

Using price indices of fish for each year, as provided by LEI, the landed amount of fish from the logbook is converted to its value in kEuros. This value is distributed and assigned to each VMS record associated to fishing activity which is then summed for each fishing trip. The CPUE[2] is calculated per fishing trip by dividing summed value (kEuro) per trip by the duration of the trip as specified in the logbook. This duration thus not only includes the time fishing, but also steaming and hauling time. The CPUE as defined here reflects the proceeds of a fishing trip, corrected for the duration of that trip. If the time available for a trip is constant and the steaming distance increases, the CPUE will be reduced. The CPUE (in kEuro/day) is log10 transformed before analysis in order to meet the statistical assumption that data are normally distributed. .

Trip Distance

For the selected gear types and ports, the trip distance is calculated for each trip. This distance is calculated by summing the product of the time interval between (interpolated) VMS records and the associated (interpolated) vessel speed for each trip. Trip distance and its variation will be visualised per port and gear type before and after restrictions in the management area. It is used as a complementary indicator, and as such not included in the statistical model.

[2] In fact, landings per unit of effort (LPUE) were calculated instead of CPUE.

Statistical model

Both VMS and logbook data provide information on a 2-hourly or daily basis. For the analyses here however, all data is summarized to the level of fishing trip (~ one week). A statistical model is fit where a relationship between Catch Per Unit of Effort (CPUE) and distribution of the fishing fleet prior to and after the closure of the area are related to each other. The hypothesis we work from is that CPUE was the same before and after management of the area. If there is no difference to be found prior and after management, we may conclude that there is no economic effect related to the displacement.

The following model is fit to the selection of datasets:

$$\log_{10} CPUE \sim Share\ in\ PA * \ PA\ status + Season,$$

The model relates CPUE (kEuro/day, here a log10 transformation of the data is applied first- in order to distribute the data normally) to the share of a fishing vessel in the bottom protection area (PA), also depending on the season. "Share in PA" is the share of the specific ship in bottom protection area, "PA status" indicates the status of the management ("open" or "closed"). Also the interaction between PA status and PA share is studied (indicated by the asterisk symbol). The interpretation of this interaction is discussed in the results section.

Share in PA, PA status and Season

<u>Season</u>

Three season categories are defined based on the landing dates: 1) from January to April; 2) from May to September; 3) from October to December. The breaks between these season have been chosen at moments at which the number of VMS pings (categorized as "fishing") change most, based on a previous analysis of VMS data in De Voordelta by Hintzen et al. (2014).

<u>Share in the managed area</u>

The value (Euro) of landings is assigned to VMS pings as described above. Per ship, the total landed value originating from the bottom protection area(prior to the management) is divided by the total landed value of that ship (prior to the management of the area). This fraction is categorized and used as predictor variable in the model.

Breaks for categorising the fraction are selected at: 0, 0.00001, 0.0001, 0.0003, 0.001, 0.005, 0.01, 0.05, 0.1, 0.25, 0.3 and 1. The bottom and/or top segments of these categories are grouped depending on the availability of data for specific subsets of the data being analysed. In the result section only relevant categories are presented.

<u>The management status</u>

Two categories indicate what the status of the "Bbottom protection area" was at the moment of the landing of a fishing trip ("open" or "closed"). Note that this factor may also be associated to other factors (such as fuel price), that are not included in the model.

4. Results

Selection of data for analyses

Based on the availability of VMS data inside the bottom protection area, the following home ports are selected for further analyses: Colijnsplaat, Stellendam, Breskens and Scheveningen (*Table 1*). For these home ports, the following gear types are selected based on data availability inside the Voordelta: small beam trawls (shrimp), small beam trawls (flatfish), large beam trawls and small otter trawls (*Table 2*).

Table 1 Number of VMS pings categorised as "fishing" per home port in the years 2004 up to 2014. Only the top ten home ports (based on absolute number of "fishing" pings inside the Voordelta) are listed. The 4 home ports selected for analyses are given in bold faced text.

Haven	*Total number of "fishing pings"*	*Number of "fishing pings" inside the bottom protection area*	*percentage of total*
Stellendam	502472	24923	5%
Colijnsplaat	142364	15808	11%
Breskens	96200	3746	4%
Scheveningen	332228	2185	1%
Neeltje Jans	2844	1893	67%
Vlissingen	373050	1298	<1%
Roompotsluis	1560	906	58%
IJmuiden	912910	901	<1%
Onbekende haven in Nederland	3520	806	23%
Lauwersoog	425371	583	<1%

Table 2 Number of VMS pings categorised as "fishing" inside the bottom protection area for the selected home ports, specified per gear type and per year. Gear types selected for analyses are in bold faced text.

