Monitoring cod catches of the Dutch demersal fleet in 2014

Investigating the effects of season and fishing gear on cod landings

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Samenvatting

In dit rapport worden de resultaten van het kabeljauwmonitoringsprogramma gepresenteerd. Dit onderzoek is uitgevoerd in opdracht van het Nederlandse Ministerie van Economische Zaken. Kabeljauwvangsten van de schepen in de tuigcategorieën BT2 (boomkor) en TR (bordenvisserij en flyshooters) moeten jaarlijks gemonitord worden, in verband met de Nederlandse implementatie van het Europese kabeljauwherstelplan. Het Europese kabeljauwherstelplan beperkt visserijinspanning voor Europese vloten die kabeljauw vangen. Visserijinspanning wordt toegewezen aan verschillende tuigcategorieën op basis van historische vangsten. Visserijinspanning in een bepaalde categorie kan overgeheveld worden naar een andere categorie, maar wel volgens een ruilfactor. In Nederland wordt visserijinspanning jaarlijks overgeheveld van de BT2 tuigcategorie naar de TR tuigcategorie volgens de ruilfactor van 1:3 (BT:TR) kilowattdagen in plaats van de Europees vastgestelde ruilfactor van 1:16. De reden hiervoor is dat een conversiefactor van 1:3 meer overeenkomt met de daadwerkelijke Nederlandse kabeljauwvangsten in de tuigcategorieën. Om de nationaal gehanteerde ruilfactor te onderbouwen heeft de Nederlandse overheid de verplichting om jaarlijks de kabeljauwvangst per eenheid van visserijinspanning (CpUE) van de schepen in deze tuigcategorieën te rapporteren aan de Europese Commissie.

In de Nederlandse demersale visserij, wordt een variatie aan vistuigen gebruikt. Het gebruik van de verschillende tuigen laat seizoensdynamiek zien en kent verschillende ruimtelijke patronen waarbij er gericht gevist wordt op variërende doelsoorten. In dit rapport worden tien tuigsoorten onderscheiden, die onder vier verschillende Europees gedefinieerde tuigcategorieën vallen. Om vergelijkingen tussen de verschillende visserijtuigen te vergemakkelijken dan wel de kennis over de verschillende visserijtuigen te vergroten, zijn de visserijinspanning en de kabeljauwvangsten van de verschillende tuigtypen in 2014 in dit rapport beschreven.

De TR-vloot heeft gemiddeld een hogere CpUE dan de BT-vloot. Wanneer de kabeljauwgerichte visserij (TR1AB) niet in beschouwing is genomen, is de ratio in kabeljauwaanlandingen per eenheid van visserijinspanning 1: 5,5 (BT:TR). De ratio gebaseerd op kabeljauw*vangsten* (aanlandingen plus discards), is 1:3,67 of 1:4,46, afhankelijk van welke discardschattingen gebruikt zijn. Deze ratio wordt uitgerekend aan de hand van de kabeljauw CpUE, welke respectievelijk rond de 0,16 en 0,10 kg per kWdag zijn voor de TR1C en TR2 vloot.
In aanvulling op de visserijinspanningsbeperkingen bevat het Nederlandse kabeljauwherstelplan ook een zogenoemde “move-on” regulering, welke niet toestaat dat de kabeljauwvangsten meer dan 5% van de totale vangst omvatten. Procentuele kabeljauwvangsten van de TR-vloot worden daarom jaarlijks gemonitord. Het onderzoek wees uit dat 90% van de visreizen van de TR1C en de TR2 vloot minder dan 5% kabeljauwaanlandingen opleverde in 2014. Wanneer dit berekend wordt voor kabeljauw*vangsten*, blijkt dat 93% van de visreizen resulteerde in minder dan 5% kabeljauw in de gehele vangst.

In 2014 vond een transitie plaats binnen de BT2 tuigcategorie. Veel vissers wisselden hun boomkortuig in voor een pulstuig. Dit pulstuig heeft een lager motorvermogen nodig, dankzij de lagere vissnelheid, het lagere gewicht van de tuigen en omdat het tuig niet meer door de bodem getrokken hoeft te worden. Dit resulteert in een lagere totale visserijinspanning van de BT2-vloot in kilowattdagen. Daarnaast kunnen visgronden worden bevist die voorheen niet konden worden geëxploiteerd. Globaal beschouwd, kunnen de wisseling in de BT2 vloot andere (lagere) kabeljauw vangbaarheid tot resultaat hebben gehad, welke mogelijk de hogere ruilfactor in 2014 (ten opzichte van 2013) kunnen verklaren.

Summary

In this report the results of the cod monitoring program are presented. This research was commissioned by the Dutch Ministry of Economic Affairs. Cod catches of the vessels in the gear groups BT2 (beam trawl) and TR (otter trawls and seines) need to be monitored yearly, due to the Dutch implementation of the European cod recovery plan. The European cod recovery plan restricts fishing efforts of European fleets that catch cod. Fishing effort, based on historical track records, is allocated to different gear groups. Fishing effort can be transferred between gear groups but then conversion factors apply. In the Netherlands fishing effort is transferred yearly from the BT2 gear group to the TR group, based on a national conversion factor of 1:3 (BT:TR) kWdays instead of the European conversion factor of 1:16, because the cod catches in the Dutch TR fleet are not as high as the European conversion factor implies. In order to substantiate for the national conversion factor, the Dutch government is obliged to report cod catches per unit of effort (CpUE) of the vessels in these gear groups to the European Commission.

The Dutch demersal fisheries are characterized by a variety in fishing gears. The use of the gear shows varying seasonal dynamics, spatial distribution and target species. In this report, ten gear types are defined, which are categorised in four different European defined gear groups. To facilitate comparisons between and increase knowledge of the different gear types, the effort and the cod catches of the different gear types in 2014 are described.

The TR fleet has on average a higher cod CpUE than the BT fleet. When the cod targeted fisheries (TR1AB) are not taken into consideration, the ratio in cod landings per unit of effort is 1:5.5 (BT:TR). For ratios based on cod catches (landings plus discards), the ratio is to 1:3.67 or 1:4.46, depending on the discard estimates that have been used to make the calculation. This is calculated based on the cod CpUE, which is around 0.16 and 0.10 kg per kWday for the TR1C and the TR2 fleet respectively (exact numbers depend on the discard estimates used).

In addition to the effort control regime, the Dutch Cod Recovery Plan implements a “move-on” regulation, which allows only 5% of the total catch to be cod. Therefore, percentage of cod in the total catches in the TR fleet also need to be monitored. It was found that 90% of the fishing trips of the TR1C and the TR2 fleet combined had less than 5% cod in the landings in 2014 (excluding the cod-directed fisheries of the TR1AB fleet). When this is calculated for total cod *catches*, this percentage increases, with over 93% of the fishing trips having 5% or less cod in the total catch.

During 2014 a large transition took place within the BT2 fleet. Many beam trawl fishermen switched to pulse gear. Due to the lower fishing speed, the lighter gears of the pulse, and the fact that the gears do not have to be pulled through the seabed, the engine power of pulse vessels can be reduced. This results in a lower total BT2 fleet effort (kWdays). Moreover, due to the changed fishing technique, formerly unexploited fishing grounds can be exploited. Overall, the changes in the BT2 fleet may have caused different (lower) cod catchability of the gear, which may explain the altered (higher) conversion ratio in 2014 compared to 2013.

1 Introduction

1.1 Monitoring obligations

This report presents the results of the Dutch Cod Monitoring Project. The monitoring program is part of the Cod Avoidance Plan developed by the Dutch Government together with the Dutch fishing sector. The aim of this monitoring program is to provide information on the Catch per Unit Effort (CpUE) in the BT and the TR fleet (bottom trawls and otter trawls/seines). This monitoring is needed in order to calculate a conversion factor for the transfer of effort from the BT to the TR fleet. The transition of kW-days between gears is regulated by the cod recovery plan (EC 423/2004 and EC 1342/2008) and depends on the yearly CpUE ratio of cod between the respective gear groups. The European established conversion factor is 1:16; meaning that 16 days of the BT2 fleet can be converted to 1 TR-day. See Appendices A and B for an explanation of the European cod recovery plan and the Dutch Cod Avoidance Plan respectively.

In the Dutch Cod Avoidance Plan, the Dutch Government distinguishes between otter trawls and seines that are cod-directed (TR1A and TR1B) and those for which cod is bycatch (i.e. TR1C and TR2) to determine a new conversion factor. The kW-days transition only applies to the TR1C and TR2 gear groups (Table 1). Other gears applied in the Netherlands, such as shrimp fisheries and gill netters are not taken into consideration in this report, as the monitoring obligation applies to the gears for which a national conversion factor for the transfer of effort is used. For the kW-days transition between the BT and the TR gears for which cod is bycatch, a conversion factor of 1:3 is used in the Netherlands. This is different than stated in the European Cod Recovery Plan and therefore the ratio should be substantiated for.

Table 1. Definitions of the fleet segments used in this report.

Fleet definition	Geartype	Meshsize (mm)	Assumed target species
TR1A and TR1B	Otter/pair trawlers and seines	>120	Cod
TR1C	Otter/pair trawlers and seines	100-119	Plaice
TR2	Otter/pair trawlers and seines	70-99	Plaice/Nephrops
BT2	Beam trawlers	70-119	Plaice/Sole

In 2011, IMARES was requested to start a monitoring program for cod catches in the TR fleet. The program consisted of an extended analysis of self-reported cod catch data (both landings and discards) in combination with the regular Data Collection Framework (DCF) discard monitoring program, an additional observer program, and the CCTV-project in TR-fisheries (see Kraan *et al.*, 2013, 2014). With experience of the first monitoring reports, the ministry of Economic Affairs and IMARES drew the conclusion that monitoring cod discards via the self-reporting scheme asked for a disproportionately high effort of the TR-skippers and resulted in large and costly data-streams while discards were hardly affecting CpUE rates (Ministry of Economic Affairs, 2014). Therefore, it was agreed to do the analysis based on the EU-logbook (hereafter logbook) data in combination with VMS-data, which are readily available.

Based on the logbook and VMS-data, an accurate estimate of the LpUE (Landings per Unit Effort) could be calculated for all four fleets. With these, the LpUE-ratio between TR (with cod as bycatch) and BT2 could be determined. As the EU requires a CpUE-ratio (Catch per Unit Effort), discard rates of STECF and the North Sea Atlas are used to calculate CpUE-ratios.

For the execution of the Dutch Cod Avoidance Plan, it is necessary that cod catches are maximally up to 5% of the total catches. Therefore, the percentage of total number of trips with 5% or less cod catches should be monitored. Hence this report will show the results of this analysis.

1.2 Differentiation within gear groups

The kW-days transition is calculated on the ratio between the cod CpUEs of BT2 and TR (TR1C & TR2). However, these fleet segments are composed of multiple different types of gears, with gear-specific regulations. For instance, within the BT2 fleet, distinction can be made based on the vessel's engine power. Bottom trawl vessels with an engine power of <300hp (so-called Eurocutters) are allowed to fish in a closed area ("Plaice-box") and the Dutch 12-mile Exclusive Economic Zone, while bottom trawl vessels with an engine power of >300hp are not. Another important distinction to make is between traditional beam trawlers and pulse trawlers. Although both metiers are classified as BT2, there are some differences that need to be considered. For instance other areas can be fished and average fishing speed is lower for pulse vessels than for traditional beam trawl vessels, both of which might affect cod catches and thus CpUE. A third differentiation is that within the TR fleet some vessels use otter trawl gear while others use the flyshoot technique. As the flyshoot technique enables fishermen to fish without dragging the net through the water, the engine power can be reduced. As fisheries effort measured in kWdays is reduced subsequently, this affects cod CpUE as cod catches are divided by the fisheries effort. Differentiations like these might impact cod CpUE and therefore these aspects (specific gear types, but also spatial distribution and seasonality) have been taken into account. In total 10 gear types are distinguished in this report (Table 2).

Table 2. Definitions of the gear types used in this report.

	Gear definition	Fleet segment	Description	Meshsize (mm)	Assumed target species
1	Beam_trad*	BT2	Engine power >300hp, traditional beam trawl	70-119	Plaice/Sole
2	Beam_puls*	BT2	Engine power >300hp, pulse gear	70-119	Plaice/Sole
3	Euro_trad*	BT2	Engine power <300hp, traditional beam trawl	70-119	Plaice/Sole
4	Euro_puls*	BT2	Engine power <300hp, pulse gear	70-119	Plaice/Sole
5	Otter_70-99	TR2	Otter/pair trawler; twinrig	70-99	Plaice/Nephrops
6	Otter_100-119	TR1C	Otter/pair trawler; twinrig	100-119	Plaice
7	Otter_120+	TR1AB	Otter/pair trawler; twinrig	>120	Cod
8	Fly_70-99	TR2	Flyshooter	70-99	Various species
9	Fly_100-119	TR1C	Flyshooter	100-119	Various species
10	Fly_120+	TR1AB	Flyshooter	>120	Various species

* These gear types may comprise more subgear-types, for instance the sumwing. However, for practical reason, the number of different gear types used in this report is limited to 10. This does not state that the subgear-types have equal cod catchability. For instance; the Beam_puls gear type comprises the pulsewing technique as well.

1.3 Interpretation of the fishing patterns

Besides demonstrating the catches and the dynamics of the fleet obtained from logbook and VMS data, a first attempt is done to interpret the observed fishing patterns by consulting fishing experts in IMARES who have extensive practical experience with the Dutch fleet. In a follow-up project within the Dutch Cod Monitoring Project, a more extensive interpretation of the observed fishing patterns will be presented. This will be conducted by interviewing multiple fishers, fisheries representatives, NGO's, and international acknowledged cod scientists.

2 Assignment

The Ministry of Economic Affairs asked IMARES in 2014 to perform an analysis on the reported cod landings in the Dutch TR and BT2 fleets with the aim to:

i) determine seasonal, spatial and gear-specific variation in cod landings and fishing activity;

ii) provide insight in the effects on cod landings of the recent transition in the BT2 fleet towards pulse gear;

iii) check whether gear specific cod catchability is constant over time;

iv) estimate the CpUE (in kilos of cod caught per days at sea * engine power (kWdays)) per TR fleet segment;

v) compare the estimated TR-CpUEs with the BT2-CpUE;

vi) calculate the percentage of trips in the TR fleet (TR2, TR1C), with less than 5% cod catches in relation to the total catch (this is referred to as ‘cod avoiding fishing trips’ in the Dutch Cod Avoidance Plan).

3 Materials and Methods

In this section, the data sources, the analysis and the final output are described. See “Appendix C. Extended Material and Methods” for a detailed description of the method to link VMS and logbook data.

3.1 Logbook data

All fishermen are obliged to report their activities on a daily basis. This includes location, gear used, vessel characteristics and estimated landing quantities (in kg). These quantities are an estimation and therefore deviate from auction data. Moreover, fishermen do not have to report catches for species with a trip-total quantity below 50 kg. As cod is a by-catch species, trips with cod landings lower than 50 kg can be expected. Therefore, the cod catches in this report are an underestimation of the total catches. Second, fishermen report all landings and vessel characteristics online and the data are immediately imported in the database of the Dutch Government. The logbook data cannot be validated or checked by IMARES on correctness of the data. Therefore, records with a type-error in the gear description will not be recognised as ‘wrong’, but will wrongly be taken into consideration.

3.2 VMS data

All vessels over 12 meters are obliged to participate in the Vessel Monitoring System (VMS). This system sends an update to a satellite every two hours, containing time and date, position, speed and name of the vessel. All these records are registered by the Dutch Government. IMARES has permission to work with these data.

3.3 Pulse list

Gear specifics, like net type, mesh size and vessel engine power are registered in the logbooks. However, the logbook does not contain information about the use of pulse gear. Therefore, IMARES has started a list of all vessels in the Dutch demersal fleet in combination with the presence of a licence to fish with pulse gear. For vessels with a license for pulse fishing, the date of actual conversion to pulse gear is registered as well. This list is based on knowledge from the ministry of Economic Affairs, the Dutch Cooperative Fisheries Organisation (CVO) and personal contact with fishermen and is updated regularly. Based on this list, all logbook and VMS data of beam trawl trips are classified “pulse” or “traditional”.

3.4 Value maps

Cod landings and fishing activity are spatially displayed in value maps for all gears together and for all gear types separately. To facilitate visual comparison between the monthly and yearly spatial distribution, values of monthly fishing activity and landings are multiplied by 12. By doing so, fishing activity and landings per month have similar value ranges as yearly fishing activity and landings value ranges. To supply actual monthly or quarterly fishing activity and landings, each map includes a box underneath with the absolute monthly value for that (those) gear(s).

3.5 Calculation of the CpUE

3.5.1 Rationale of conversion factor

The conversion factor, which is used to compensate the (higher) cod catches of the TR-gears, is based on the assumption that mean CpUE per gear group is an appropriate measure of that gear group's efficiency to catch cod. By applying this conversion factor, the total cod catch of the Dutch demersal fleet is not affected by the transfer of fishing capacity among gears, but only if the CpUE estimates are unbiased. The theoretical background is the catch-equation that relates fishing-output (catches) to fishing efficiency (CpUE) and fishing-input (effort) (Baranov, 1918):

$$C = q \cdot E \cdot B$$

Where *C* represents the catch, *B* is total biomass of the exploited population, *E* is the fishing effort, and *q* is the catchability coefficient, which represents the proportion of the stock captured by one unit of effort. From this equation it can be concluded that CpUE (*C/E*), is proportional to the biomass of the stock provided that *q*, the catchability coefficient of the gear applied, is constant in the period over which CpUE's are compared. Under the assumption that the transfer gears exploit the same cod population (with biomass *B*) it follows that the CpUE ratio of the gears equals the ratio of *q* and hence is appropriately used as conversion factor.

3.5.2 Verification of conversion factor usage

The various Dutch demersal gear types that catch cod are active in different areas and season. This implies that the assumption that gear specific *q*'s are constant in the period over which the conversion factor is calculated, is likely to be violated. If cod catchability is affected by season and area, this should be corrected for when calculating conversion factors. Standardized CpUE's -in which the spatial and seasonal effects are removed- could be used to calculate a conversion factor reflecting true differences in efficiency of the gears. To get such standardized CpUE estimates, the spatial and seasonal effects are removed by statistical generalized linear modelling (GLM) techniques. In this report, a first step is made in the process to standardized CpUE estimates, which will identify factors affecting cod catchability in the different gears and quantify their impact. The first step consists of an initial screening of the candidate explanatory variables.

3.5.3 Methodology

As cod is not a target species of the Dutch demersal fleet, individual –reported- cod landings (kg/trip) are characterized by a large number of zeros. This makes it difficult to use the standard GLM models as these cannot deal with dependent variables that contain excessive amounts of zeros. To account for zeros, Hurdle (Mullahy, 1986) and zero-inflated (Lambert, 1992) models have been proposed (both cited by Zuur et al., 2012). Hurdle models are two part models that handle zeros and non-zeros separately. Due to this nature of the Hurdle model, it is less adequate to analyse cod landing data. A zero-inflated model is a two part model as well, but combines a standard distribution like Poisson or negative binominal and a degenerate or deterministic distribution of zeros. Therefore, the zero-inflated model is a more appropriate method to analyse the zero-observations in cod landings.

As a first step in the analysis, the main objective here is to identify the main factors that affect cod landings by gear type. Cod landing per trip by gear type was used as the dependent variable and total landings per trip, effort (both DAS and kWd) per trip, quarter, year and area are independent variables (quarter, year and area are factors). Fishing locations are classified as north-, south- and central area. The central area is bounded at 51^0 N at the south. The northern boundary of the central area is 53.5^0 N for Eurocutters and $56\ ^0$ N for large cutters

Zero Inflated Negative Binomial (ZINB) models are used. The procedure takes the covariates into account to describe the variation of cod landings per trip. To determine which of the covariates has the largest effect on cod landings, a (stepwise) forward selection procedure, based on the Akaike Information Criterion (AIC), is applied. The procedure begins with no variables in the model. Then, each candidate variable is modelled individually and the model selects the variable that has the lowest Akaike Information Criterion (AIC) to add to the model. At each step, the model adds a new candidate variable, based on the lowest AIC. A variable that enters the model cannot be deleted and hence, after each step, the model consists of more variables. When none of the remaining variables result in a significant improvement of the model, the procedure stops. The model with the best fit and the least number of covariates has the lowest AIC and is selected as best final model. This first step results in a list of covariates that affect cod landings for each gear type and reveals the order of importance.

3.6 Expert knowledge

To interpret observed patterns and identify possible underlying reasons explaining fishermen behaviour, the findings in this report were discussed with two fisheries experts at IMARES. These two experts have extensive experience at sea on board commercial fishing vessels and an in-depth knowledge of the different gear types deployed in demersal fisheries. They were asked to give possible explanations for observed patterns in spatial distribution, seasonal and inter-annual variation and cod catches of the different gear types. Their ideas are summarized in this report and can be used as starting point in future in-depth investigation of fishermen behaviour in Dutch demersal fisheries and the drivers that impact it. This follow-up research is scheduled in 2016, as part of the Dutch Cod Monitoring Project

4 Results

In the results section, spatial distributions of the fishing activity and cod landings of total fleet and the 10 gear types separately are presented for 2014 in average and per month. Landings- and effort values might be higher than those presented in the quarterly reports (Reijden et al. 2015a,b,c,d) because the database was not fully synchronized at time of data extraction for quarterly reports. In addition, fishing activity and cod landings of 2011-2012 and 2013-2014 are shown. Eventually, the calculated CpUE and the percentage of fishing trips with <5% cod catches are given.

4.1 Overall activity and landings

In 2014, fishing activity of all demersal fisheries together was a little over 21 million kW-days (Figure 1). Fishing activity was dominated by the larger beam trawl vessels, consisting of traditional tickler chains (~7.9 million kW-days) and pulse gears (~10 million kW-days) (Figure 2).

