Cefas contract report C5586

Fishing Spatio-Temporal Pressures and Sensitivities Analysis for MPAs

Report 2: Comparison of fishing information from VMS data and on-board plotter systems (Fishing Industry Collaboration Pilot)

Fishing Spatio-Temporal Pressures and Sensitivities Analysis for MPAs

Fishing Industry Collaboration Pilot

(C5586)

Milestone Report No. 2:
Comparison of fishing information from VMS data and on-board plotter systems

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Report No 2: Comparison of fishing information from VMS data and on-board plotter systems

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Executive summary

This second report for the project ‘Fishing spatio-temporal pressures and sensitivities analysis for MPAs: fishing industry collaboration pilot’ analyses 32 sets of plotter data provided by 17 vessels that fish on and around the UK portion of the Dogger Bank Special Area of Conservation (SAC). The absence of information on the dates and times that tracks recorded in the plotter data are fished means that a vessel-by-vessel comparison with VMS data cannot be undertaken. Instead the bulk plotter data are summarised to provide an indication of the spatial extent of the area that has been fished using a method to delineate the core fishing ground. Data were summarised for ‘demersal trawling’ and for ‘all other fishing’ to maintain consistency with the VMS-based analysis (see report 1) however, as information on the gears deployed was not given in the plotter data, the core grounds that were identified cannot be linked to specific fishing gears.

After initial screening to remove duplicates and other information, the tracks recorded in the plotter data can be used to describe the location of fishing areas. The length of fishing tracks *n* in each 3 minute grid cell in the study area was calculated and cells were ranked from high to low track length. The most highly ranked grid cells that included 70, 80 and 90% of the total track length in all grid cells were identified. These cells were assumed to be the core fishing areas. The method and tools were based on the approach of Jennings and Lee (2012) but using total track length rather than an estimate of total fishing time. Data derived from VMS were also processed to identify core fishing areas. The core areas based on the analysis of plotter data and VMS were compared.

Further analysis was carried out on plotter data from 2 vessels that could be compared directly with VMS. The methods for delineating fishing grounds returned comparable results for both plotter data and VMS data. The identification of core fishing grounds is of importance to the fishing industry and will assist in supporting advice on how to meet conservation objectives and the effects of alternate management measures. Similar vessel speed profiles were obtained from both the VMS and the plotter data. Plotter tracks were used to estimate impact from gear components to illustrate the potential use of such data to support pressure assessments on sensitive habitats.

It is anticipated that this work will help to catalyse further discussion on the use and limitations of VMS and plotter data for mapping fishing activity.

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1. Scientific objectives of the project

1.1 To review plotter data provided by skippers of commercial fishing vessels and assess their utility as a means of providing information concerning fishing activity for the Dogger Bank SAC (see Figure 1).

1.2 To provide any possible information on patterns of fishing activity that can be derived from these data.

1.3 To describe the methodology used for processing along with its known limitations.

1.4 To compare results derived from plotter data with those derived from VMS data.

Notes:

a. The bulk plotter data supplied (Section 2 and Section 4) do not identify the date or time when they were collected. No indication is given as to whether the plotter data cover a single year or multiple years. These data cannot therefore be compared directly with VMS data for the same time vessels. The analyses presented in section 6 seek to address this limitation by investigating more detailed data for two vessels which can be directly compared with the VMS data.

b. The bulk plotter data supplied were linked to the predominant code for the gear(s) used by the vessel supplying the data. There is no indication whether this was the *actual* gear employed for all data supplied by that vessel.

c. It is known that skippers of commercial fishing vessels share plotter track information. There is no indication whether the bulk plotter data supplied originated from the vessel supplying the data or whether it had been collected on a different vessel and then circulated. There may, therefore, be duplicate information included in the plotter data that were supplied. The sharing of data among vessels may also mean that the fishing gear attributed to the data is incorrect.

d. VMS data were provided by the UK's Department for Environment, Food and Rural Affairs (Defra) and Marine Management Organisation (MMO) in raw, uninterpreted form. The Secretary of State for the Environment, Food and Rural Affairs does not accept any liability whatsoever as to the interpretation of the data or any reliance placed thereon.

e. Bulk plotter data were provided by skippers of commercial fishing vessels. The data were made anonymous prior to delivery to remove vessel and date/time details. These data were provided to Cefas by The Crown Estate as a series of point and line GIS datasets.

f. The more detailed data for two vessels described in Section 6 were provided to Cefas by NFFO as a series of comma delimited text files. Issues directly relating to the quality of these data are discussed in Section 6.

g. Cefas does not accept any liability whatsoever as to the interpretation of the data or any reliance placed thereon.

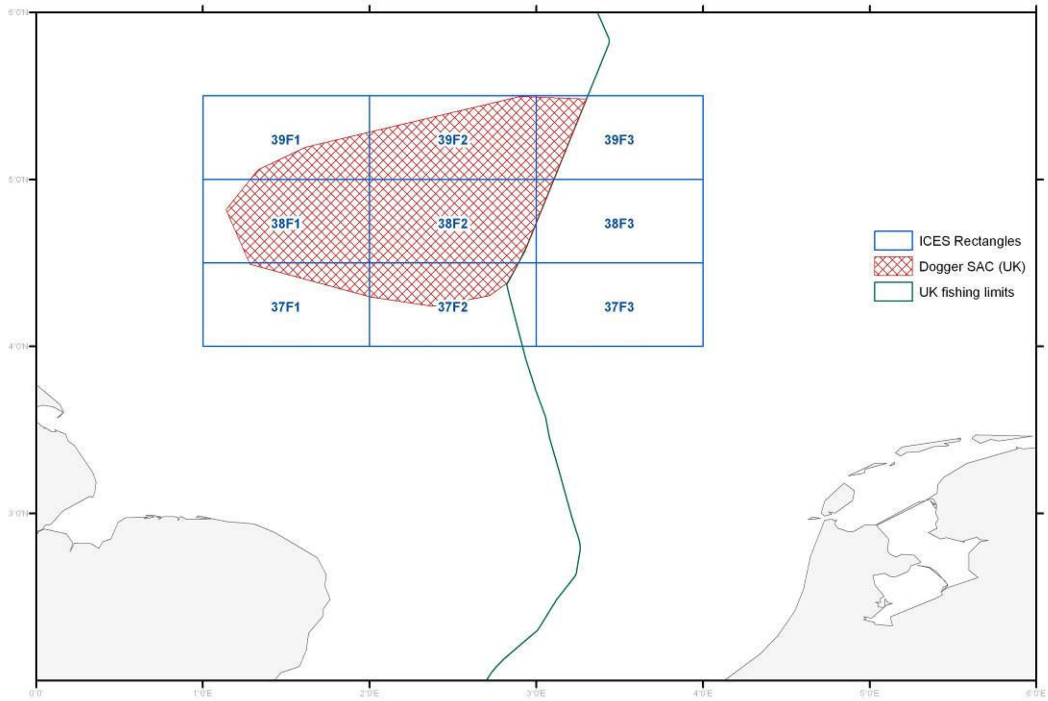


Figure 1: The study area: UK Dogger Bank SAC

2. Plotter data for vessels fishing within the Dogger SAC

2.1 Thirty-two set of data were provided from 17 commercial fishing vessels. Nineteen of these data sets were defined as beam trawlers (code = TBB), three as Danish seine netters (code = SDN), one as a dredger (code = DRB). The remaining nine were defined as other unspecified mobile gears. A summary of the vessel characteristics is provided in Table 1.

2.2 Table 1 also details the number of data sets provided by each vessel. Some vessels provided data sets for multiple gears. Table 2 quantifies the number of features within each data set. In total 354,841 line features were provided.

2.3 An initial analysis to search for duplicate features within data sets was undertaken based on line length. A total of 37,343 features were identified as potential duplicates. The geometry of these features was then compared and 21,961 features were found to be exact geometrical duplicates of other features. In some case multiple copies of a feature existed. The duplicate features were removed prior to further analysis to leave just a single record of each feature. The total number of individual features was therefore reduced to 332,880.

2.4 In some of the plotter data it was evident that some features were marking chart elements: names were spelled out, grid lines were evident, or symbols had been drawn. Figure 2 shows some examples of such features. These features could not be identified using any systematic method, but rather required manual (and time-consuming) review of the dataset. An initial investigation of these features identified in excess of 580, and these were removed from the data. However, it must be noted that some such, non-fishing, line features may remain in the dataset.