Gear type	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*Grand Total*
Small beam trawls (shrimp)	1,189	725	1,843	2,569	2,234	1,533	3,632	3,008	5,358	5,768	14,898	42,757
Small beam trawls (flatfish)	822	372	213	231	143	89	44	164	16	163	20	2,277
Large beam trawls	141	49	77	62	58	44	50	43	46	27	14	611
Small otter trawls	154	13	10	156	79	56	24	18	1	0	0	511
Set gillnets	4	132	66	99	30	0	0	1	5	0	0	337
Pots	0	3	9	42	9	0	29	1	0	0	0	93
Miscellaneous	8	4	20	3	0	0	0	0	0	0	0	35
Otter trawls (midwater)	0	15	5	4	1	1	0	0	2	0	0	28
Large Scottish seines	0	0	0	0	0	2	2	4	0	2	2	12
Large otter trawls	0	0	0	0	1	0	0	0	0	0	0	1

Share of landed value caught inside the bottom protection area

The percentage of landed value caught inside the bottom protection area is calculated per ship as described in the method section. *Table 3* shows per home port how many ships have a large share (>75%) in the bottom protection area, a small share (≤25%) or a share in between for the selected home ports and most frequently used gear types. Each ship is only listed once in this table, under its most frequently used gear (as some ships fish with multiple gears). This table thus provides an indication of the fleet. A "zero" does thus not mean that that gear is not being used at all.

All ships in the home ports Breskens, Colijnsplaat and Scheveningen have a small share in the bottom protection area (≤25%). Only some small beam trawlers (both shrimp and flatfish) from Stellendam have a large share (>75%) in the bottom protection area.

After the area closure in 2008 shrimp fishing was still allowed. Under the shrimp vessels a number of vessels had a significant share in the bottom protection area. However, results related to shrimp fishers are not presented because the completeness and reliability of the log data could not be guaranteed. Data distribution of shrimp fisheries showed incompleteness and unreliable data as only since 2010 these data are available in proper descriptions. This fact did not allow to carry out a comparison of CPUE before and after management.

Table 3 Number of ships per gear type (most frequently used[3]) and share (as percentage of total) of landed fish value caught in the bottom protection area before management per home port. Provides indication of the fleet.

Share caught in bottom protection area	*Large beam trawls*	*Small beam trawl (shrimp)*	*Small beam trawl (flatfish)*	*Small otter trawl (bottom)*
Breskens				
≤25%	3	5	3	0
>25%, ≤75%	0	0	0	0
>75%	0	0	0	0
Colijnsplaat				
≤25%	0	6	6	0
>25%, ≤75%	0	0	0	0
>75%	0	0	0	0
Scheveningen				
≤25%	5	3	4	3
>25%, ≤75%	0	0	0	0
>75%	0	0	0	0
Stellendam				
≤25%	21	5	11	1
>25%, ≤75%	0	1	0	0
>75%	0	3	2	0

3 Most frequently used: ships can use e.g. large beam trawl, but if this gear is not the most frequently used gear, it will not appear in this table. Hence: data in figures 2-4 present data per gear (not only the most frequently used).

Model results

The statistical model components should be interpreted as follows:

- "PA status" ("open" / "closed"): indicates whether ships behave differently (in terms of CPUE) before and after management of the bottom protection area. Note that effects found for this factor may be indirect or could be caused by confounding factors (e.g., fuel price).
- "Share in PA": indicates whether ships with a large share in the closed area behave differently (in terms of CPUE) from ships with a small (or no) share. As the selected home ports are all close to the managed area it is expected that this factor has some effect on the CPUE.
- Interaction between the two factors listed above: when the status of the area affects the relationship between the share in the bottom protection area and CPUE, there is said to be an interaction between the 'share' and the 'status'. We assume that that interaction is actually due to displacement effects.
- "Season": indicates whether the season in which the fish were landed affects the CPUE.

For nearly all subsets of the data (based on home port and gear type), the largest portion of variance in CPUE data remains unexplained (residuals in *Figure 2*). The available dataset contains limited number of ships, which results in a larger variance in the used model.

All selected subsets of the data show a small effect of the season on CPUE (*Figure 2* and Appendix B), most notably for the small otter trawls at Scheveningen and Stellendam.