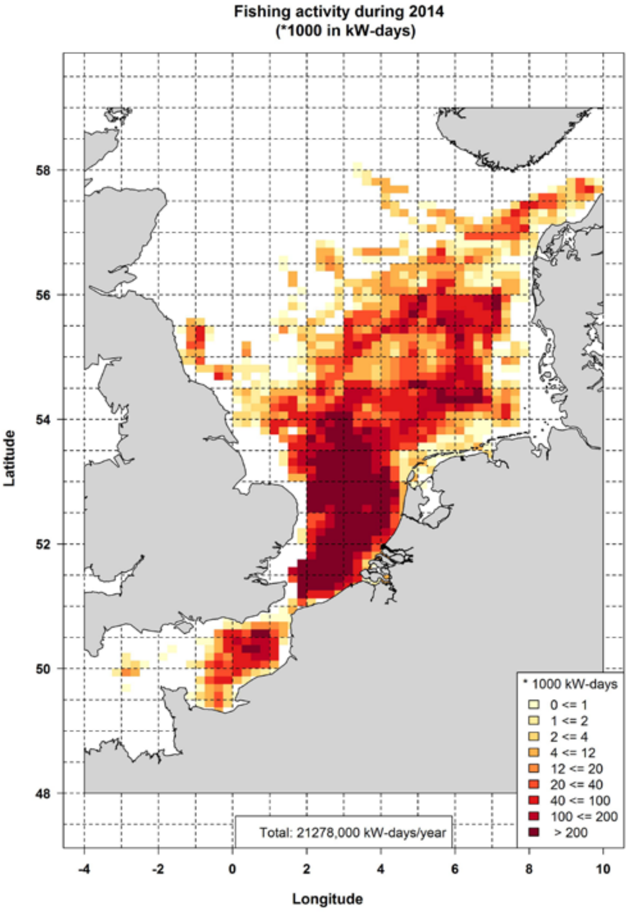

Figure 1. *Fishing activity (in *1000 kW-days) for the Dutch demersal fleet for which the Dutch Cod Avoidance Plan was in place in 2014. Landings- and effort values might be higher than those presented in the quarterly reports (Reijden et al. 2015a,b,c,d) because the database was not fully synchronized at time of data extraction for quarterly reports.*

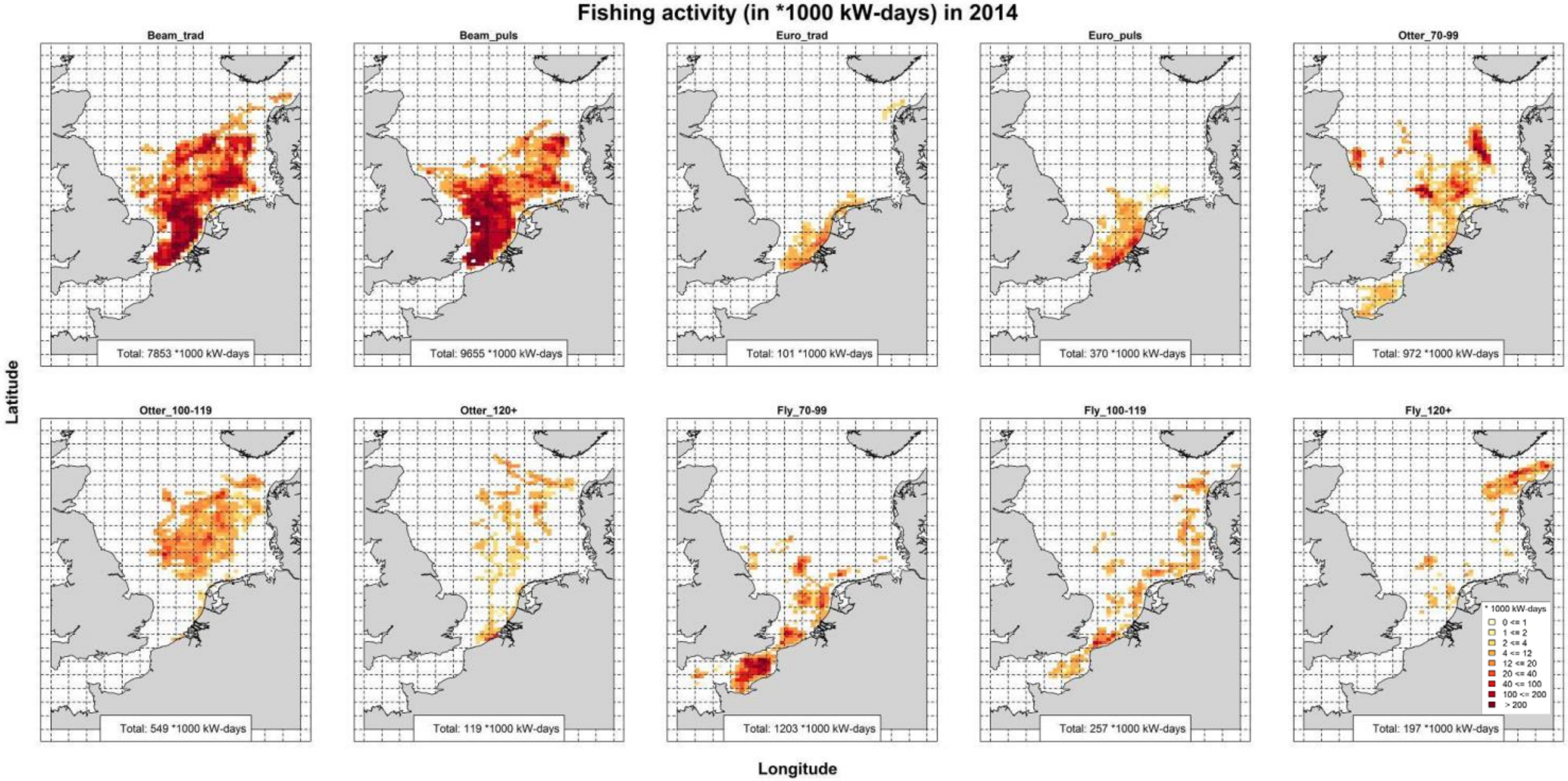

Figure 2. *Fishing activity (in *1000 kW-days) for ten demersal fishing gears separately in 2014. Landings- and effort values might be higher than those presented in the quarterly reports (Reijden et al. 2015a,b,c,d) because the database was not fully synchronized at time of data extraction for quarterly reports. Descriptions for the gear types are given in Table 1. Colour index is similar to Figure 1*

A total of 1585 ton cod was caught in 2014 (Figure 3). The majority of the cod was caught from the opening of the Skagerrak. Other locations with relative high cod landings were the Cleaver Bank (around 54° N, 3° E) and The Falls (around 51.5° N, 2-3° E).

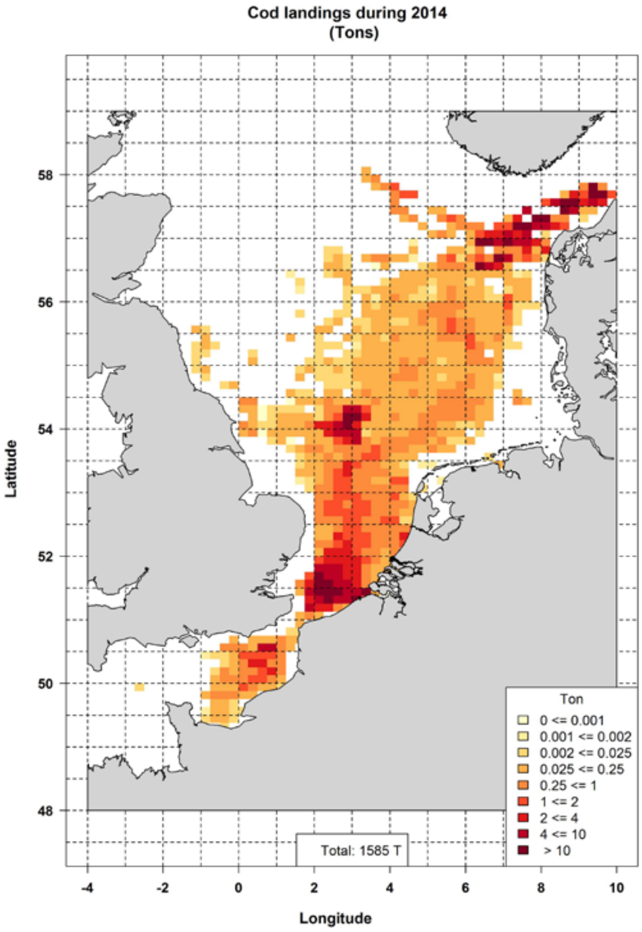

Figure 3. *Cod landings (in Ton) for the Dutch demersal fleet for which the Dutch Cod Avoidance Plan was in place in 2014. Landings- and effort values might be higher than those presented in the quarterly reports (Reijden et al. 2015a,b,c,d) because the database was not fully synchronized at time of data extraction for quarterly reports.*

The ten gear types identified in this report differ greatly in cod landings, with the large meshed flyshooters (>120mm) landing the majority of the cod (Figure 4). This fleet segment, together with the medium meshed flyshooters (100-119mm), is mainly responsible for the cod landings from the opening of the Skagerrak. The observed high landings from the Cleaver Bank are mainly caught by small meshed (70-99mm) flyshooters and the otter trawlers (Figure 4). The beam trawlers and the Eurocutters (both pulse and traditional gears) are the main gear types landing cod from The Falls.

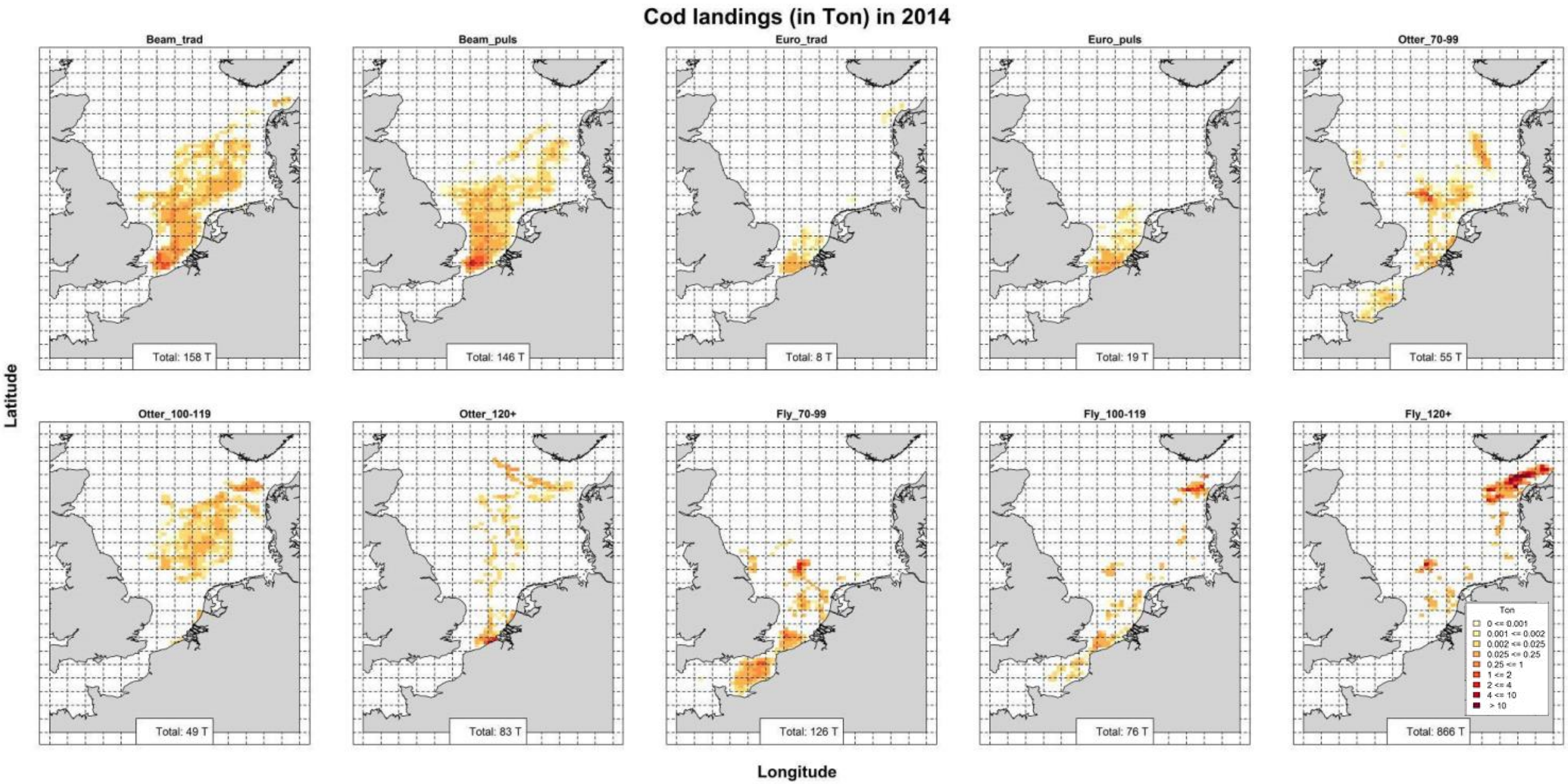

Figure 4. *Cod landings (in Ton) for ten demersal fishing gears separately in 2014. Landings- and effort values might be higher than those presented in the quarterly reports (Reijden et al. 2015a,b,c,d) because the database was not fully synchronized at time of data extraction for quarterly reports. Descriptions for the gear types are given in Table 1. Colour index is similar to Figure 3.*

4.2 Seasonality

Seasonality is a well-known factor in fisheries that should be taken into account when looking at catches, landings or fishing behaviour. Seasonality in fisheries is caused by underlying explanatory factors, amongst others: changes in fish abundance, fish quality, weather (e.g. wind force and direction), quota, days at sea, fish prices. In earlier reports we observed that the TR1AB gears (Fly_120+, Otter_120+) are inactive in winter (Kraan *et al.*, 2013, 2014, Reijden *et al.*, 2015a, 2015d). This observation can partly be explained by the fact that fishermen go further out (north) when using large mesh sizes thus weather conditions need to be good. This example shows how a combination of factors often explains fishing intensity at certain areas at certain times.

Table 3. Fishing activity (*1000 kW-days) in 2014* for the gears separately per month.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Beam_trad	1093	960	921	788	540	496	392	448	604	604	573	435	**7853**
Beam_puls	750	611	655	653	686	708	858	821	1059	1116	945	795	**9655**
Euro_trad	12	10	15	22	23	11	2	1	4	1	1	1	**101**
Euro_puls	41	32	30	34	35	35	29	22	26	30	27	28	**370**
Otter_70-99	40	42	57	83	118	139	124	110	125	54	53	27	**972**
Otter_100-119	27	13	47	60	75	57	79	53	38	46	51	4	**549**
Otter_120+	3	5	10	22	10	14	4	14	23	8	1	4	**119**
Fly_70-99	163	119	162	123	77	61	49	36	87	119	108	101	**1203**
Fly_100-119	0	3	0	14	35	26	56	40	28	16	31	10	**257**
Fly_120+	0	0	0	4	26	55	44	43	21	5	0	0	**197**
Total	**2130**	**1795**	**1897**	**1802**	**1625**	**1600**	**1638**	**1587**	**2015**	**1998**	**1790**	**1403**	**21278**

***** Landings- and effort values might be higher than those presented in the quarterly reports (Reijden et al. 2015a,b,c,d) because the database was not fully synchronized at time of data extraction for quarterly reports.

Table 4. Cod landings (Tonnes) in 2014* for the gears separately per month.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Beam_trad	55.3	48.1	23.1	7.2	3.2	0.3	0.0	1.1	2.0	4.8	6.1	6.7	**157.9**
Beam_puls	30.3	19.5	8.3	5.4	4.1	1.9	2.1	5.3	11	10.8	19	27.9	**145.6**
Euro_trad	4.7	1.8	0.5	0.4	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.2	**7.7**
Euro_puls	7.1	4.2	0.9	0.1	0.0	0.0	0.0	0.0	0.1	0.9	1.4	4.3	**19.0**
Otter_70-99	6.5	2.6	6.6	5.9	7.7	8.6	4.5	2.0	0.5	2.9	5.7	1.7	**55.2**
Otter_100-119	1.5	2.6	4.1	3.3	4.3	1.6	18.9	5.9	0.7	3.7	2.5	0.3	**49.4**
Otter_120+	6.5	16.1	20.4	11.7	5.3	0.2	3.5	0.2	12.1	2.9	1.1	2.7	**82.7**
Fly_70-99	16.7	10.7	7.0	5.0	25.9	14.7	10.9	5.5	8.0	12.8	5.6	2.8	**125.6**
Fly_100-119	0.0	0.4	0.0	1.2	0.1	10.8	4.2	14.8	34.1	5.5	3.6	1.5	**76.2**
Fly_120+	0.0	0.0	0.0	9.2	63.4	377.5	208.6	122.9	79.4	4.9	0.0	0.0	**865.9**
Total	**128.6**	**106.0**	**70.9**	**49.4**	**114.0**	**415.7**	**252.7**	**157.7**	**147.9**	**49.2**	**45.0**	**48.1**	**1585.2**

***** Landings- and effort values might be higher than those presented in the quarterly reports (Reijden et al. 2015a,b,c,d) because the database was not fully synchronized at time of data extraction for quarterly reports.

Because of these combined factors, no two years, or even months are equal. However, trends in time over the different seasons or different years can be observed and in this section, we will discuss such trends for the ten demersal fishery types. For this end, the monthly fishing activity and cod landings in 2014 for the ten gears separately are presented in Table 3 and 4 respectively. Spatial distributions of both activity and landings can respectively be found in appendices D and E. To determine differences over time, Table 5 and 6 represent the average (quarterly) fishing activity and cod landings for the time periods 2011-2012 and 2013-2014 for the ten gears separately. Average spatial distributions of fishing activity in both time periods are shown in appendix D. Together with the input of our fisheries experts, the observed patterns for each gear type will now be discussed and possible explanations for the observations made are given.

Table 5. Average fishing activity (in *1000 kW-days) per quarter for the ten gears separately in 2011-2012 and 2013-2014.

Gear type	2011-2012					2013-2014					Relative change 2013-2014 to 2011-2012
	Q1	Q2	Q3	Q4	Total	Q1	Q2	Q3	Q4	Total	
Beam_trad	5032	3702	3456	3927	**16117**	3151	2262	1945	2350	**9708**	**0.60**
Beam_puls	1039	1258	1452	1698	**5447**	2021	1985	2381	2431	**8818**	**1.62**
Euro_trad	160	184	102	78	**523**	40	52	25	15	**132**	**0.25**
Euro_puls	58	71	89	83	**300**	105	116	97	94	**411**	**1.37**
Otter_70-99	122	238	377	153	**889**	107	230	393	161	**890**	**1.00**
Otter_100-119	31	278	310	30	**649**	56	195	196	96	**544**	**0.84**
Otter_120+	32	98	54	12	**197**	35	49	39	8	**131**	**0.66**
Fly_70-99	397	292	119	309	**1117**	440	285	153	296	**1174**	**1.05**
Fly_100-119	0	76	163	54	**293**	2	87	119	54	**262**	**0.89**
Fly_120+	0	44	112	16	**172**	0	47	152	35	**234**	**1.36**
Total	**6869**	**6240**	**6235**	**6360**	**25703**	**5957**	**5307**	**5500**	**5540**	**22304**	**0.87**

Table 6. Average cod landings (in tons) per quarter for the ten gears separately in 2011-2012 and 2013-2014.

Gear type	2011-2012					2013-2014					Relative change 2013-2014 to 2011-2012
	Q1	Q2	Q3	Q4	Total	Q1	Q2	Q3	Q4	Total	
Beam_trad	462.6	63.2	72.2	156.6	**754.6**	163	12.3	9.6	35.4	**220.3**	**0.29**
Beam_puls	46.1	10.9	7.6	33.8	**98.4**	63.1	12.8	12.4	45.8	**134.1**	**1.36**
Euro_trad	38.3	3.0	0.9	8.3	**50.5**	7.9	0.5	0.0	0.9	**9.3**	**0.18**
Euro_puls	7.3	0.6	0.0	4.0	**11.9**	10.9	1.2	0.1	6.4	**18.6**	**1.56**
Otter_70-99	22.2	32.5	29.1	14.5	**98.3**	12.1	16.3	10.9	7.6	**46.9**	**0.48**
Otter_100-119	3.0	17.3	17.5	3.8	**41.6**	5.1	10.2	16	7.0	**38.3**	**0.92**
Otter_120+	82.4	45.6	49.6	28.5	**206.1**	43.6	13.1	9.7	4.5	**70.9**	**0.34**
Fly_70-99	31.2	51.1	16.6	8.8	**107.7**	36	35.4	31.8	14.4	**117.6**	**1.09**
Fly_100-119	0.0	13.7	33.7	19.8	**67.2**	0.5	9.4	31.8	7.6	**49.3**	**0.73**
Fly_120+	0.0	92.4	272.9	28.9	**394.2**	0.0	228.6	427.6	68.6	**724.8**	**1.84**
Total	**693.1**	**330.3**	**500.1**	**307**	**1830.5**	**342.2**	**339.8**	**549.9**	**198.2**	**1430.1**	**0.78**

4.2.1 Beam trawls; traditional and pulse gears.

Beam trawlers are mainly targeting plaice and sole in the southern and central part of the North Sea. They are active year round, but show a lower activity in summer (May – August) and in December (Table 3), mainly due to non-fishing activities as national (religious) days (e.g. Christmas, Eastern, Ascension day), self-maintenance of the vessel (e.g. painting) and holiday leave. In February, a small dip in fishing activity can be observed as well, this is most likely caused by the so-called “Bidweek” (the week including the ‘day of prayer’) every second Wednesday of February at Urk (a village in the Netherlands with many fishers). However, some variation in effort can be ascribed to switches to a different fishing gear, such as shrimps or otter trawls targeting Nephrops.

During 2014, the beam trawl fleet underwent an extensive shift from traditional gears towards pulse gears. This can be observed in Table 3, with a decrease in beam_trad activity the second halve of the year, whilst the beam_puls activity increased in this period. That explains the large decrease of traditional beam trawls in 2013-2014 relative to 2011-2012 and the congruent increase for pulse beam trawlers (Table 5). The huge decrease in Beam_trad is not compensated for by a similar increase in Beam_puls. This ‘mismatch’ is believed to have several causes: In December 2012, several traditional beam trawl fishermen quit the fishing industry. Moreover, this may be caused by fishermen who switched to pulse gear and in addition set back the vessel engine's power[1]. Due to the lower towing speed in pulse trawls and the lighter gear, such a high engine power is not necessary anymore (van Marlen *et al.*, 2011). Finally, the observed mismatch in fishing activity between Beam_trad and Beam_puls could be caused by a switch from traditional beam trawl gears towards other fisheries (for instance shrimpers, otter trawlers or flyshooters).

Traditional beam trawlers have a specific distribution over the year; in winter and spring (October-May), the fishery is concentrated at the Falls (51-52° N; 2-4° E) in the southern North Sea (Figure D1). The Doggersbank (54-56° N; 2-5° E), a relative shallow area in the central North Sea, is fished more frequently during spring, summer and fall (March-October) than in winter. Near Off Horns Reef (55-56° N; 7° E), fishing activity is also higher in spring and the beginning of summer (May-July) (Figure D1). Most likely, this pattern is caused by seasonal difference in main target species. In summer, fisheries are more directed towards plaice and therefore concentrated at the central North Sea. During winter the fisheries are aiming for sole, which is then concentrated at the southern North Sea. Aggregations of fishing activity at specific sites within the general north-south migration could be due to targeting valuable commercial by-catch species, as turbot, brill or lemon sole.

Pulse beam trawlers are concentrated year-round at the southern parts of the North Sea and at the Falls, with no fishing activity at the Doggersbank and limited activity near Off Horns Reef (Figure D2). This makes sense, as halve of the pulse vessels are restricted in their fishing grounds by their licence, not allowed to fish North of 55 °N. In the southern North Sea, the pulse beam trawlers have expanded the traditional fishing grounds east and southwards, fishing in areas where traditional gears could not fish (due to gear-substrate combined effects) (Figures D1, D2).

In general, the beam trawl fleet is landing more cod in the winter period (September-March) than in summer (Table 4), when the majority of traditional and pulse beam trawls are concentrated in the southern part of the North Sea. In the rest of the year, cod is landed very infrequently from all regions of the North Sea (Figures E1, E2). This may indicate cod aggregations in the southern North Sea during winter, as higher cod catchability for a different season in one gear type is unlikely.

In addition to seasonal variation in cod abundance, variation among years is suggested from the time-period comparisons. The 40% decrease in fishing activity of Beam_trad in 2013-2014 relative to 2011-2012 is not proportionate to the observed decrease of cod landings of 70% over the same time period by this gear type (Table 5, 6). Likewise, the Beam_puls is landing less cod than expected from the increase in fishing activity over both time periods. With only 35% increase in cod landings, relative to 62% increase in fishing activity is suggesting that overall, less cod is landed by the beam trawl fleet in 2013-2014 than in 2011-2012. As fishing grounds have not changed drastically over the years (Figures F1, F2), this may indicate a decrease in cod abundance in the southern North Sea or a decrease of cod catchability by the pulse. This hypothesis is supported by the estimates of cod biomass in the southern North Sea by the WGNSSK working group of ICES (Figure 5).

4.2.2 Eurocutters; traditional and pulse gears

Eurocutters deploy similar gear types as beam trawlers, but have lower engine power and are therefore generally smaller in vessel length and gear width. Several Eurocutters are able to deploy both beam and otter trawl gears and are known to switch regularly. However, the classification of Eurocutter is only applied when beam trawl gears are deployed. As can be observed, overall fishing activity of Eurocutters is low in general, as there is a limited number of vessels. At the end of 2012, many fishers quit, resulting in a small number of active Eurocutter vessels (Table 5). Most of the remaining vessels employ pulse gears (Table 5). Over the years, despite the changes in Eurocutter fleet effort, no remarkable changes can be observed in spatial distribution or cod landings (Table 6, Figures F3, F4).

[1] According to their logbooks.

Whereas Eurocutters with pulse gears have a fairly constant fishing activity over the year, traditional gears are only active in the first halve of the year with almost no activity in the second halve of 2014 (Table 3). In June 2014 new pulse licences became available and some remaining traditional vessels shifted towards pulse gears. This is however not reflected as an increase in fishing activity of pulse Eurocutters (Table 3), probably because these fishers with new pulse licences chose for shrimp fishing that season. Shrimp abundance is known to peak in autumn and winter, resulting in good catches during that period. Shrimp fishery activity is not shown in Table 3.

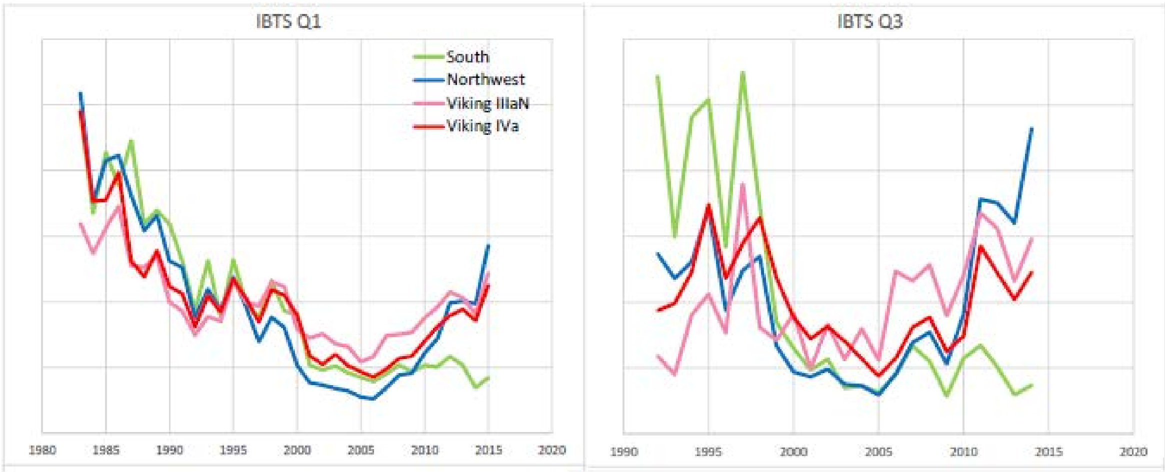

Figure 5. *Relative biomass indices of cod in different sub regions by WGNSSK (ICES, 2015). South includes ICES areas IVb, IVC and VIId*

Eurocutters, both traditional and pulse gears, are concentrated close to the shore and in the southern North Sea, but go a little more offshore in winter (September – March; Figures D3, D4). This probably reflects migration patterns of sole, which come closer to shore with increasing temperatures. During the winter period (December-February), cod landings are much higher than in the rest of the year (Table 4, Figures E3, E4). This may indicate cod aggregations in the southern North Sea during winter, congruent with the observations made for the beam trawl fleet. However, it could also be that a limited number of cod-targeted trips are performed during winter.