Table 1. Details of vessels contributing plotter data

Vessel ID	**Gear Code(s)**	**Number of datasets supplied**		**Vessel ID**	**Gear Code(s)**	**Number of datasets supplied**
AA1001	TBB	1		AA1020	TBB	1
AA1002	TBB	1		AA1021	TBB	1
AA1003	TBB	1		AA1023	OTHER	1
AA1004	SDN	1		AA1024	DRB	1
AA1005	TBB	1		AA1025	OTHER	1
AA1006	TBB	1		AA1026	OTHER	1
AA1007	TBB	1		AA1033	OTB	1
AA1012	TBB	2		AA1040	SDN, TBB, OTHER	3
AA1019	TBB	1		AA1041	SDN, TBB, OTHER	12
					TOTAL	*32*

Table 2. Details of contributed track data

DataSet_ID	Gear Code(s)	Number of tracks
AA1001_1	TBB	113,446
AA1002_1	TBB	67
AA1003_1	TBB	110
AA1004_1	SDN	145
AA1005_1	TBB	7,399
AA1006_1	TBB	3,858
AA1007_1	TBB	10,038
AA1012_1	TBB	9,556
AA1012_2	TBB	21,443
AA1019_1	TBB	510
AA1020_1	TBB	41
AA1021_1	TBB	383
AA1023_1	OTHER	7,452
AA1024_1	DRB	845
AA1025_1	OTHER	1,035
AA1026_1	OTHER	851
AA1033_1	OTB	587
AA1040_1	OTHER	985
AA1040_2	SDN	24
AA1040_3	TBB	362
AA1041_1	OTHER	794
AA1041_2	TBB	320
AA1041_3	TBB	92
AA1041_4	TBB	23,113
AA1041_5	OTHER	9,277
AA1041_6	TBB	140,557
AA1041_7	OTHER	35
AA1041_8	TBB	302
AA1041_9	OTHER	12
AA1041_10	TBB	67
AA1041_11	TBB	667
AA1041_12	SDN	468
		354,841

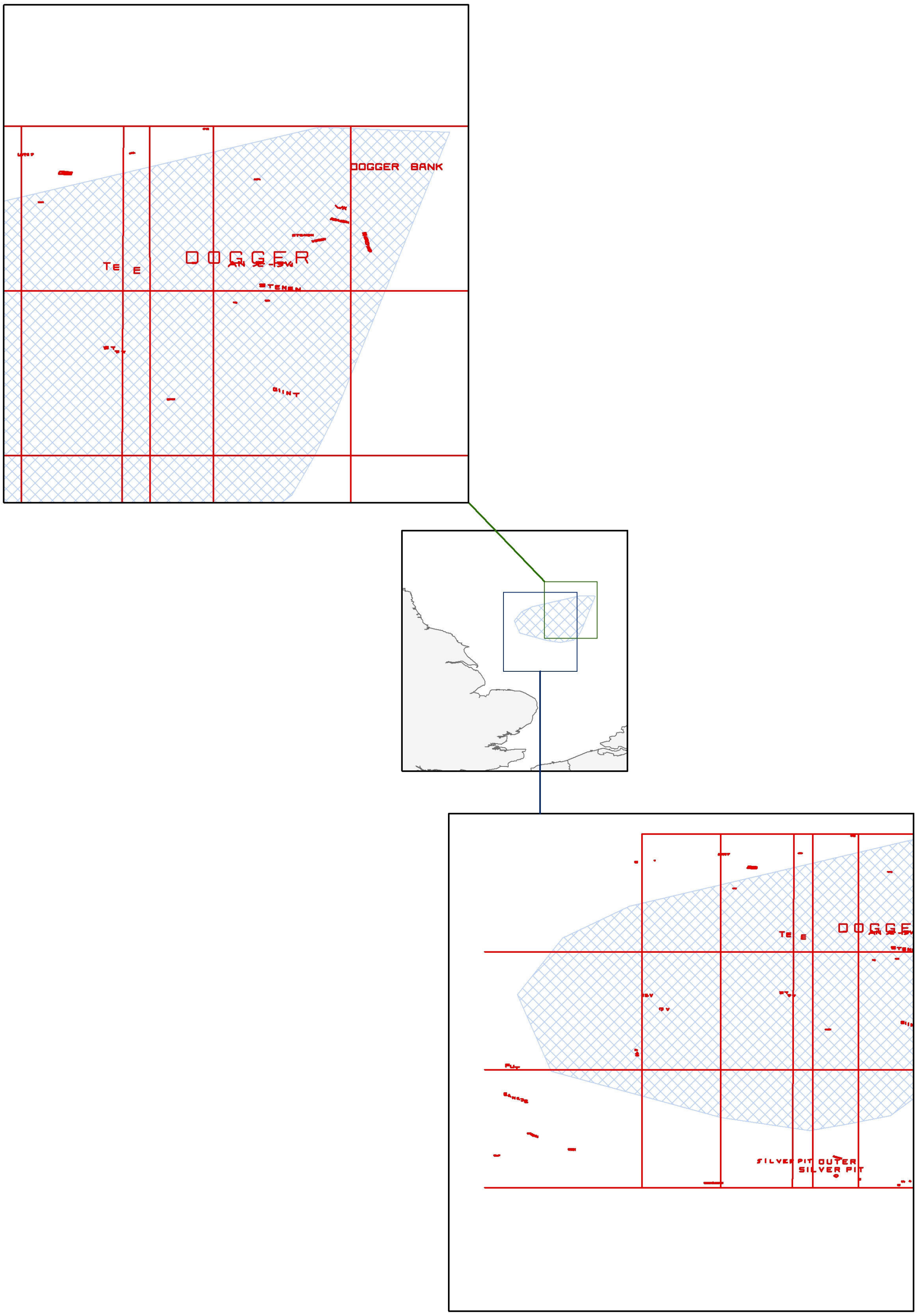


Figure 2: Examples of erroneous (non fishing) features present in the plotter data

3. Defining core fishing grounds using the VMS data

3.1 Information on the distribution and intensity of fishing activity was based on the analysis of VMS vessel identity, position, and speed data (as presented in milestone report No. 1). The data for the four study years (2007 – 2010) were summarised to give a total estimated fishing effort for the area of interest. Data were summarised within square 3' (0.05 decimal degrees) grid cells. A total of 1,800 cells covered the 9 ICES rectangles of interest, each ICES rectangle (dimension 1 degree by 0.5 degree) being covered by 200 of these grid cells.

3.2 The spatial extent of fishing was evaluated. Boundaries were defined encompassing given proportions (70, 80, and 90%) of the total activity for each of the gear groups (demersal trawls and all other fishing) and for the fishing activity for all gears combined. The grid cells were ranked from high to low activity. Cumulative activity was calculated by summing activity by individual grid cell in rank order.

3.3 Figure 3 shows the defined fishing grounds for the area of interest which encompass 70, 80 and 90% of the modelled fishing activity as identified using the VMS data for the UK vessels. A summary of the fishing grounds is presented in Table 3 while their overlap with the Dogger Bank SAC is presented in Table 4.

3.4 Further details of the method that was used to define core fishing areas can be found in "Defining fishing grounds with vessel monitoring system data", Simon Jennings and Janette Lee. ICES Journal of Marine Science, doi:10.1093/icesjms/fsr173.

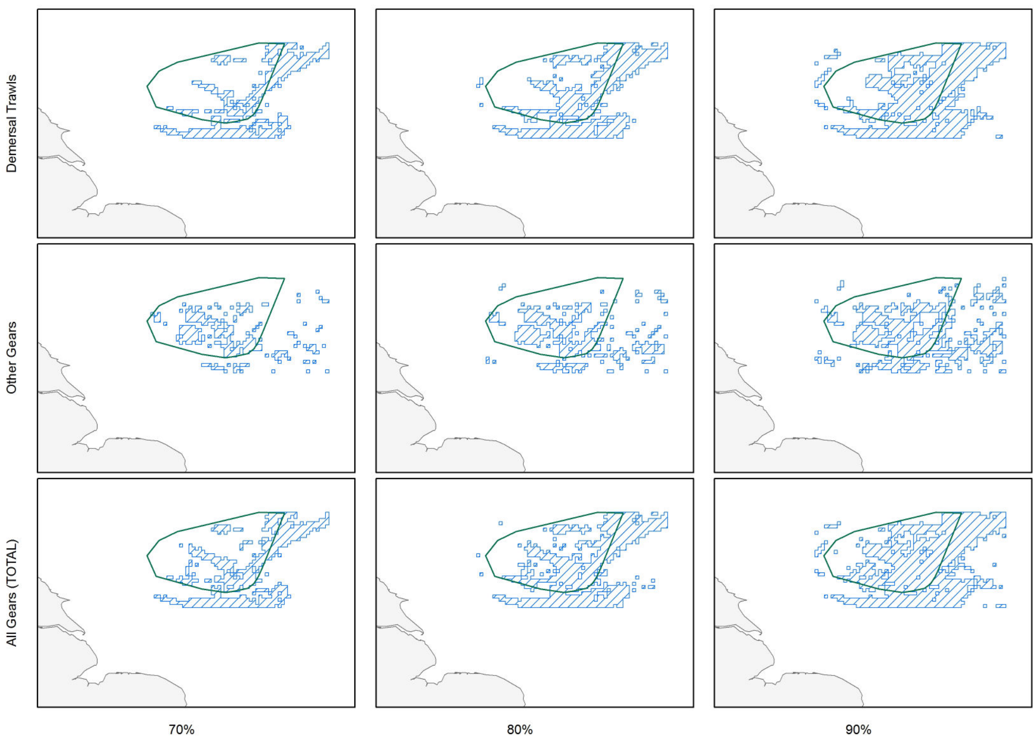


Figure 3: Fishing grounds derived from the VMS data

4. Defining core fishing grounds using the plotter data

4.1 Core fishing grounds were also defined using the plotter data. As no temporal information was provided with these data it was not possible to estimate a total fishing time and so the track length was used as an alternative measure of fishing activity. Tracks varied in length from a few metres to hundreds of kilometres in length which would suggest that, for some of the data sets, the tracks included steaming activity as well as fishing activity. The absence of any date/time information made it impossible to determine speed and therefore to remove any (potentially) steaming activity.

4.2 Track lengths were summed for each 3' grid cell to give an estimate of total track length. As for the VMS data, the spatial extent of fishing for these summarised data was evaluated and boundaries were defined encompassing 70, 80, and 90% of the total track lengths for the demersal trawl tracks, for all other tracks, and for the total tracks lengths from all datasets combined. The grid cells were ranked from high to low activity. Cumulative activity was calculated by summing track length by individual grid cell in rank order.

