# Best Practices II

## Spatial distribution of the discards of the Dutch beam trawler fleet

Author(s): Thomas Brunel, Ruben Verkempynck, Wouter van Broekhoven and Jurgen Batsleer

Wageningen University & Research report C015/19

# Best Practices II

Spatial distribution of the discards of the Dutch beam trawler fleet

Author(s): Thomas Brunel[1], Ruben Verkempynck[1], Wouter van Broekhoven[2] and Jurgen Batsleer[1]

1: Wageningen Marine Research

2 : VISNED

Wageningen Marine Research
IJmuiden, Februari 2019

CONFIDENTIAL NO

Wageningen Marine Research report C015/19

Keywords: spatial model, discards, beam trawl.

Client: VISNED
Attn.: W. Visser
Postbus 59
8320 AB, Urk

European Maritime and Fisheries Fund (EMFF)

This report can be downloaded for free from https://doi.org/10.18174/470889
Wageningen Marine Research provides no printed copies of reports

Wageningen Marine Research is ISO 9001:2015 certified.



Wageningen Marine Research, an institute within the legal entity Stichting Wageningen Research (a foundation under Dutch private law) represented by Dr. M.C.Th. Scholten, Managing Director

KvK nr. 09098104,

WMR BTW nr. NL 8113.83.696.B16.

Code BIC/SWIFT address: RABONL2U

IBAN code: NL 73 RABO 0373599285

# Contents

# Summary


This study aims at describing the spatial distribution – and its temporal variations - of discarding intensity (i.e. expected weight of discards for a standard trawl haul) for the 6 main species discarded by the Dutch beam trawl fisheries.

For each species, the spatial distribution (quarterly maps for the period 2013 to 2017) is estimated using statistical models that take spatial and temporal correlation into account, which also allowed to test for the effect of a number of factors related to geography, environment, fishing practices and operational aspects on discarding. The data used to fit those models came from the observer trips and self-sampling program conducted at Wageningen Marine Research and from discards sampling trips conducted by the fishing industry. As by-product, the models provide descriptors of the temporal and spatial scales at which the discards of a given species are structured.

The distribution of the expected discards per haul for dab was highly variable from quarter to quarter, with generally high discarding intensity in front of the southern coast of the Netherlands in quarter 1, a discarding intensity which is high on the German bight and low in front of the Dutch coast in quarter 3, and variable distributions for quarter 2 and 4.

For plaice, the distribution was more stable, with high values consistently observed in the south of the area (between the south of the Netherlands and England), with occasional hot spots on the German bight.

For sole, discards were not observed on the north-western part of the area, and a hotspot of sole discarding was found consistently in front of the southern coast of the Netherlands, occasionally expanding towards England or to the northern coast of the Netherlands.

Discarding of turbot first occurred with a low intensity along the coast from Belgium to Germany. After the fourth quarter of 2015, high discarding started to occur, first limited to the small area in the southern North Sea, but progressively expanding to a larger area in the southern and central part of the North Sea, while discarding intensity remained low in the northern part of the area and in front of England.

The distribution discarding intensity for whiting was highly variably, characterised by hotspots suddenly appearing for most years in the fourth quarter, and disappear in the following first quarter.

Discarding of rays occurred mainly in the western part of the area, especially in front of southern England, with an increasing level since the fourth quarter of 2016.

The distributions observed and their variability were further discussed in the light the available information on the distribution and migration of the species and on the management measures potentially influencing discarding.

# 1 Introduction

Discarding is one of the main issues in demersal fisheries. It can occur for a variety of reasons, involving the spatial overlap of unwanted fish (undersized individuals, non-targeted species of insufficient commercial value, ...) with the targeted fish, the fishing gear used (and its selectivity) and fishing strategies or quota availability, among others.

This study specifically focusses on the spatial distribution of the discards for some of the main species caught by the Dutch beam trawler fleet. The central question was to determine whether discards display any specific spatial structure or if they occur randomly in space. In addition, if indeed discards are structured spatially, the study also needed to propose a descriptor of the scale of this structuration. Finally, a description of the temporal variability of this distribution should also be provided. Such a characterisation of the geographical distribution of discards can provide information that can potentially help the industry reducing discards, such as avoiding recurrent areas of high discarding (hot spots), assess the necessary distance to steam away from areas where discarding is high, assess how long discarding hot-spots persist and should therefore be avoided.

Aside from spatial aspects, this study also investigated the influence of a range of factors related to geography, environment, fishing practices and operational aspects on discarding.

These questions were addressed by the mean of spatial-temporal modelling of discard data collected during 3 different sampling programs. This type of method is frequently used to extract information on spatial distribution and the effect of other factors from data with high variability as it is often the case for fisheries data. That is for the example the case for abundance indices from scientific surveys, which can be estimated as year effects in spatio-temporal models (e.g. Jansen et al, 2015). Such methods have also been used on discards (Feekings et al 2012) or bycatch (Cosandey-Godin et al, 2015) data to identify spatial patterns

A new statistical framework was used here to model the spatio-temporal distribution of the discarding intensity of the Dutch beam trawlers and investigate the influence of a number of explanatory variables. The data used came from three different data collection programs : the scientific observer trips and the self-sampling program available at WMR and discard trips conducted by the industry in the context of this project.

Models are fitted separately for the main species of interest. The response variable analysed corresponds to the discarding intensity, which can be viewed as the average weight of discards of each given species occurring during a standardised fishing operation. Therefore the maps produced do not represent the spatial distribution of the total discards of the fleet, which also depends on the total fishing effort and its distribution in time and space, but rather maps of the expected discard weight for a single haul.

# 2 Data

The discards data used in this study came from 3 data collection program :

- The scientific observers program run at WMR
- The discard self-sampling program run at WMR
- The discard trips conducted by the industry in the context of Best Practices II.

The data set collated covered the period 2013 to 2017, and contained data from a total of 561 trips during which a total of 2042 hauls were sampled. The data from the 3 programs were collected following different sampling strategies. For the self-sampling program, every fortnight, 7 vessels are chosen randomly (out of a pool of around 22 vessels) and each take samples from 2 hauls. The number of trips sampled is therefore large with respect to the number of hauls sampled (table 1). For the observers program, data is collected for a smaller number of trips (6 to 8 per year), but the sampling intensity per trip is higher. This results in a different spatial distribution of the hauls sampled, with samples taken during observers trips being usually more clustered in space than samples from the self-sampling program (figure 1). The discard trips conducted by the industry provide data only since 2016. The number of trips conducted per year is lower than for the observers program, but the number of hauls sampled per trip is higher: every haul of the entire trip was sampled in the industry program, so that maximum spatial resolution was obtained.

*Table 1 : number of trips and hauls sampled per year and per data collection program*

| | **Number of trips sampled** | | | **Number of hauls sampled** | | |
|---|---|---|---|---|---|---|
| **year** | **industry** | **observer** | **Self-sampling** | **industry** | **observer** | **Self-sampling** |
| **2013** | | 7 | 85 | | 124 | 171 |
| **2014** | | 6 | 115 | | 106 | 228 |
| **2015** | | 7 | 94 | | 137 | 188 |
| **2016** | 5 | 8 | 114 | 165 | 179 | 227 |
| **2017** | 3 | 7 | 110 | 158 | 142 | 217 |

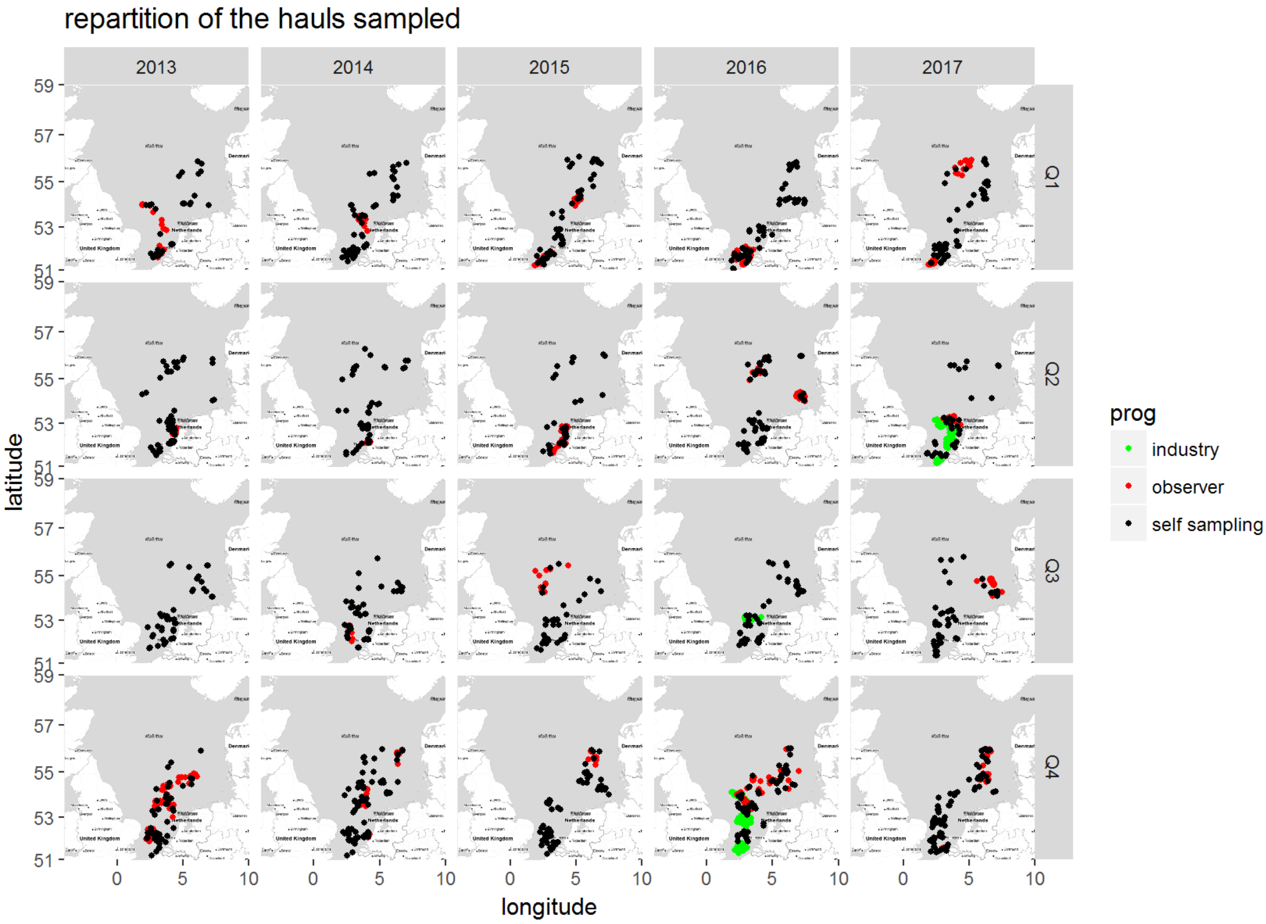



*Figure 1 : distribution of the hauls sampled per year, quarter and data collection program*

For the data collected by WMR, the raw data consisted in the number of fish caught per length class and per species for each trawl haul sampled, together with a number of variables related to the trawl haul (position, duration, bottom track, total catch of the haul) or related to the vessel (size, power, gear specifications). The raw data was aggregated in order to obtain a total catch per haul expressed both in number or in weight of fish, for the main species of interest (cod, dab, haddock, whiting, plaice, rays, turbot, brill, sole). Only the fraction of the discards corresponding to fish below the Minimum size were kept in this calculation (except for the rays, for which all sizes were kept).

The data from the industry trips was provided already aggregated in number or weight of fish discarded per haul, with the same complementary information as for the data from WMR.

In addition to the information available from the data bases, additional variables were added to the data based because they were considered (during project meeting with representatives of the industry) as potentially influencing the discarding intensity. These variables were : depth at shooting position of the haul, moon phase, bottom temperature, type of substrate. These variables were taken from data bases available online, from which the specific values for the location and time of each haul were extracted.

The main species discarded were dab and plaice, both with over 100kg on average per haul (figure 2), and almost discarded in 100% of the hauls sampled (figure 3). Discards of sole and whiting were found in around 70% of the hauls, but with much lower weight per haul than plaice and dab (around 8kg/haul). Other species were found less frequently in the discards (from 35% for the rays and turbot to around 10% for cod and brill, haddock was almost never discarded).

Because these species are less abundant and common in the discards, no spatial analyses were carried out for cod, brill and haddock.

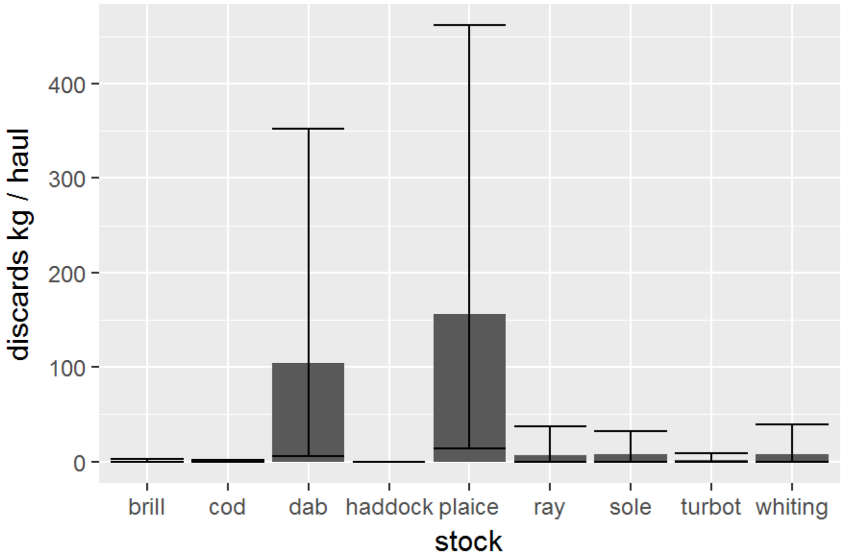



*Figure 2 : mean discard weight per species (bars) with 5% and 95% quantiles of the distribution (error bars)*

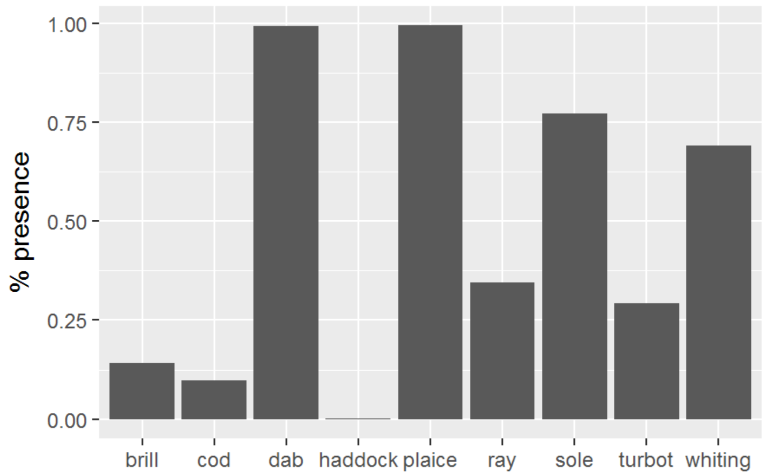



*Figure 3 : proportion of the sampled hauls with discards for each species*

# 3 Methods

## 3.1 Modelling approach

The discards in weight per haul were modelled using generalised linear model (GML) with spatial-temporal dependency. The models were fitted using INLA[1], a new computing effective method for Bayesian estimation, using the R package INLA. The spatial component in the model is represented by a Gaussian Markovian Random Field. This is a continuous Gaussian (spatial) field, in which correlation between nearby observations is estimated. This correlation between nearby located observations is represented using a Matern equation (mathematical expression in which correlation between observations decreases as a function of the distance between them). The estimated spatial component gives a representation of the spatial distribution of the data (i.e. a distribution map), when the effect of other factors is removed, and when the residual variability (according to the statistical distribution chosen) is removed.