4.2.3 Otter trawlers 70-99mm

Otter trawlers with small meshes are a mixed fisheries, mainly targeting Nephrops (*Nephrops norvegicus*) with bycatches of plaice. Nephrops fisheries are characterized by small vessels (in both length and engine power) using gears with small meshes (70-99mm). Particularly due to the overall small vessel length, fishing activity is chiefly in summer (May – September), when weather conditions allow for small vessels to fish. In the remaining part of the year Nephrops fisheries are performed by somewhat larger vessels, while small vessels shift towards shrimp fisheries (Table 3).

Cod landings in Nephrops fishery have no seasonal trend, but are relatively equally distributed over the year (Table 4). One remarkable observation can be made. In winter (December – April), the Nephrops fishing ground Farn Deep (55° N, -1° E) is fished (Figure D5) with almost no cod landings in that area (Figure E5). Congruent with observations in beam trawlers and Eurocutters, this may indicate an aggregation of cod in the southern North Sea during winter.

Fishing activity is concentrated at specific Nephrops fishing grounds (Figure D5) and changed little over the years in both absolute effort as spatial distribution (Figure F5, Table 5). Interestingly, the cod landings have halved compared with the period 2011-2012 (Table 6). This could suggest a decrease of cod abundance at Nephrops fishing grounds compared to 2011-2012. However, it could also be a result of the Dutch Cod Avoidance Plan as RTC's are actually working and less cod is caught overall. This second hypothesis will be investigated in a follow-up studies which will evaluate RTC's.

4.2.4 Otter trawlers 100-119mm and >120mm

Almost all otter trawlers (mesh size >100mm) are targeting plaice, while a minority of trawlers with >120mm meshes is aiming for cod. The cod-targeting part of the fleet is dominated by small vessels (probably switched Eurocutters, which are not classified as Eurocutters because of the gears deployed) targeting cod in waters close to shore in the southern North Sea during winter and spring (November –May; Figures D6, D7). Plaice targeted fisheries are located in the central North Sea and –due to spatial-technical measures (not fishing above 55°N with mesh size <100mm)- more to the Skagerrak for the Otter_120+ (Figures D6, D7). The difference in target species (plaice or cod) is reflected in the cod landings; whereas otter_100-119 has low cod catches with relative stable CpUE over the year, CpUE of otter_120+ is much higher in winter and spring than in the rest of the year (Tables 3, 4). These high CpUEs are obtained in the coastal waters, reflecting the division in the two target species of the Otter_120+ (Figures D7, E7).

Fishing effort is relatively constant over the year, although a summer-peak (April – August) can be observed in otter_100-119mm (Table 3). Most likely during winter, some vessels switch to beam trawling gears targeting sole in the southern North Sea. Relative to 2011-2012, fishing effort has decreased a little for both gears (Table 5). No clear explanation for this can be given, however, the cod avoidance plan might be a factor causing the decrease in fishing activity of Otter_120+. Cod landings have decreased for both gears compared with 2011-2012 (Table 6). For Otter_120+, this decrease in cod landings is not comparable with the decrease in fishing activity; the cod landings have almost decreased double compared with the decrease in fishing activity. This is congruent with the observations in Otter_70-99, suggesting a decrease of cod abundance compared to 2011-2012. For Otter_100-119 this pattern cannot be observed. For both gears, no differences in fishing grounds can be observed between the time periods (Figures F6, F7).

4.2.5 Flyshooters; 70-99mm, 100-119mm and >120mm

In contrast to the other demersal fisheries, which mainly target 1 or 2 species, flyshooters target a variety of species. Main target species of Fly_70-99 are tub gurnard (*Chelidonichthys lucerna*) and red mullets (*Mullus surmuletus and M. barbatus*). These species are caught in the winter in the English Channel, which is reflected as an aggregation of fishing activity located in the English Channel (Figure D8, Table 3). For different reasons, flyshoot fisheries are less profitable in the English Channel in summer. In addition, some of the fly_70-99 have contracts for plaice deliveries in summer, which they cannot catch at the English Channel due to their quota portfolio.

Part of the Fly_70-99 fishers continue to fish with this gear in the central North Sea, targeting tub gurnard and red mullets, combined with (horse) mackerel (*Trachurus trachurus and Scomber scombrus*) and plaice (Figure D8). Other fishers change not only fishing ground, but change towards larger mesh sizes. This can be observed as the sudden increase in fishing activity of both Fly_100-119 and Fly_120+ during summer (Table 3). These large meshed flyshooters are targeting plaice (Fly_100-119) and cod (Fly_120+) and therefore have different fishing areas. Fly_100-119 is concentrated at coastal waters of Denmark, the coastal waters of the Netherlands and in the Skagerrak whereas Fly_120+ is almost exclusively active in the Skagerrak (Figures D9, D10).

Flyshooters land the majority of the cod in the demersal fleet, especially when compared to effort, with Fly_120+ landing the most cod (Table 4). These catches are mainly caught in the Skagerrak, with only few landings caught in the coastal waters of the Netherlands and Denmark (Figures E8, E9, E10). Cod is landed by the Fly_70-99 year round, with no remarkable peaks in CpUE (Tables 3, 4; Figure E8).

Over the years, flyshooters have changed in composition. Fishing activity of Fly_70-99 is fairly constant, while Fly_100-119 has decreased and Fly_120+ has increased (Table 5). Cod landings follow a similar pattern; no change for Fly_70-99, a decrease for Fly_100-119 and an increase for Fly_120+ (Table 6). However, the observed increase in cod landings for Fly_120+ is much higher than the increase in fishing activity. This can be explained by the participation of multiple Fly_120+ fishers to a CCTV-project of IMARES, commissioned by the Ministry of Economic Affairs (van Helmond *et al*., in prep). In this project, which is aimed at gaining insight in the potential of fully documented catch-quota management schemes, participating fishers can obtain more cod quota and a derogation of effort control regulations. From interviews with participating fishers it became clear that fishing behaviour was changed towards more selective fishing for cod (van Helmond *et al.*, in prep). It can be observed in the spatial distribution of fishing activity as well; whereas Fly_70-99 and Fly_100-119 have no remarkable differences in spatial distribution, the Fly_120+ is fishing deeper in the Skagerrak (Figures F8, F9, F10).

4.3 Variance analysis

As described above, demersal fisheries are subject to high seasonality with multiple external factors affecting fisher behaviour. Therefore it is possible that cod CpUE estimates are biased towards season, year or fishing area, which results in unrealistic indicators of cod abundance estimates. Consequently, the use of CpUE-ratios as basis for the conversion factor could result in unequal transfers of fishing capacity among gears and unexpected variance in total cod catch.

To test whether the observed seasonal and spatial variation is undermining the assumption that cod catchability is stable over the year(s), we performed a variance analysis to identify the main factors affecting cod landings of each gear separate using a zero-inflated model.

The results are shown in Table 7, with for six different potentially important explanatory variables (total landings, effort, both in kWdays and days-at-sea, quarter, year and area) their effect on cod landings for each gear type. The magnitude of the effect is displayed as the reduction in AIC-value (Akaike Information Criterion Value). It is important to see the reduction in AIC in respect to the base level of the AIC for that specific gear. For instance, the total landings quantity is the most important explanatory factor of cod catches in the traditional beam trawler, with an AIC-reduction of 841. However, the AIC-reduction of the explanatory factor “area” in the Fly_100-119 (223), is relatively to the gear-specific base-level AIC a larger reduction.

Table 7. Factors affecting cod landings (per trip) for each gear type separately, based on the zero-inflated model. For each gear, a base level AIC is given, together with the ranked explanatory factors (1-6) affecting the cod landings and their respective reduction in AIC.

		Explanatory factor 1	Explanatory factor 2	Explanatory factor 3	Explanatory factor 4	Explanatory factor 5	Explanatory factor 6
	Base level AIC	AIC-reduction					
Beam_trad	76578	Total landings 841	Quarter 867	Year 744	Days-at-sea 405	kWdays 379	Fishing area 10
Beam_puls	34729	Total landings* 531*	Fishing area* 531*	Quarter 337	Year 220	Days-at-sea 46	kWdays 28
Euro_trad	10728	Total landings 404	Quarter 181	kWdays 96	Year 54		
Euro_puls	8175	Days-at-sea 168	Quarter 48	Total landings 44	kWdays 18	Year 11	Fishing area 10
Otter_70-99	21337	Total landings 775	Year 131	Days-at-sea 114	Quarter 108	kWdays 46	Fishing area 6
Otter_100-119	8535	Total landings 278	Days-at-sea 39	Year 20	kWdays 16	Fishing area 32	
Otter_120+	10495	Days-at-sea 75	Year 56	Quarter 26	kWdays 14	Total landings 40	
Fly_70-99	21108	Fishing area 376	Days-at-sea 364	Quarter 243	Total landings 135	Year 32	kWdays 23
Fly_100-119	6001	Fishing area 223	Total landings 103	Days-at-sea 27	Year 18	Quarter 7	
Fly_120+	7378	Total landings 293	Days-at-sea 31	Fishing area 10	Quarter 8		

* These explanatory factors have similar effect size.

For halve of the gears, the quantity of the total landings has the largest effect on cod landings (Table 7). For Euro_puls and Otter_120+, the cod landings are mostly affected by days-at-sea. Area of the trip is the most important factor affecting cod landings in Beam_puls, Fly_70-99 and Fly_100-119. It is important to note that multicollinearity, variates that are correlated with other explanatory variates, is not dealt with in the procedure used in this stage. Multicollinearity might be causing a higher value when the next explanatory variable is included in the model. For instance, it is very likely that total landings are correlated with fishing area or with Days-at-sea. Also year and quarter are important factors affecting cod landings, which could already been concluded from the spatial distributions of cod landings and fishing activity in appendices D-F.

Main conclusion from this analysis is that cod CpUE of each gear type is biased towards multiple explanatory factors, violating the assumption that catchability of cod is constant for each gear. Therefore, the usage of CpUE as basis of the conversion factor is not scientifically sound and could result in unfair conversion factors.

4.4 Catch per Unit Effort transition ratio

The European Cod Recovery Plan includes effort limitations per fleet segments. It also includes a transition factor in kW-days to transfer kW-days between fleets, based on the cod catches of the fleets. In the Netherlands, an adjusted transition factor is used for the TR1C and TR2 fleets. These fleets are not targeting cod, but catch cod as bycatch. The TR1AB feet is expected to target cod and is therefore no subject of the adjusted transition factor.

4.4.1 LpUE

The genuine transition factor for 2014 is calculated based on landings registered in the EU-logbooks and fishing effort obtained from VMS-data. Both the fishing effort and the cod landings are already shown in this report (Tables 3 and 4 respectively) for each gear type separately. However, for convenience, Table 8 shows both fishing effort and cod landings in 2014 per fleet segment per quarter. It also includes the LpUE (Landings per Unit Effort, in kg/kW-day). Based on these data, a transition factor of 5.55:1 is calculated between (TR1C + TR2): BT2.

Table 8 . Total cod landings (in Ton), fishing effort (*1000 kW-days) and LpUE (kg/kW-day) in 2014* for each fleet segment separately and combined, per quarter and for the total year.

	Landings					**Effort**					**LpUE**				
	TR1AB	**TR1C**	**TR2**	**BT2**	**Total**	**TR1AB**	**TR1C**	**TR2**	**BT2**	**Total**	**TR1AB**	**TR1C**	**TR2**	**BT2**	**Total**
Q1	43	8	50	204	**305**	19	90	583	5119	**5811**	2.263	0.089	0.086	0.040	**0.052**
Q2	467	21	68	22	**578**	130	266	600	3997	**4993**	3.592	0.079	0.113	0.006	**0.116**
Q3	427	79	31	22	**559**	150	294	532	4249	**5225**	2.847	0.269	0.058	0.005	**0.107**
Q4	12	17	31	82	**142**	18	157	461	4545	**5181**	0.667	0.108	0.067	0.018	**0.027**
2014	**949**	**125**	**180**	**330**	**1584**	**317**	**807**	**2176**	**17910**	**21210**	**2.994**	**0.155**	**0.083**	**0.018**	**0.075**

***** Landings- and effort values might be higher than those presented in the quarterly reports (Reijden et al. 2015a,b,c,d) because the database was not fully synchronized at time of data extraction for quarterly reports.

4.4.2 CpUE

In the European Cod Recovery Plan, the transition factor is based on total cod catches. Therefore the above calculated LpUE transition factor should be transformed to a CpUE transition factor. The landings from Table 8 should therefore be extrapolated to include cod discards as well. As no monitoring program is currently available in the Netherlands to estimate accurate cod discard rates in all the fleet segments, the discard rates of both the STECF (Scientific, Technical and Economic Committee for Fisheries) data of 2014 as the average of the 2010-2012 data from the North Sea Discards Atlas are used (Table 9) to reconstruct total cod catches. Then, CpUE and the ratio between CpUE for the different fleet segments can be calculated.

Table 9. Cod discards rates and their source.

	2010 (NSDA)	2011 (NSDA)	2012 (NSDA)	2014 (STECF)	Average (NSDA)
TR1	0.09	0.03	0.07	0.02	0.07
TR2	0.12	0.08	0.13	0.16	0.11
BT2	0.21	0.34	0.25	0.41	0.27

NSDA: North Sea Discards Atlas
STECF: Scientific, Technical and Economic Committee for Fisheries

In 2014, in total 1584 ton cod was landed (Table 10). Based on the STECF discard estimates, this resulted in 1870 ton cod catch (Table 10). For the NSDA discard estimates, the total cod catch was 1809 ton (Table 10). For the fleet segments, the differences in cod discard estimates between NSDA and STECF result in differences in cod catch estimates. As a consequence, the CpUE ratios differ between the two discard estimates: 3.67 for STECF estimates and 4.46 for NSDA estimates. These CpUE ratios are based on the catches and fishing effort of the TR1C and TR2 fleets, in comparison with the BT2 fleet.

Table 10. Calculated cod catches and CpUE rates per fleet segment for the two discard estimates sources.

	Landings	Effort	Catch (STECF)	Catch (NSDA)	CpUE (STECF)	CpUE (NSDA)
TR1AB	949	317	968	1020	3.05	3.22
TR1C	125	807	128	134	0.16	0.17
TR2	180	2176	214	202	0.10	0.09
BT2	330	17910	559	452	0.03	0.03
Total	**1584**	**21210**	**1870**	**1809**	**0.09**	**0.09**

To estimate a conversion factor in kW-days between fleet segments, the ratio between fleet CpUE may not be the best solution. As shown in Table 9, discard estimates of cod vary over the years (NSDA 2010-2012) and between sources (STECF vs NSDA). For instance, when solely based on discards estimates of 2011, the final CpUE ratio calculation will result in a lower ratio than 4.46, while for the year 2012, the ratio will be higher than 4.46. Whereas the total cod landings and total effort are well known per fleet segment, the extrapolated cod catches have a relative large uncertainty. This is reflected in the difference in transition factor in CpUE when using both STECF and NSDA discard estimates, with over 21% difference between the conversion factors. Nonetheless, both factors are still below the LpUE transition factor of 5.55

4.5 Cod avoidance trips: 5%-rule.

Within the Cod Recovery Plan, fleet segments with low cod catches are subject to less rigid regulations. Therefore an overview is given of the average percentage landed cod in total landings and catch for the different TR gear types separately, aggregated gear types in fleet segments and all combined.

4.5.1 Landings

Table 11 shows -for each aggregation level- per quarter the total number of trips, the number of trips with 5% or less cod in the landings and the total fraction of trips in which the cod landings contribute 5% or less to the total landings. The Fly_120+ has the lowest percentage (15%) of trips with 5% or less cod landings in the total landings. The Otter_70-99 and Otter_100-119 have the highest percentages (91% and 94% respectively) of trips with 5% or less cod landings in the total landings. On average 90% of the TR2 trips and 89% of the TR1C trips contain less than 5% cod in the landings. During quarter 4 the percentage of landings with less than 5% cod is highest for TR1C (95%).

4.5.2 Catches

In the Cod Recovery Plan, "cod avoidance trips" are defined as trips with 5% or less cod in the total catch. Above calculated percentages are based on landings data only. To estimate the percentages of actual cod avoidance trips, discards should be included. This includes discards of both cod and other (fish) species. As cod discards percentages (relative to total catch) are low compared with other species like dab, plaice and/or sole, the total proportion of cod in the total catch is likely lower than the proportion of cod landings in the total landings. Therefore, the calculated percentages of cod avoidance trips based on landings data is probably an underestimation.

To estimate the percentage of trips with 5% or less cod in the total catch, two assumptions are used.

1) Cod discard percentages in 2014 (per fleet segment) are similar to reported discard percentages in the Discard Atlas of 2010-2012 (Quirijns and Pastoors 2014).
2) Total discards fraction, relative to the total catch, is similar for all gear types and is 40%. This discard fraction estimate is chosen based on the results of the discards self-sampling program of IMARES (Reijden et al., 2014).

All cod landings are multiplied with the gear-specific cod discard ratio to estimate cod catches. All other landings are multiplied with an average discards ratio (40%) to estimate total catch ratio. Then, a similar calculation could have been performed as described above. This resulted in slightly higher percentages of cod avoidance trips, with 93% of the trips in both the TR2 and TR1C having 5% or less cod catches.

Table 11. Fractions of TR trips with less than 5% cod in the landings per gear category

		Nr of trips					#: 5% Cod or less					Percentage (≤ 5%)				
		Q1	Q2	Q3	Q4	2014	Q1	Q2	Q3	Q4	2014	Q1	Q2	Q3	Q4	2014
Gear type																
Otter_70-99	TR2	268	275	226	147	**916**	244	237	222	134	**837**	91	86	98	91	**91**
Otter_100-119	TR1C	34	99	79	83	**295**	29	94	73	81	**277**	85	95	92	98	**94**
Otter_120+	TR1A	50	53	11	18	**132**	2	20	8	7	**37**	4	38	73	39	**28**
Fly_70-99	TR2	253	188	156	246	**843**	223	155	133	230	**741**	88	82	85	93	**88**
Fly_100-119	TR1C	2	42	75	63	**182**	1	36	52	58	**147**	50	86	69	92	**81**
Fly_120+	TR1A	1	55	50	4	**110**	1	5	11	0	**17**	100	9	22	0	**15**
Fleet segment																
TR1A		51	108	61	22	**242**	3	25	19	7	**54**	6	23	31	32	**22**
TR1C		36	141	154	146	**477**	30	130	125	139	**424**	83	92	81	95	**89**
TR2		521	463	382	393	**1759**	467	392	355	364	**1578**	90	85	93	93	**90**
All		**608**	**712**	**597**	**561**	**2478**	**500**	**547**	**499**	**510**	**2056**	**82**	**77**	**84**	**91**	**83**

5 Discussion

The conversion factor calculated in this report should be considered with caution. The reason for this is that the CpUE, on which the conversion factor is based, is itself a ratio. This is because total catch is based on landings plus an estimated level of discards, and hence, exact discard rates are unknown as catches are not fully documented. The alternative, to calculate the conversion factor based on LpUE, would result in the problem that discards are not taken into account at all.

Another problem with the conversion factor is that the cod CpUEs of the vessels of the TR1C and TR2 fleet segment that participate in the CCTV program are included in the calculation. As was explained in text box 2, the fleet that fishes with cameras on board to fully document cod catches are exempted from effort regulations. In addition these vessels receive 30% cod quota on top of their usual quota. This group of vessels consist of TR1A vessels (if mesh is>120 mm) but also of vessels with smaller mesh sizes (TR1C, TR2) (van Helmond, 2015). However, these vessels may influence the CpUE level of the TR1C and TR2 fleet segment and thereby the conversion factor. This to the disadvantage of the other vessels in the TR1C and TR2 categories.

In this report it was also demonstrated that the overarching gear categories (BT2, TR1C, TR2) consist of multiple different gear types. For instance, the TR segments consist of both otter trawlers and flyshooters. These different gear types have very different fishing distributions, even between gears with similar mesh sizes. However, the same effort regulations apply to them. This results in a-specific regulations for these fishers. It became clear that the BT2 gear category consists of traditional beam trawlers and pulse trawlers. In the recent year many vessels changed from beam trawl to pulse trawl, which has probably effected the cod CpUE of the BT2 gear group significantly and thus also the conversion factor.

6 Conclusions

This report investigated the cod catches of the BT2 and the TR fleet. We mainly focus on the TR1C and TR2 fleets, as they catch cod as a bycatch species. With 93% of all trips having less than 5% cod in the total catches, this general assumption is validated. It was found that in 2014 the cod CpUE of the TR1C and the TR2 fleet was around 0.16 or 0.17 and 0.10 or 0.09 kg per kWday respectively (first STECF, then NSDA discard estimate applied). Two values are provided of the CpUE of each gear because they differ slightly depending on whether STECF or NSDA discard data have been used to calculate the CpUE. Although a difference of 0.01 is easily interpret as insignificant, this difference can have much larger effects on the CpUE calculation. With a cod CpUE of 0.03 of the BT2 fleet in 2014, this results in a conversion factor of 3.67:1 or 4.46:1. Both are higher than the ratio calculated in 2013, i.e. 3.12:1 (Kraan *et al.,* 2014). Again, the exact value of the conversion factor depends on whether the STECF or the NSDA discard data have been used.

In this report the assumption underlying the conversion factor (constant cod catchability) has been focus of interest. The variance analysis showed that cod landings are affected by inter alia total landings, fishing ground and season. Moreover, it is known that more factors affect fishing behaviour and as a consequence landings, such as; quota, fish prices, oil prices, contract obligations, weather, etc. As a result, the scientific basis underlying the CpUE ratio as a conversion factor of fishing effort regulations proved to be unfair. As the gear-specific cod catch coefficient is erroneously assumed constant, the exchange of fishing activity with a CpUE-based conversion factor does not result in equal total cod catches but may vary with external factors such as fishing ground and season.

This analysis also found that the BT2 fleet segment has been subject to a large transition. Many beam trawl fishermen switched to the pulse gear. This had at least two effects; first, the spatial distribution of the fishing activity has changed, with non-fished areas suddenly becoming available for fisheries. And secondly, due to the lower fishing speed, the lighter pulse gears, and the fact that the gear does not have to be dragged through the seabed, the engine power of pulse vessels can be reduced. This results in a lower total BT2 fleet effort (kWdays), which may explain the higher conversion ratio in 2014 compared to 2013. This is important to know as although the conversion factor has increased over the last year, it does not mean that TR fishermen have started catching more cod, but that the BT fishermen have caught less cod.

7 Recommendations

Based on the above conclusions, the efficiency of the CpUE-based conversion factor to exchange fishing effort between TR and BT gears is questioned. The use of a CpUE-based conversion factor is based on the assumption of constant cod catchability by the different gear types. However, the variance analysis in this report proved that the gear-specific cod catchability is not constant but varies with external factors such as fishing ground, season and total landings. Due to the variable cod catchability of the different gears over time, the CpUE-corrected exchange of fishing effort does not necessarily result in equal cod catches as the originally distributed fishing effort would result in.

Next to the questioned scientific base for the usage of a CpUE-conversion factor, this report showed that small differences in gear-specific cod discard estimates result in large differences in CpUE-ratios between fleet segments. In addition, the conversion factor is applied to overarching fleet segments that could be divided in very distinct gear types. Ultimately, external factors that drive fishermen behaviour are not taken into account although this report shows that these factors have large impact. Altogether, this results in a mismatch between regulations and fishermen intentions.

We recommend to evaluate whether the goals set in the Dutch Cod Avoidance Plan and the European Cod Recovery Plan are achieved in the best possible way by the current regulations. This evaluation would not only include the fishing effort restrictions but would include the current RTC system as well. Based on the conclusions of this report, we recommend to organise new regulations at fisheries-specific levels, similar to the landing obligation. By creating less generic regulations, we expect that more stimulus is given to become more selective in both gear-adaptions and fishermen behaviour. However, such an approach would require a closer look to the technical measures currently in place.

Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 187378-2015-AQ-NLD-RvA). This certificate is valid until 15 September 2018. 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. The scope can be found at the website of the Council for Accreditation (www.rva.nl).

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Justification

Report C010/16
Project Number: 4302301308

The scientific quality of this report has been peer reviewed by a colleague scientist and an interim member of the Management Team of IMARES.