4.3 It was not possible to determine when tracks were last fished, so it was assumed that the cumulative length of tracks in any given grid cell was indicative of the importance of that cell to the fishing industry.

4.4 Figure 4 shows the fishing grounds for the area of interest which encompass 70, 80 and 90% of the modelled fishing activity as identified using the plotter track data provided. A summary of the fishing grounds is presented in Table 3 while their overlap with the Dogger Bank SAC is presented in Table 4.

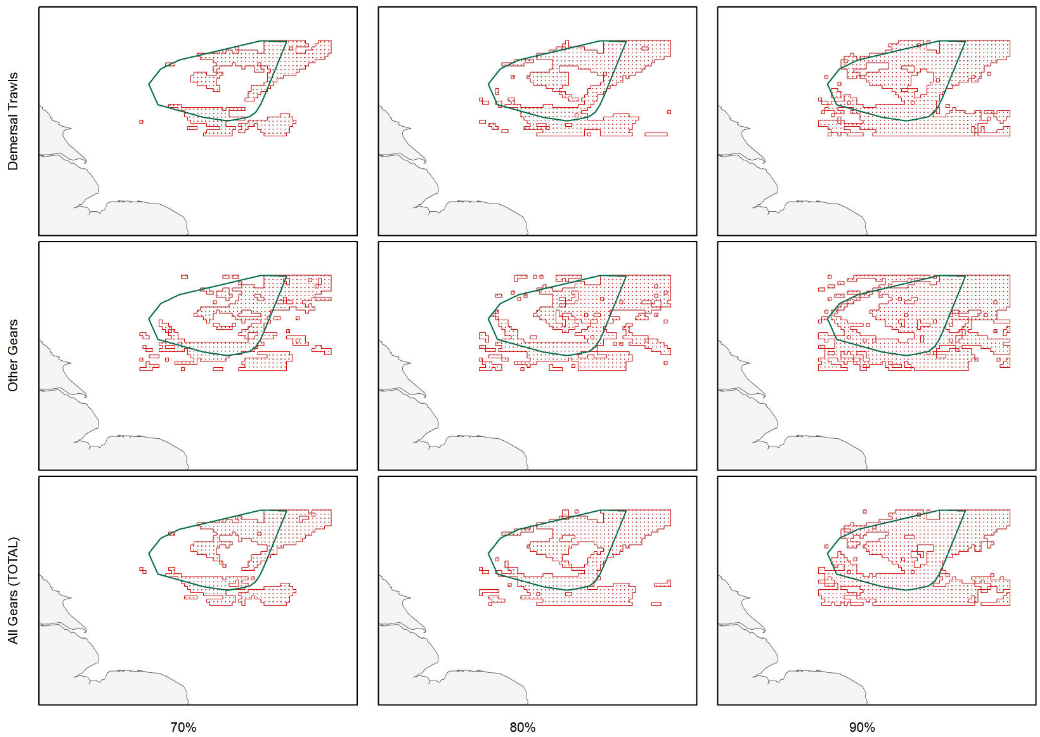


Figure 4: Fishing grounds derived from the plotter data

Table 3. Dimensions of delineated fishing grounds

Area of fishing ground (number of grid cells)				
		VMS fishing ground	**Plotter fishing ground**	**VMS as % of Plotter**
Demersal Trawls	70%	404	512	78.9
	80%	573	708	80.9
	90%	817	1020	80.1
Other Gears	70%	235	659	35.7
	80%	349	863	40.4
	90%	545	1151	47.4
TOTAL fishing	70%	446	569	78.4
	80%	624	780	80.0
	90%	874	1101	79.4

Table 4. Overlap of Dogger SAC and delineated fishing grounds

		VMS fishing ground	**Plotter fishing ground**
Demersal Trawls	70%	21.8	35.4
	80%	34.9	49.4
	90%	52.3	67.6
Other Gears	70%	23.7	44.5
	80%	30.4	56.0
	90%	39.9	69.6
TOTAL fishing	70%	28.3	40.7
	80%	41.6	54.6
	90%	59.0	72.3

5. Limitations on use of plotter data

Demersal Trawls

5.1 Despite the differences between the sources of input data, there was a strong similarity between the results derived from VMS and plotter data for the demersal trawling activity. The VMS data captures approximately 80% of the spatial extent covered by the plotter data.

5.2 Plotter data also include non-UK activity and are not directly comparable with the results from the UK VMS analysis presented in report 1. To interpret the comparison between the plotter and VMS data, the assumption is made that vessels fishing demersal gear codes, regardless of their nationality, will target their efforts on similar fishing grounds.

5.3 Figure 5 shows, for the demersal trawl gear, those grid cells which contribute to the fishing grounds defined by the VMS data, by the plotter data, and common to both methods.

5.4 For the 70% fishing grounds there is a substantial area to the North East of the Dogger SAC where the plotter data indicate significant fishing activity which is not evident from the UK VMS data. Further (limited) investigation of the VMS data indicates that non-UK vessels fished this area prior to 2009. A more detailed analysis of the VMS data for the non-UK vessels would be required to determine the nationality of vessels previously active within this north-eastern area. At present, we do not have access to the information needed to link non-UK VMS data to vessel identity.

Other Gears

5.5 Figure 6 shows, for the ‘other gears’ category (gears other than demersal trawl), those grid cells which contribute to the fishing grounds defined by the VMS data, by the plotter data, and common to both methods. The results from the VMS and those from the plotter data for these gears do not show any notable similarity.

5.6 The 70% and 80% grounds are dominated by plotter activity which is not apparent in the UK VMS data. As much of the plotter data is categorised as an ‘unknown’ gear code it may be that much of this activity is demersal trawling which should therefore be excluded from the ‘other gears’ category and included with the demersal trawl results.

5.7 An area to the centre, and west, of the Dogger SAC shows activity by UK vessels (as captured by the VMS data) which is not captured in the plotter data.

5.8 Further investigation of the VMS data to identify activity by foreign vessels would be helpful in determining the extent to which these areas are exploited differentially by the UK and non-UK fleets.

All gears combined

5.9 As would be expected, given the dominance of the beam trawling activity in this region, the patterns generated using the data for all gears combined is similar to that found for the demersal gear codes.

5.10 Figure 7 illustrates, using all of the available data for all gears, those grid cells which contribute to the fishing ground defined by the VMS data, by the plotter data, and common to both methods.

5.11 The area to the North East of the Dogger SAC, which was also an area for demersal trawling, can again be identified as an area where the plotter data indicate significant fishing activity and which is not substantiated by the UK VMS data. Other areas, in particular following the southern-western and north-western boundaries of the SAC, appear to be important areas of activity based on plotter data but were not identified as important using VMS data.

Impact on seabed habitats

5.12 The JNCC UKSeaMap data for 2010 were used to determine seabed characteristics within the majority of the study area. These data do not extend to the full area of interest (as defined by the ICES rectangles) as they are only available out to the UK territorial limits. The data are shown in Figure 8.

5.13 There are six seabed types evident within the Dogger SAC with two making up in excess of 93% of the SAC. Table 5 shows the proportion of the SAC covered by the seabed types.

Table 5. Seabed types within Dogger SAC

Code	Description	Proportion of SAC
A5.23 / A5.24	Infralittoral fine sand / Infralittoral muddy sand	71.1
A5.13	Infralittoral coarse sediment	22.5
A5.25 / A5.26	Circalittoral fine sand / Circalittoral muddy sand	4.4
A5.14	Circalittoral coarse sediment	1.2
A5.27	Deep circalittoral sand	0.7
A5.43	Infralittoral mixed sediments	0.1

5.14 The fishing grounds delineated using the VMS data and the plotter data were superimposed on the seabed types in order to determine the proportion of each seabed type within the SAC that intersect with the fishing grounds. The results are shown in Table 6.

5.15 The fishing grounds delineated using the plotter data, being larger in size, show a proportionate increase in intersection with given seabed types.