When the data are collected in different periods of time (the case here) the model can be made more complex by the inclusion of temporal correlation (correlation of the successive values at a specific location). Temporal correlation was introduced here using a autoregressive model of order 1 (AR1). The model can then be thought of a combination of a GLM model with linear covariates, with a spatio-temporal latent process.

In addition to the spatial and temporal correlation structure, linear covariates were also incorporated in the model, as in a common GLM. The covariates investigated here were :

Continuous variables

- Duration of the haul
- Total catch of the haul
- Bottom depth
- Bottom temperature

Discrete factors

- Data collection program (observers, self-sampling or industry)
- Width of the beam trawl (4 or 12m)
- Type of beam trawl (conventional v.s. pulse)
- Moon phase
- Type of substrate

By using the duration of the haul as covariate, the effort corresponding to each haul is explicitly taken into account in the model.

## 3.2 Model formulation

Spatial models were fitted separately for each species. Owing to the difference in the statistical distribution of the discard weight values of the different species, and specifically the number of zero's (absence of discards in a given haul), different models were used depending on the species.

[1] integrated nested Laplace approximation

### 3.2.1 Stock with few zero's

For the species with few zero observations (5 for plaice and 8 for dab), the discard weight per haul were modelled using a Gamma model. A formal definition of the model is as follows:

$$y(s_i) \sim Gamma(\mu(s_i), \sigma^2)$$

$$\mu(s_i) = covariates(s_i) + \nu(s_i)$$

$$\nu(s_i) = \rho \ \nu(s_{i-1}) + u_i$$

$$u \sim GF(0, \Sigma)$$

The observed discard weight $y(s_i)$ for the *i*st haul, taken on location $s_{i,}$ , is distributed according to a Gamma distribution with a mean $\mu(s_i)$ and a variance $\sigma^2$. The mean is a linear function of covariates $covariates(s_i)$ plus a spatio-temporal correlation term $\nu(s_i)$ which follows an AR1 process with temporal correlation $\rho$ and $u_i$ is the Gaussian field (i.e. spatial distribution) for the time step in which observation *i* occurred.

### 3.2.2 Stock with many zero's

The analysis is complicated by the occurrence of exactly zero observations. It makes many statistical methods for continuous data inappropriate. For the species with many zero observations (sole, whiting, turbot and rays), a "delta-gamma" model approach was adopted. This approach consists in modelling separately the presence-absence using a binomial distribution and the positive data using a Gamma distribution (e.g. Bigelow, 2006, Lecomte et al. 2013). The expected discard weight is then obtained as the product of the probability of discard occurring times the expected discard weight for non-zero data.

A formal definition of the model is as follows:

$$y(s_i) \sim deltaGamma\left(\pi\ (s_i), \mu_{nonZero}(s_i), {\sigma_{pres}}^2, {\sigma_{nonZero}}^2\right)$$

$$\mu(s_i) = \pi\ (s_i)\ \times\ \mu_{nonZero}(s_i)$$

Where the expected discard weights $y(s_i)$ at the location $s_i$ is the product of the probability of non-zero discard at location $s_i$, $\pi\ (s_i)$ by the expected discard weight for non-zero data $y_{nonZero}(s_i)$ with :

- The probability of non-zero discard, $\mathrm{pres}(s_i)$, modelled as a binomial distribution

$$\mathrm{pres}(s_i) \sim binomial\left(\pi(s_i), {\sigma_{pres}}^2\right)$$

$$logit(\mu(s_i)) = covariates(s_i) + \nu(s_i)$$

$$\nu(s_i) = \rho \ \nu(s_{i-1}) + u_i$$

$$u \sim GF(0, \Sigma)$$

- The discard weight for non-zero data modelled as above using the Gamma GLM :

$$y_{nonZero}(s_i) \sim Gamma(\mu_{nonZero}(s_i), {\sigma_{nonZero}}^2) \qquad \text{for } s_i \text{ with non-zero discards}$$

$$\mu_{nonZero}(s_i) = covariates(s_i) + \nu'(s_i)$$

$$\nu'(s_i) = \rho \ \nu'(s_{i-1}) + u'_i$$

$$u' \sim GF(0, \Sigma)$$

Other methods can be applied to biomass data set with zero data, such as compound Poisson-gamma models which were found to be more robust to deviations from model assumptions (Lecomte et al. 2013, Foster and Bravington, 2013). Such methods were not investigated here as they, to our knowledge, have never been applied in combination with the estimation of spatio-temporal correlation structure, as done here.

## 3.3 Model selection

The model selection approach consisted in building a series of models of increasing complexity, and choosing the best model on the basis of the lowest deviance information criterion (DIC). Given a collection of models for the data, DIC estimates the quality of each model by balancing the quality of the fit and the number of degree of freedom used, relative to each of the other models. The range of models tested were:

Model 1 : linear covariates

Model 2 : linear covariates + spatial structure

Model 3 : linear covariates + spatial-temporal structure with annual time steps

Model 4 : linear covariates + spatial-temporal structure with quarterly time steps

In addition, to take into account the fact that data collected from a same vessel might be correlated (e.g. due to difference of fishing efficiency between vessels) the model 1 to 4 were also run with vessel name as random effect.

The logNormal distribution was an alternative to Gamma distribution for modelling positive only continuous data (Dick, 2004). The choice of the Gamma distribution was made after fitting all the models using a logNormal distribution instead of a Gamma distribution and comparing the DIC. In all cases, the models with Gamma distribution performed better than with logNormal distribution

# 4 Results

## 4.1 Best models

For all species, the model with the lowest DIC was the model 4 (i.e with spatial distribution estimated quarterly) with random effects for vessels (except for the Gamma model for turbot and rays and the binomial model for sole and rays).

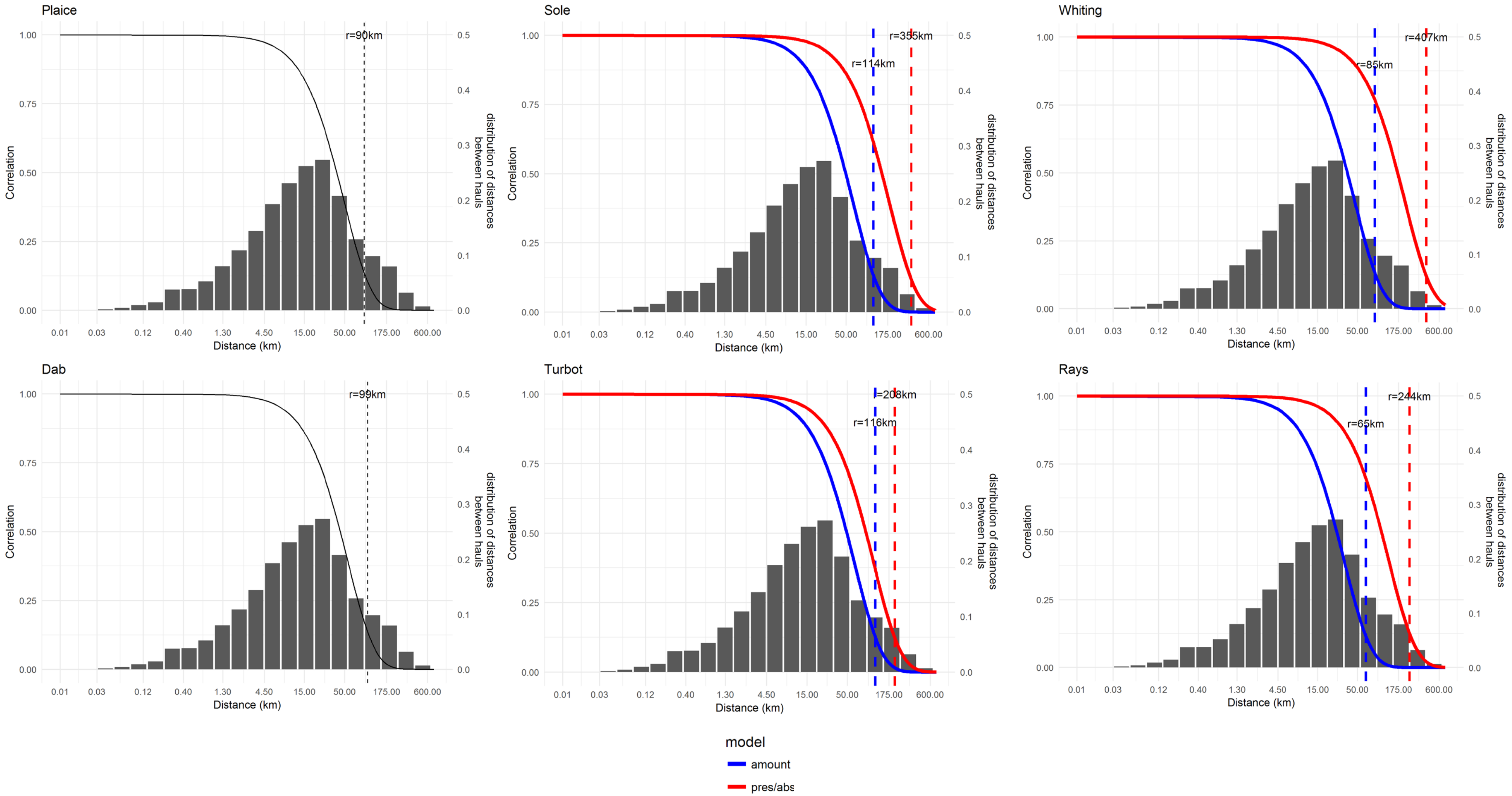
## 4.2 Spatial correlation

The spatial structure of the discards is estimated as a Gaussian process in which nearby observations are correlated according to a Matern covariance function. This function defines the covariance (i.e. correlation) between two contemporary (i.e. from the same quarter of the year) observations with respect to the distance separating the 2 observations. Following this function, a decorrelation distance can be defined, beyond which 2 observations are no longer correlated.

One of the parameters of the Matern function is the range, which corresponds to the distance where the correlation drops below 0.1. This estimated "decorrelation distance" is difficult to interpret concretely, but provides a useful descriptor to compare the degree of spatial correlation for different species. For the two species for which discards occur in every sampled haul, plaice and dab, the decorrelation distance is similar between 90 and 100km (table 2). For the species that do not always occur in the discards, the probability of occurrence is structured at a larger scale, with decorrelation distances varying from 208km for turbot to 407km for whiting. For these same species, the spatial structuration of the non-null observations is at a finer scale, particularly for rays (65km) and less so for sole and turbot (around 115km).

The value of the Matern function corresponding to the standard distance between two successive hauls is another, more concrete, descriptor of the spatial correlation in the discards. The histogram of the distances between successive hauls (based on the midpoints) show that successive hauls are typically 15 nm apart (bars on table 2). For this typical distance, the correlation for plaice and dab is high (0.65 and 0.70, respectively) which indicates that when a vessel has high (or low) discard for these species in one haul, it is usually also the case for the next haul. For the species that do not always occur in the discards, the probability of occurrence of discards in two successive hauls is correlated at around r=0.90 (for the typical distance between 2 hauls). This indicates that when a vessel is in an area where one of these species is found in (or is absent from) the discards, it is almost certain that the species will also occur in (or be absent from) the discards of the next haul. Correlation in the amount of discards (when discards a occurring) between two successive hauls 15 miles apart is high for turbot and sole ( around 0.75), but lower for whiting and even more so for the rays (0.6 and 0.5).

*Table 2 Matern correlation functions for the Gamma models for dab and plaice (black line) and for the presence-absence and gamma models for presence only for the other species (red and blue lines) with decorrelation distances (vertical lines) and distribution of the distances between the midpoint of successive trawl hauls (bars).*



## 4.3 Temporal autocorrelation

Similarly to the decorrelation distance, the Gaussian latent process is also characterised by its temporal persistence, defined by the temporal autocorrelation in the AR1 process, $\rho$. Contrasting results are observed across species.

For the 2 species with the highest discards, dab has a low $\rho$ value (table 3), indicating that the distribution of discards is susceptible to change substantially from one quarter to the next. The $\rho$ value for plaice is higher, meaning that there is more stability in discards distribution between quarters.

Among the species modelled with the deltaGamma approach, all display a high $\rho$ value (close to 0.90) for the presence-absence model, indicating that the spatial pattern of the probability of occurrence in the discards is very stable from quarter to quarter for these species. For the Gamma part of the model, sole and turbot show strong persistence of discard pattern through time (high $\rho$) while rays and whiting show highly variable distribution (low $\rho$ ).

*Table 3 : estimated autocorrelation $\rho$ in the AR1 process*

| MODEL | DAB | PLAICE | SOLE | TURBOT | RAYS | WHITING |
|---|---|---|---|---|---|---|
| **BINOMIAL** | | | 0.98 | 0.88 | 0.87 | 0.93 |
| **GAMMA** | 0.37 | 0.69 | 0.89 | 0.78 | 0.26 | 0.04 |

## 4.4 Spatio-temporal distributions

The spatial-temporal component (Gaussian Markovian Random Field) estimated for all the models are presented in the annexes 1 to 6. The main features of these distribution and their variations are briefly described here.

### 4.4.1 Dab

Some patterns are observed recurrently from year to year. During the first quarter, high discarding intensity is generally observed in the southern part of the area (in front of the southern coast of the Netherlands, more rarely in front of the Wadden islands, as in 2017). Quarter 2 distribution is quite variable, with years with high discard values (e.g. 2013 and 2016) and years with little discarding of dab (2014 and 2017). In quarter 3, discards are consistently high in front of the German coast and lower in front of the Dutch cost. Finally, the situation is also quite variable for quarter 4, with years of low discards over the whole area (2014) and year with some hotspots (e.g. 2015).

As expect from the value of the autocorrelation $\rho$, discard distribution is highly variable from one quarter to the next (e.g. quarter 1 to 4 in 2017).

### 4.4.2 Plaice

As expected from the higher value of $\rho$, the distribution of plaice discards is less variable from one quarter to the next. Discards are consistently high in the south of the area (between the south of the Netherlands and England), with occasional hot spots in front of Germany. Discards tend to be lower in the north-western part of the area.

### 4.4.3 Sole

Probability of occurrence of sole discards is remarkably stable though time (for this species, the difference in DIC between model 3 and 4 was smaller than for other species, suggesting that a model with yearly time steps could have been equally good). Probability of discarding sole is high in the south-eastern part of the area and low in the north-western part of the area.

The distribution of the non-zero values is similar to the distribution of combining the binomial and gamma models. It shows a hotspot of sole discarding found consistently in front of the southern coast of the Netherlands, occasionally expanding towards England or to the northern coast of the Netherlands.