Approved: Ralf van Hal
Fisheries researcher

Signature:

Date: 1 February 2016

Approved: Dr. N.A. Steins
Interim Management Team member

Signature:

Date: 1 February 2016

Appendix A. The EU Cod Recovery Plan

Following serious depletion of Europe's four cod stocks[2] in the early 2000s, the EU member states agreed to develop a plan to recover the cod stocks. Following short-term recovery plans from 2001 and 2002, the first long-term cod recovery plan was agreed upon in 2004, laid down in Regulation (EC) 423/2004. This long-term plan included a top down prescribed approach to reach biomass targets for all four stocks, and a schedule to reduce days at sea. In the run up to the reform of the Common Fisheries Policy (CFP) in 2002, ideas of more participatory fisheries management and differentiated implementation in different regions had gained popularity in the EU. Recognizing this shift in ideas about fisheries management and in light of the limited improvement of the cod stocks following the first cod recovery plan, a second cod recovery plan was agreed upon in 2008 (Kraak et al., 2013).

This second cod recovery plan, laid down in Regulation (EC) 1342/2008, entered into force in January 2009. It had the objective to ensure sustainable exploitation of the cod stocks on the basis of maximum sustainable yield. The second cod recovery plan sets rules about setting Total Allowable Catches (TACs) and effort restrictions. Yearly effort reductions will be based on the same percentage as specified by the fishing effort (F) used in the estimations of TAC.

Through article 11 and 13 it encourages nationally developed plans for the reduction of cod catches. Article 11 allows member states to request exemption from the effort regime for groups of vessels that of which total cod catches do not exceed 1,5% of the total catch of the group. Article 13 allows members states to allocate additional effort within groups in case of the use of highly selective gear or if cod is avoided, resulting in a maximum of 5% cod per fishing trip. The implementation of these articles were delegated to Member States and industry (Kraak et al., 2013).

Table A1. Gear groups as distinguished in the European Cod Recovery Plan

	Fleet definition	Gear type	Mesh size in mm
1.	TR1	Bottom trawls and seines	>100
2.	TR2	Bottom trawls and seines	70-99
3.	TR3	Bottom trawls and seines	16-31
4.	BT1	Beam trawls	>120
5.	BT2	Beam trawls	80-119
6.	GN	Gill nets	
7.	GT	Trammel nets	
8.	LL	Longlines	

Fishing effort, in kW-days, was allocated to different gear categories within Member States based on track records over the years 2004 till 2006 (Website Visned, 2009). Transfer of effort between gear groups is permitted according to art. 17, provided that Member States provide the commission with information of the cod CpUE of the donor gear group and the receiving gear group. When the CpUE of the receiving group is higher, the transfer of the effort occurs on the basis of a correction factor (STECF, 2001). A standard correction factor is calculated by STECF. If the correction factor calculated for an individual Member State differs by more than 15% from STECF's correction factor, Member States can apply at the European Commission for national transfer rates (ibid.).

[2] In the geographical areas of the Kattegat, the North Sea including the Skagerrak and the Eastern Channel, West of Scotland and the Irish Sea.

Appendix B. The Dutch Cod Avoidance Plan

Around the time the second cod avoidance plan was approved, an increasing number of Dutch skippers switched from the beam trawl gear to twinrig and flyshoot gears. They (mainly) did this to reduce fuel consumption, as the latter fishing methods require less fuel. This meant that the number of vessels in the TR category increased and the number of vessels in the BT category decreased, while effort allocation to the two groups did not change. This gradually resulted in a shortage of days in the BT2 fleet and a difficulty for the skippers in the TR-fleet, who did not have sufficient days at sea. In 2012 for instance, to get one day extra for the TR1 fleet, 16 BT2 days were needed, and for getting an extra day in the TR2 fleet, 5 BT2 days were needed. From 2011 onwards, the Dutch government got permission from the EC to distinguish between TR1A and TR1B as a cod directed fishery and TR1C as cod-as-bycatch fishery. Also the TR2 fleet was classified as cod-as-bycatch fishery. The difference between TR1A and TR1B was that TR1A participated in a fully documented fisheries project, meaning that they had a camera on board to monitor all cod catches. For transferring effort from BT2 to TR1C and TR2, a correction factor of 3:1 was permitted.

To compensate for this specific Dutch regulation, extra measures were agreed upon in consultation with the Dutch fishing industry. These extra measures included additional technical measures, seasonal closures (RTC's) and cooperation of the fleet in cod CpUE related data collection about catch compositions (Ministry of Economic Affairs, Agriculture and Innovation, 2012).

The British and the Dutch governments have agreed to close nine areas every month where vessels in the gear categories TR1 and TR2 (otter trawl, twinrig and flyshoot) are not allowed to fish (Website Vissersbond, n.d.). The areas, referred to as Real Time Closures are 1/16 share of an ICES rectangle in size, and they are closed with the intention to reduce Cod catches. The location of the RTC is based on cod CpUE of the previous year during the same month. The RTC's are not closed for the Belgian and German TR-fleets who have no interest in the lowered conversion factor (Visserijnieuws, 2015). Besides these RTC's, seasonal closures are implemented for certain areas from January until May in order to protect spawning and juvenile cod (Website Vissersbond, 2015).

Appendix C. Extended Materials and Methods

The method used in this report is consistent with the method described in Hintzen *et al*. 2013.

Data pre-processing

VMS and logbook data were received from the Ministry of Economic Affairs and stored in a local database at IMARES.

VMS records are considered invalid and are therefore removed from the analyses if they :

- o Are duplicates or pseudo-duplicates (indication of malfunctioning of VMS device)
- o Identify an invalid geographical position
- o Are located in a harbour
- o Are located on land
- o Are associated with vessel speeds > 20 knots

Logbook records are removed from the analyses when they:

- o Are duplicates
- o Have arrival date-times before departure date-times
- o Overlap with other trips of that vessel

Link VMS and logbook data

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. The following gear types were selected as TR gear: OTB (Otter bottom trawls), OTT (Otter Twin Trawls), PTB (Pair Bottom Trawls), SDN (Danish Seine), SSC (Scottish Seines), SPR (Pair Seine). All TR gears are further divided based on their mesh size, following TR1AB: >=120mm, TR1C: 100 – 119mm, TR2: <100mm. The BT gear is defined as TBB (Beam Trawls) gear type. This consists not only of the traditional beam trawl; all innovative sub-gears like sumwing, pulse and pulswing are included in the BT gear. Next, the BT gear is further classified into categories, based on mesh size. The used geartype BT2 includes all BT vessels operating with a mesh size of 70-99mm.

Define fishing activity

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 harbour/floating, a peak around the average fishing speed and a peak around the average steaming speed. Using the frequency plots, activity is determined for each VMS-point based on the speed recorded. Activity analyses are performed separately for each gear category.

Spatial distribution

The fishing activity determined from the logbooks (kW-days) and the cod landings recorded in the logbooks (kg), are assigned to those (fishing) VMS records that have vessel id, fishing date and fishing position in common. At the spatial scale of 1/4 degree longitude* an 1/8 degree latitude (1/16 ICES rectangle), the total landings of cod (kg) and fishing activity (kW-days) are calculated. Subsequently LpUE (landings per unit effort) can be calculated for each 1/16 ICES rectangle by dividing the landings by the activity.

Appendix D. Monthly fishing activity for the ten gear types

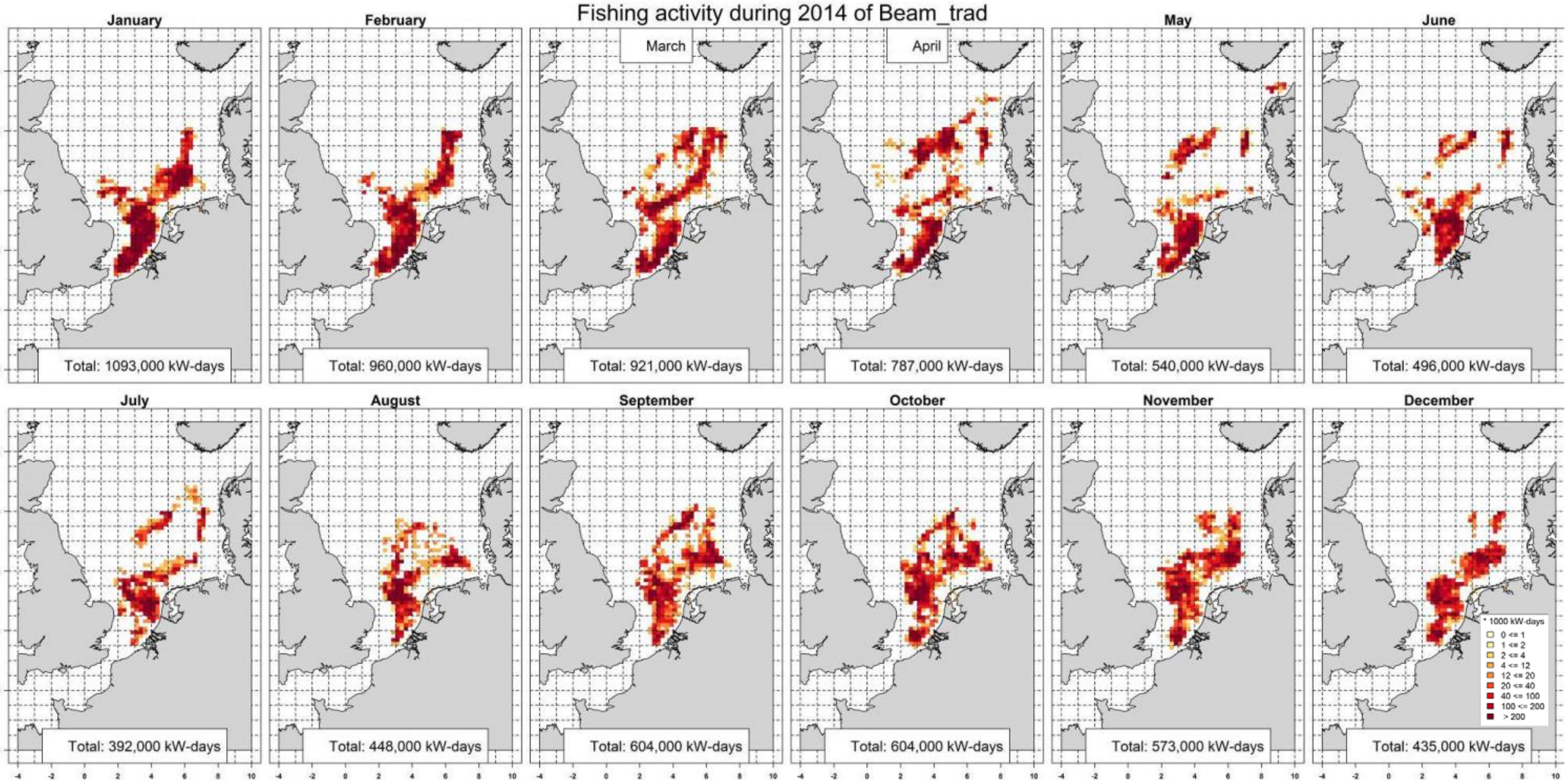

Figure D1. *Fishing activity (in *1000 kW-days) for the beam trawls with traditional gear in 2014. Colour index is similar to Figure 1.*

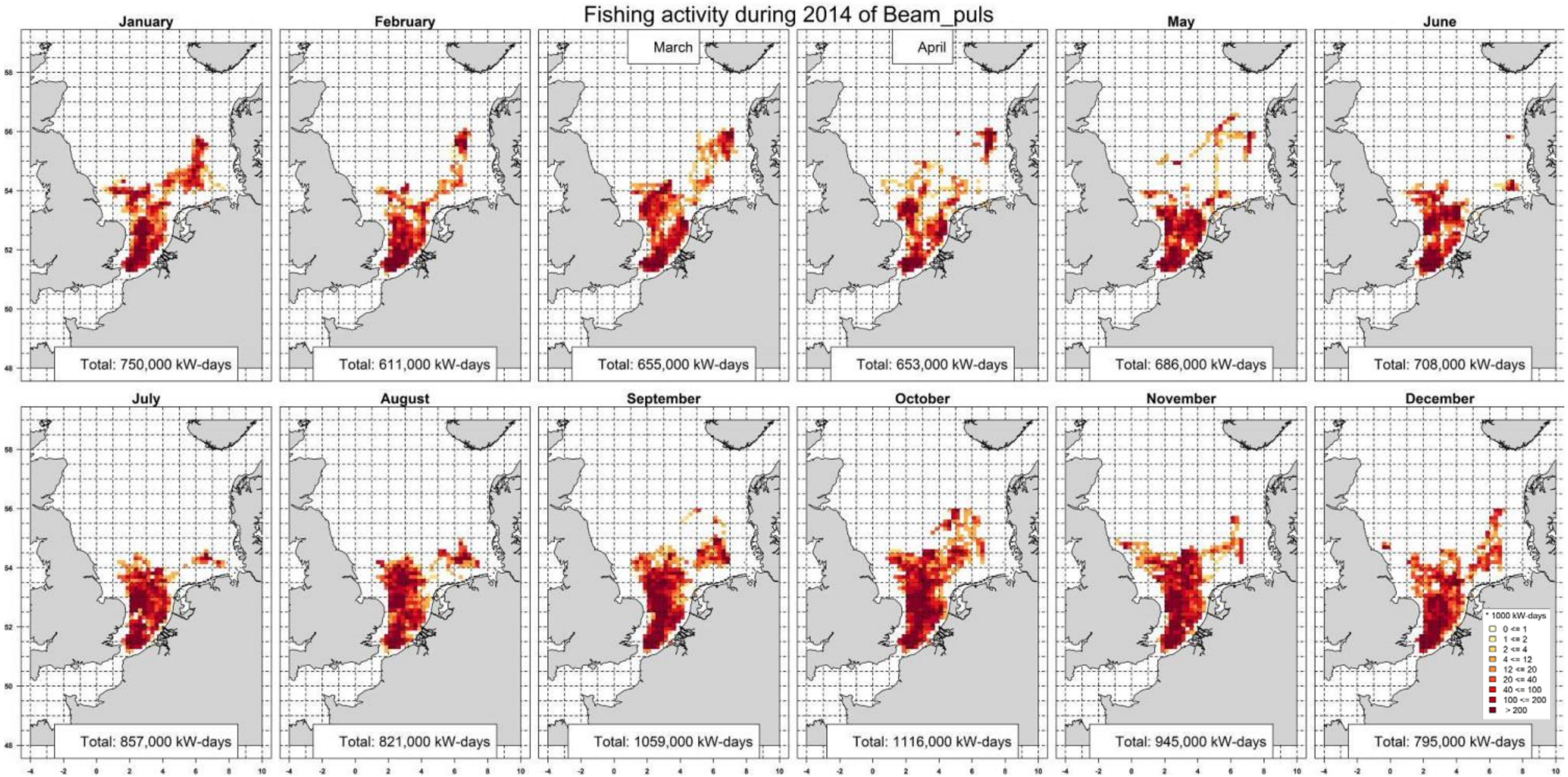

Figure D2. *Fishing activity (in *1000 kW-days) for the beam trawls with pulse gear in 2014. Colour index is similar to Figure 1.*

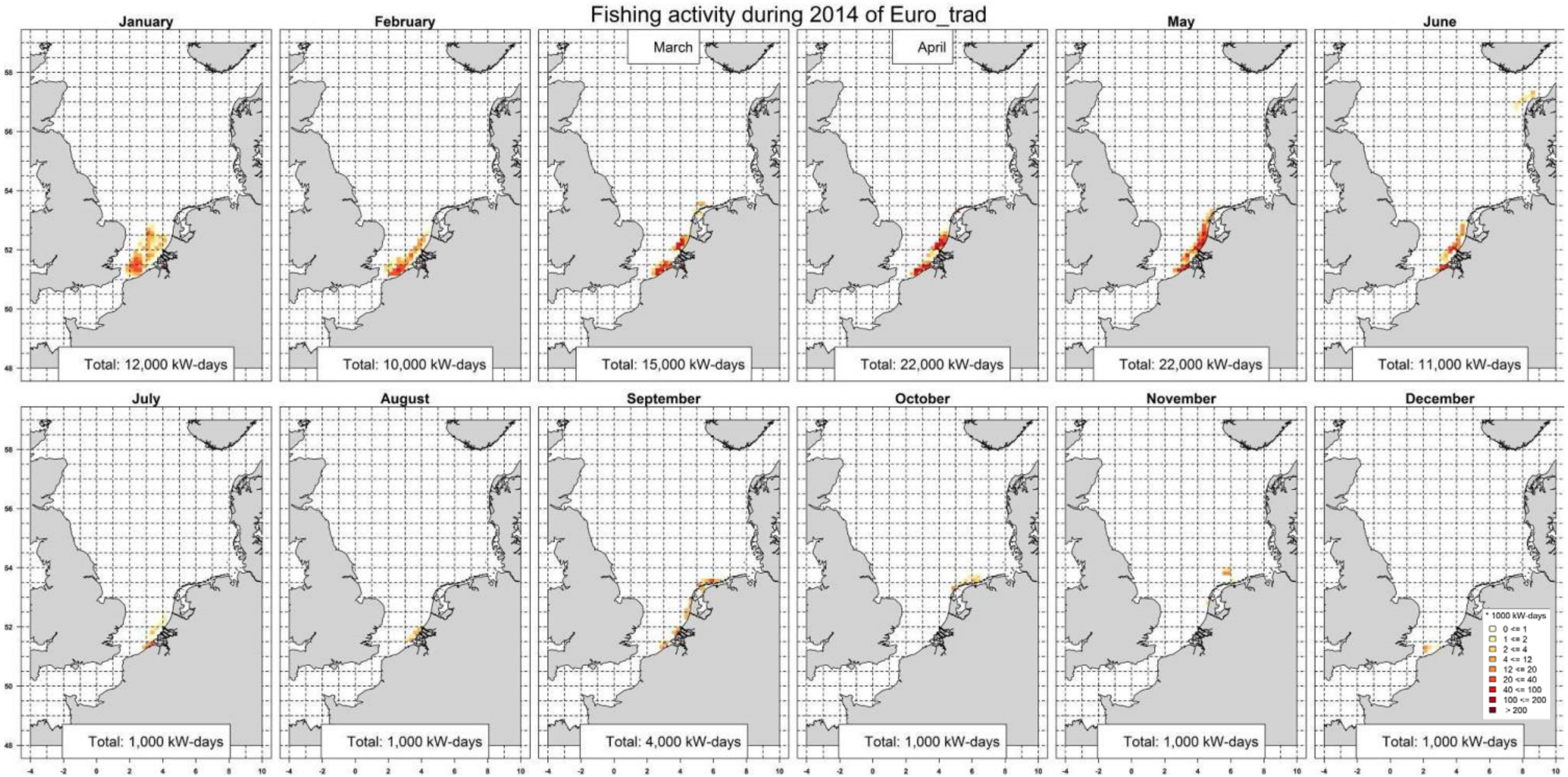

Figure D3. *Fishing activity (in *1000 kW-days) for the Eurocutters with traditional gear in 2014. Colour index is similar to Figure 1.*

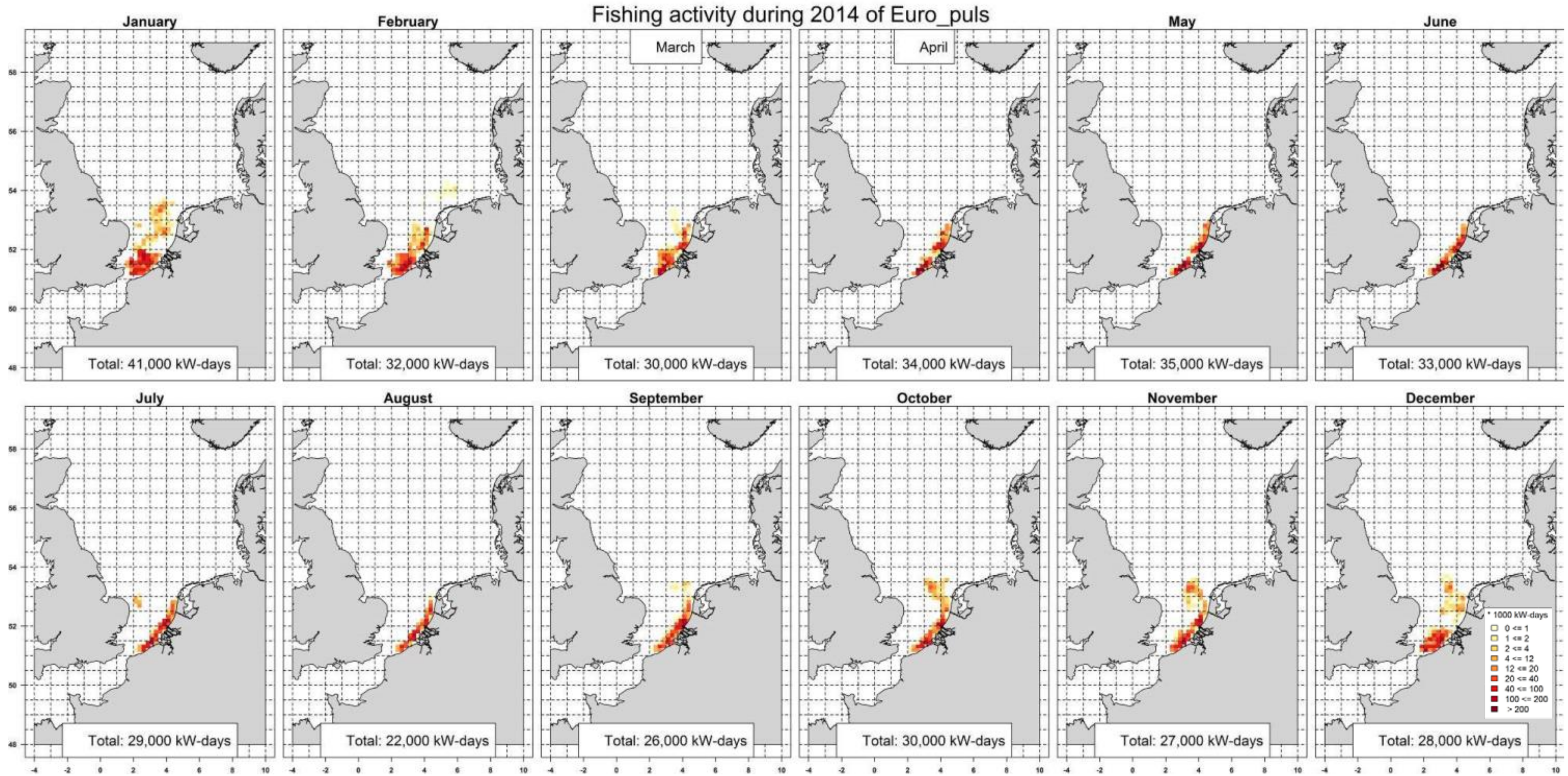

Figure D4. *Fishing activity (in *1000 kW-days) for the Eurocutters with pulse gear in 2014. Colour index is similar to Figure 1.*

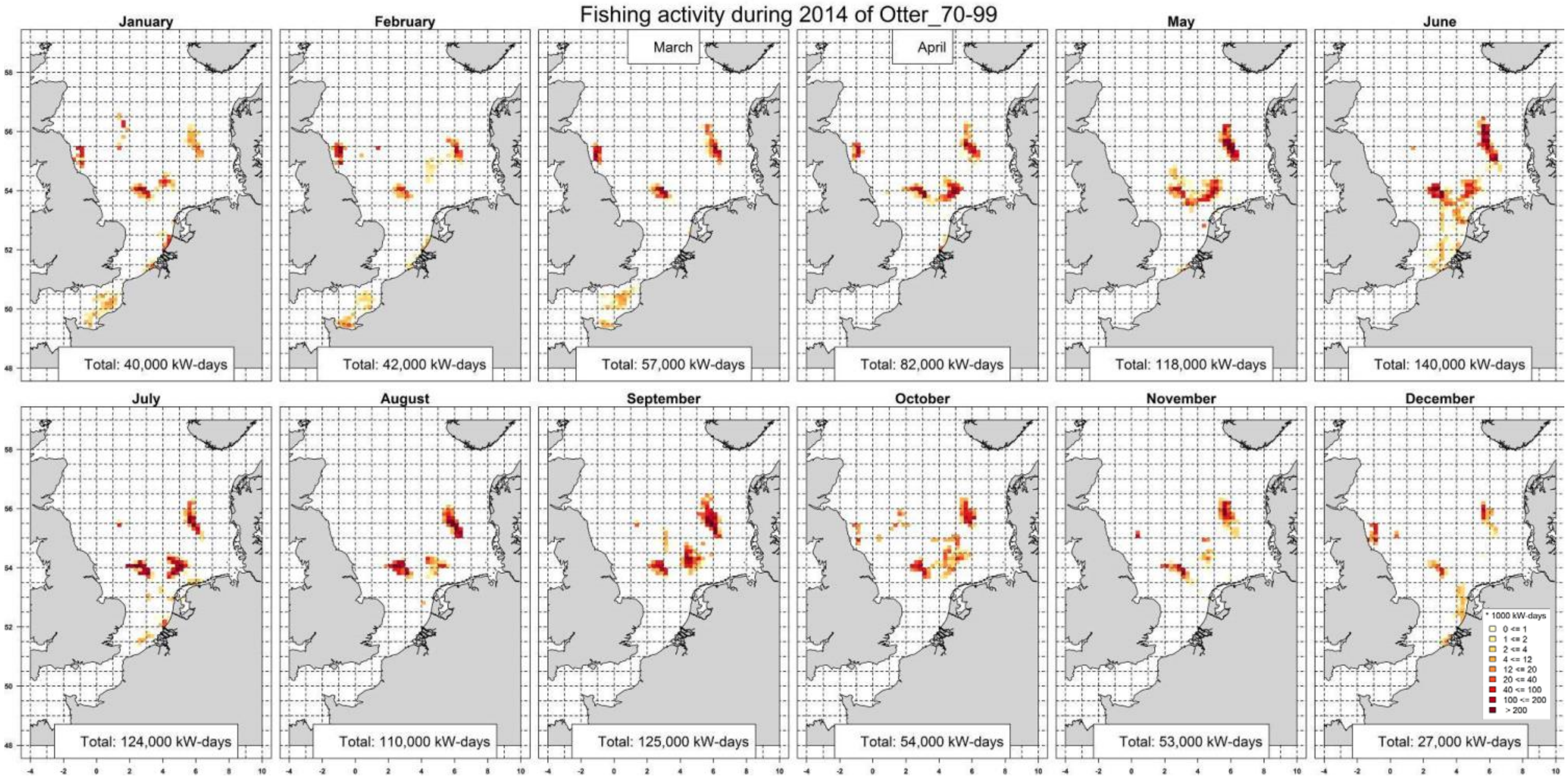

Figure D5. *Fishing activity (in *1000 kW-days) for the otter trawls with mesh sizes of 70-99mm in 2014. Colour index is similar to Figure 1.*