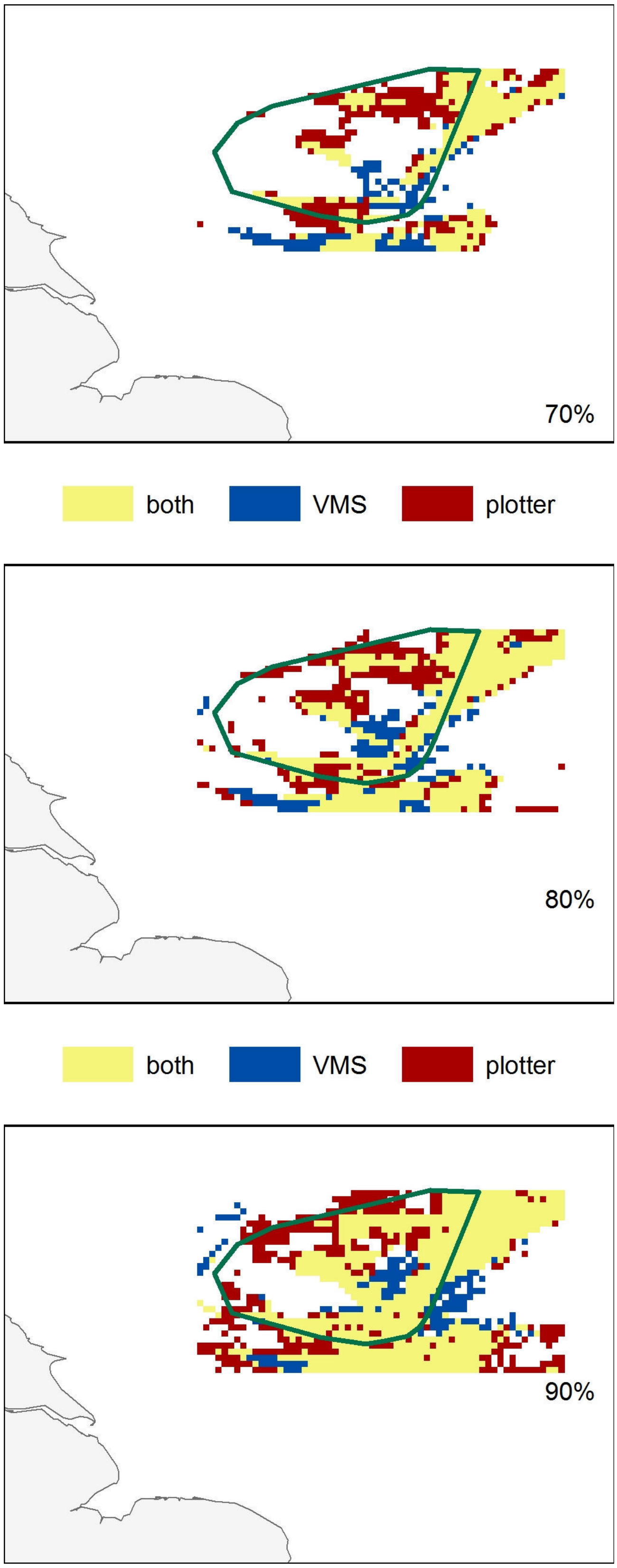


Figure 5: Fishing grounds for ‘demersal trawl’ gears

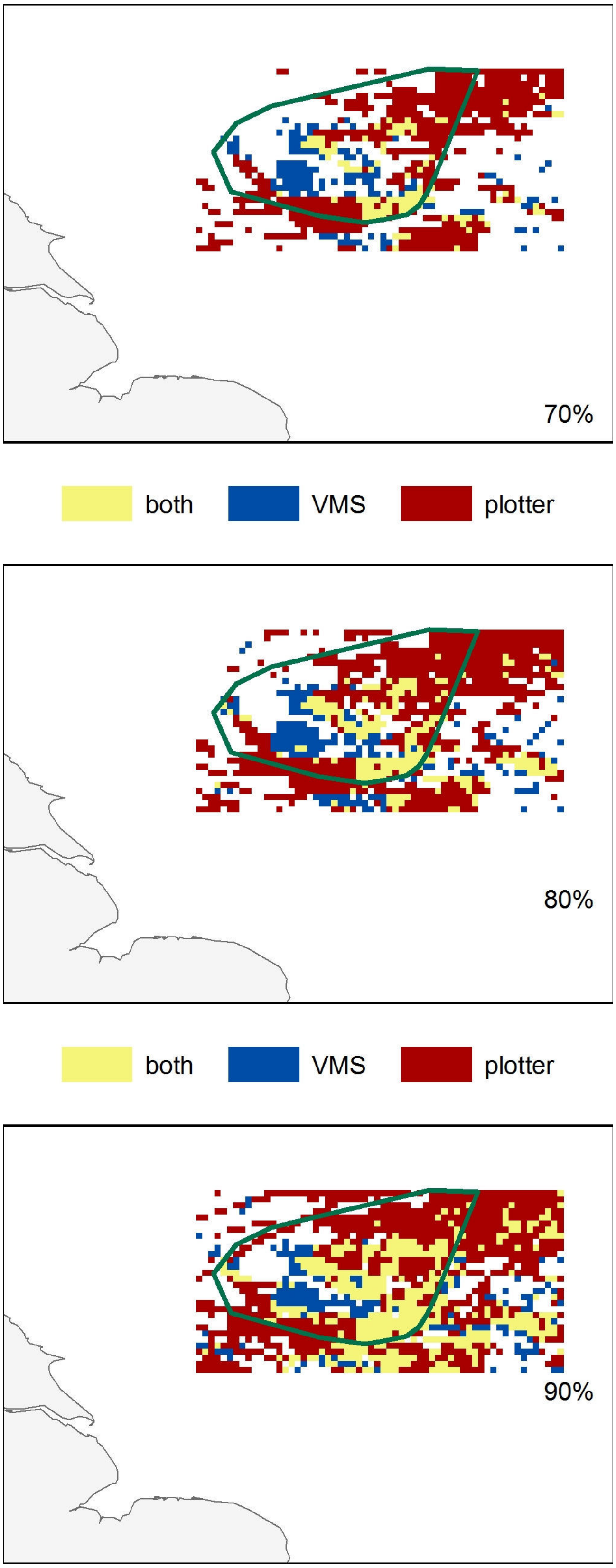


Figure 6: Fishing grounds for ‘other’ gears

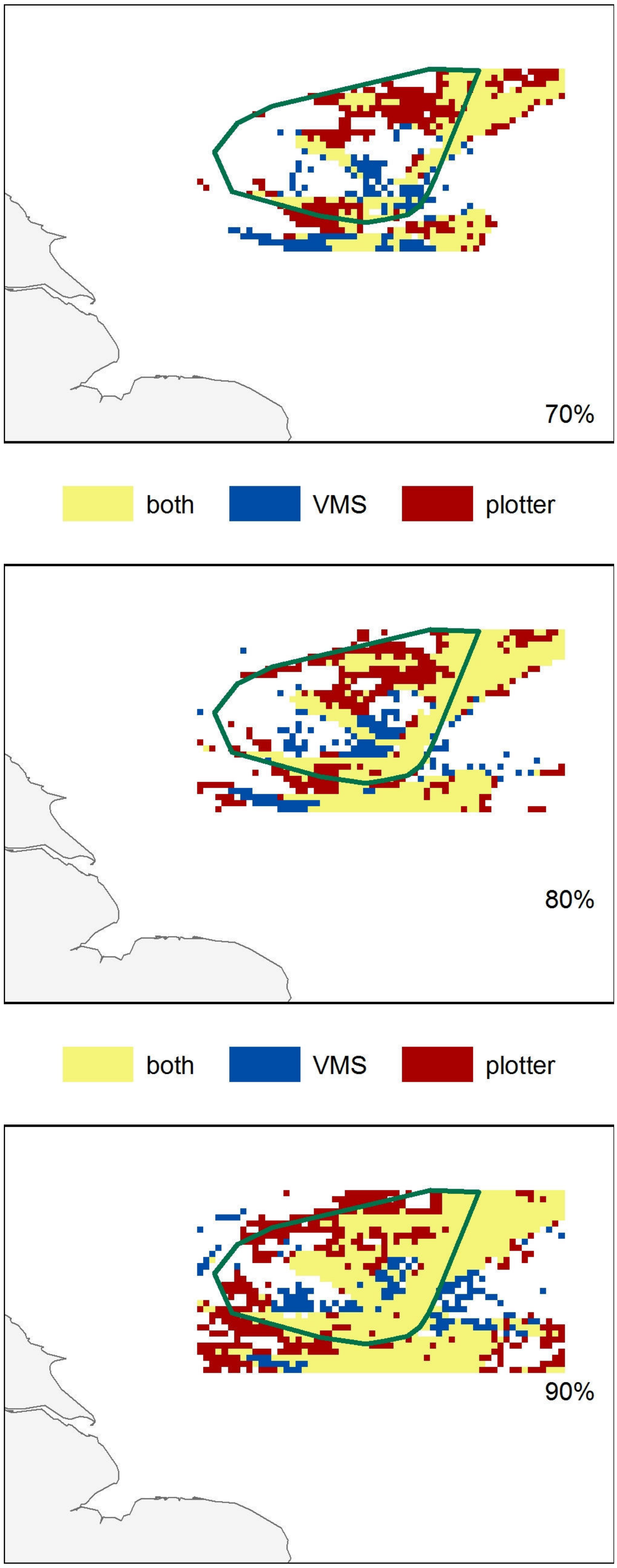


Figure 7: Fishing grounds for ‘total’ activity

Table 6. Intersection between habitat types and fishing grounds

DEMERSAL TRAWLS	VMS data			Plotter data		
	70%	**80%**	**90%**	**70%**	**80%**	**90%**
A5.23 / A5.24	21	33	50	32	48	67
A5.13	16	32	52	35	46	64
A5.25 / A5.26	29	43	61	59	65	72
A5.14	8	31	40	41	71	93
A5.27	36	55	71	39	73	96
A5.43	0	0	53	69	71	79
OTHER GEARS	**VMS data**			**Plotter data**		
	70%	**80%**	**90%**	**70%**	**80%**	**90%**
A5.23 / A5.24	30	37	47	41	52	67
A5.13	11	18	25	44	59	71
A5.25 / A5.26	6	15	20	65	72	81
A5.14	0	1	1	48	51	53
A5.27	0	0	17	53	77	100
A5.43	0	0	0	56	86	86
ALL GEARS	**VMS data**			**Plotter data**		
	70%	**80%**	**90%**	**70%**	**80%**	**90%**
A5.23 / A5.24	29	41	58	38	54	71
A5.13	19	34	56	40	48	69
A5.25 / A5.26	29	44	57	62	66	74
A5.14	5	31	40	45	63	89
A5.27	36	55	68	55	87	100
A5.43	0	0	53	71	71	86