### 4.4.4 Turbot

Probability of occurrence of turbot discards shows a spectacular trend in time. The occurrence of discards is generally lower for the first years of the period studied, and mainly limited to the Dutch and German coasts. Starting from 2015, the probability of discarding increases, first remaining with a similar spatial distribution, but expanding to almost the entire area after the second quarter of 2016.

The distribution of the non-zero values is similar to the distribution of combining the binomial and gamma models. Overall discards are low until the last quarter of 2015, when higher values are observer in the southern part of the area. Then, high values progressively expand to a larger area in the southern and central part of the North Sea, while discards remain low in the northern part of the area and in front of England.

### 4.4.5 Whiting

The probability of occurrence of discards of whiting is in general high in the southern and eastern parts of the area (except in an area in the west of the Wadden Islands), and low in the north-western corner. The early part of the period studied (until the second quarter of 2014) does not conform to this pattern, as the probability of non-null discards is high only in the south-western part of the area.

The distribution of the non-zero values is similar to the distribution of the combined binomial and gamma models. The level and the distribution of whiting discards appears to be highly variables from one quarter to the other (very low $\rho$ value for the Gamma model). In particular, discarding hotspot suddenly appear most years in the fourth quarter, and disappear in the following first quarter. Those hotspots do not occur consistently in the same areas. Higher discard values are also occasionally observed in small areas in other quarters (e.g. west of England in Q2 in 2014, southern area in Q1 and Q2 in 2017).

### 4.4.6 Rays

The probability of discarding rays is in general higher in the north-western half of the area and lower in the south-eastern part. In the earlier part of the period, most of the area has a low probability of discards of rays, but progressively the boundary between low and high probability moves to the east, and in 2017, the area of low probability is confined to the west of the German coast.

The distribution of the combined binomial and gamma models is also variable, with hotspots appearing for one or two specific quarters and disappearing afterwards (also a low $\rho$ value for the Gamma model). In general, areas of higher discard value tend to be found in the front of the English coast, and in the north. Since the fourth quarter of 2016, higher discard values are consistently observed in front of the English coast

## 4.5 Effect of covariates

The GML included also effect of linear predictors. The table 4 gives a summary of which covariates were found to have a significant effect on the discarding intensity (the actual values of the estimated parameters with confidence intervals are given in annex 7).

In most cases, discard weights or the probability of discarding were not significantly influenced by the duration of the trawl haul (except for plaice discard weight and sole probability of discarding). For all species, discard weight per haul was positively related to the total catch of the haul. The probability of discarding of turbot, whiting and rays to occur (presence-absence model) was, however, negatively linked to the total catch of the haul. For these 3 species, this means that they are generally discarded in hauls that have a lower total catch, but among these hauls, the weight of discards increases with the weight of the total catch.

For all species, except for sole and turbot, discard weight and probability were higher for the large beam trawls (12m) compared to the smaller ones (4m). The effect of the pulse trawl (compared to the conventional gear) was significant for 4 species with different signs (higher discard weight of whiting, and higher chance of sole discarding to occur, but lower discard weight for turbot and rays).

Significant differences were also found between data collection programs. The hauls from trips conducted by the industry had higher plaice discards than hauls from observer trips or self-sampling trips. Hauls from industry trips also had a higher chance of containing discards of turbot, whiting and rays. Discard weights in the hauls sampled by the self-sampling program are higher for dab and lower for turbot than in other programs. The probability of sole discarding to occur is lower in hauls sampled during observer trips and the weight of whiting and rays are respectively lower and higher than in hauls sampled during other programs.

Environmental covariates also had significant influences in some of the models. Certain types of substrate influenced the probability of discard to occur (e.g. for turbot and rays). Temperature had a positive effect on discard weights for dab and a negative effect on the probability of whiting and rays discards to occur. Discards of sole, whiting and rays increased (both in probability of occurrence and in weight) with depth, while the probability of turbot discards to occur decreased. Finally, discards were linked to moon phase for plaice, sole and rays.

*Table 4 : direction of the different effects included in the models, on discard amounts or presence /absence per species (only for statistically significant effects). Positive effect means that higher values of the covariate is associated to higher discard amounts or probability of discarding*

| Species | dab | plaice | sole | | turbot | | whiting | | Rays | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Model** / **co-variate** | **Discards amounts** | **Discards amounts** | **Discards presence/absence** | **Discards amounts** | **Discards presence/absence** | **Discards amounts** | **Discards presence/absence** | **Discards amounts** | **Discards presence/absence** | **Discards amounts** |
| Haul duration | | Positive | Negative | | | | | | | |
| Total catch haul | Positive | Positive | | Positive | Negative | Positive | Negative | Positive | Negative | Positive |
| Beam width | Higher for 12m | Higher for 12m | | | | | Higher for 12m | Higher for 12m | Higher for 12m | Higher for 12m |
| Conventional or pulse | | | Higher in pulse | | | Lower in pulse | | Higher in pulse | | Lower in pulse |
| Data collection program | Higher in self sampling | Higher in industry trips | Lower in observer trips | | Higher in industry trips | Lower in self sampling | Higher in industry trips | Lower in observer trips | Higher in industry trips | Higher in observer trips |
| Bottom substrate | | | | | Lower in sand to muddy sand | | | | Higher in mixed sediments | |
| Bottom temperature | Positive | | | | | | Negative | | Negative | |
| Depth | | | | Positive | Negative | | Positive | Positive | Positive | Positive |
| Moon phase | | Lower for full moon and last quarter | Lower for full moon and new moon | | | | | | Higher at new moon | |

# 5 Discussion and conclusions

Using a modelling approach to study the spatial distribution of discards has many advantages compared to simply plotting the raw data in space:

- It provides descriptors for the spatial and temporal characteristic of the distribution
- It provides a framework to deal with the residual variability (noise) in the data with an appropriate statistical distribution, and therefore reduces the impact of extreme values or outliers on the distribution maps produced
- It allows for the estimation of the effect of covariates, and therefore produce maps in which these effects have been accounted for.

This work highlighted some general features of the distribution of the discards from the Dutch beam trawler fleet. First, the models estimated the decorrelation distance for the distribution of the discards of each species. Practically, this means that if a vessel has high discards of a given species in a given trawl haul, any other trawl haul realized at a distance smaller than the decorrelation distance is likely to also yield high discards (and the reverse also holds for trawl with low discards). This distance is comprised between 65km for rays and 114km for sole.

For species that did not occur systematically in the discards, the presence absence models show that there are large scale structures of the probability of occurrence (from 200km for turbot to 400km for whiting).

More generally, the distribution patterns observed probably reflect to a large extent the distribution of the undersized part of the populations. In the case of sole, the distribution of discards (especially for the presence-absence) from the model (annex 3) broadly corresponds to the distribution of undersized sole perceived from the Beam Trawl Survey (figure 4). A continuation to this study could consist of producing maps similar to figure 4 from available survey data for the other species and analyze the similarity between distribution of undersized fish in the surveys and spatial-temporal patterns estimated here in the discards. for instance, it would be interesting to compare the distribution of whiting in different survey to see if higher aggregations are observed in Q4 which would explain the higher discards in this quarter.

For some species, hotspots with high discarding intensity have been identified. In the case of rays, the hotspot of discards found in the model east of the English coast correspond to a known breeding ground for some species (e.g. Thornback ray, Hunter et al., 2006). For the rays, in addition to localized hotspots, there was also a general increase in the weights of discards per haul, especially since 2016, which could reflect the increase of population sizes observed in the surveys (ICES, 2018a).

Apart from the distribution of the resource, some other factors - not explicitly represented by the list of covariates incorporated in the models in this study – might also be responsible for the spatial-temporal components estimated by the models. For instance in the case of turbot (annex 4), the sharp increase in the level of the discards since the start of 2016 cannot be explained by changes in the abundance of undersized fish. Recruitments in 2015 and 2016 were indeed higher than previous and following years, but not by a magnitude that would explain the changes in the discards for 2016 and 2017. A more likely explanation is the change in the minimum size implemented by the Dutch producers organizations, which went from 27cm in January 2016 to 32cm in May 2016. This measure was implemented together with limitations on the amount of turbot landed per trip in order to regulate the landings, in a context were quota were insufficient. Similar measures are also implemented by the producer organizations for rays, but with landing limits per trip which are susceptible to be adjusted along the year. This might explain the high temporal variability in the discard patterns described for the rays.

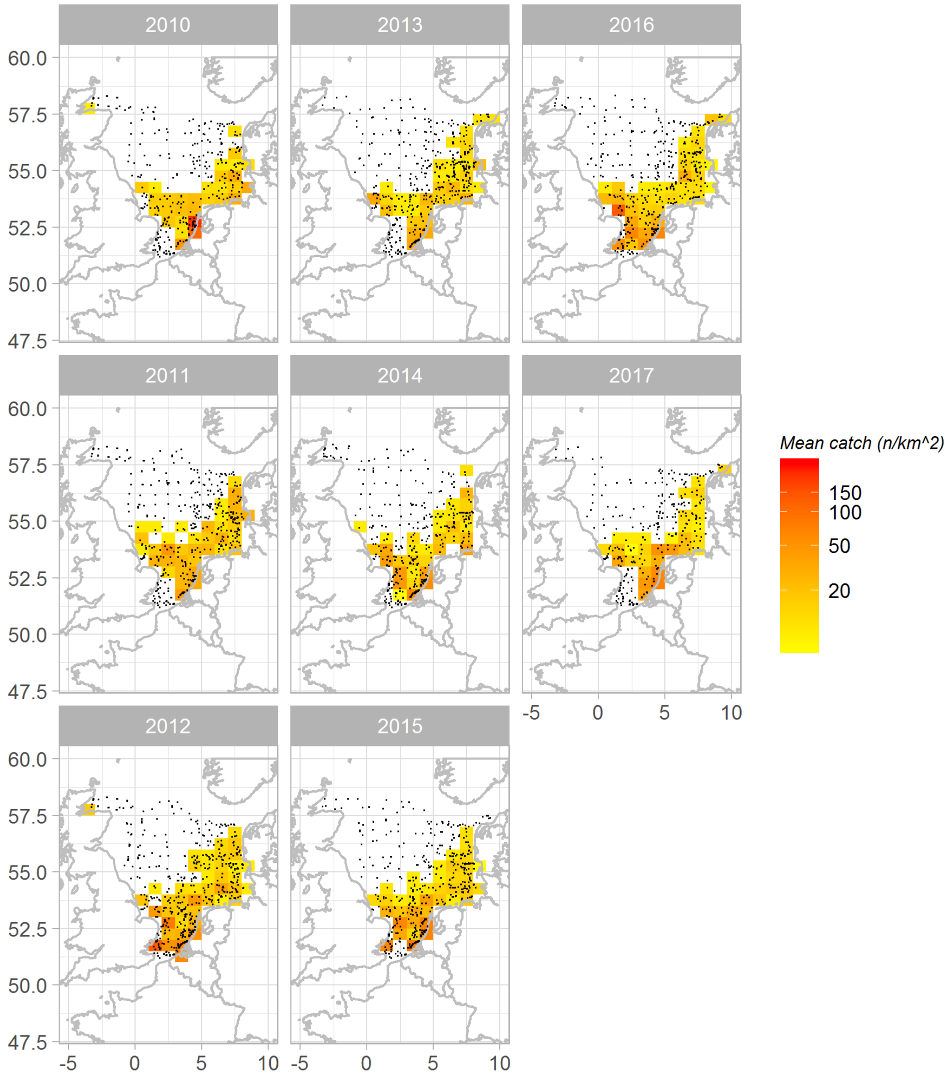



*Figure 4 : perception of the spatial distribution of sole <24cm in Q3 from the Beam Trawl Survey (from Brunel and Verkempynck, 2018).*

Interpretation of the effect of the different covariates is not straightforward. The models indicate here that for most species, the duration of the haul has no influence on the discards per haul. This goes again the expectation that the catches should be proportional to the fishing effort. The relationship between catch and effort, however, stands only if the effort measures the time spent actively targeting the species. In the present case, the dataset contains a collection of trips, potentially with different targeted species, which explains that the relationship effort-catch would not hold across trips for a given species. Furthermore, even when the species is targeted, the effort is mainly directly towards catching the marketable size fish, and not the undersized fish which will be discarded.

Discards weights were, on the other hand, almost always positively linked to the total catch of the haul. Since discards is an important compartment of the catch, the two should be inherently related. But other factors can explain this relationship. For instance, a saturation effect can affect the selectivity of the net and reduce the escapement rate of undersized fish when a large biomass is filling the cod end.

The probability of having sole discards was found to be higher in the pulse trawl. This is in agreement with the improved catch efficiency of sole by the pulse compared to the conventional tickler chain beam trawl (ICES, 2018b). For whiting, the higher discard weight in the pulse gear could be associated to a stronger reaction for gadoid species to the effect of the electric stimulation preventing them from escaping the gear. For turbot and rays, the lower probability of having discards in the pulse gear could be related to a lower catchability of these species by the pulse trawl compared to the conventional gear. The reduced catchability may be caused by specific gear characteristics (e.g. no tickler chains) as well as the fact that these species are strong swimmers and may have a higher chance to escape the pulse gear, which is towed at a lower speed (4.5Nm v.s 6Nm for the conventional gear).

The sampling program was frequently found to have an impact on the discards, suggesting some species related observation biases. In the case of the self-sampling program, only two boxes of discards are collected by haul sampled, and the crews might tend not to keep the larger fish which do not easily fit in the buckets used to take samples. This might explain the lower weight of turbot for the hauls sampled during this program.

Finally, for almost all cases, the models indicated that the vessels also had a significant effect on discards, even when the difference between small and large trawlers was taken into account (via the beam width effect). These differences might have a technical cause (related to vessel and gear characteristics) but also reflect different fishing strategies of the skippers.

The data used in the work come from a collection of fishing trips, which were not selected in order to obtain a balanced experiment (in which all the levels of all the factors would be sampled with a same intensity). This can, to some extent, make the model prone to confounding between different effects. For instance, the fleet was composed of two types of vessels (large and small cotters, using respectively 12 and 4m beams). Smaller cotters usually fish closer to the coast, while larger ones have the ability to fish offshore. If there is a gradient in the distribution of the undersize fish for a given species, there might be a risk that the model is not able to able to distinguish a beam width effect from a spatial effect. However, if the distribution of the hauls from both types of vessels has enough overlap (in space and time) the model might be able to estimate the effect of beam width independently from the effect of sampling the stocks in different areas. The fact that for some species (e.g. plaice and dab), the 12m beam result in higher discards and at the same time discards are high in the coastal areas (where most of the effort of the smaller vessels is concentrated) suggest that the model was able to estimate separately spatial components and gear effect.

# 6 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. This certificate is valid until 15 December 2018. The organisation has been certified since 27 February 2001. The certification was issued by DNV GL.

Furthermore, the chemical laboratory at IJmuiden has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1$^{th}$ of April 2021 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation. The chemical laboratory at IJmuiden has thus demonstrated its ability to provide valid results according a technically competent manner and to work according to the ISO 17025 standard. The scope (L097) of de accredited analytical methods can be found at the website of the Council for Accreditation (www.rva.nl).