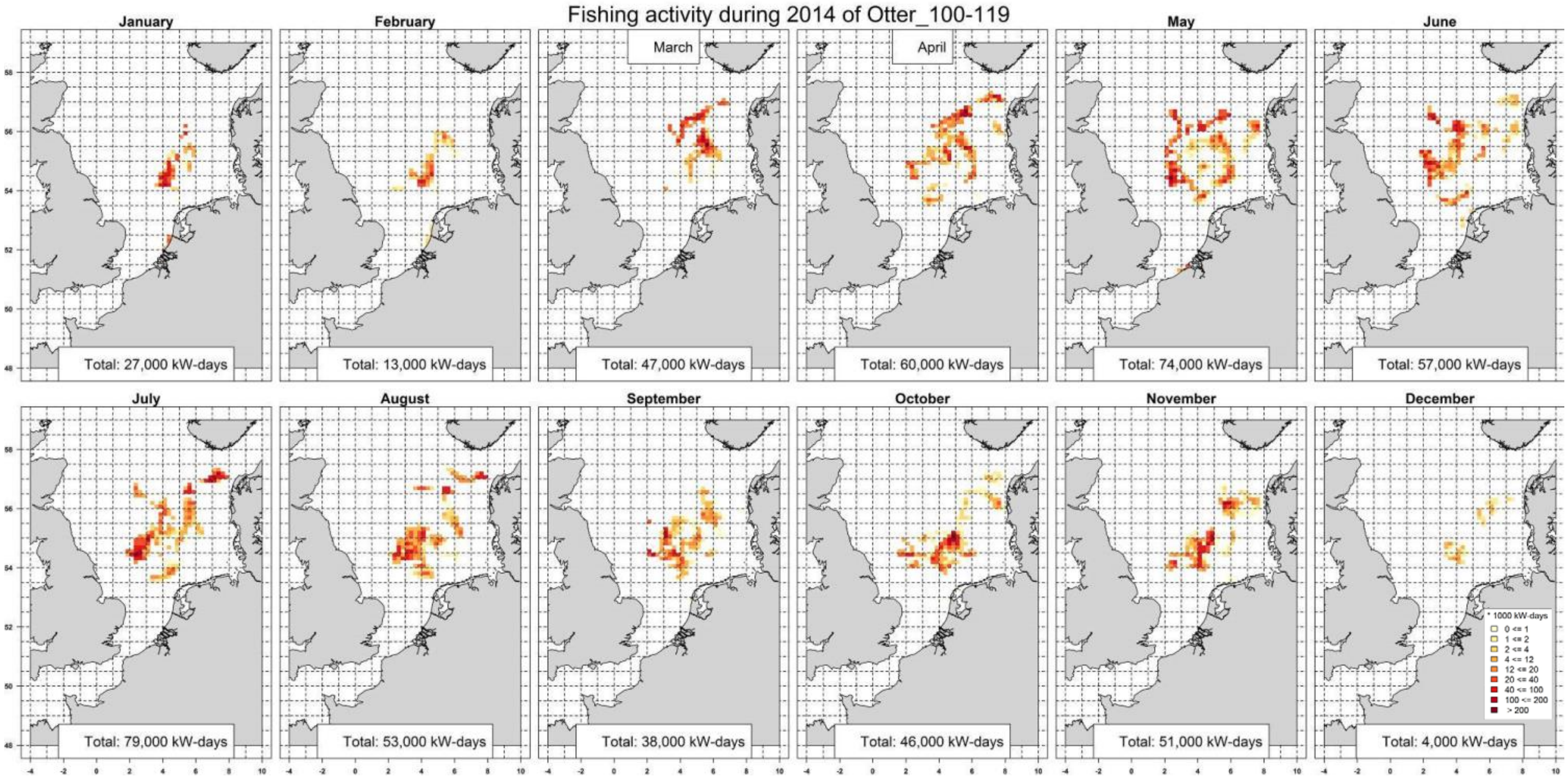

Figure D6. *Fishing activity (in *1000 kW-days) for the otter trawls with mesh sizes of 100-119mm in 2014. Colour index is similar to Figure 1.*

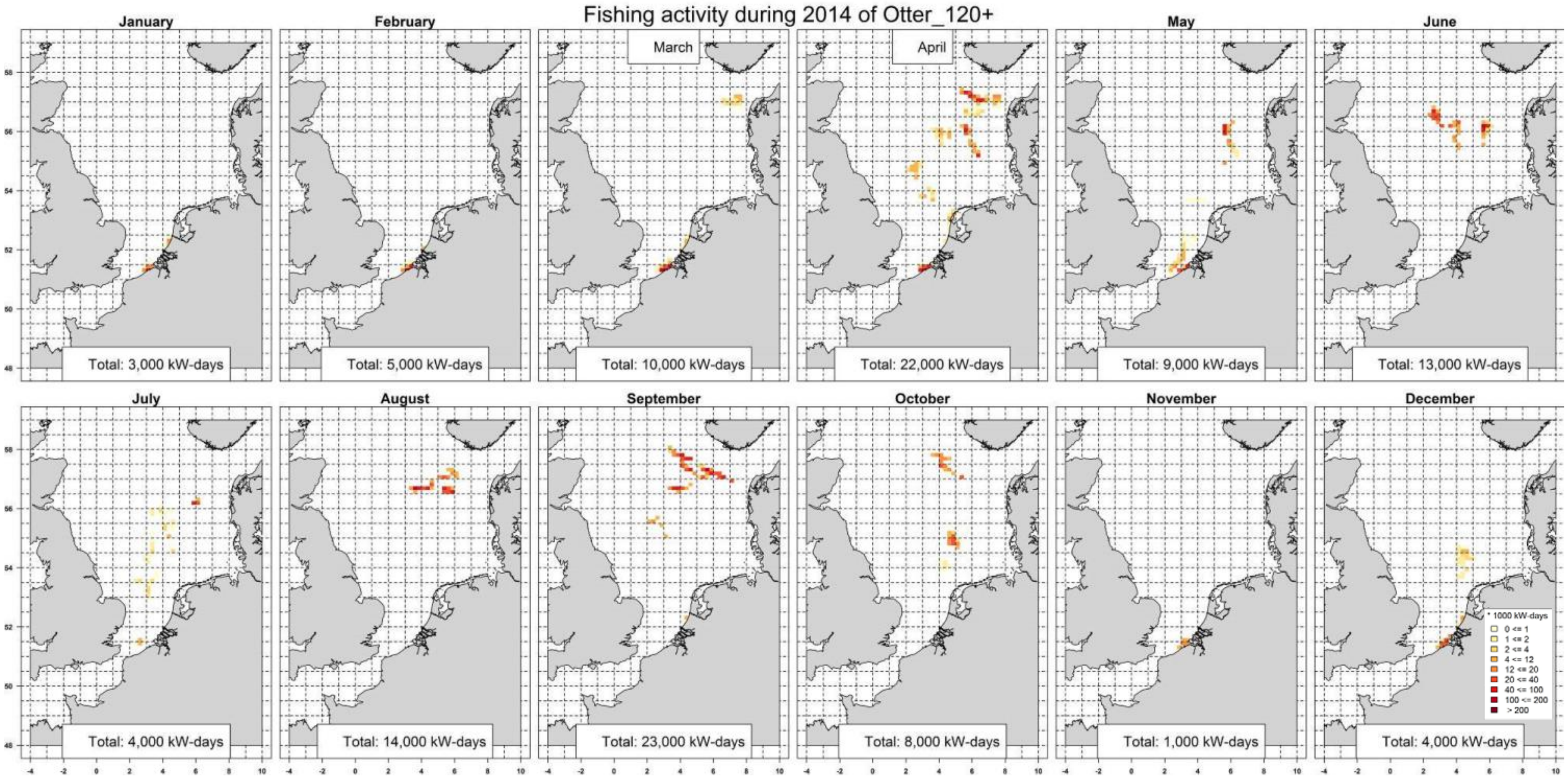

Figure D7. *Fishing activity (in *1000 kW-days) for the otter trawls with mesh sizes of 120+mm in 2014. Colour index is similar to Figure 1.*

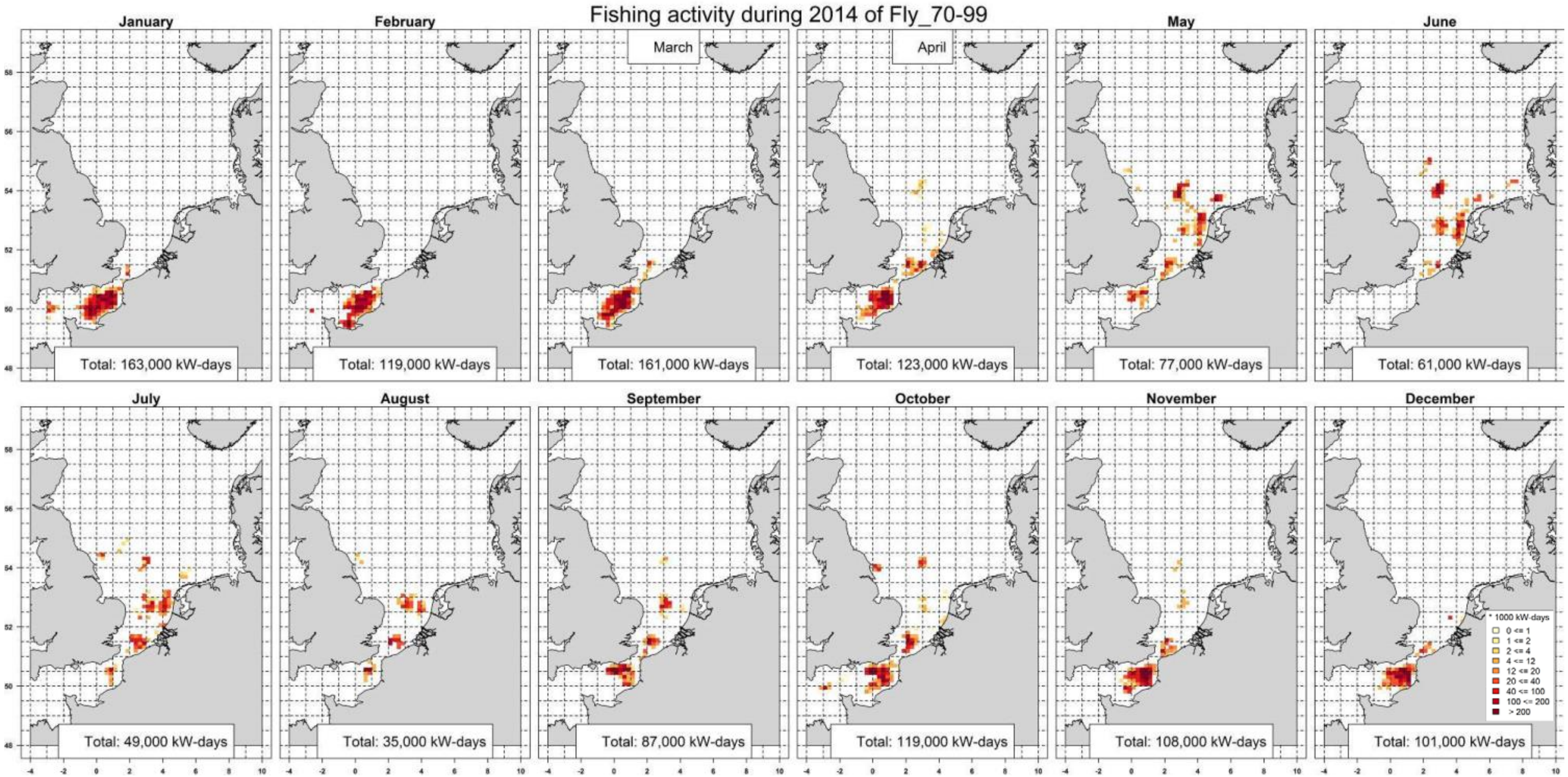

Figure D8. *Fishing activity (in *1000 kW-days) for the flyshooters with mesh sizes of 70-99mm in 2014. Colour index is similar to Figure 1.*

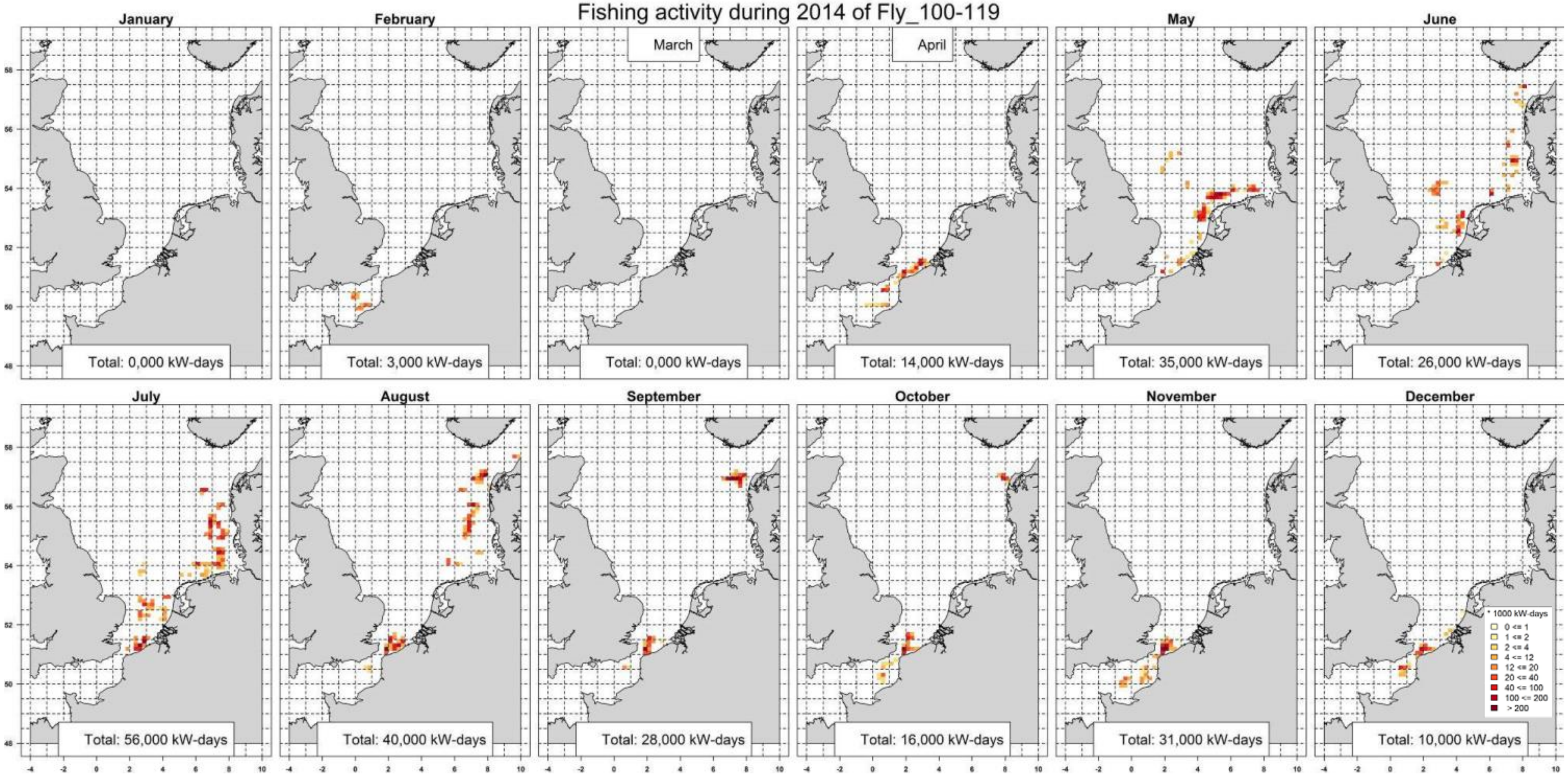

Figure D9. *Fishing activity (in *1000 kW-days) for the flyshooters with mesh sizes of 100-119mm in 2014. Colour index is similar to Figure 1.*

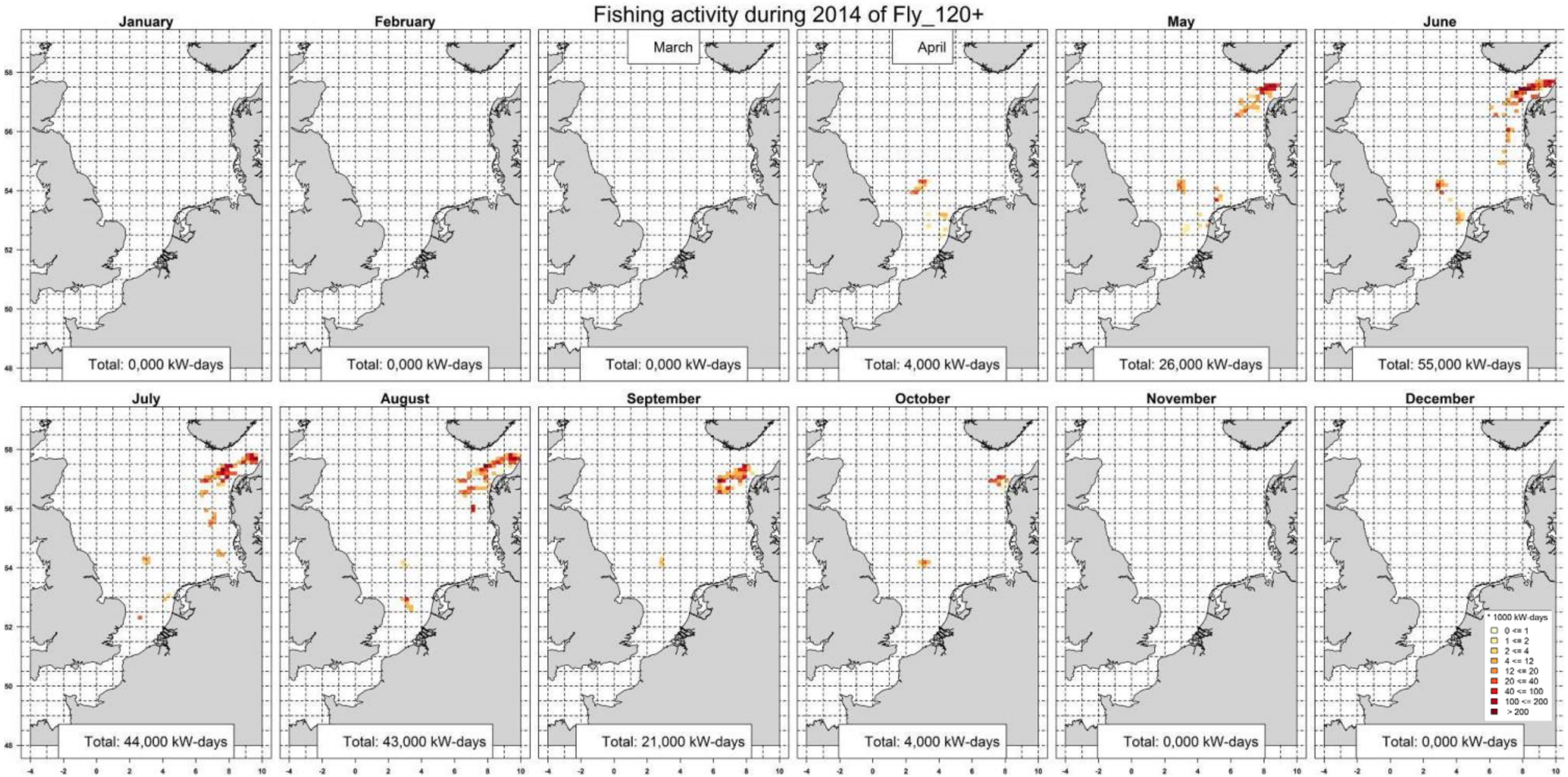

Figure D10. *Fishing activity (in *1000 kW-days) for the flyshooters with mesh sizes of 120+mm in 2014. Colour index is similar to Figure 1.*

Appendix E. Monthly cod landings for the ten gear types

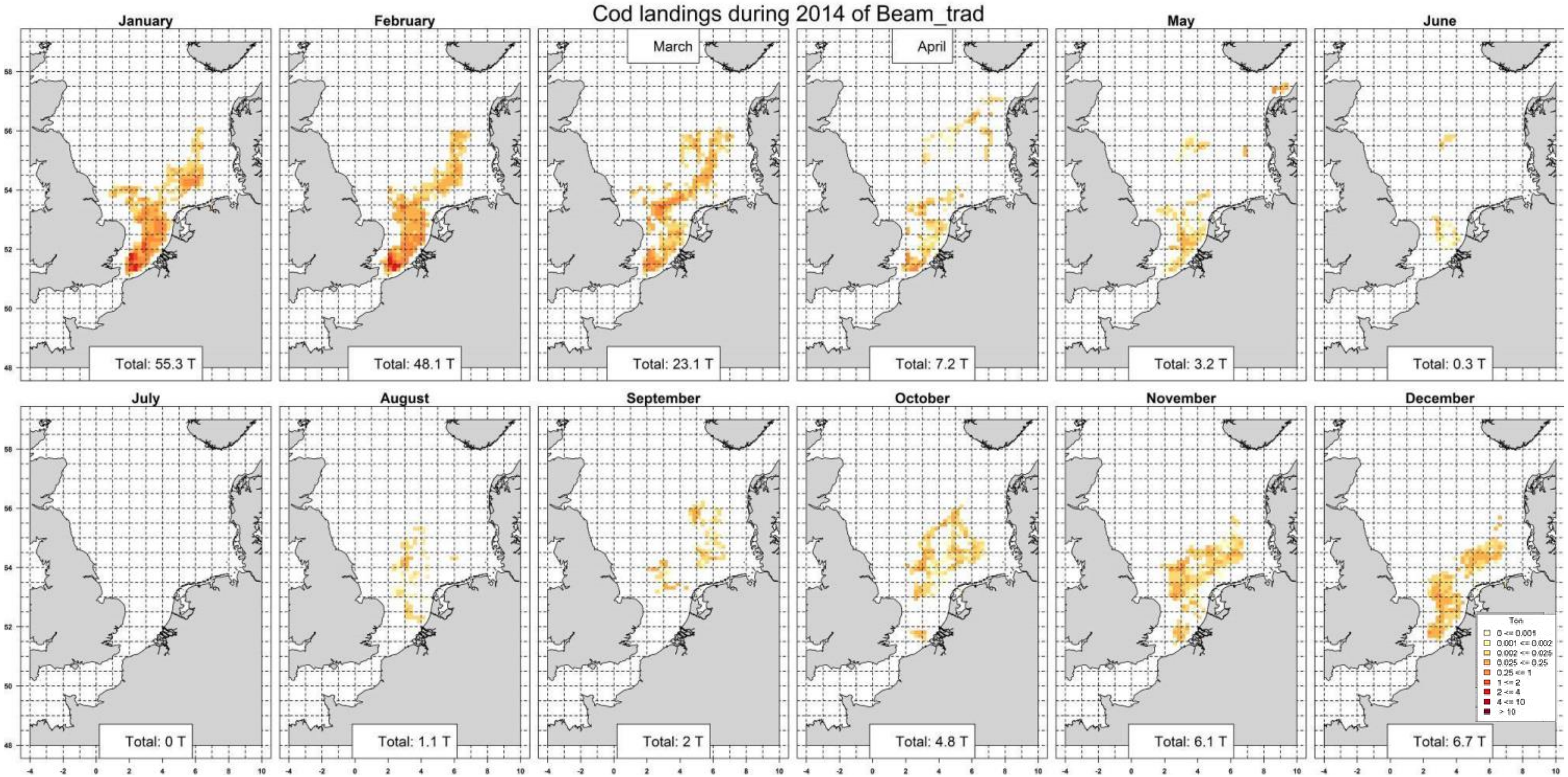

Figure E1. *Cod landings (in Ton) for the beam trawls with traditional gear in 2014. Colour index is similar to Figure 3.*