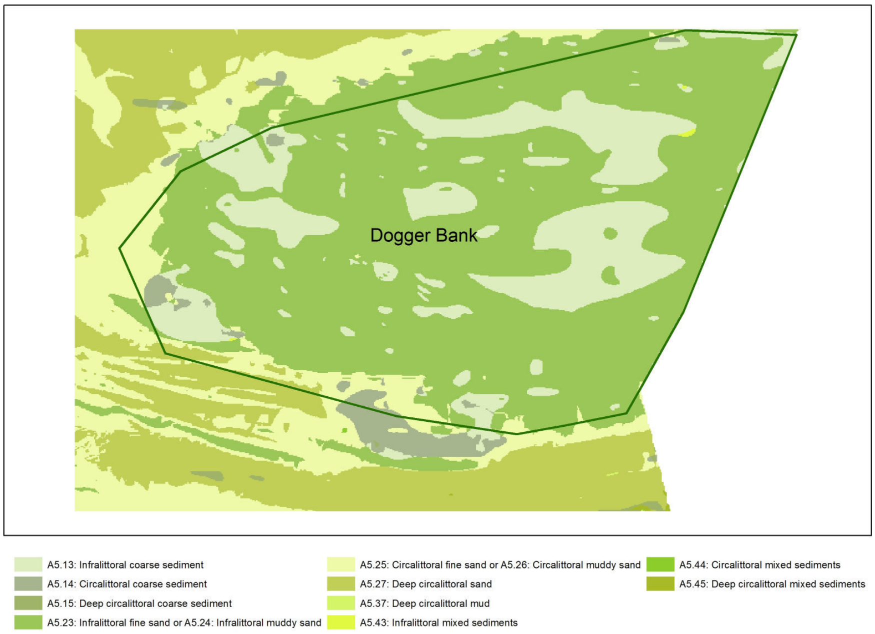


Figure 8: Seabed types on the Dogger Bank (data from JNCC, 2011)

Discussion and recommendations

5.16 The analysis helped to identify the strengths and limitations of plotter data.

5.17 Without consistent links to the time of fishing and the fishing gear deployed, the plotter data indicate potential fishing locations rather than the times when locations are fished. This limits the extent of possible comparisons between plotter and VMS data. Plotter data linked to records of the dates and times of fishing and the actual gear used would allow a more substantive and reliable analysis of the extent of fishing grounds and their intersection with habitats.

5.18 More detailed plotter data, containing date/time/speed/gear information could also be useful in quality checking or refining the speed rules used to separate 'fishing' and 'steaming' activity in the VMS data.

5.19 The inclusion of plotter data from both UK and foreign vessels makes it difficult to accurately compare fishing locations with those recorded in the UK VMS data. Currently, non-UK VMS data cannot be linked to vessel and gear type by UK scientists.

5.20 The data as provided do not permit any analysis of the effectiveness of the fishing undertaken as no information on landings is supplied.

5.21 Further analysis of higher quality plotter data, for two beam trawlers, are presented in section 6 to investigate the potential uses of these higher quality data.

6. *High quality plotter data*

Preparation of the data

6.1 Plotter data were made available from two vessels. The data from one vessel had date and time information while the data from the second vessel was grouped by week (approximately) but with no further date and time information. Plotter data were available for four years from 2007 to 2010.

6.2 Despite having date and time stamp information included, the data for vessel 1 contained significant anomalies which required correction prior to further processing. Many erroneous dates e.g. 30th February or 31st April were included and some dates referred to a day '0' for some months. As the data were supplied in text files containing some date information e.g. week 32 these dates were amended to an appropriate date to allow inclusion in the analysis. It must be noted however that this level of manual pre-processing would limit the utility of such data in larger scale analyses.

6.3 VMS and plotter data for the two nominated vessels were used to create tracks which were then clipped to the extent of the UK Dogger SAC as shown in Figure 1. Two sets of VMS tracks were created for each vessel: one utilising all VMS data points and one including just those points which were deemed to be fishing (following the method of Lee *et al.,* 2010).

6.4 These tracks were then summarised for the SAC as a whole (see Table 7) and for grids of three sizes (0.6', 1.5' and 3') as shown in Figures 9-14.

Table 7. Total track length of delineated fishing grounds

Length of track (km) within SAC (% of plotter track in brackets)					
		2007	**2008**	**2009**	**2010**
Vessel 1	VMS, all (% of plotter)			4378 (54.1)	4599 (66.9)
	VMS, fishing (% of plotter)			2796 (34.5)	3458 (50.3)
	Plotter	8617	3593	8098	6872
Vessel 2	VMS, all (% of plotter)	5181 (21.2)	3190 (19.9)	2878 (20.4)	4518 (17.5)
	VMS, fishing (% of plotter)	2965 (12.1)	2119 (13.2)	1355 (9.6)	3136 (12.1)
	Plotter	24413	16068	14140	25826

6.5 Core fishing grounds were defined using both the plotter data and the VMS data for the two vessels. As temporal information was not available for both vessels it was not possible to determine the *'estimated time fished'* metric as used by Lee *et al* (2010) and so track length was used as the measure of fishing activity.

6.6 Track lengths were summed for each grid cell (at each of the three spatial resolutions) to give annual estimates of fishing effort and facilitate the delineation of fishing grounds. The spatial extent of fishing for these summarised data was evaluated and boundaries were defined encompassing 70, 80, and 90% of the total track lengths. The grid cells were ranked from high to low activity and cumulative activity was calculated by summing track length by individual grid cell in rank order (see Jennings and Lee, 2012).

6.7 Figures 9-14 show the fishing grounds within the SAC for the two vessels and illustrate 70, 80, 90 and 100% of the modelled fishing activity derived from VMS data (Figures 9 and 10), VMS 'fishing' data (Figures 11 and 12) and plotter data (Figures 13 and 14). Each figure shows the data for years 2007-2010 and for the three grid cell sizes. A summary of the sizes of the fishing grounds is presented in Tables 8-10.

6.8 Using the date, time and position information for Vessel 1, a determination was made of the speed of the vessel between successive points for four subsets of the data falling in August and October 2009 and in March and June 2010. Speed profiles were generated. The data for these four subsets were further used to investigate the relationship between track lengths and polling frequency.

6.9 Vessel 1 was first registered in April 2009 and licensed in May 2009. VMS data were therefore only available for this vessel from May 2009 onwards. Figures and tables are left blank for the periods for which data were not available. Values and summary statistics for 2009 must be interpreted accordingly as the data represent 9 months data rather than a full year.