On the basis of this accreditation, the quality characteristic Q is awarded to the results of those components which are incorporated in the scope, provided they comply with all quality requirements. The quality characteristic Q is stated in the tables with the results. If, the quality characteristic Q is not mentioned, the reason why is explained.

The quality of the test methods is ensured in various ways. The accuracy of the analysis is regularly assessed by participation in inter-laboratory performance studies including those organized by QUASIMEME. If no inter-laboratory study is available, a second-level control is performed. In addition, a first-level control is performed for each series of measurements.
In addition to the line controls the following general quality controls are carried out:

- Blank research.
- Recovery.
- Internal standard
- Injection standard.
- Sensitivity.

The above controls are described in Wageningen Marine Research working instruction ISW 2.10.2.105. If desired, information regarding the performance characteristics of the analytical methods is available at the chemical laboratory at IJmuiden.

If the quality cannot be guaranteed, appropriate measures are taken.

# References


Brunel, T. and Verkempynck, R. 2018. Variations in North Sea sole distribution. Wageningen Marine Research report C87/18. 27 pp

Cosandey-Godin, A., Teixeira Krainski, E., Worm, B. and Mills Flemming, J. 2015. Applying Bayesian spatiotemporal models to fisheries bycatch in the Canadian Arctic. Canadian Journal of Fisheries and Aquatic Sciences, 72(2): 186-197

Dick, E.J., 2004. Beyond 'lognormal versus gamma': discrimination among error distributions for generalized linear models. Fisheries Research 70 (2004) 351–366

Feekings J, Bartolino V, Madsen N, Catchpole T (2012) Fishery Discards: Factors Affecting Their Variability within a Demersal Trawl Fishery. PLoS ONE 7(4): e36409

Hunter E., Berry F., Buckley A.A., Stewart C. and Metcalf J.D. 2006. Seasonal migration of thornback rays and implications for closure management. Journal of Applied Ecology 43(4): 710-720.

ICES. 2018a. Report of the Working Group on Elasmobranch Fishes (WGEF), 19–28 June 2018, Lisbon, Portugal. ICES CM 2018/ACOM:16. 1306 pp.

ICES. 2018b. Report of the Working Group on Electric Trawling (WGELECTRA). ICES Report WGELECTRA 2018 17 - 19 April 2018. IJmuiden, the Netherlands. 155pp.

Jansen, T., Kristensen, K., van der Kooij, J., Post, S., Campbell, A., Utne, K.U., Carrera, P., Jacobsen, J.A., Gudmundssdottir, A., Roel, B.A. and Hatfield, E.M.C. 2015 Nursery areas and recruitment variation of Northeast Atlantic mackerel (*Scomber scombrus*), *ICES Journal of Marine Science*, 72 (6) :1779–1789

# Justification

Report C015/19

Project Number: 4311400005

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved: Ir. N.T. Hintzen
Research scientist

Signature:

Date: 14 February 2019

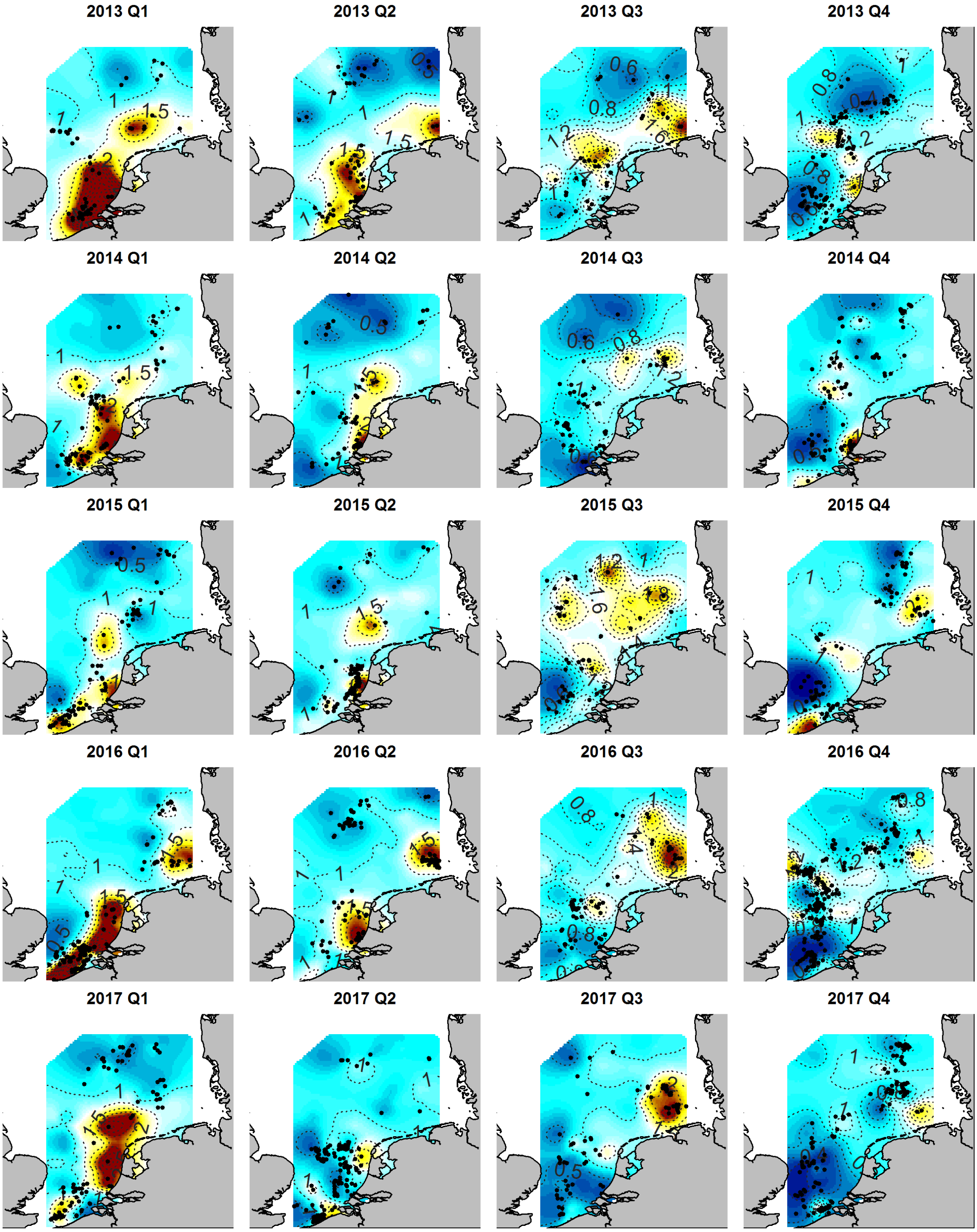
Approved: Dr.ir. T.P. Bult
Director

Signature:

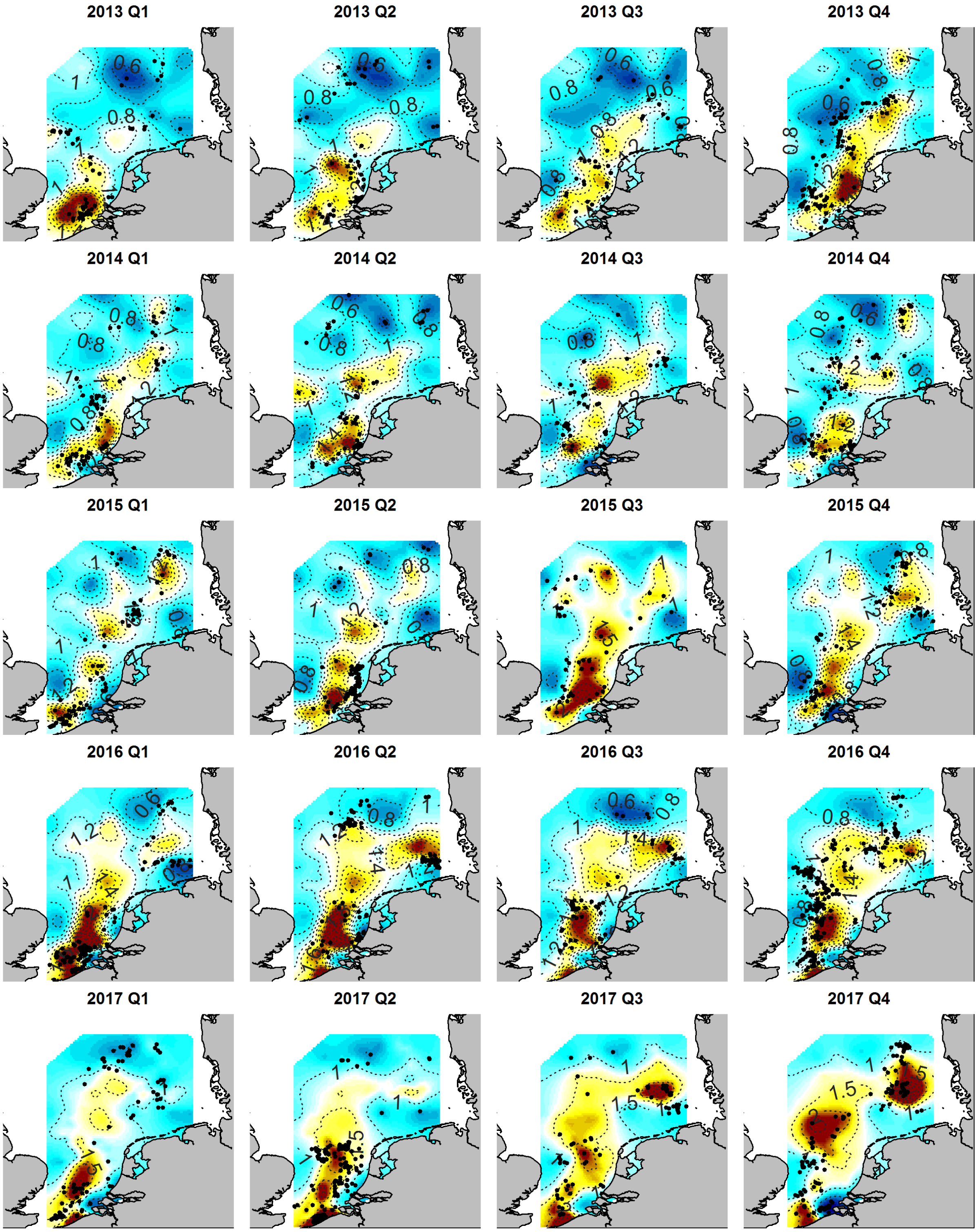
Date: 14 February 2019

# Annexes

## Annexe 1 : spatial-temporal component (Gaussian Markovian Random Field) estimated for DAB

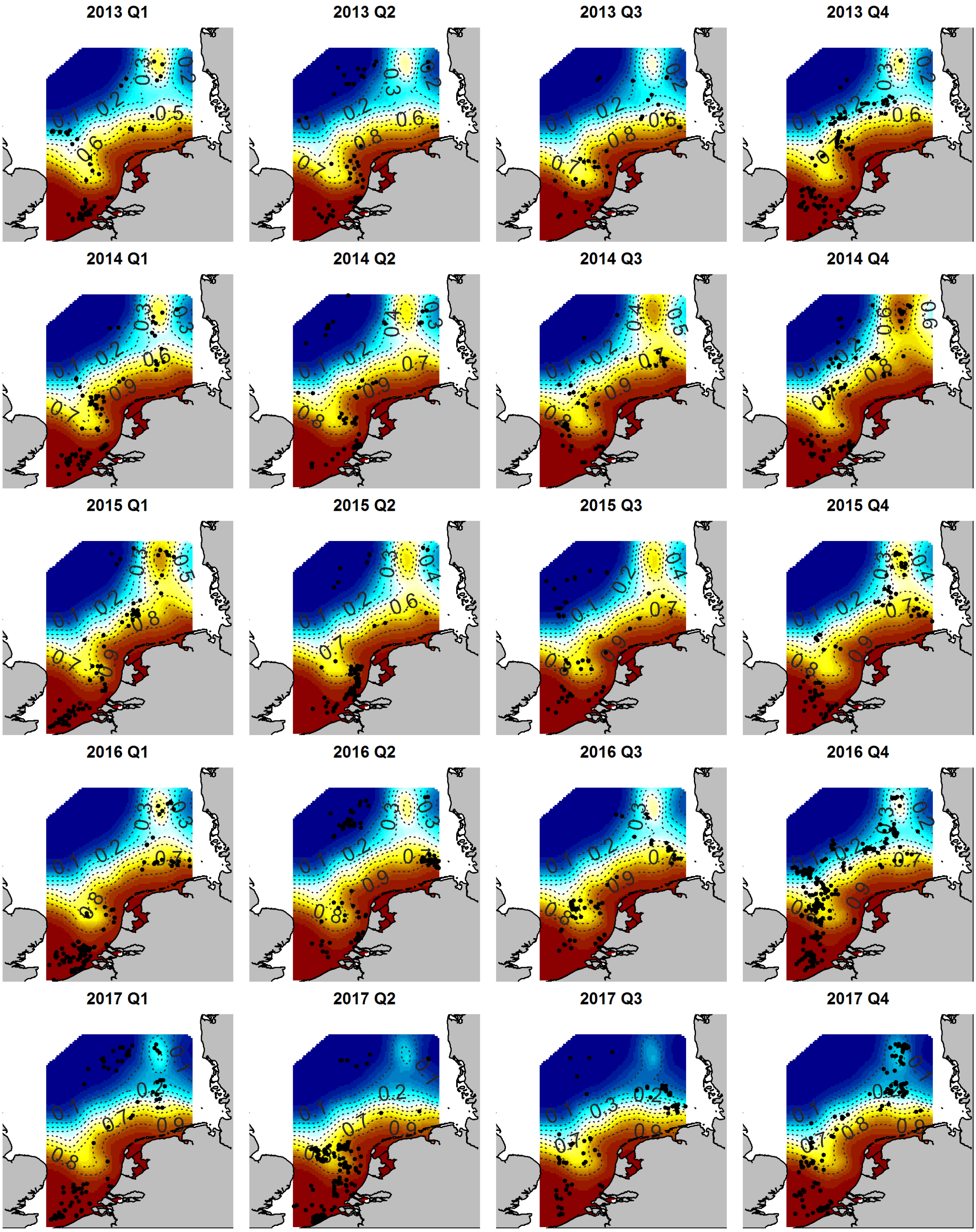


## Annexe 2 : spatial-temporal component (Gaussian Markovian Random Field) estimated for PLAICE

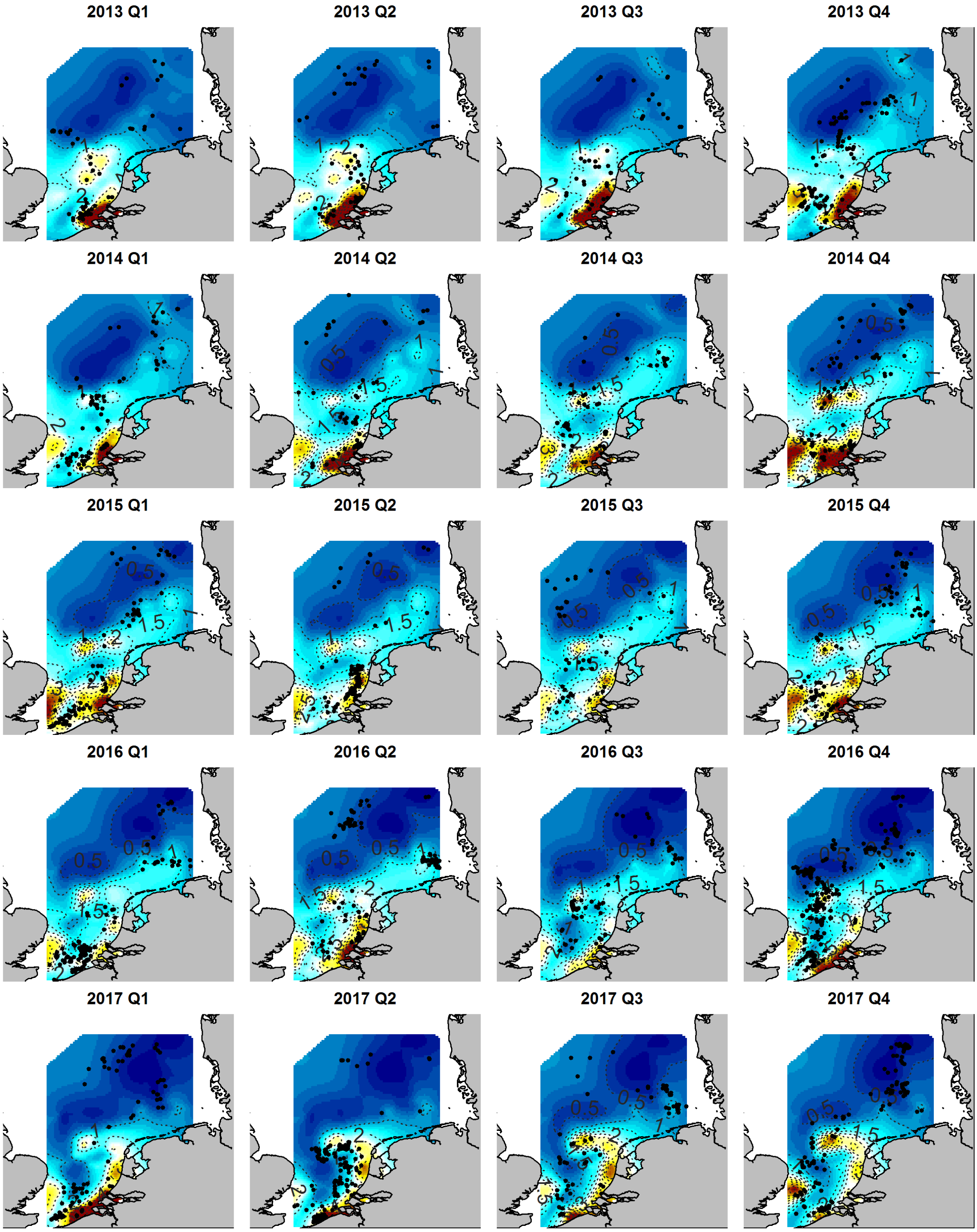


## Annexe 3 :

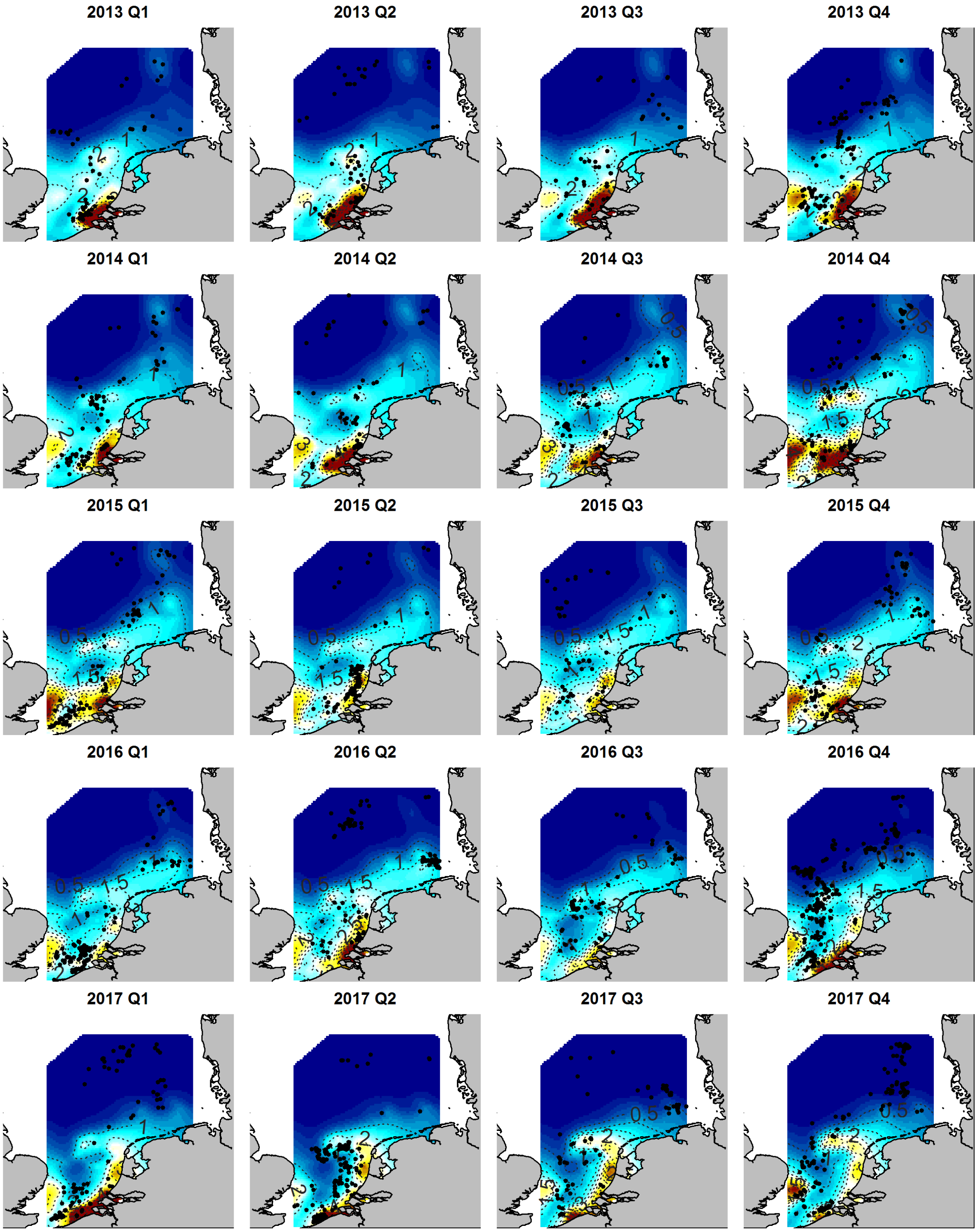
**spatial-temporal component (Gaussian Markovian Random Field) estimated for SOLE for the presence absence model**



**spatial-temporal component (Gaussian Markovian Random Field) estimated for SOLE for the presence only model**

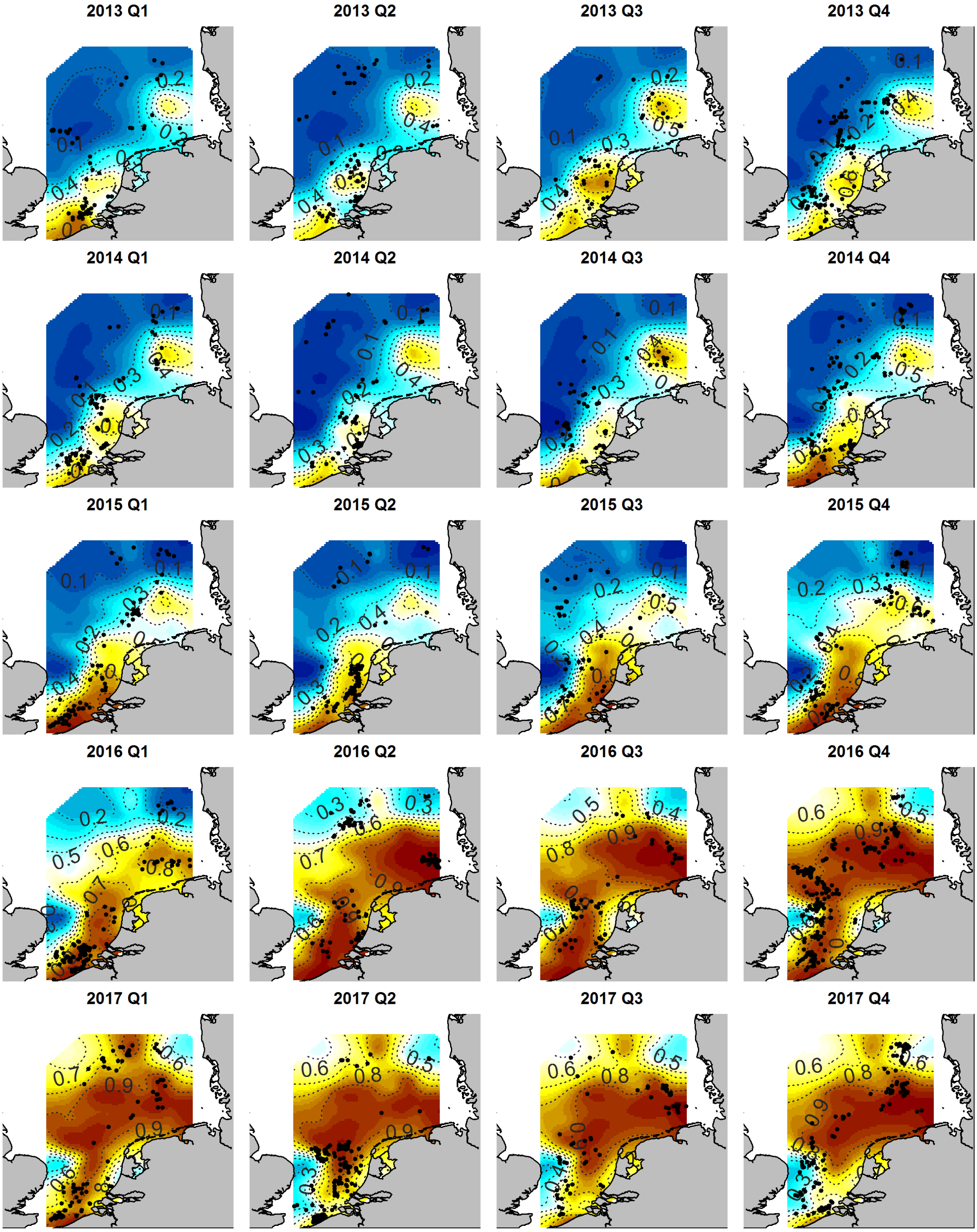


## Product spatial-temporal components (Gaussian Markovian Random Field) estimated for SOLE for the presence-absence and for presence only models combined