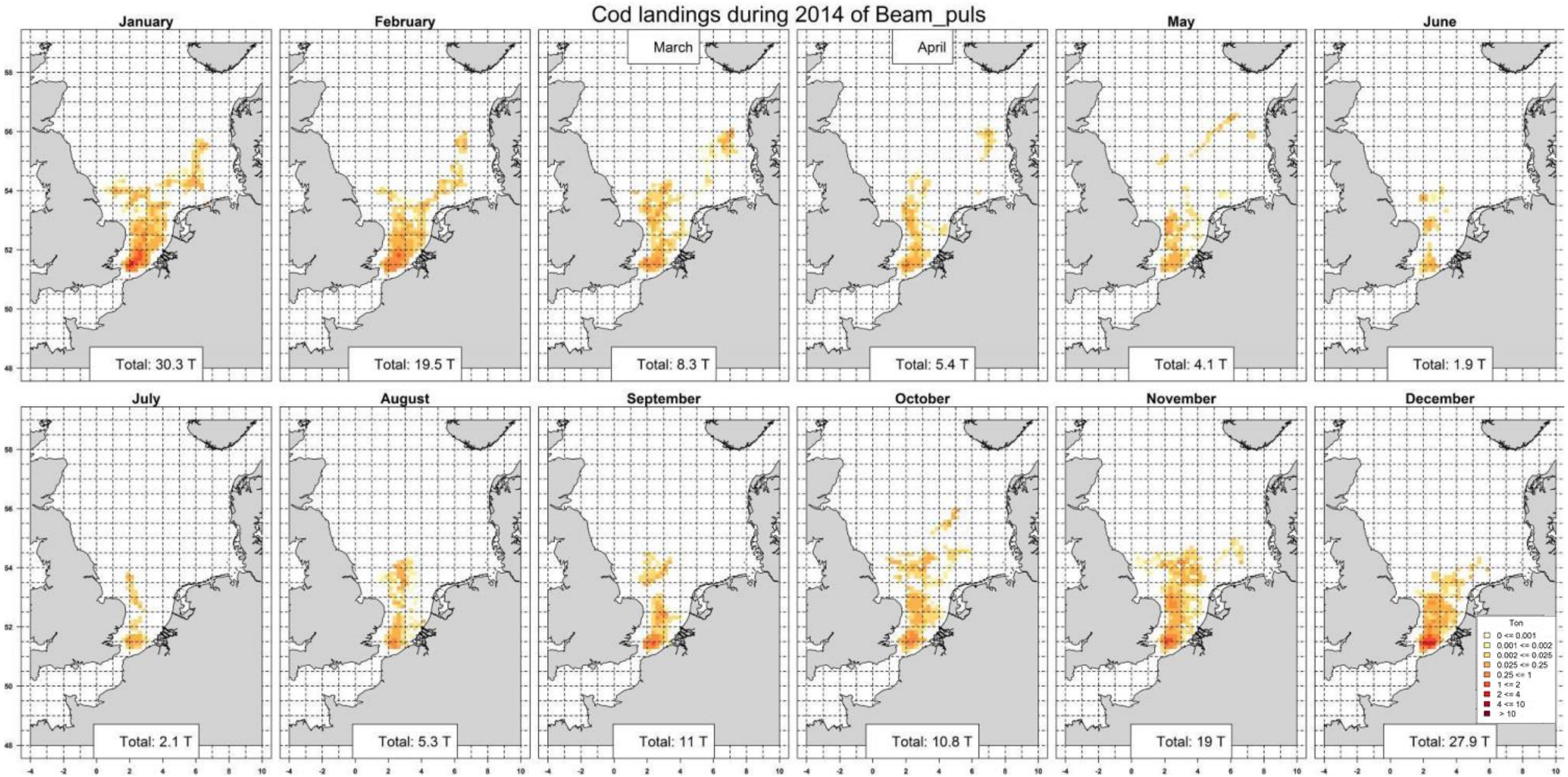

Figure E2. *Cod landings (in Ton) for the beam trawls with pulse gear in 2014. Colour index is similar to Figure 3.*

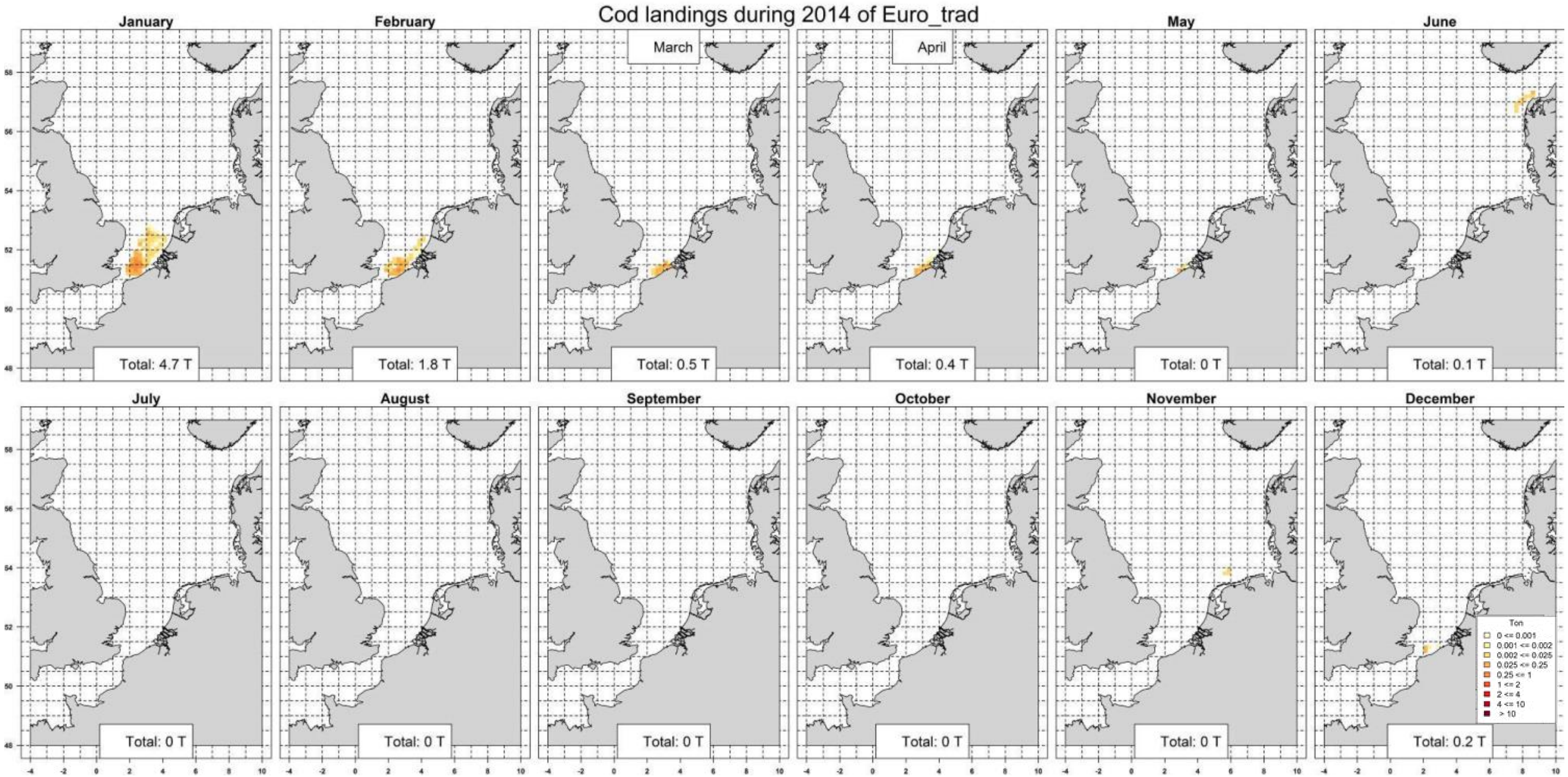

Figure E3. *Cod landings (in Ton) for the Eurocutters with traditional gear in 2014. Colour index is similar to Figure 3.*

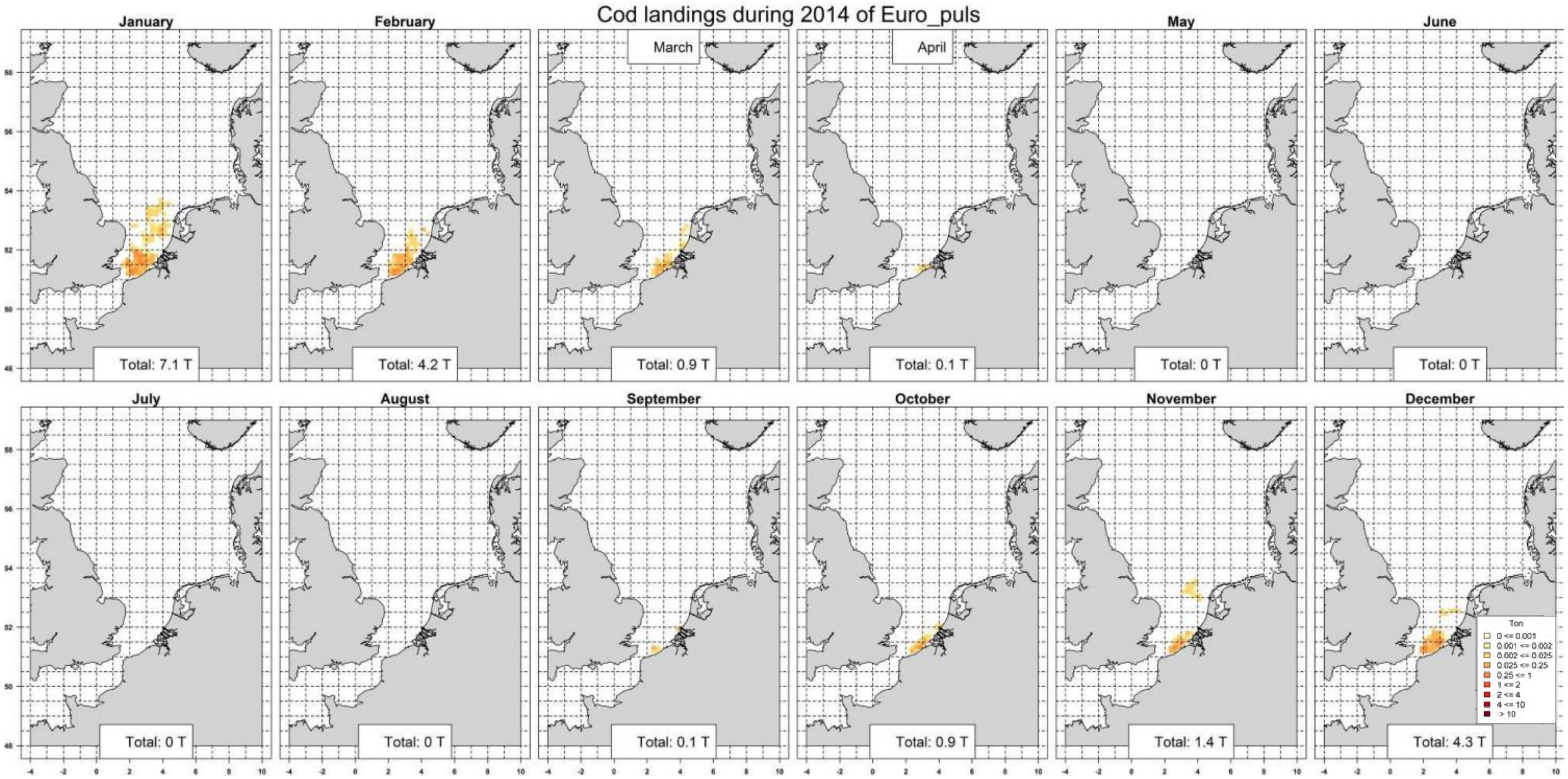

Figure E4. *Cod landings (in Ton) for the Eurocutters with pulse gear in 2014. Colour index is similar to Figure 3.*

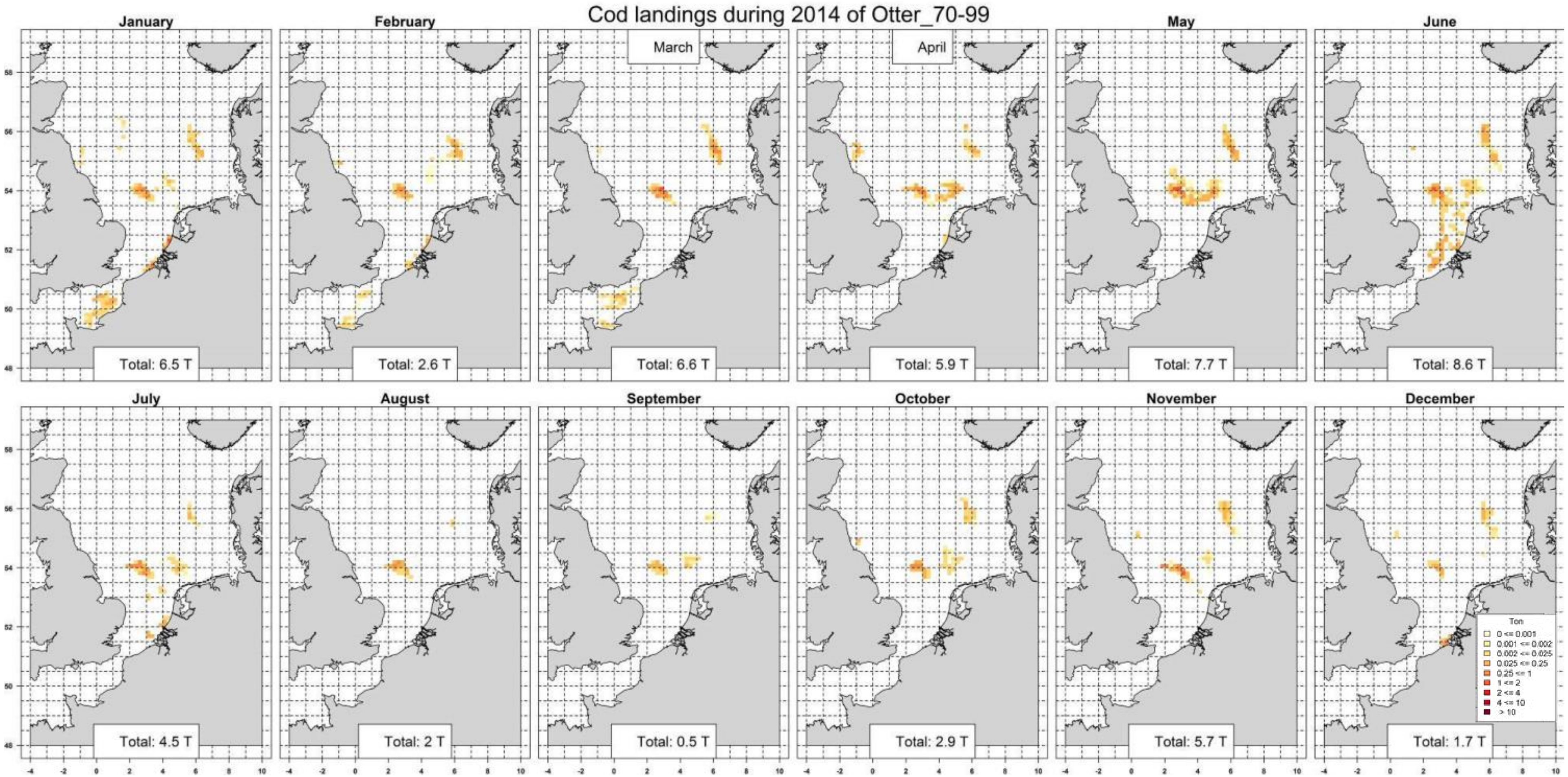

Figure E5. *Cod landings (in Ton) for the otter trawls with mesh sizes of 70-99mm gear in 2014. Colour index is similar to Figure 3.*

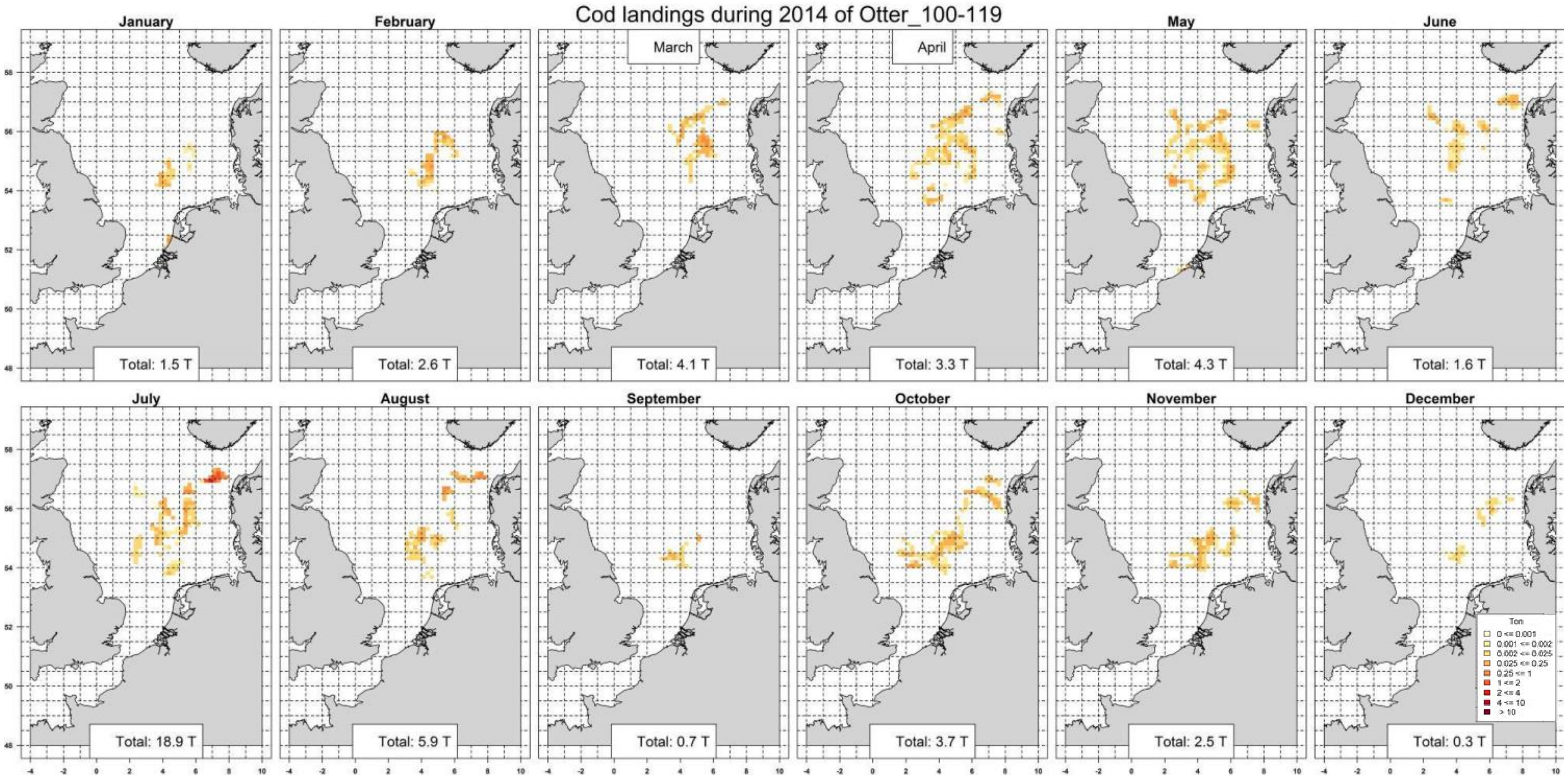

Figure E6. *Cod landings (in Ton) for the otter trawls with mesh sizes of 100-119mm gear in 2014. Colour index is similar to Figure 3.*

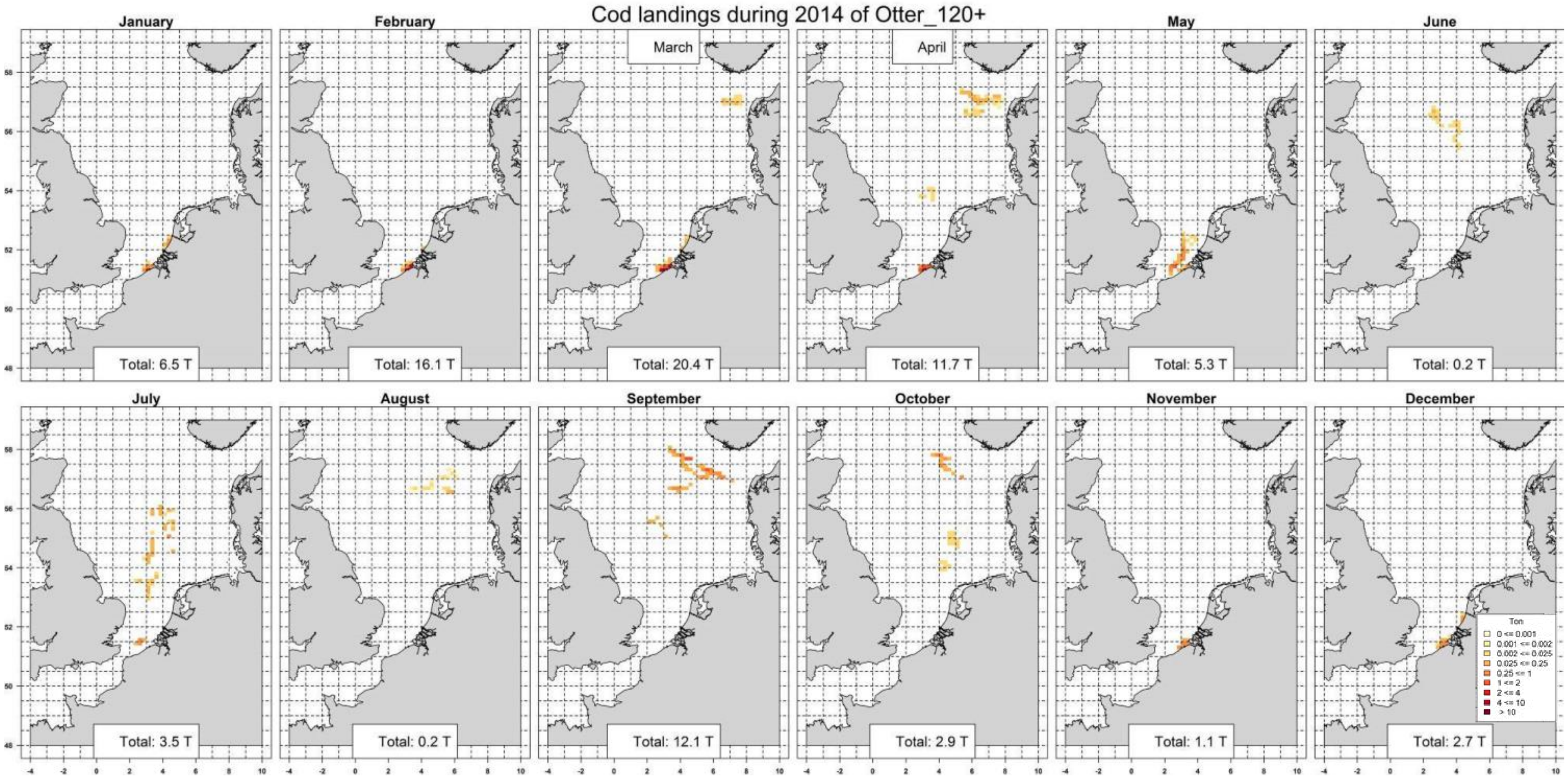

Figure E7. *Cod landings (in Ton) for the otter trawls with mesh sizes of 120+mm gear in 2014. Colour index is similar to Figure 3.*