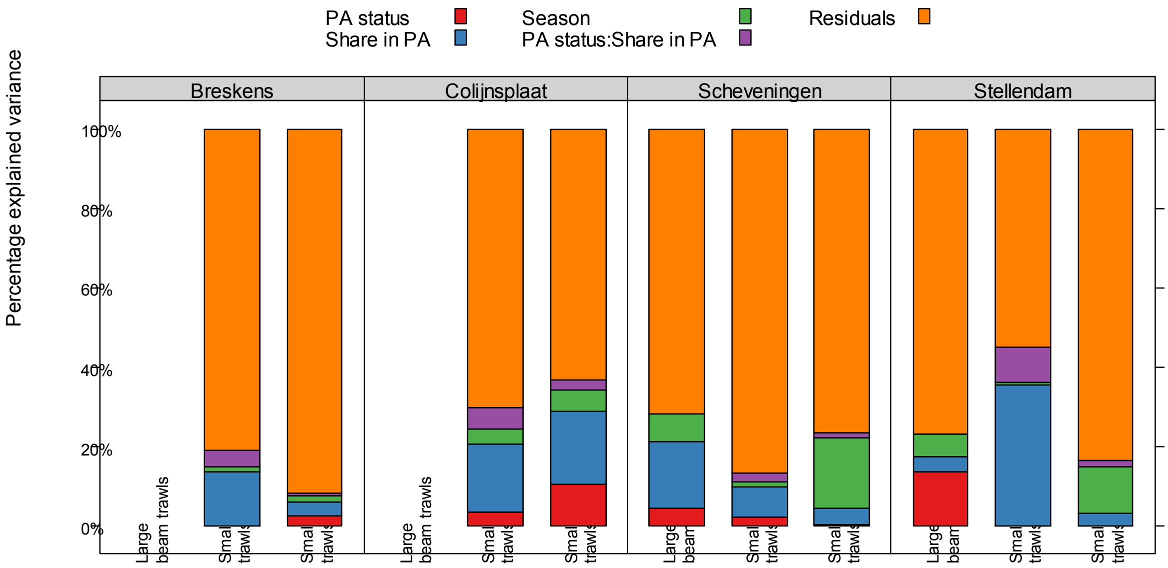


Figure 2 Percentage variance (in log10 transformed CPUE) explained by predictor variables. "PA status : Share in PA" indicates interaction between the two factors.

Effects of closure on CPUE for the selected gear types and ports for ships with a share of more than 5% are presented in *Figure 3*, *Figure 4* and *Figure 5*. Results for Scheveningen are not shown, as the share in the bottom protection area was for those ships 5% or less.

For the small beam trawls (flatfish) a decrease of fishing distance is observed in some cases (*Figure 2*), whereas there was little to no effect on the CPUE by the closure of the bottom protection area (figure 3-5). For these trawls the steaming distance is most likely reduced, resulting in a similar effort.

Fig 3- fig 5- in combination with figure 2 illustrate that there is no clear explanation for effect of displacement in terms of CPUE. The effect on CPUE can be explained by the metier, share, and/or port, but a large proportion of unexplained variance remains.

Some key observations per port are[4]:

Colijnsplaat:

- small beam trawlers on flatfish showed an increase of CPUE after management, which depends on the share. Closure explains only a small part of the observed effect.
- Otter trawlers do not seem to fish in the area after management

Stellendam:

- Small beam trawlers on flatfish show a decrease in CPUE after management, only when having a larger share. Closure then explains a moderate part of the effect
- Ottertrawlers do not seem to fish in the area after management (resulting in zero CPUE)

Breskens:

- Small beam trawlers on flatfish show an small increase in CPUE

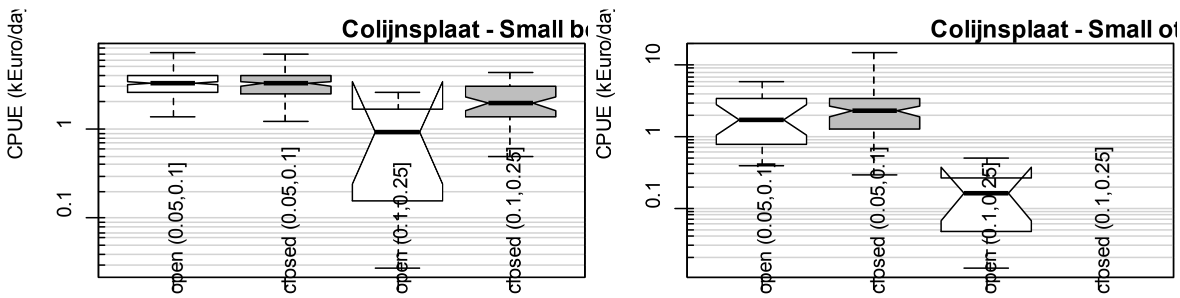


Figure 3 Per gear type the effect of the status of the bottom protection area ("open" coloured white or "closed" coloured grey) and share (fraction of value caught inside the area, between brackets) on the CPUE for ships from Colijnsplaat. Only ships with a share of more than 5% (0.05) in the bottom protection area are shown.

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4 No effect: <1% explain by predictor, small effect: 1-5%, moderate effect: 5-20% and large effect: more than 20% explained by predictor variable.