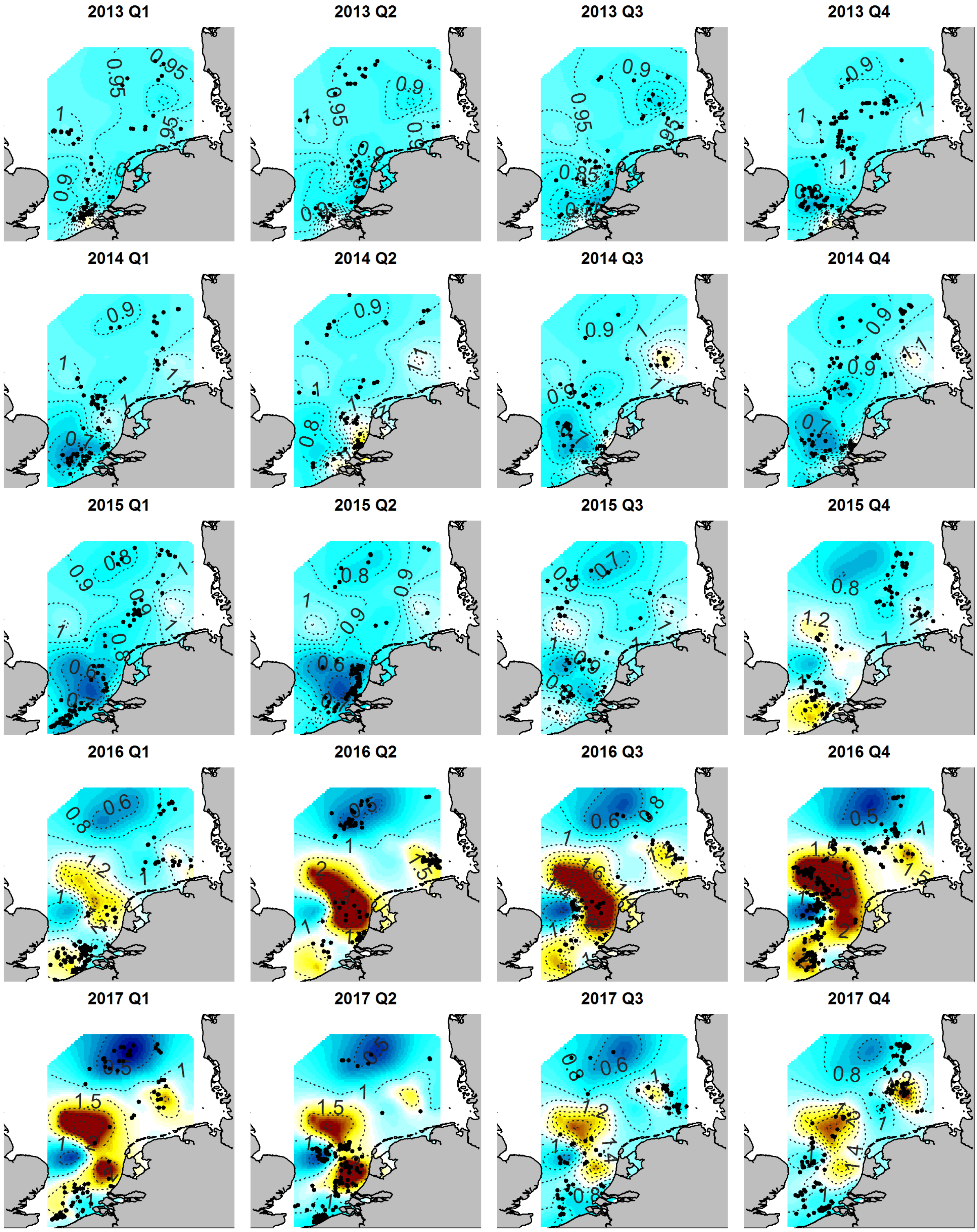


## Annexe 4 :

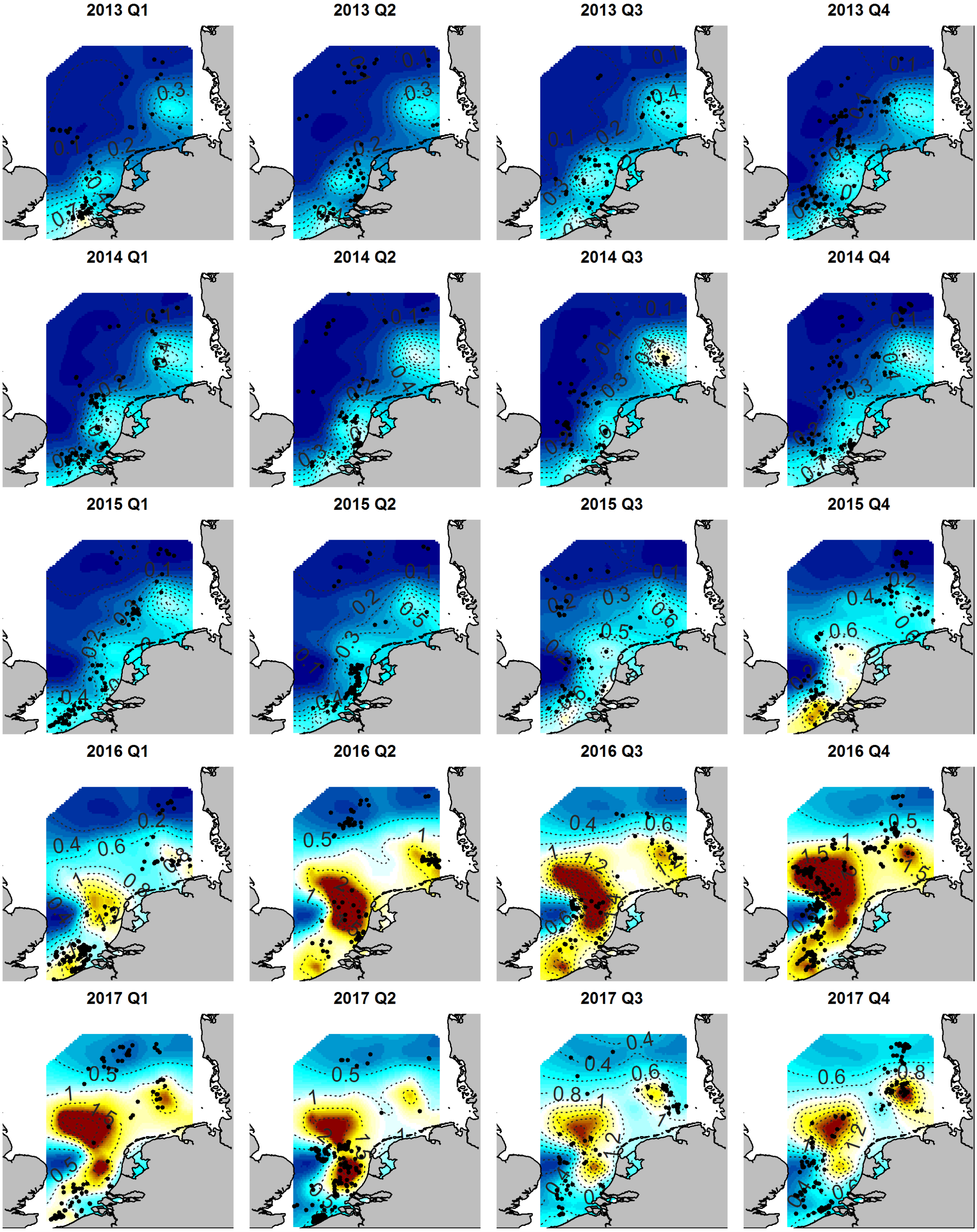
## spatial-temporal component (Gaussian Markovian Random Field) estimated for TURBOT for the presence absence model



**spatial-temporal component (Gaussian Markovian Random Field) estimated for TURBOT for the presence only model**

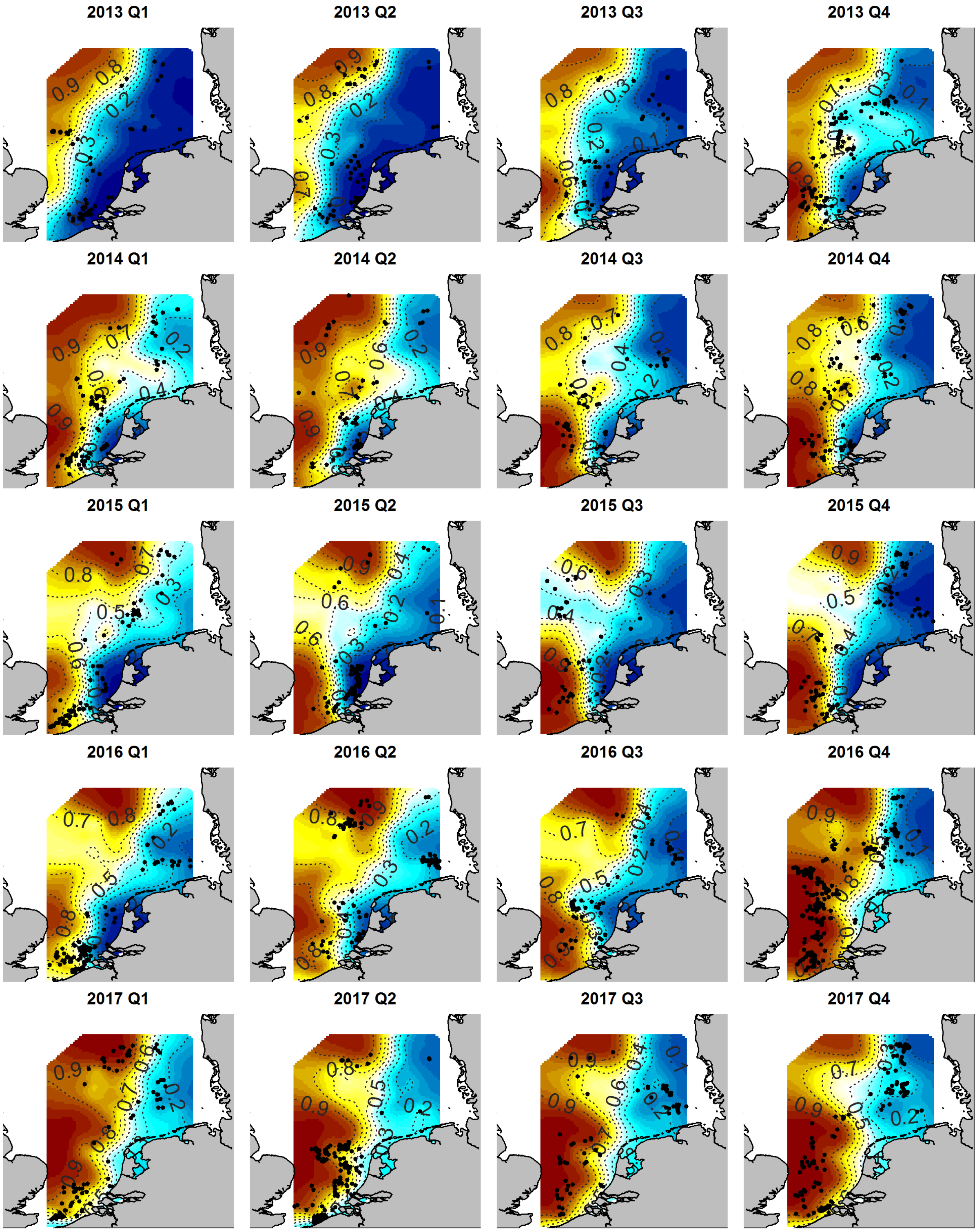


**Product spatial-temporal components (Gaussian Markovian Random Field) estimated for TURBOT for the presence-absence and for presence only models combined**

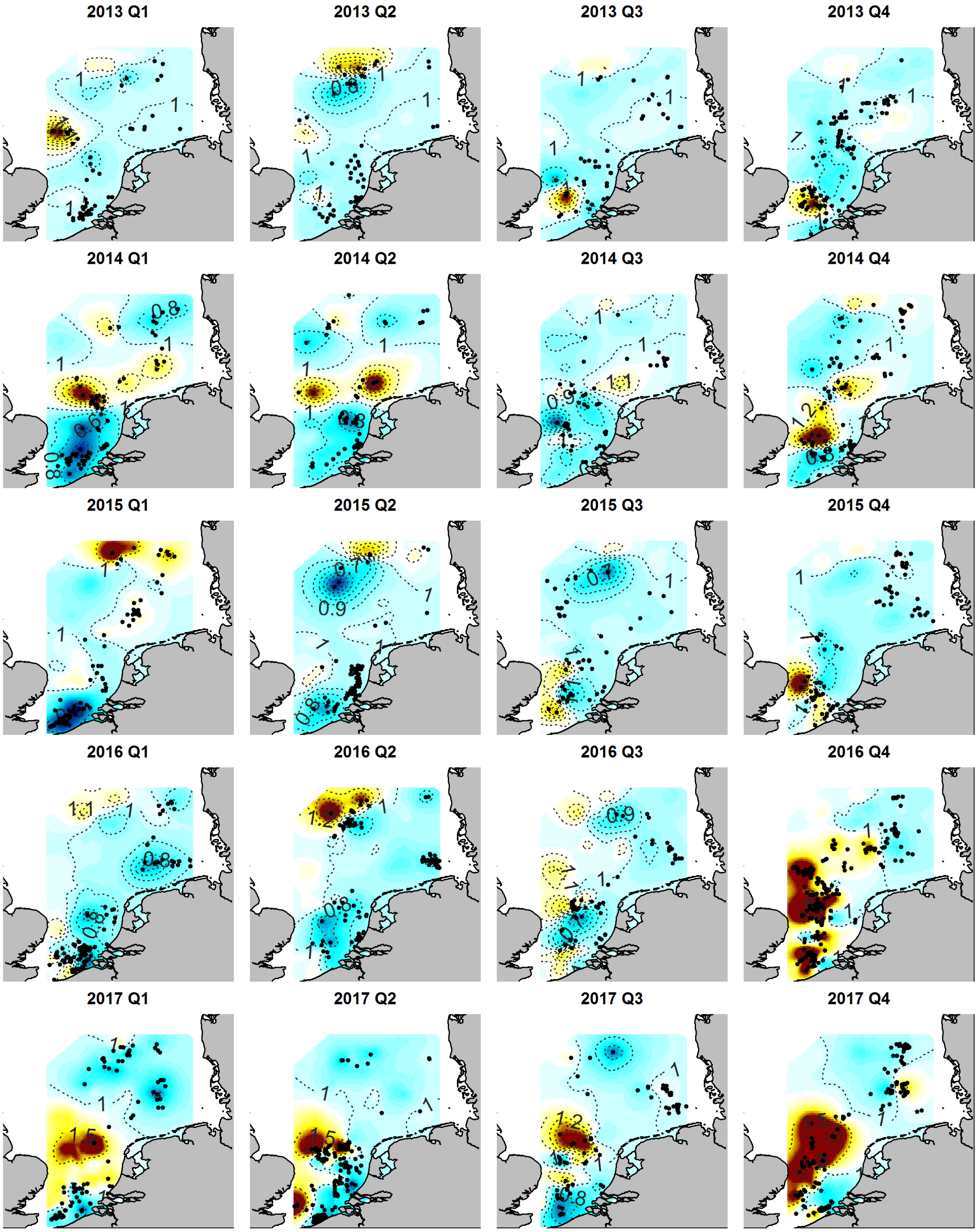


**Annexe 5 :**

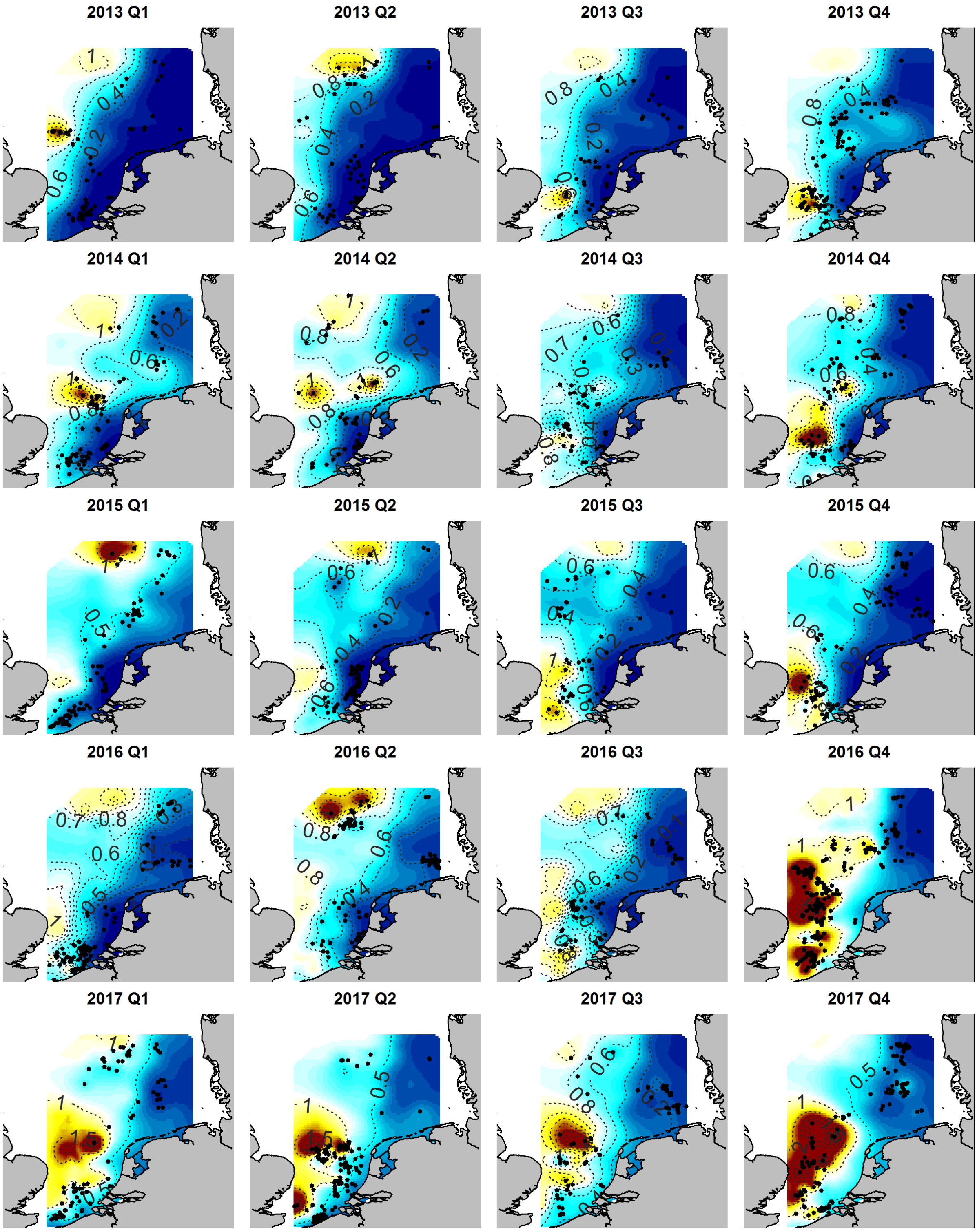
**spatial-temporal component (Gaussian Markovian Random Field) estimated for RAYS for the presence absence model**



spatial-temporal component (Gaussian Markovian Random Field) estimated for RAYS for the presence only model