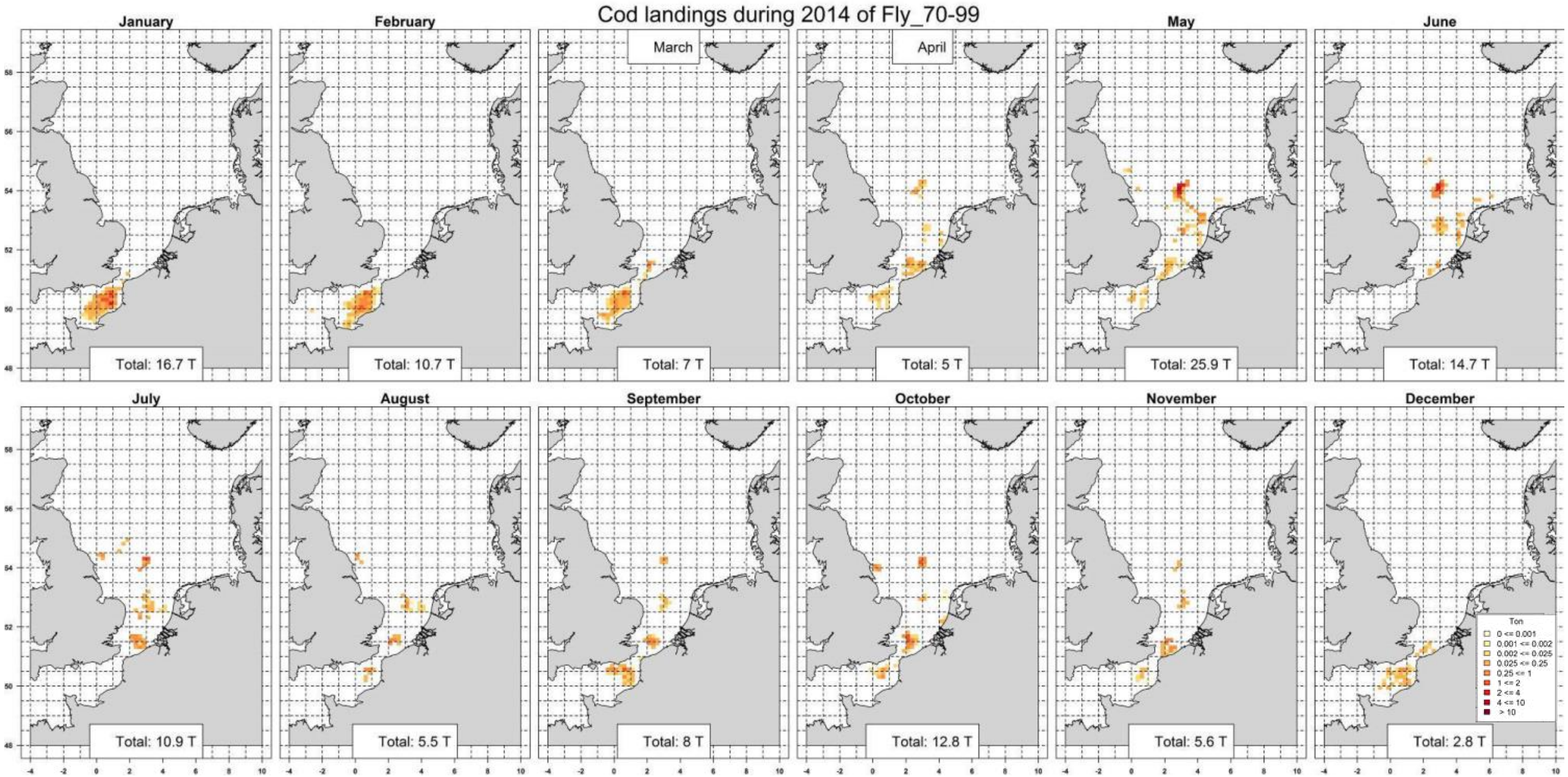

Figure E8. *Cod landings (in Ton) for the flyshooters with mesh sizes of 70-99mm gear in 2014. Colour index is similar to Figure 3.*

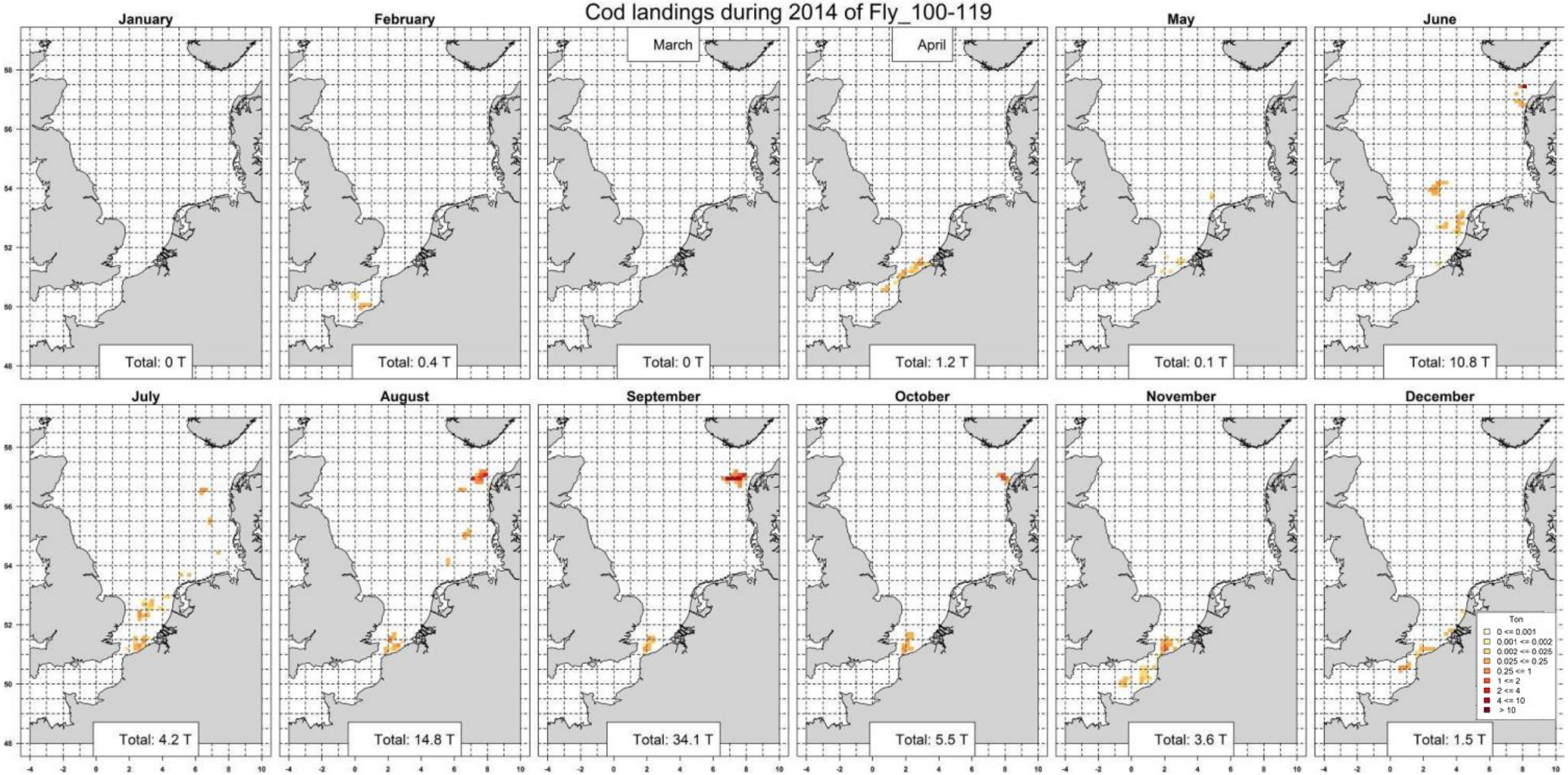

Figure E9. *Cod landings (in Ton) for the flyshooters with mesh sizes of 100-119mm gear in 2014. Colour index is similar to Figure 3.*

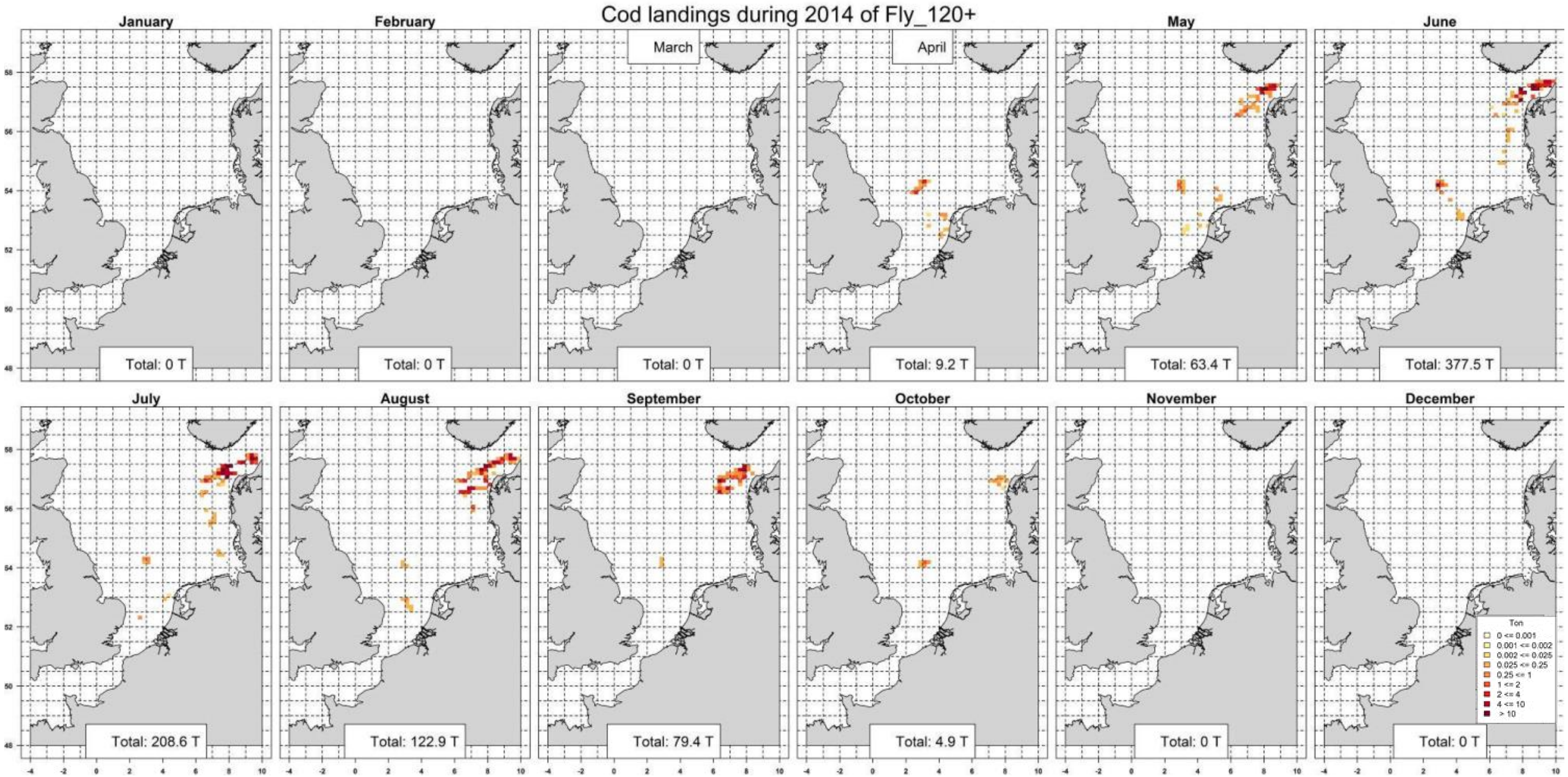

Figure E10. *Cod landings (in Ton) for the flyshooters with mesh sizes of 120+mm gear in 2014. Colour index is similar to Figure 3.*

Appendix F. Fishing activity for the ten gear types in 2011-2012 and 2013-2014.

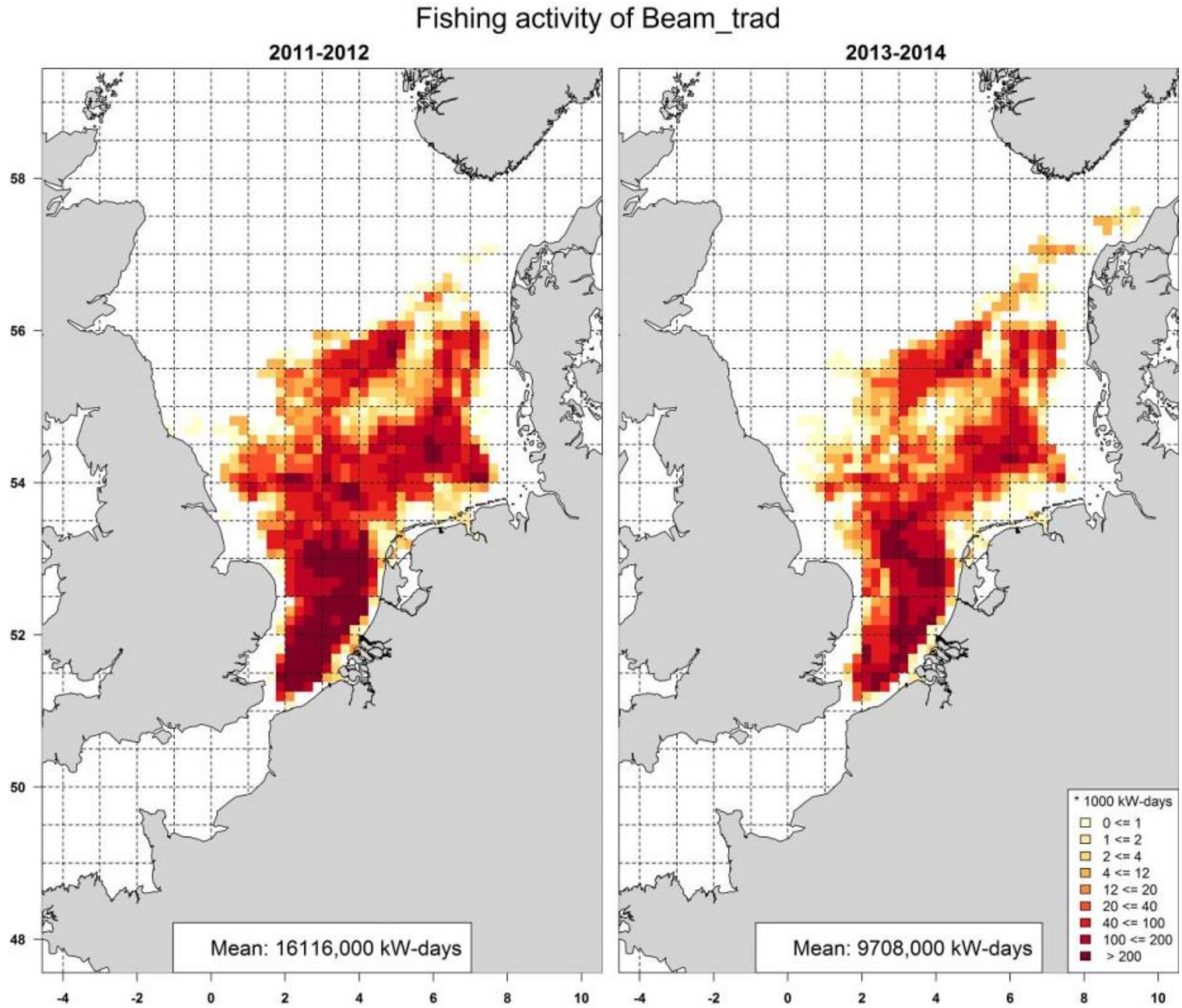

Figure F1. *Average fishing activity (in *1000 kW-days) for the beam trawl fleet with traditional gears in 2011-2012 and 2013-2014.*

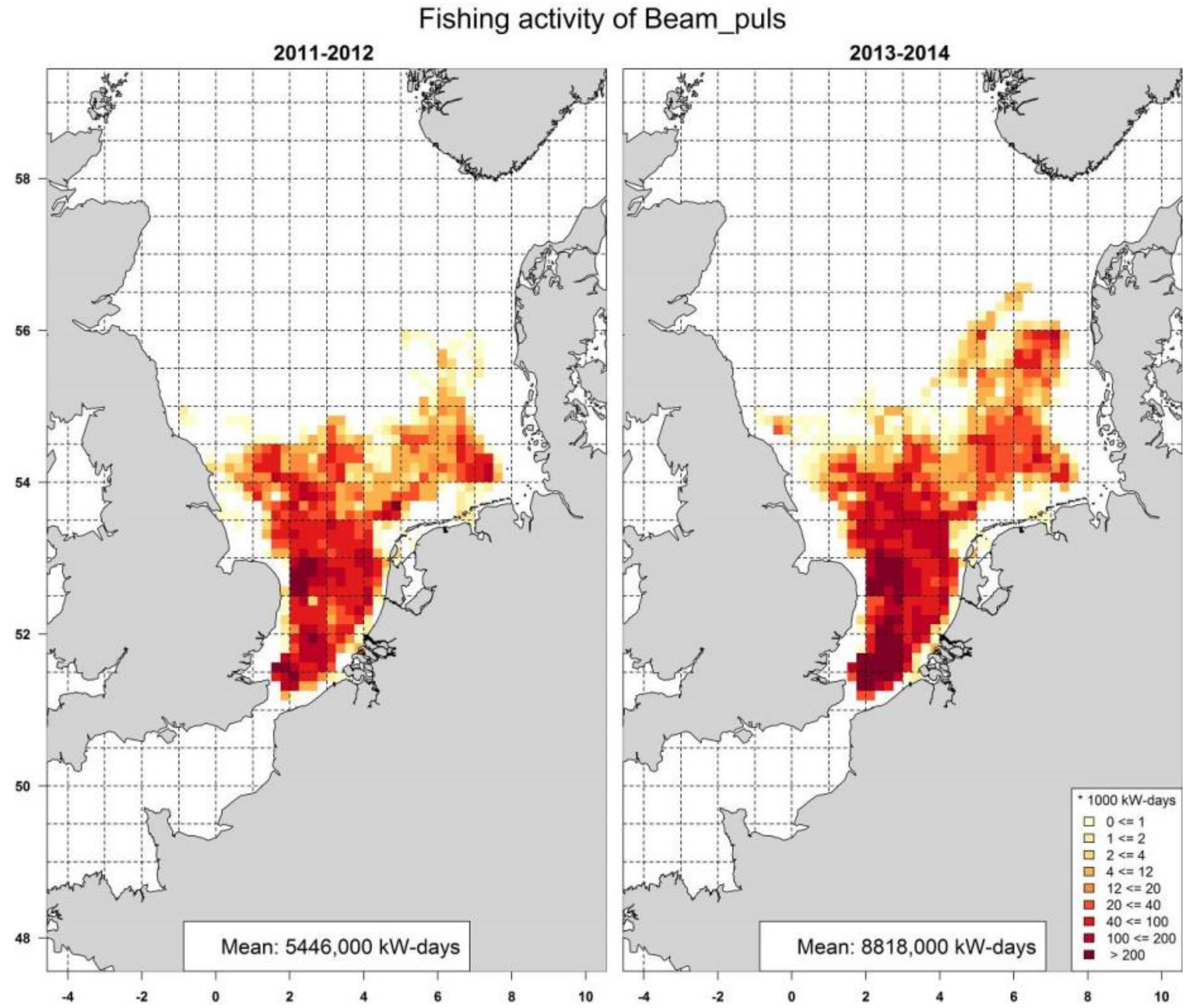

Figure F2. *Average fishing activity (in *1000 kW-days) for the beam trawl fleet with pulse gears in 2011-2012 and 2013-2014.*

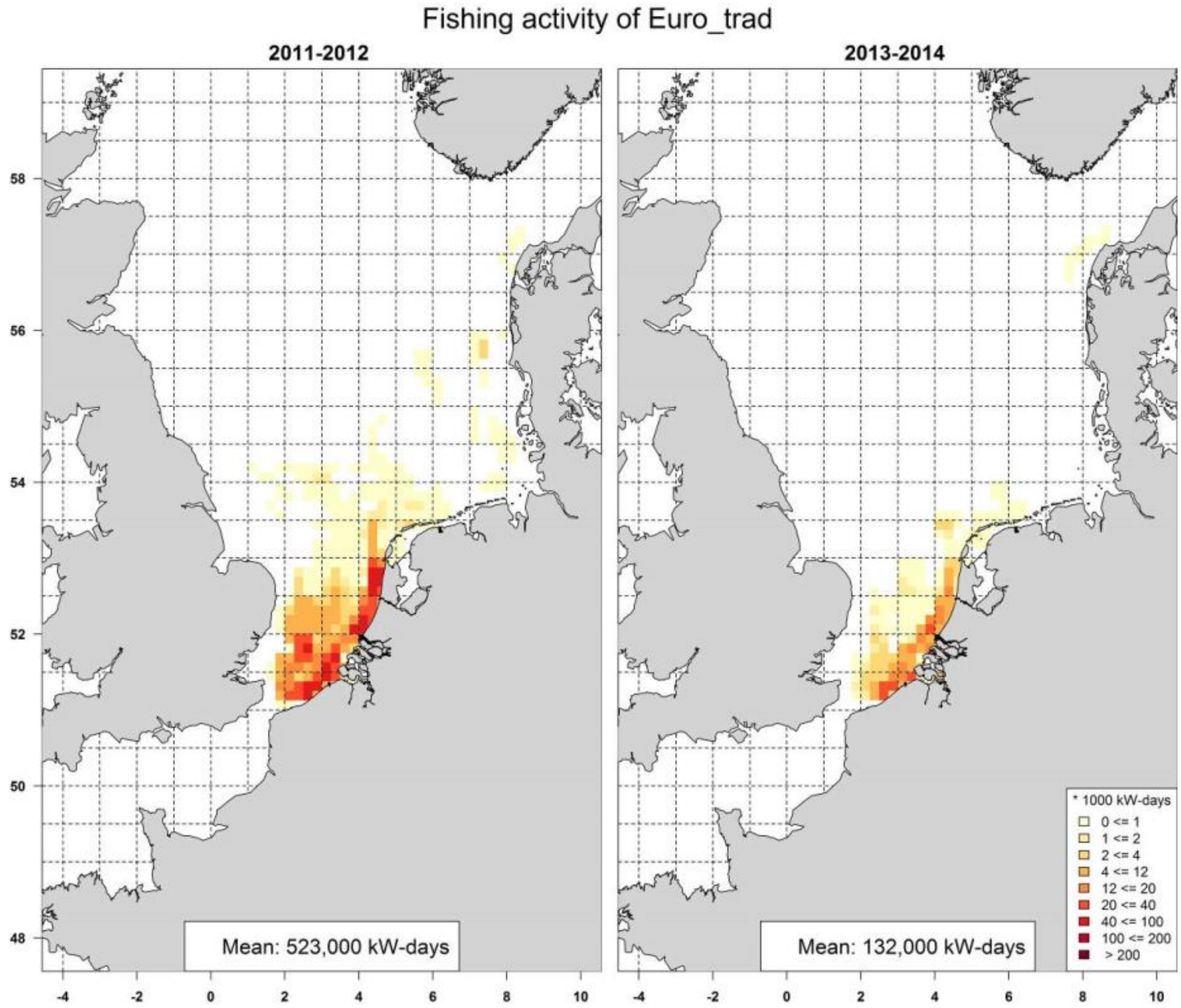

Figure F3. *Average fishing activity (in *1000 kW-days) for the Eurocutter trawl fleet with traditional gears in 2011-2012 and 2013-2014.*

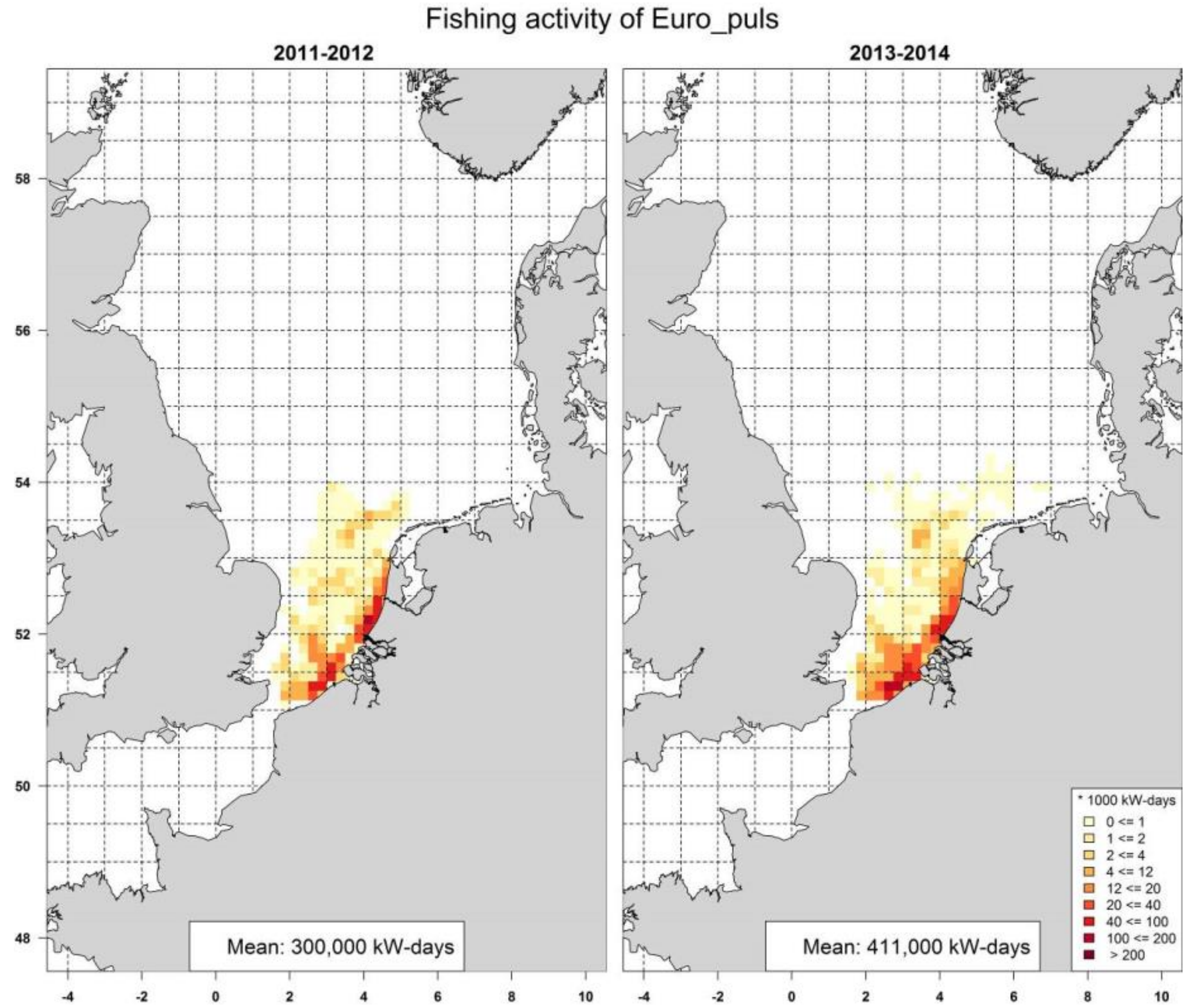

Figure F4. *Average fishing activity (in *1000 kW-days) for the Eurocutter trawl fleet with pulse gears in 2011-2012 and 2013-2014.*