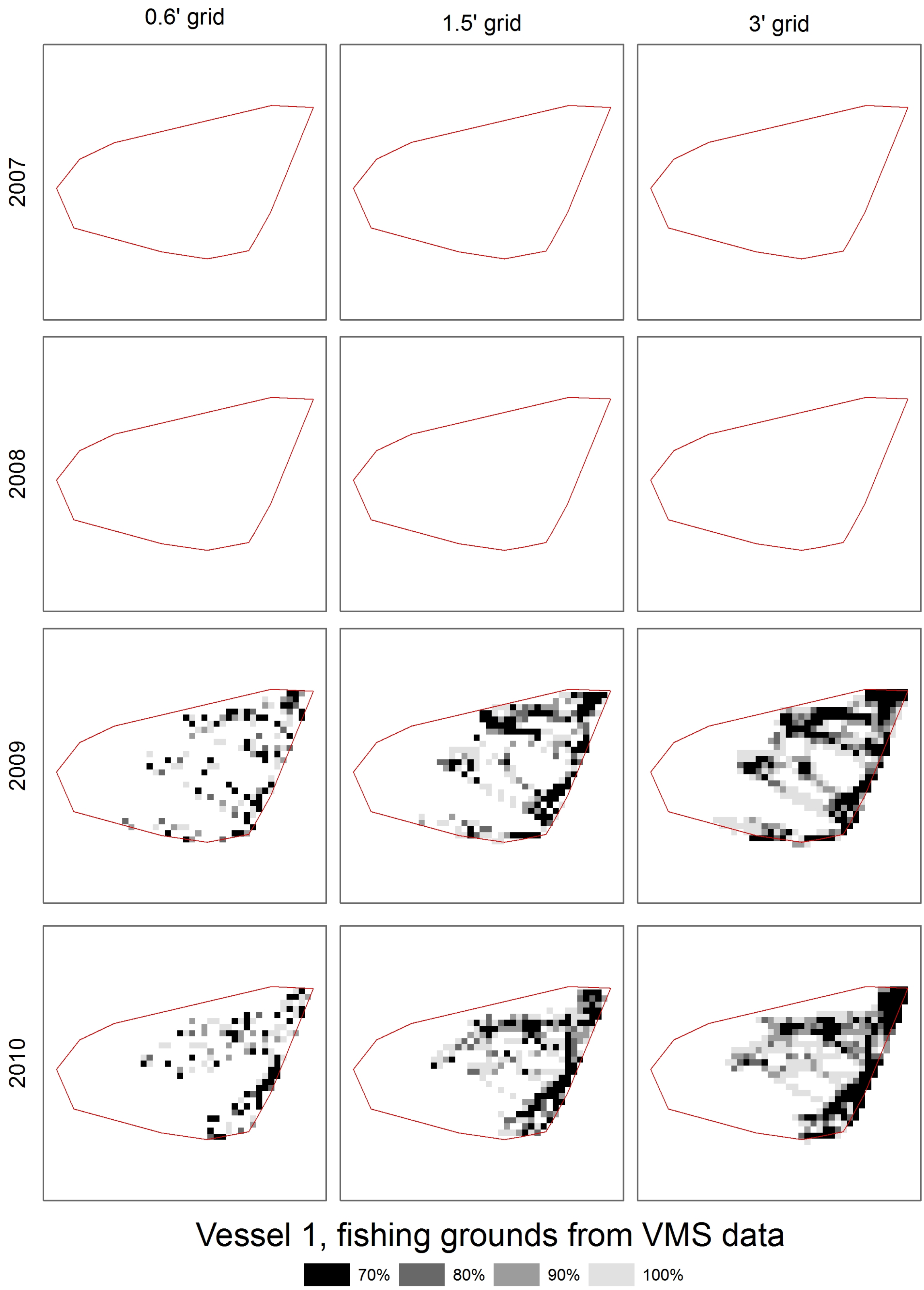


Figure 9: Vessel 1, fishing grounds from all VMS data

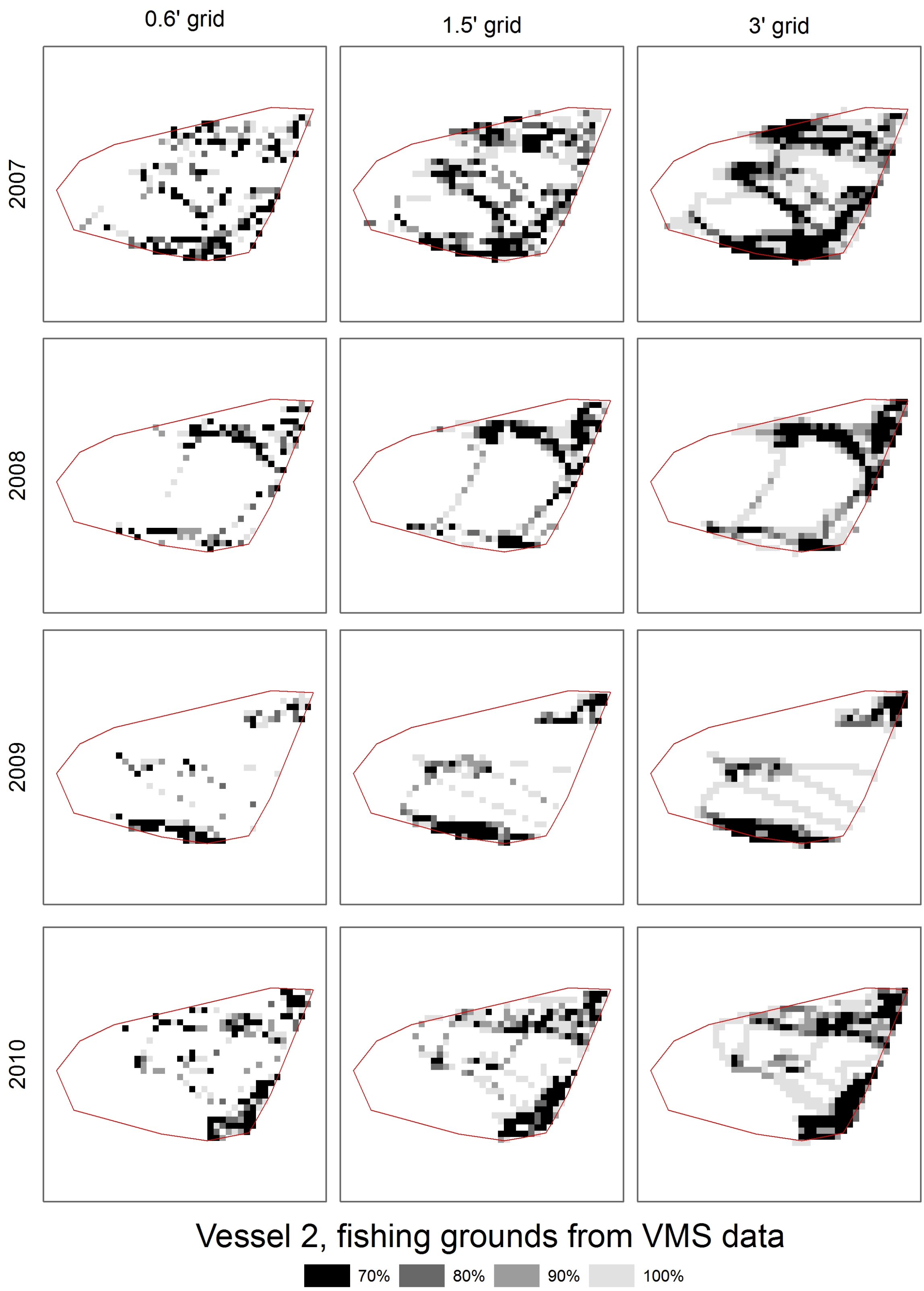


Figure 10: Vessel 2, fishing grounds from all VMS data

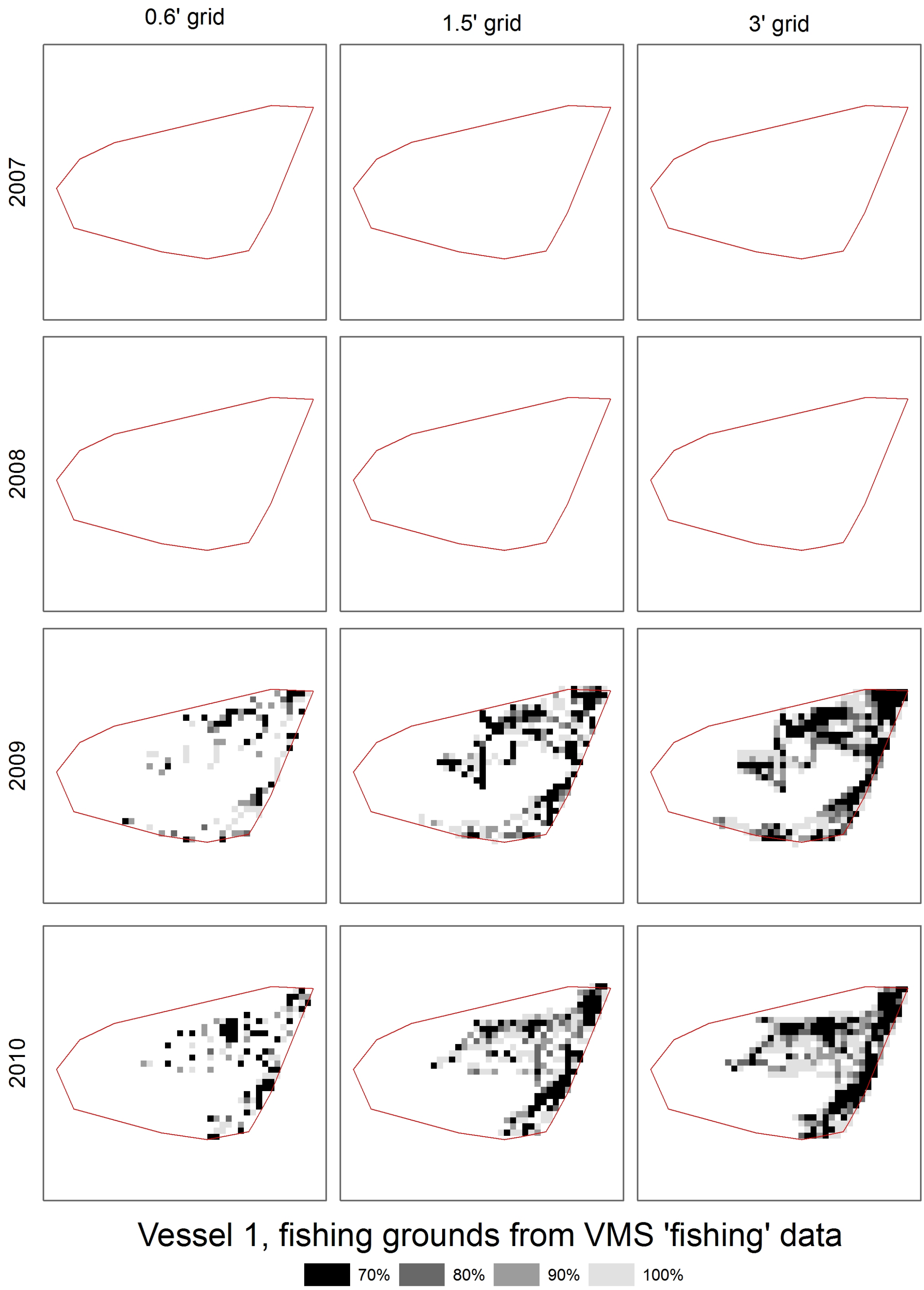


Figure 11: Vessel 1, fishing grounds from VMS 'fishing' data

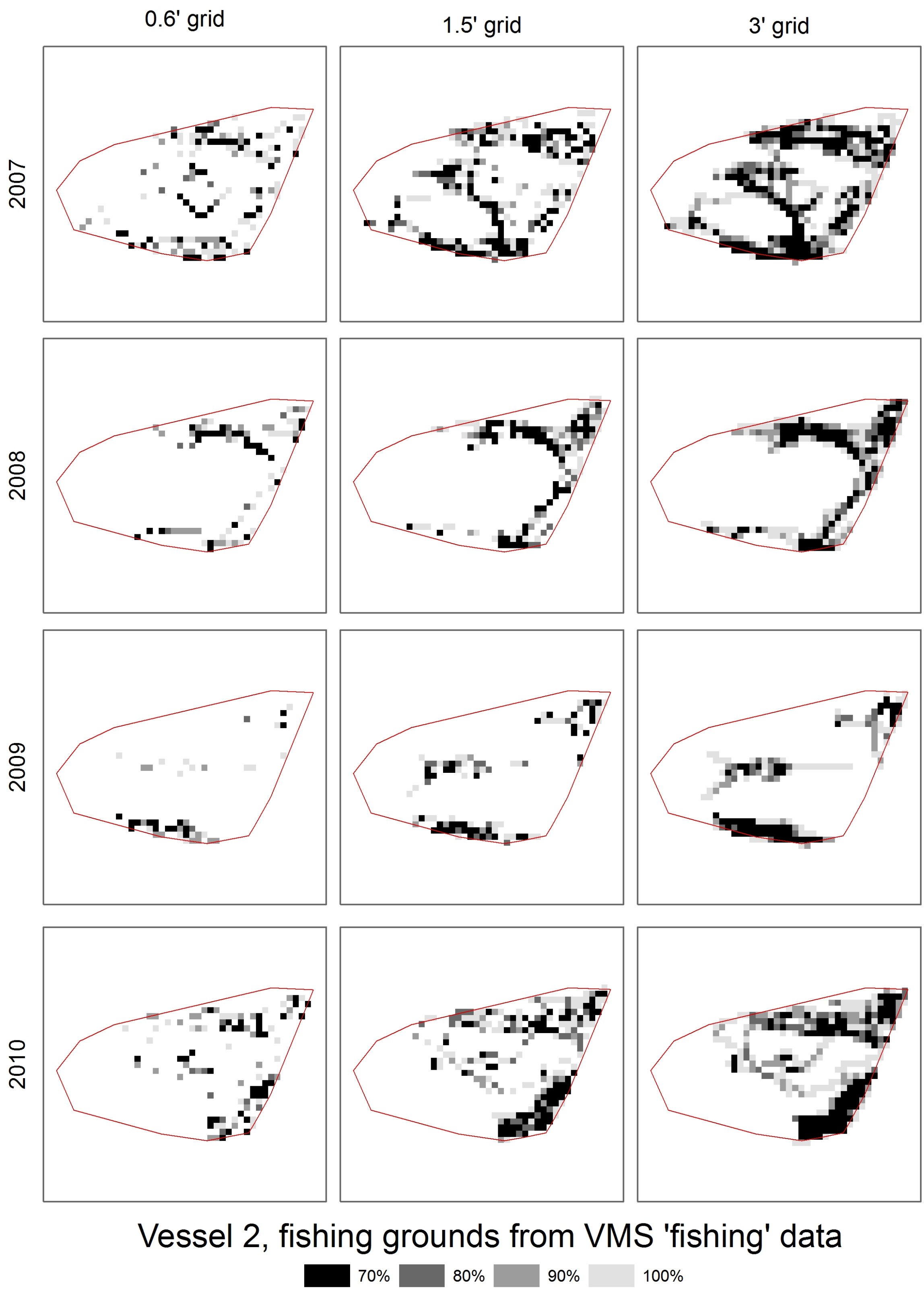


Figure 12: Vessel 2, fishing grounds from VMS ‘fishing’ data

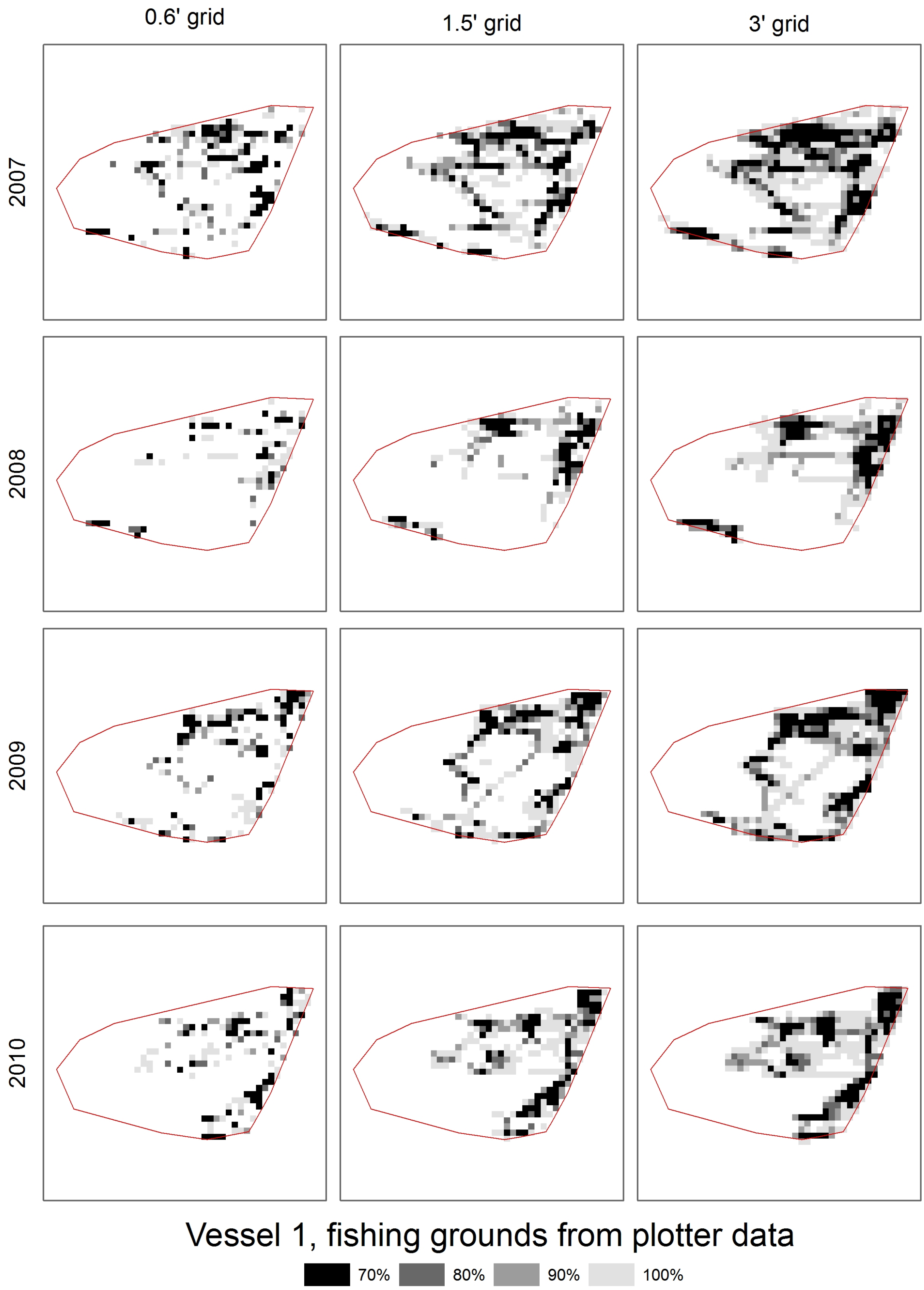