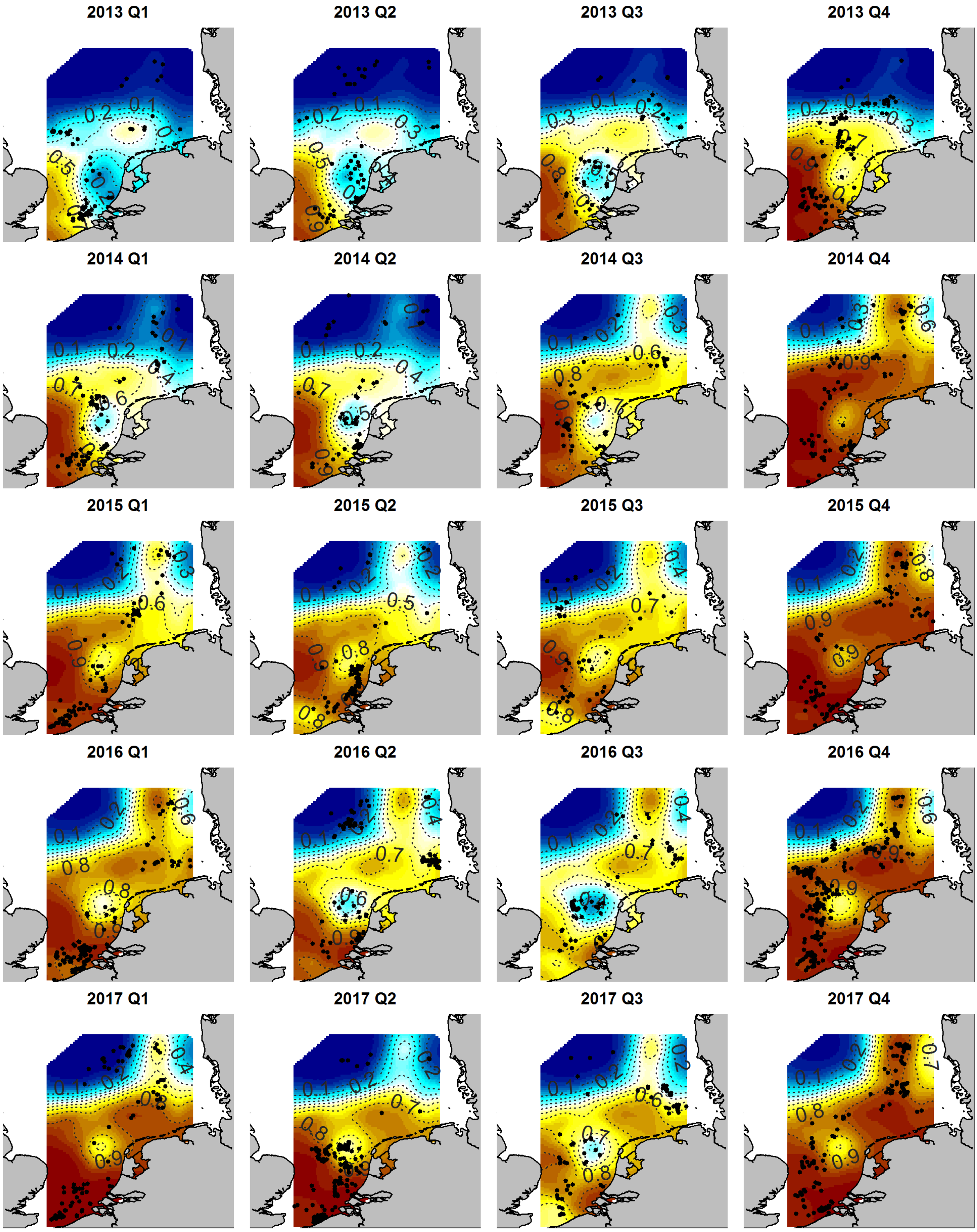


**Product spatial-temporal components (Gaussian Markovian Random Field) estimated for RAYS for the presence-absence and for presence only models combined**

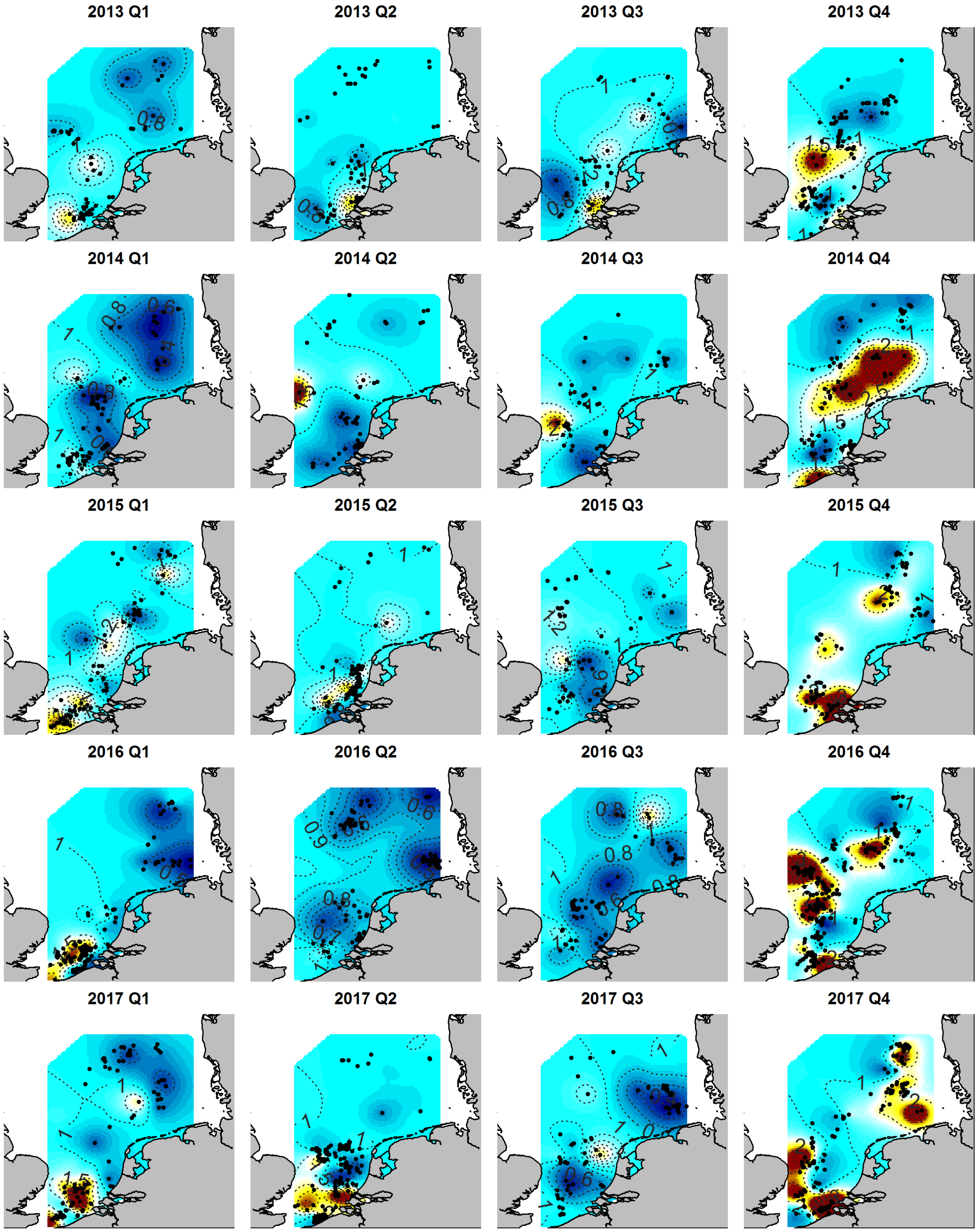


**Annexe 6 :**

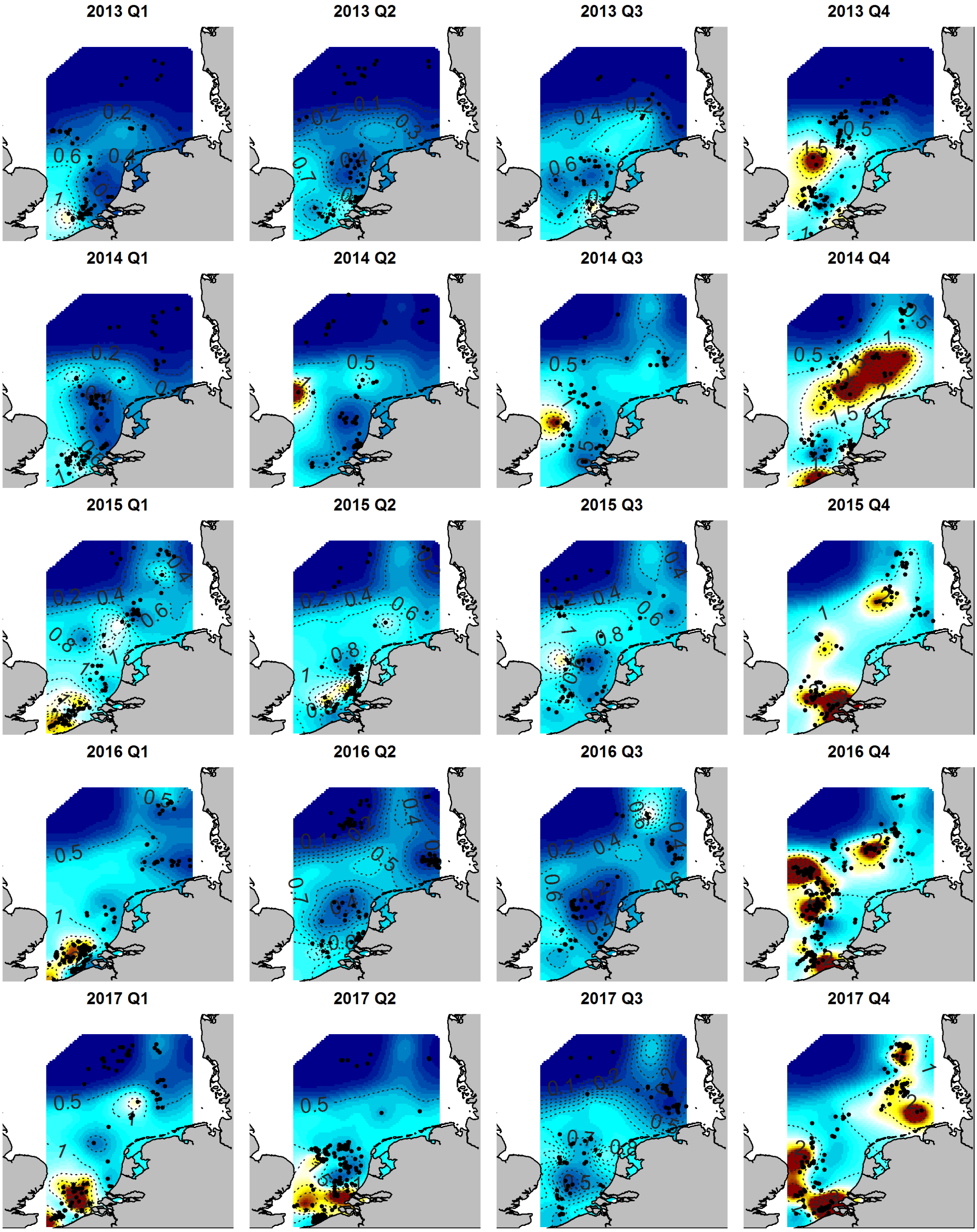
**spatial-temporal component (Gaussian Markovian Random Field) estimated for WHITING for the presence absence model**



**spatial-temporal component (Gaussian Markovian Random Field) estimated for WHITING for the presence only model**

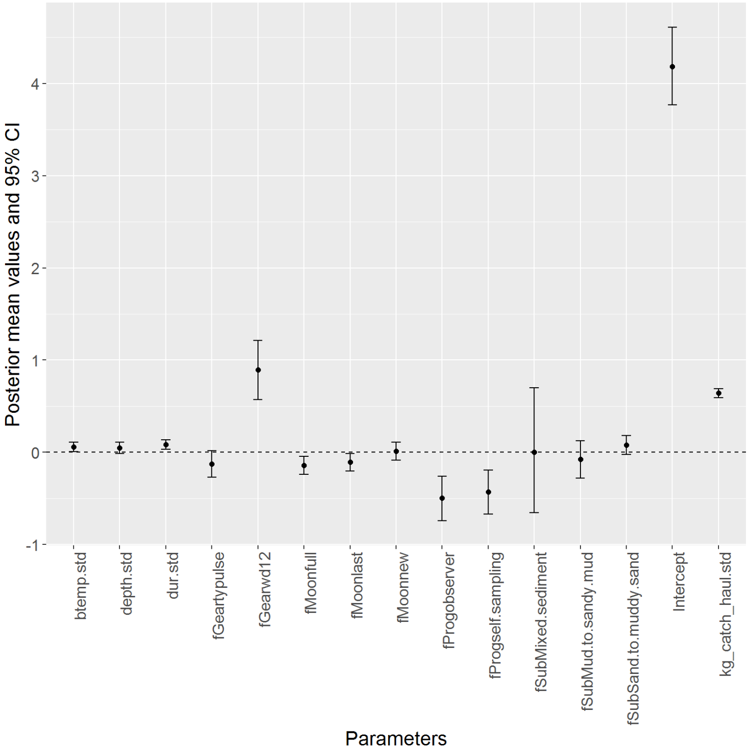


**Product spatial-temporal components (Gaussian Markovian Random Field) estimated for WHITING for the presence-absence and for presence only models combined**

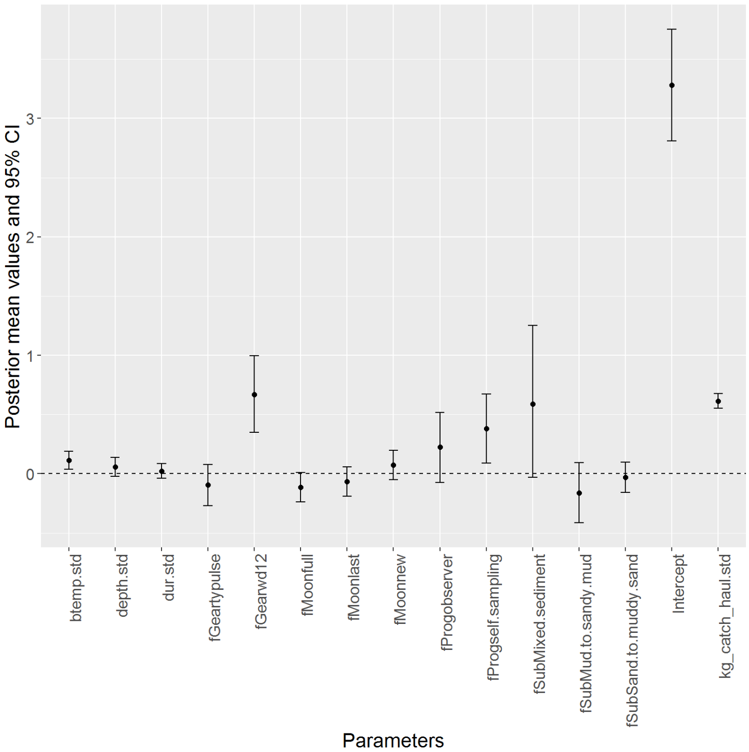


## Annex 7 : estimated parameters for the covariates in the models

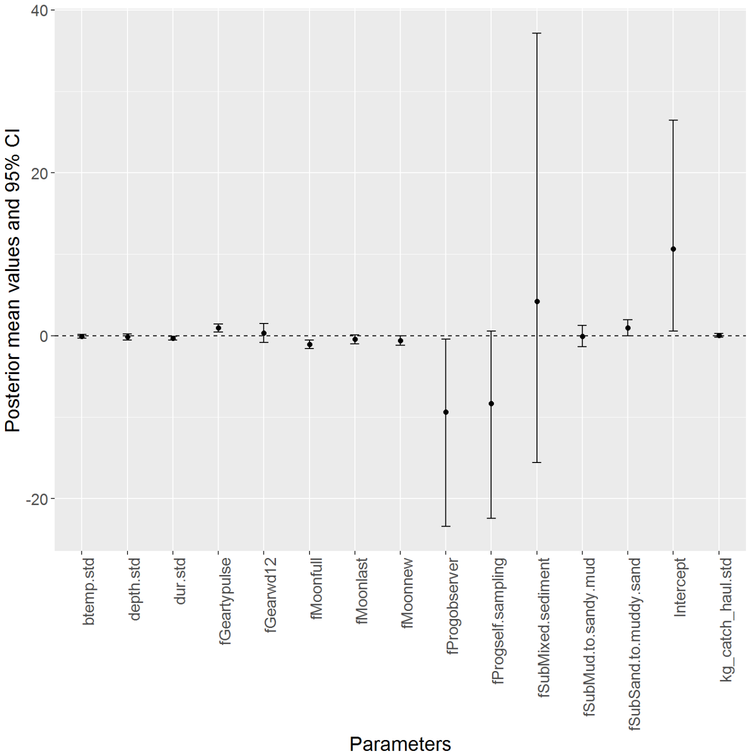
PLAICE (Discards amounts model)