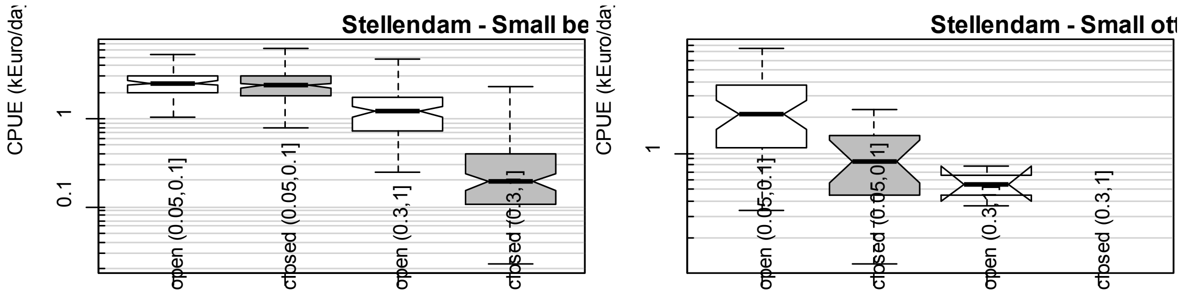

Figure 4 Per gear type the effect of the status of the bottom protection area ("open" coloured white or "closed" coloured grey) and share (fraction of value caught inside the area, between brackets) on the CPUE for ships from Stellendam. Only ships with a share of more than 5% (0.05) in the bottom protection area are shown.

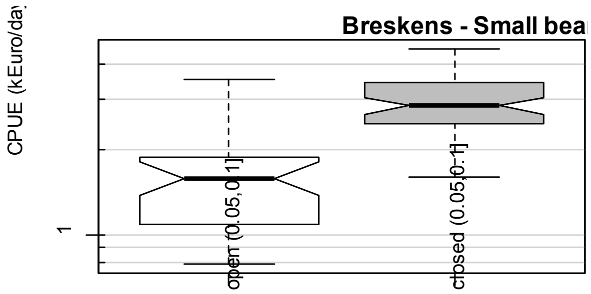

Figure 5 Per gear type the effect of the status of the bottom protection area ("open" coloured white or "closed" coloured grey) and share (fraction of value caught inside the area, between brackets) on the CPUE for ships from Breskens. Only ships with a share of more than 5% (0.05) in the bottom protection area are shown.

Trip distance

Figure 6 shows the mean trip distance for each selected port and gear type, before and after management the bottom protection area. In some cases, this distance seems to change after management.
In general, data show that small otter trawlers (bottom) from Scheveningen display effects that are opposite to the other ports. The mean trip distance for Scheveningen ships decreases whereas the trip distance for the other ports increases.

Large beam trawlers showed an increased variance within the data after management, indicating a search for new fishing grounds further away. However, no clear increase or decrease is observed for this metier.

Trip distance plots show large variation and significant differences are not likely. Therefore the following descriptions are only indications. Small trawlers on fish seem to decrease trip distance (Breskens and Schevingen ships), indicating these ships fished closer to their home port after de Voordelta was managed- although they were still allowed to fish in this area (< 260 hp). Ships from Colijnsplaat and Stellendam did not show this behaviour, what can be explained by the fact that these ports are closer to the bottom protection area. Scheveningen fishers might have used new fishing grounds closer to home. Ottertrawlers from Scheveningen fished closer to their home port after management of the Voordelta. Most probably, these ships are > 260 hp, and excluded from the Voordelta.