Figure 13: Vessel 1, fishing grounds from plotter data

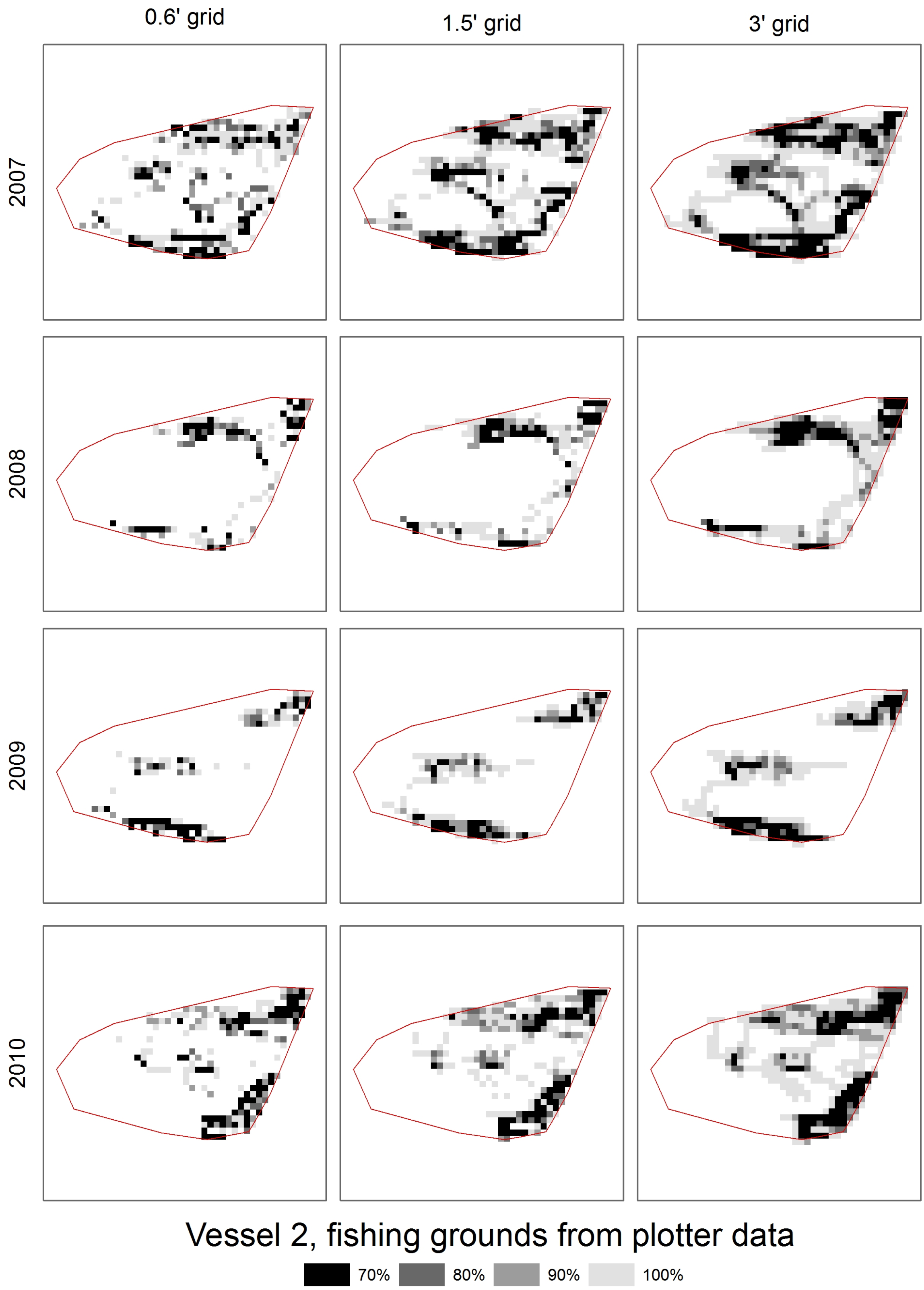


Figure 14: Vessel 2, fishing grounds from plotter data

Table 8. Dimensions of delineated fishing grounds from all VMS data

Area of VMS ground (km²) **3' grid cell**					
		2007	**2008**	**2009**	**2010**
VESSEL 1	70%			2106	1840
	80%			2785	2502
	90%			3750	3464
	100%			5990	5468
VESSEL 2	70%	2958	1640	1151	1808
	80%	3906	2159	1544	2413
	90%	5210	2982	2189	3393
	100%	8160	4919	4164	5857