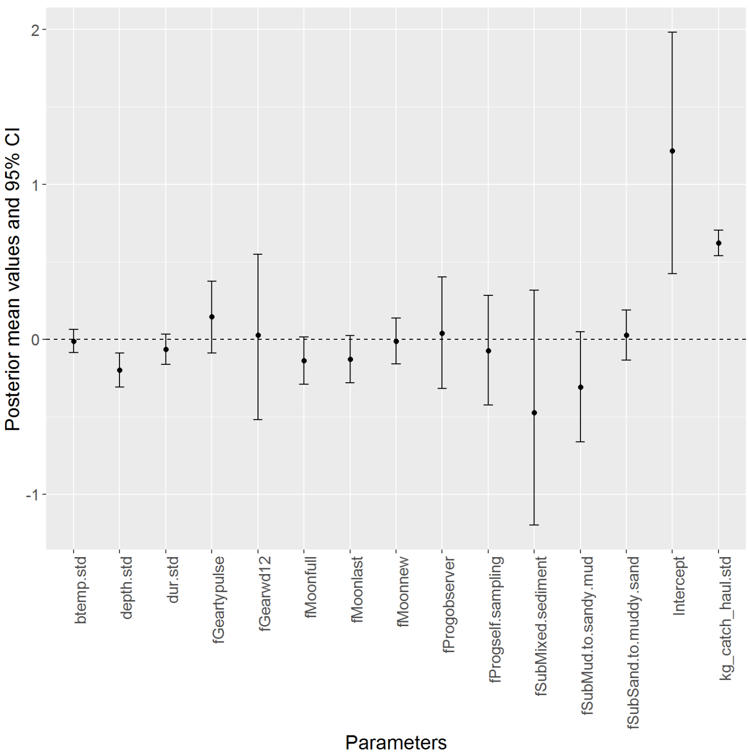

DAB (Discards amounts model)



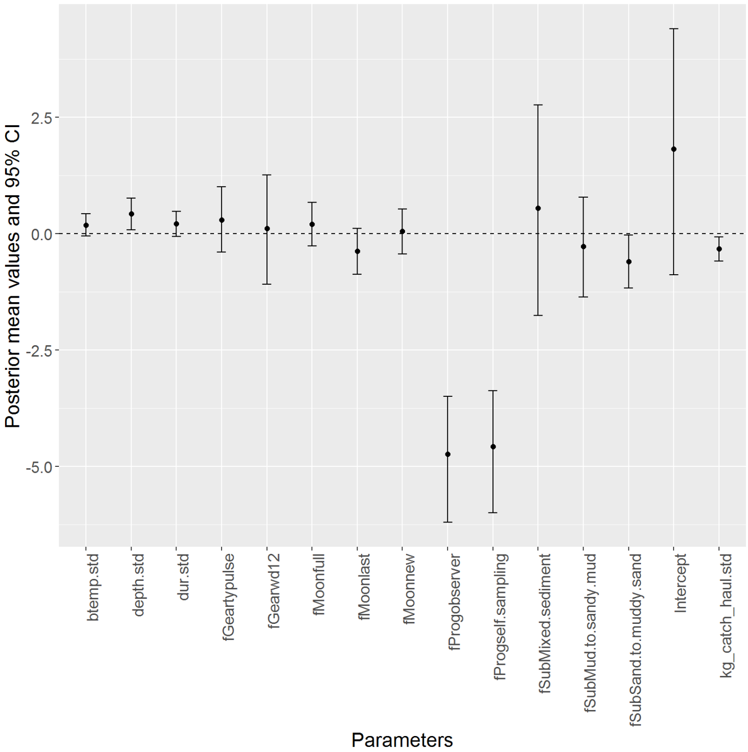
SOLE (presence –absence model)



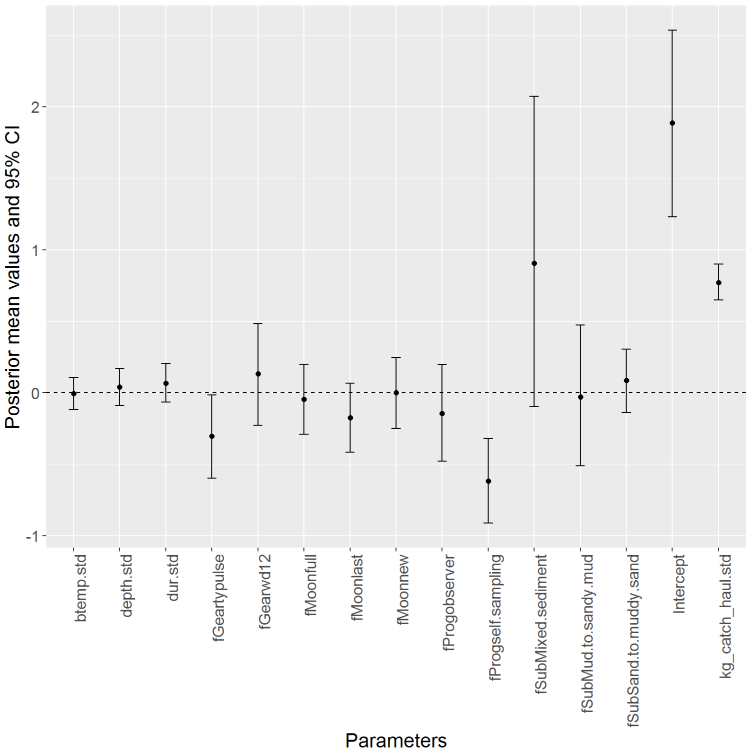

SOLE (Discards amounts for presence only)



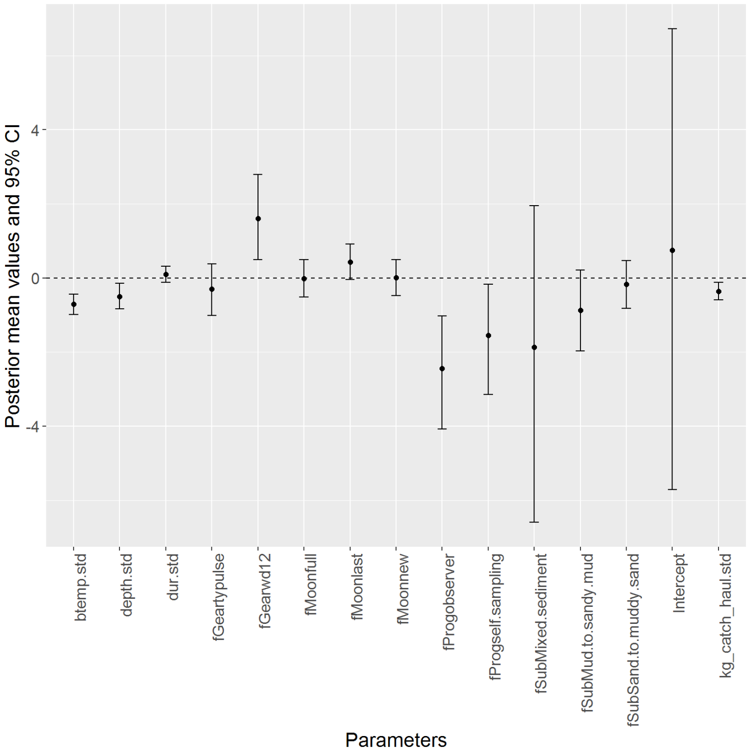
TURBOT (presence –absence model)



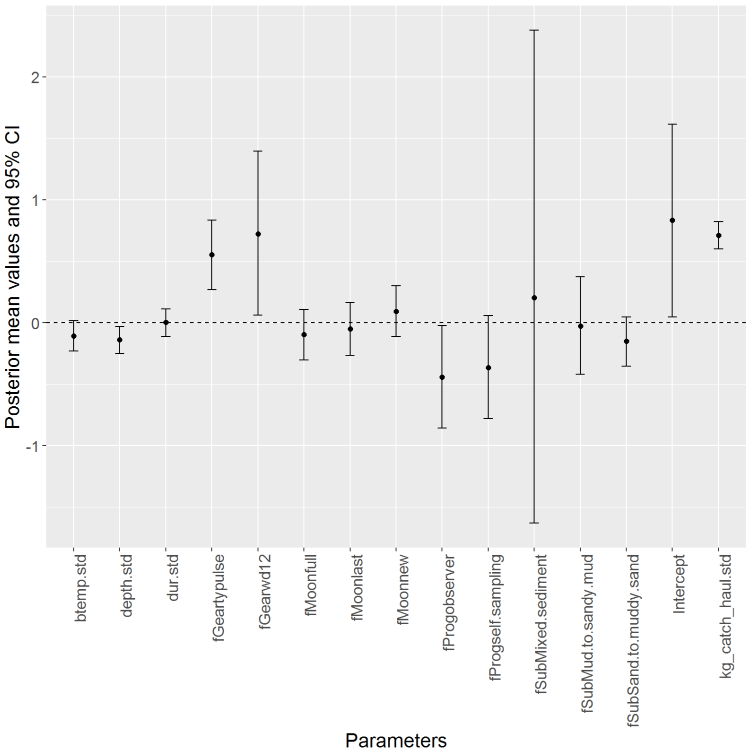

TURBOT (Discards amounts for presence only)



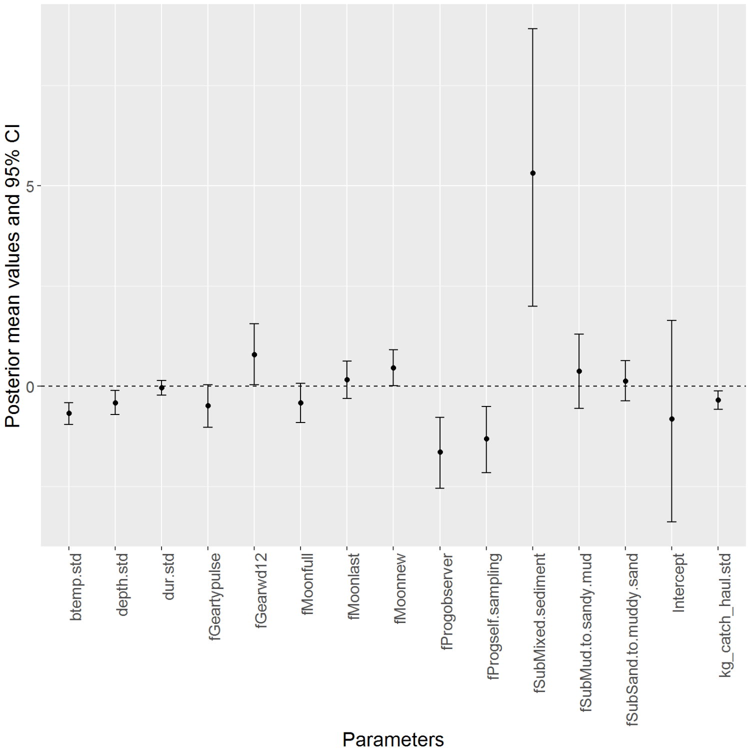
WHITING (presence –absence model)



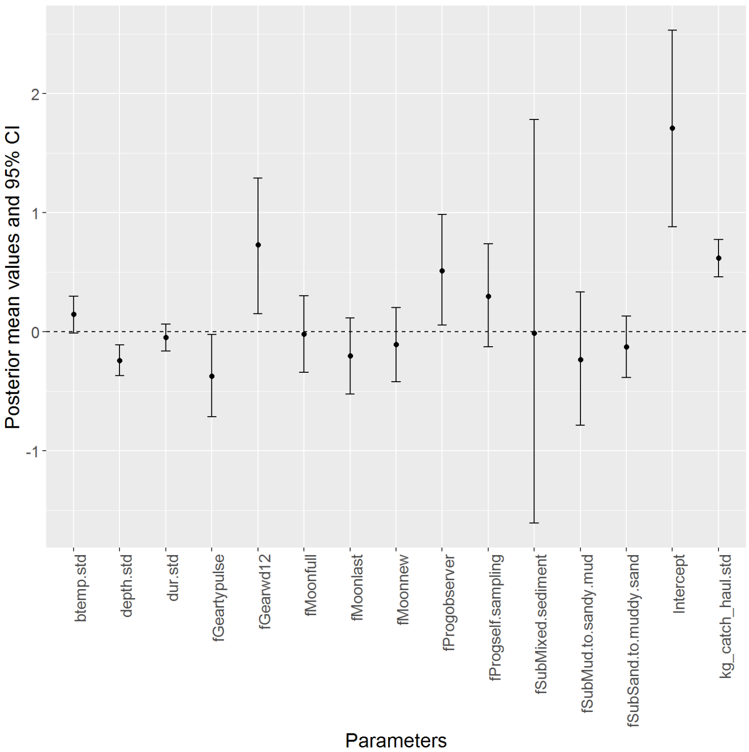

WHITING (Discards amounts for presence only)



RAYS (presence –absence model)




RAYS (Discards amounts for presence only)



Wageningen Marine Research

T +31 (0)317 48 09 00

E: marine-research@wur.nl

www.wur.eu/marine-research

Visitors' address

- Ankerpark 27 1781 AG Den Helder
- Korringaweg 7, 4401 NT Yerseke
- Haringkade 1, 1976 CP IJmuiden

With knowledge, independent scientific research and advice, **Wageningen Marine Research** substantially contributes to more sustainable and more careful management, use and protection of natural riches in marine, coastal and freshwater areas.

Wageningen Marine Research is part of Wageningen University & Research. Wageningen University & Research is the collaboration between Wageningen University and the Wageningen Research Foundation and its mission is: 'To explore the potential for improving the quality of life'