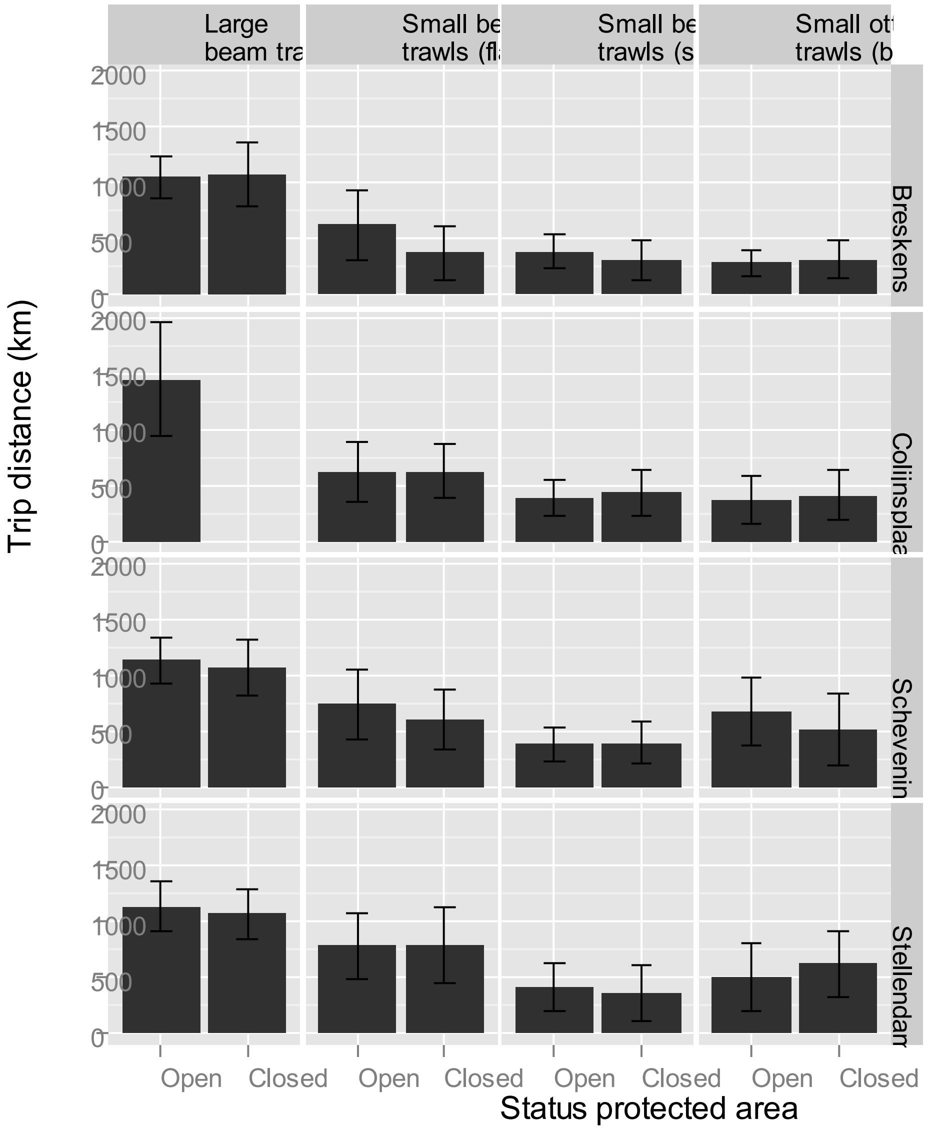

Figure 6 Mean distance (sum of fishing distance and steaming distance) per trip before and after the area is managed (error bars indicate standard deviation of the trip distance per trip).

5. Discussion and conclusions

5.1 Methodology: Can we use VMS and logbook data to observe displacement

This study shows that the selected parameters (season, home port, gear type used, share in the management area prior to measures) and methodology (using VMS and logbook data) are both useful to analyse displacement effects. Results in this study however showed that most of the variation in the data was left unexplained. This is common in behavioural studies due to the fact that not all explaining variables can be included or quantified. The fact that up to 60% could be explained in some combinations of port and gear shows that some main variables that were included were very relevant, but not for all gears or ports. Additional variables for future studies could be e.g. fuel price and target species price.

Although the fleet for some home ports was limited in size, behavioural effects were detected.
The CPUE expresses the landed value of fish per day at sea and indicates the economic efficiency of fishing trips. A lower CPUE indicates a decrease in fishing efficiency due to e.g. lack of information of newly explored fishing grounds or a lack of good fishing grounds. Besides this, if steaming distances increase, CPUE will decrease (and vice versa). Our data showed that this combination of parameters is valuable in explaining observed effects. For example, Breskens fishermen fishing on flatfish showed a small increase in CPUE. This increase could be explained from the shorter trip distances.

It is important to have substantial amounts of data available to study displacement effects. E.g. Scheveningen CPUE results were not included in the results as the share of individual fishermen in the bottom protection area were only <5% and for this purpose discarded from the report.
Fleet sizes and metiers change over time, not only due to management. Additional measures on segments of the fleet can have effects on behaviour as well. Socio–economic factors and changes in stock might influence the fleet as well. Therefore, the included fleet has to be large enough in order to detect any additional changes due to displacement. Inclusion of different home ports give information on variation in behaviour and the possibilities a fleet has to move to other areas when managed areas are closed for fishing. Differences in effect of displacement on trip distance between Scheveningen and Stellendam show this importance to distinguish home port.