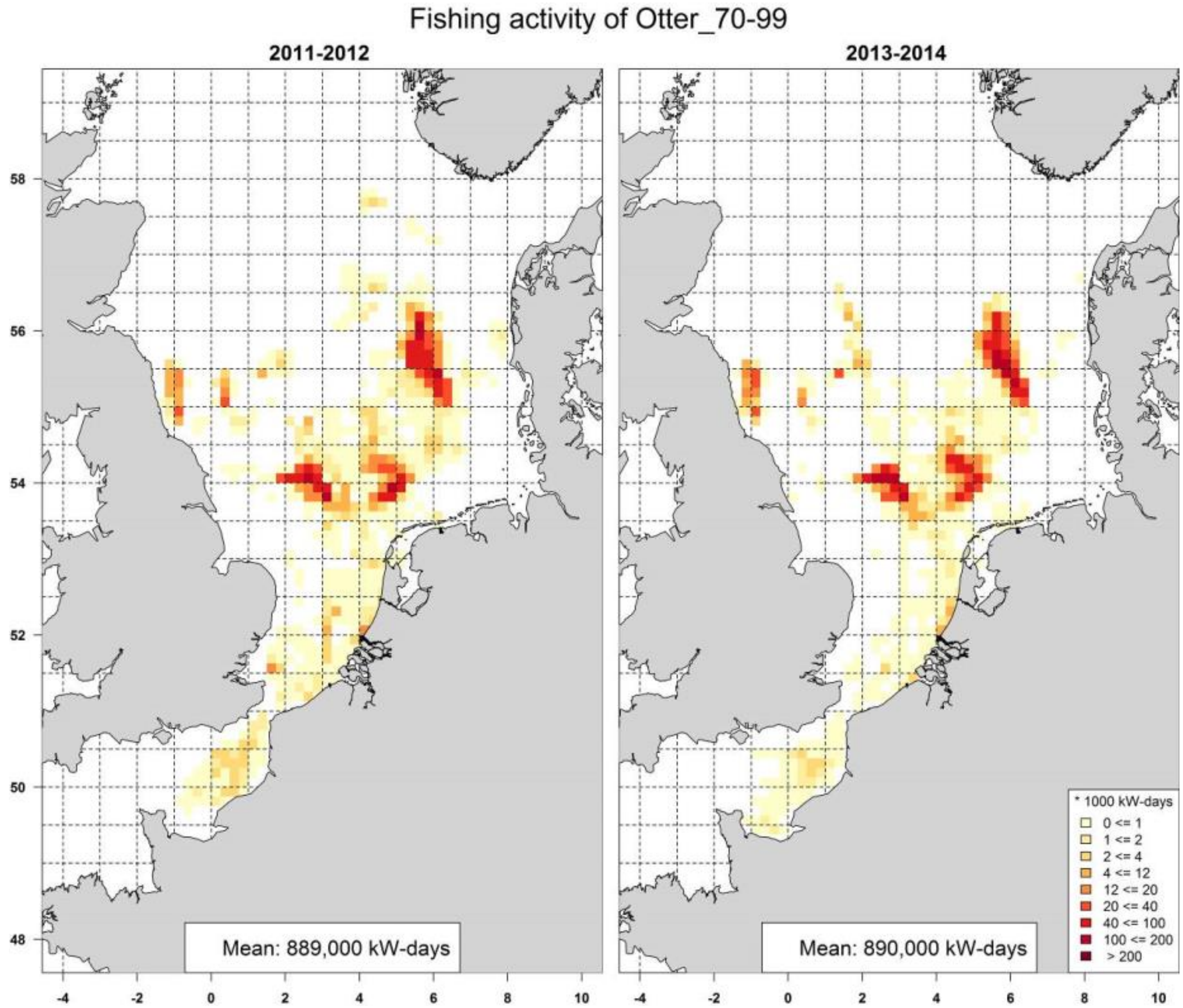

Figure F5. *Average fishing activity (in *1000 kW-days) for the otter trawl fleet with mesh sizes of 70-99mm in 2011-2012 and 2013-2014.*

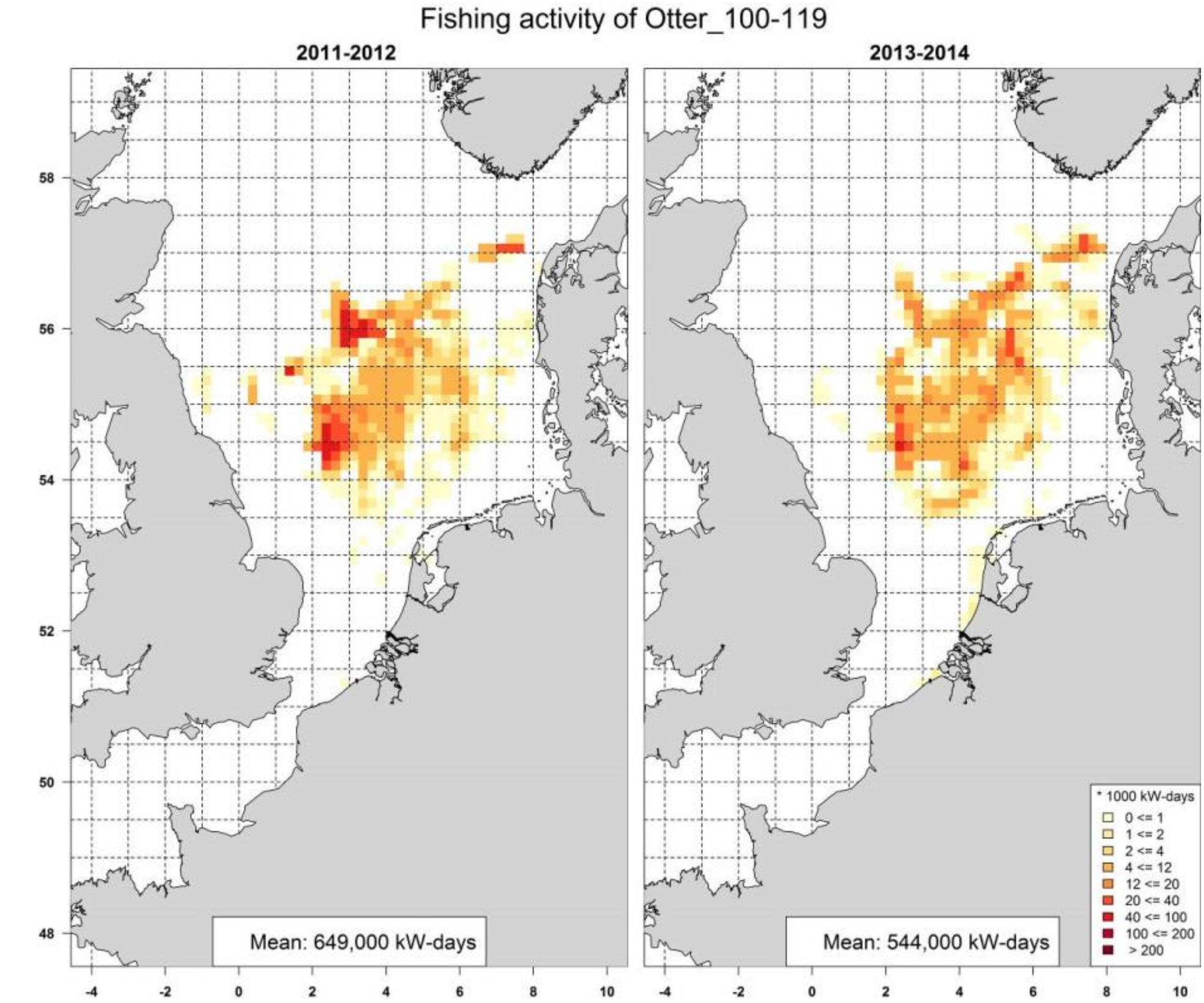

Figure F6. *Average fishing activity (in *1000 kW-days) for the otter trawl fleet with mesh sizes of 100-119mm in 2011-2012 and 2013-2014.*

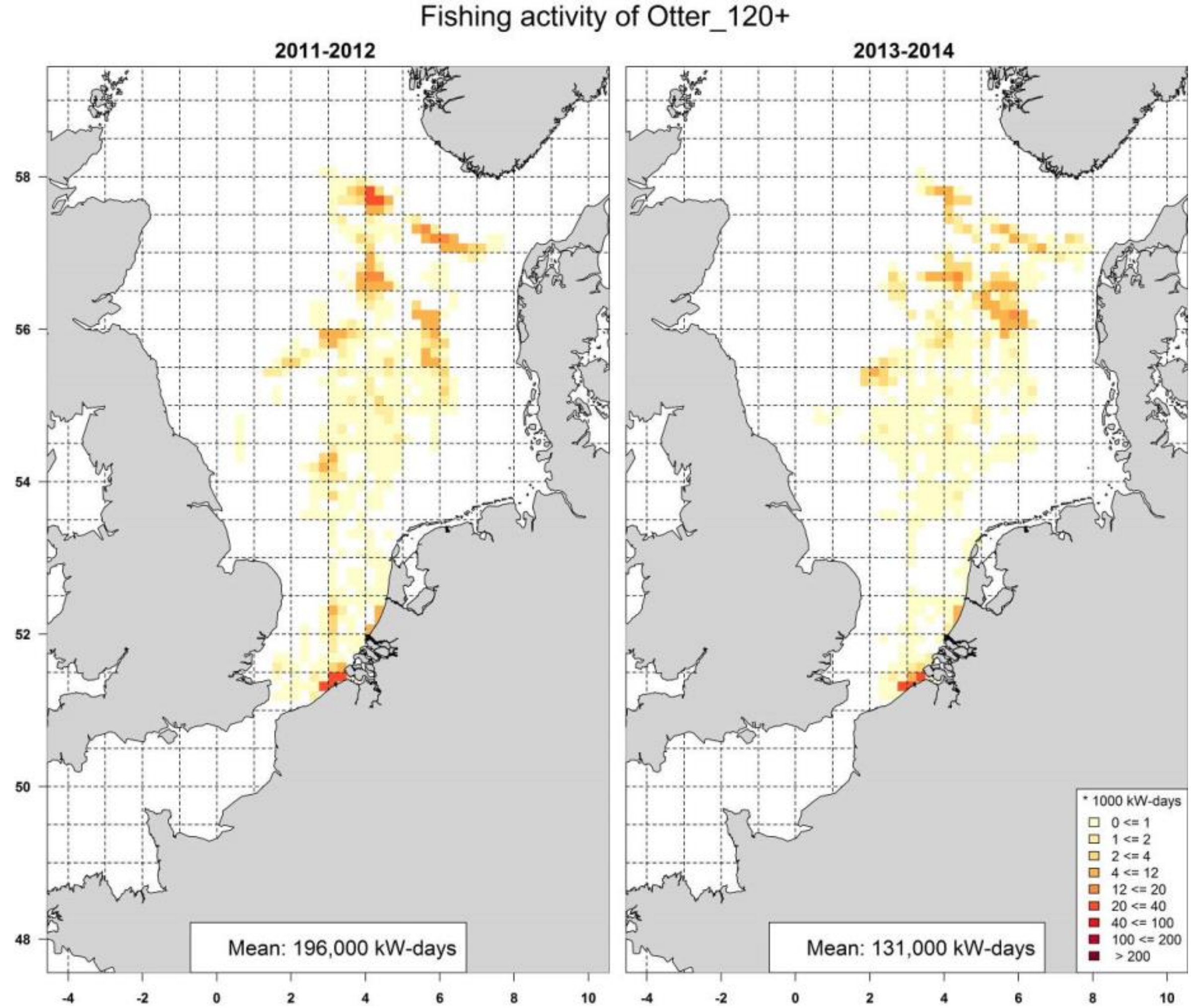

Figure F7. *Average fishing activity (in *1000 kW-days) for the otter trawl fleet with mesh sizes of 120+mm in 2011-2012 and 2013-2014.*

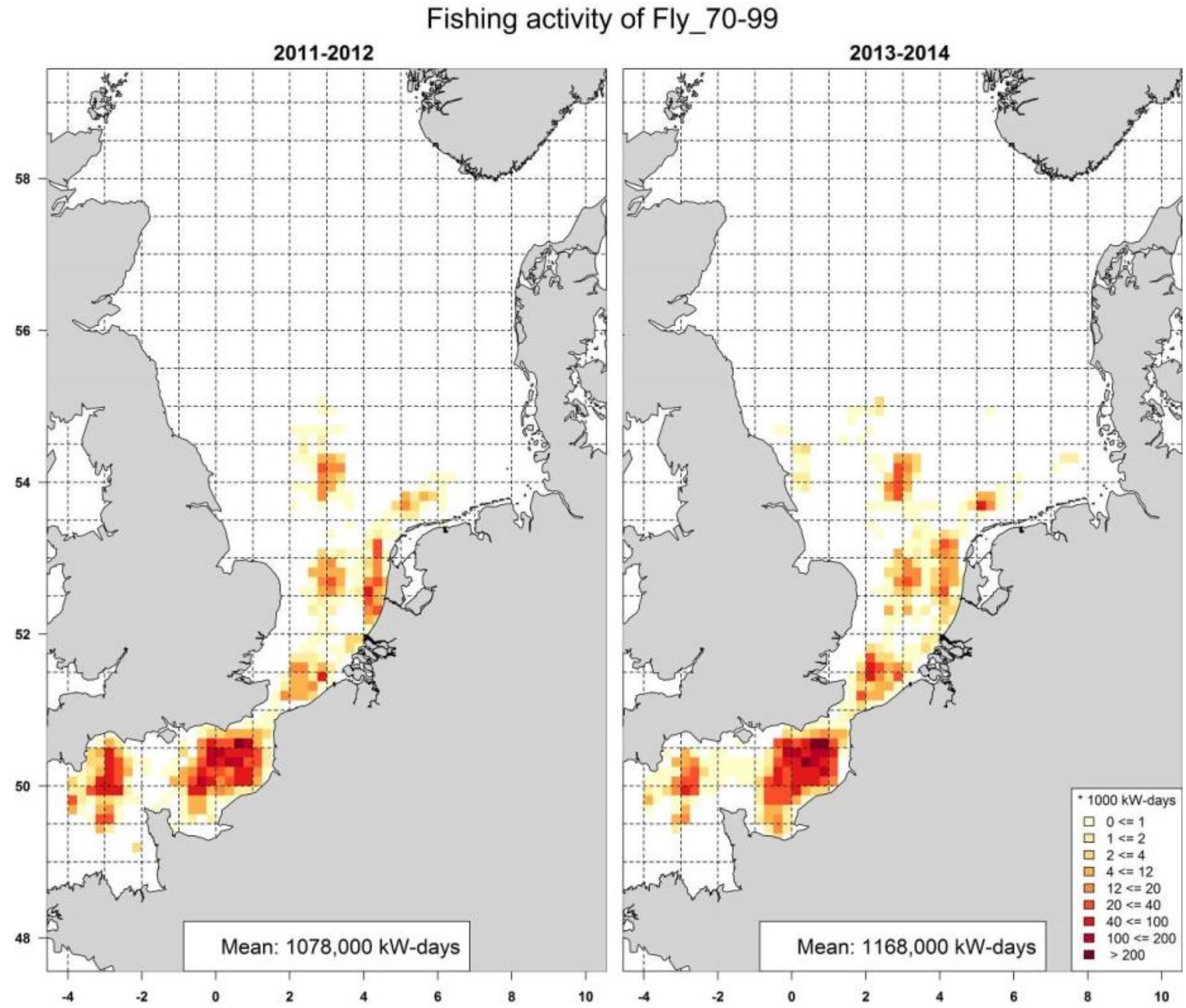

Figure F8. *Average fishing activity (in *1000 kW-days) for the flyshooter fleet with mesh sizes of 70-99mm in 2011-2012 and 2013-2014.*

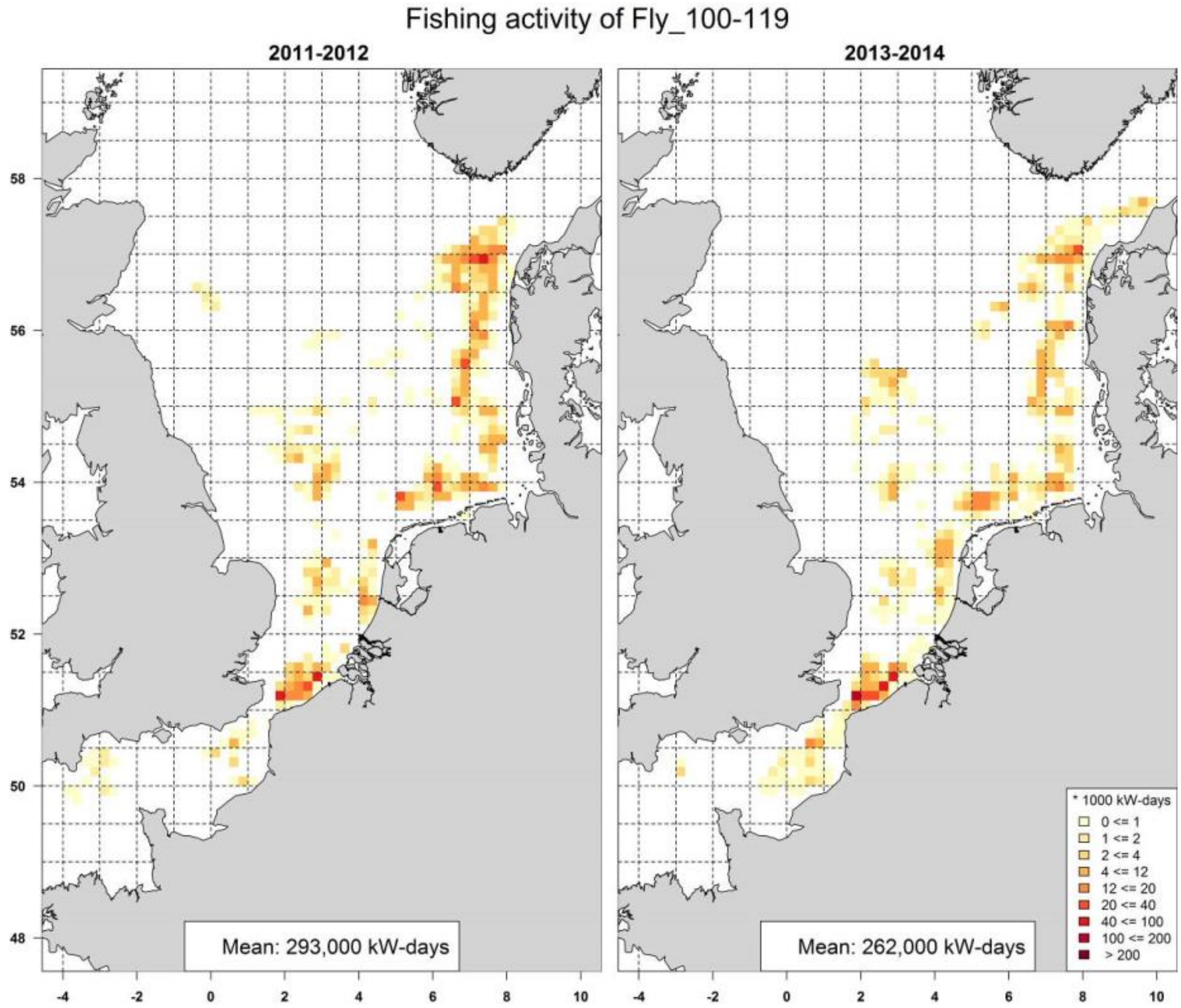

Figure F9. *Average fishing activity (in *1000 kW-days) for the flyshooter fleet with mesh sizes of 100-119mm in 2011-2012 and 2013-2014.*

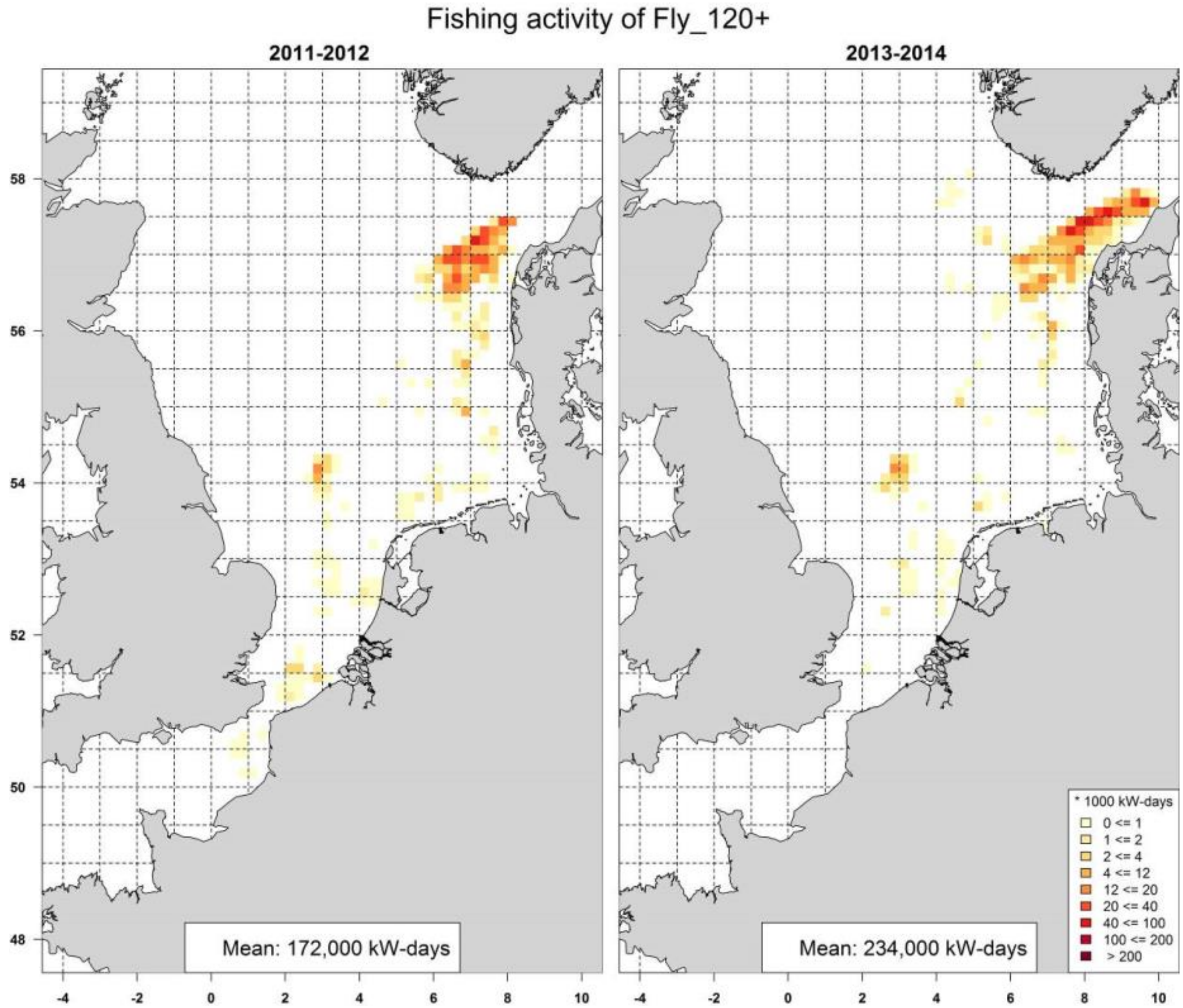

Figure F10. *Average fishing activity (in *1000 kW-days) for the flyshooter fleet with mesh sizes of 120+mm in 2011-2012 and 2013-2014.*

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The IMARES mission
- To conduct research with the aim of acquiring knowledge and offering advice on the sustainable management and use of marine and coastal areas.
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