For this study additional socio-economic factors were clearly influencing the fleet. It is important to note that the fisheries in the south was in transition a few years before actual closure in 2008. A decrease of the fleet started around 2006 due to the flatfish management plan, bad economic conditions for the fishers, combined with a buy-out regulation (Tulp et al., 2015). These conditions and changes in the fleet have possibly influenced the data of the period 2004-2008 for which we pooled our data. In future studies it is important to identify and quantify these factors and to include them as additional explaining variables.
Furthermore, changes in days at sea (das) and hp-das (engine power- das) could be additional variables to include in upcoming studies. ICES working group on shrimp fisheries recently reported that in 2012, 2013 and 2014 there were more active shrimpers with stronger engines especially in the Dutch fleet. This was reflected in the stronger increase in hp-days at sea and in relation to days at sea. Thereby the increase in hp-das was, on a relative scale, higher than the increase in das. While between 2012 and 2013 Dutch effort (in das) increased by 12% the effort in hp-das increased by 55%. This shows that more large and more effective boats entered the fleet. It is unknown at which scale this was relevant for our case study area, but could partly explain the observations (section 5.2).

5.2 Displacement effects Voordelta

Management of the bottom protection area in the Voordelta resulted in displacement effects for several metiers.

The available data on shrimp vessels did not allow to make a comparison of CPUE before and after the closure. Still, it is likely that an effect of displacement is present. After all, the shrimp vessels encounter less competition from other fishing vessels that were also active in the closure area. Whether this was beneficial or a disadvantage cannot not determined at this time. Analyses of the crangon (shrimp) ICES Working Group (ICES, 2014) shows no clear change in CPUE (Either LPUE) between the periods before and after closure in North Sea and Dutch areas.

Effect on flatfish fishers depended on the origin and share they had in the bottom protection area. Colijnsplaat and Stellendam fishers- both closest by the bottom protection area (*Figure 1*)- did not show any changes in their trip distance. An increase in CPUE was observed, most probably due to lack of competition of larger trawlers.
Small trawlers from Scheveningen and Breskens, further away from the managed area, fish closer to their home port after closure. Most probably, ships are > 260 hp and < 290 hp and not allowed in the closed area, but categorised as small ships in this study (< 290 hp). Horta e Costa et al., (2013) concluded as well that distance to the landing port is an important factor explaining fisheries aggregations around MPAs. They associated this observation with costs for fuel.
Large beam trawlers were no longer present in the datasets. After the change of management state of the area, ports in which the large beamtrawl fleet was already small, the number of trips with this gear has declined or even disappeared. Meaning that the ships were either decommissioned, moved to another port or switched fishing gear.

5.3 MSFD context

The displacement effects observed in this study are unique for the closure of the Voordelta, and the fleets depending on this area. As such, the data and observations cannot be used to draw specific conclusions for closure in de Frisian Front and Central Oystergrounds, but the results from this study do allow us to draw up more concrete expectations for the potential effects of displacement in those areas:

- After closure of areas at the Frisian Front and Central Oysterground area, displacement can be analysed, giving the fact that individual areas are large enough. As the minimum area size will be 400km2, we do not foresee problems.
- If a specific fisheries will be permitted, it could be that this fisheries increases and benefits from the exclusion of other fisheries
- Position of the managed area: Voordelta is a coastal area, whereas FF and CO locations lay offshore. Behaviour of the fleet is thus different. Instead of likely 1-3 day trips, week trips are relevant, and steaming distance is much longer.
- Port: most likely Northern ports are of high relevance, but due to the offshore location of the future managed areas, the relative differences in distance between the various ports is much smaller than the case of the Voordelta showed. Port and distance may be less important, but should be included to be sure. The number of relevant ports is assumed to be higher than in the Voordelta.
- Metier and transition of metier: In future managed areas, different gear types and ships are active, each with their own type of behaviour. In the Frisian Front and Central Oystergrounds areas a large transition has been observed from large beam trawls to innovative gear types such as pulse trawling. This transition leads to a more complex detection of behaviour based on

available data as there is only limited information available for the new gear types (such as pulse trawling) well before a potential management. Changed effectivity of innovative gears and thus effect on CPUE is something to take into account.

- Target species: depending on the position of managed area, the relative importance of the target species is different. Frisian Front is especially targeted for plaice (~460 tonnes/year) and sole (~126 tonnes/year), whereas the more northern and deeper areas of the CO are targeted for plaice (~400 tonnes/year), but only ~20 tonnes/yeas for sole. As well, the relative importance of the areas for fisheries differs: Frisian front is more important for fisheries (~765 day at sea, ~4.4 Meur/year) compared to the Oystergrounds (~225 days at sea, ~1.1 Meur/year) (Van Kooten et al., 2014). This implies that the effect of displacement is likely to be different depending on the area fished. Seasonality can be more important in FF and CO than observed in the Voordelta.

6. Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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Van Kooten, C. Deerenberg, R.G. Jak, R. van Hal & M.A.M. Machiels (2015) Proposed Marine Protected Areas in the Dutch North Sea: An exploration of potential effects on fisheries and exploited stocks. Report number C093/14 - phase 2

Justification

Rapport C136/15
Project Number: 4315810001

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: Dr. T. van Kooten
Senior reseacher

Signature:

Date: 6 October 2015

Approved: Drs. John Schobben
Department head Fish

Signature:

Date: 6 October 2015

Appendix A. Voordelta

TOEGANGSBEPERKINGSBESLUIT BODEMBESCHERMINGSGEBIED VOORDELTA

Beperkingen bodemberoerende visserij

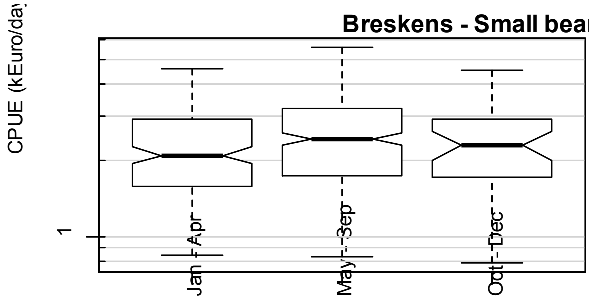
Uit onderzoek2 is gebleken welke vormen van bodemberoerende visserij in welke mate beperkt moeten worden om 10% kwaliteitsverbetering te realiseren. Daaruit blijkt dat het effect van bodemberoerende visserij sterk wordt gedomineerd door de boomkorvisserij met eurokotters (met een motorvermogen van meer dan 260 pk). Deze zwaardere vorm van visserij veroorzaakt een relatief hoge sterfte van het bodemleven. Op grond van dit onderzoek is daarom de visserij met de boomkor met een motorvermogen groter dan 260 pk in het gehele bodembeschermingsgebied verboden. Uitsluiting van deze visserij leidt tot een verhoging van de bodemdierenbiomassa met minimaal 10%.

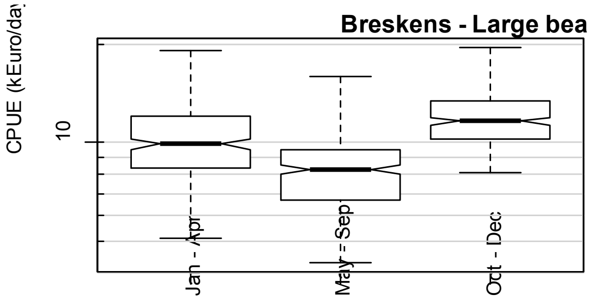
Een grotere kwaliteitsverbetering (tot ruim 20%) is haalbaar, maar niet op voorhand zeker. Daarom wordt veiligheidshalve uitgegaan van een verbetering van 10%. Indien uit de monitoring blijkt dat de behaalde verbetering groter is, dan zal worden onderzocht in hoeverre de maatregelen ten behoeve van de compensatie van de effecten van Maasvlakte 2 kunnen worden beperkt.

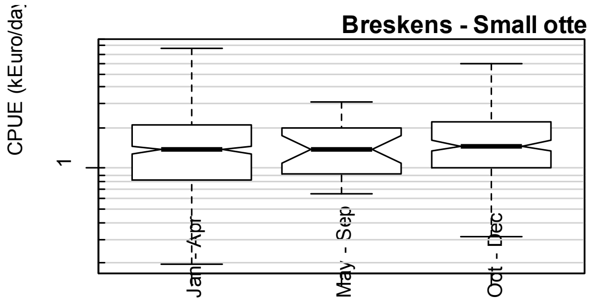
De overige vormen van visserij hebben veel minder effecten op het bodemleven en behoeven niet op voorhand te worden geweerd. Deze vormen van visserij en ander gebruik worden geregeld in andere toegangsbeperkingsbesluiten in de Voordelta, het Beheerplan, dan wel daarvoor af te geven vergunningen op grond van de Nb-wet 1998.

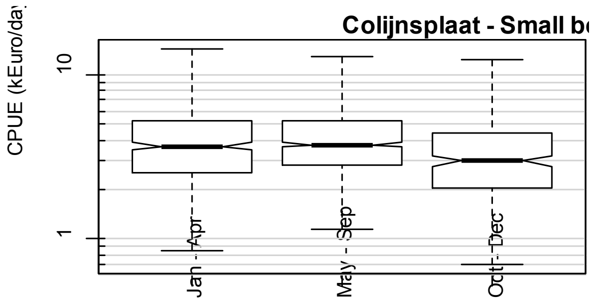
Appendix B. Seasonal effects on CPUE

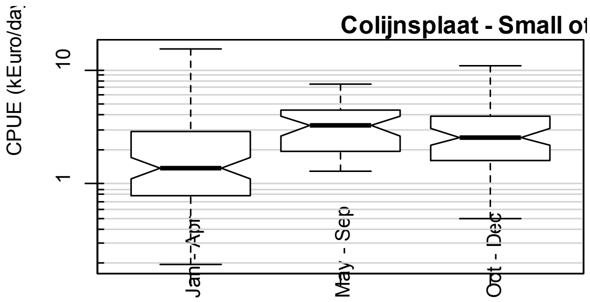
Per home port and gear type the effect of season on CPUE.

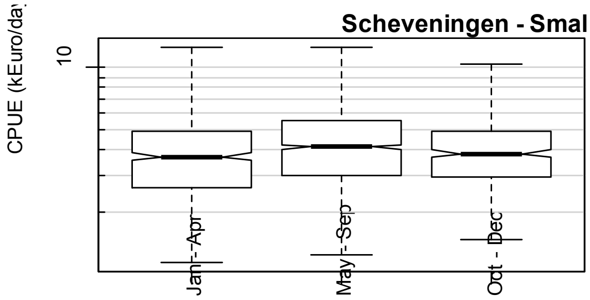


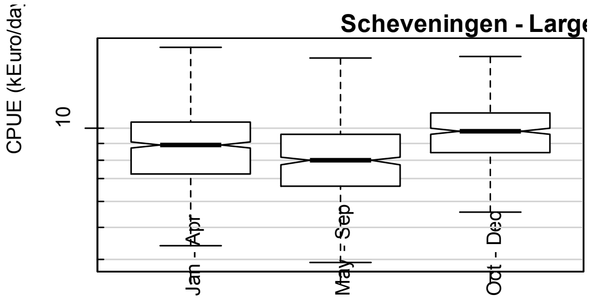


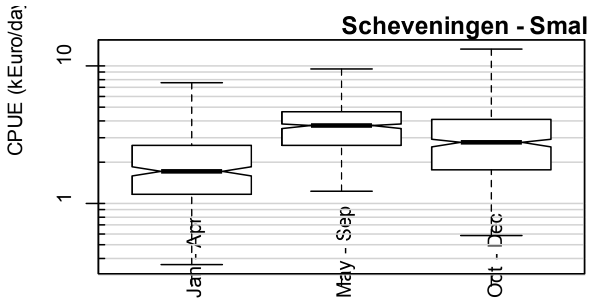


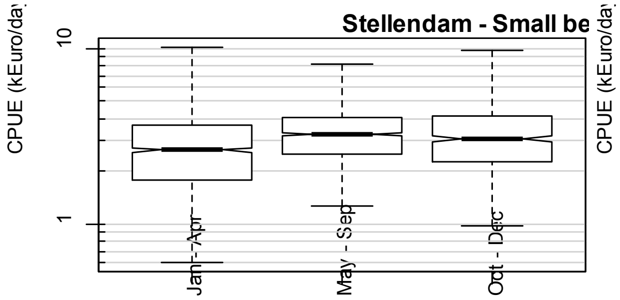




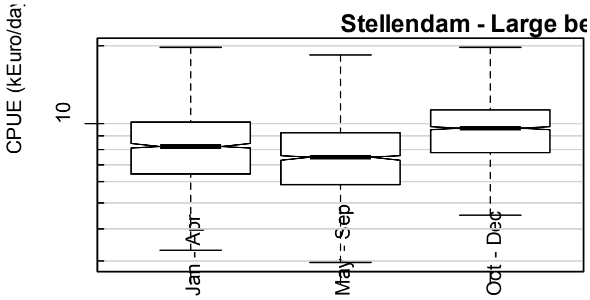

Scheveningen - Smal
CPUE (kEuro/day
10
Jan - Apr
May - Sep
Oct - Dec


Scheveningen - Large
CPUE (kEuro/day
10
Jan - Apr
May - Sep
Oct - Dec

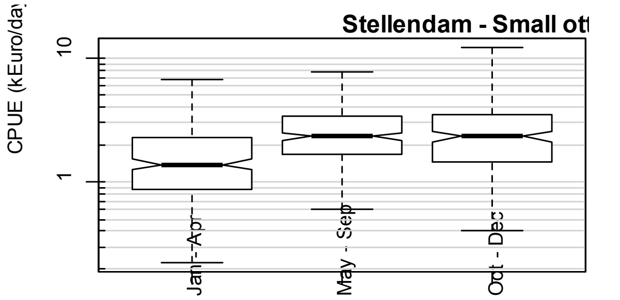

Scheveningen - Smal
CPUE (kEuro/day
10
1
Jan - Apr
May - Sep
Oct - Dec



Stellendam - Small be
CPUE (kEuro/day
10
1
Jan - Apr
May - Sep
Oct - Dec



Stellendam - Large be
CPUE (kEuro/day
10
Jan - Apr
May - Sep
Oct - Dec



Stellendam - Small ott
CPUE (kEuro/day
10
1
Jan - Apr
May - Sep
Oct - Dec