Area of VMS ground (km²) **1.5' grid cell**					
		2007	**2008**	**2009**	**2010**
VESSEL 1	70%			1517	1340
	80%			1981	1822
	90%			2552	2572
	100%			3947	4108
VESSEL 2	70%	1954	1319	916	1378
	80%	2901	1640	1257	1824
	90%	3973	2160	1741	2519
	100%	5867	3340	2672	4284

Area of VMS ground (km²) **0.6' grid cell**					
		2007	**2008**	**2009**	**2010**
VESSEL 1	70%			839	823
	80%			1107	966
	90%			1430	1287
	100%			2197	2071
VESSEL 2	70%	1507	874	648	1198
	80%	1955	1178	827	1502
	90%	2491	1519	1132	2003
	100%	3545	2037	1615	2682

Table 9. Dimensions of delineated fishing grounds from VMS ‘fishing’ data

Area of VMS fishing ground (km^2) 3’ grid cell					
		2007	**2008**	**2009**	**2010**
VESSEL 1	70%			2104	1839
	80%			2820	2464
	90%			3733	3321
	100%			5539	5217
VESSEL 2	70%	2632	1392	989	1862
	80%	3436	1873	1311	2538
	90%	4511	2534	1795	3469
	100%	6638	4020	2851	5410

Area of VMS fishing ground (km^2) 1.5’ grid cell					
		2007	**2008**	**2009**	**2010**
VESSEL 1	70%			1658	1286
	80%			2051	1749
	90%			2498	2410
	100%			3802	3874
VESSEL 2	70%	1809	1035	664	1325
	80%	2293	1357	951	2020
	90%	2811	1695	1076	2414
	100%	4310	2622	1757	3911

Area of VMS fishing ground (km^2) 0.6’ grid cell					
		2007	**2008**	**2009**	**2010**
VESSEL 1	70%			534	893
	80%			713	964
	90%			1160	1267
	100%			1786	1857
VESSEL 2	70%	824	500	253	662
	80%	1003	624	288	824
	90%	1433	999	523	1287
	100%	2506	1428	792	1751

Table 10. Dimensions of delineated fishing grounds from plotter data

Area of plotter ground (km^2) 3' grid cell					
		2007	**2008**	**2009**	**2010**
VESSEL 1	70%	2195	1052	1746	1321
	80%	2963	1479	2426	1893
	90%	4123	2283	3464	2768
	100%	7505	4279	5936	5285
VESSEL 2	70%	2473	1121	1042	1610
	80%	3312	1513	1363	2162
	90%	4491	2157	1810	3070
	100%	8175	4467	3851	6338

Area of plotter ground (km^2) 1.5' grid cell					
		2007	**2008**	**2009**	**2010**
VESSEL 1	70%	1536	819	1194	1036
	80%	2089	997	1694	1464
	90%	3034	1638	2408	2106
	100%	5500	2691	4377	3802
VESSEL 2	70%	1916	801	682	1180
	80%	2559	979	968	1627
	90%	3488	1533	1380	2445
	100%	6597	2875	2848	4478

Area of plotter ground (km^2) 0.6' grid cell					
		2007	**2008**	**2009**	**2010**
VESSEL 1	70%	1124	428	872	698
	80%	1499	625	1105	947
	90%	1891	714	1532	1232
	100%	3052	1427	2464	2143
VESSEL 2	70%	1220	695	666	1145
	80%	1773	927	916	1484
	90%	2542	1248	1130	2036
	100%	4577	1945	1826	3160

Discussion: track length

6.10 Vanstaen (Defra project MF1217, 2012) calculated the relationship between the time interval of positional data and the associated reduction in track length reported. Taking a 1 minute interval as representing the 'true' track length they found that a 15 minute interval captured approximately 54% of the total track, while a 2 hour interval (as per VMS data) reduced this to approximately 16% of the track length.

6.11 While a useful 'rule of thumb' those proportions will be affected by the pattern of fishing activity undertaken. Vessel 1 routinely towed trawls in straight lines for more than one hour. Joining the VMS 'fishing' points for this vessel created tracks which captured between 35 and 50% of true track length (based on the plotter data) while joining all of the VMS points created tracks which captured between 54 and 67% of the true track length (see Table 7). Vessel 2 fishes in a less structured manner. The tracks created by joining the VMS 'fishing' points for this vessel captured only 10-13%, and those created by joining all of the VMS points captured between 17 and 21%, of the plotter track (see Table 7 and Figure 15).

6.12 Lambert *et al*. (2012) suggested that tracks for smaller vessels are often more complex compared to those of larger vessels and that for smaller vessels going back and forth over the same ground, the track reconstruction based on two-hourly VMS pings will be less satisfactory. The two vessels studied here are both > 40m length and thus the results indicate that, even for larger vessels, the complexity of the path followed will affect the accuracy with which VMS can be used to recreate tracks. Assumptions cannot therefore be made that similar sized vessels within a fleet will operate in a consistent manner.

6.13 Tracks were also generated for the four subsets of data for vessel 1 (used to investigate speed profiles). In all cases the track length from the plotter data exceeded that generated from the VMS data with the VMS data capturing between 32% and 48% of the true track length.

6.14 Further investigation using data from a greater number of vessels might allow the determination of a method for determining an index of sinuosity for differing fleets which could assist more accurate modelling of seabed impacts from fishing activity.

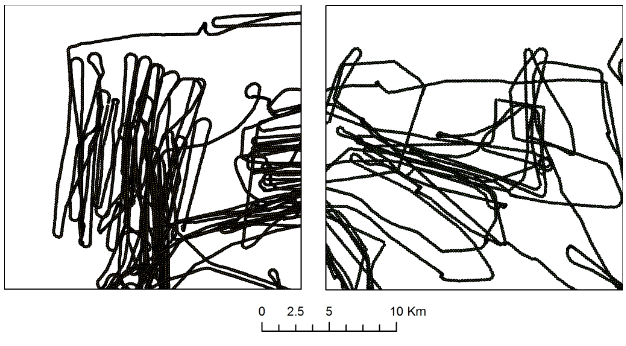


Figure 15: Patterns of fishing activity identified from plotter data
Vessel 1 (left) and Vessel 2 (right)

Discussion: delineation of fishing grounds

6.15 While detailed track information is essential to inform studies into impacts on the seabed, data on fishing vessel behaviour also forms an important input into the wider marine planning debate. Robust methods are required to identify main fishing grounds and to demonstrate a track record of fishing activity within those areas. VMS data have been used to delineate fishing grounds of importance to various UK fleets (Jennings and Lee, 2012).

6.16 The detailed plotter data provided to this project provide a useful verification on the utility of the methods developed and their application to individual vessels or smaller sections of the fleet.

6.17 Figures 9 to 14 show that, for both vessels, the spatial extents of the fishing grounds delineated using the VMS data are similar to those identified using the more detailed plotter data. Although there were differences in the absolute track lengths, the use of percentage bands to delineate fishing areas delivers a high level of consistency in results.

6.18 The data presented in Tables 8 to 10 were plotted to show the relationship in the size of fishing ground determined using the plotter data and those determined using the VMS data. Comparisons were made using just the VMS 'fishing' data and the full VMS data set. The results are show in Figures 16 and 17.

6.19 Using the plotter data for the two vessels, the area extent of the fishing grounds correlated very strongly with the grounds delineated using the VMS data. The correlation at all scales of output (0.6', 1.5' and 3' grids) was stronger when using the full set of VMS data (r^2 between 0.95 and 0.98). This may be due to the fact that the plotter data also contained a significant amount of 'non fishing' activity. It was not clear, from the data supplied, exactly how each skipper utilised their plotter and some steaming activity may be included (see Figure 18).

6.20 The data for 2010 at the 3' grid resolution were compared to see the similarity in spatial pattern of the fishing grounds delineated using the plotter data and the VMS data. The results are shown in Figure 19 and indicate that the majority of the areas designated as fishing ground are common to both methods (the yellow cells in the maps) with a small number of cells forming part of the VMS-derived fishing ground but not the plotter-derived grounds (blue cells) and some cells which formed part of the plotter-derived grounds but did not appear in the VMS-derived outputs (red cells). Similar patterns are evident in the other years for which data are available (as shown in Figures 9, 10, 13 and 14).

6.21 These results indicate that VMS data may provide a useful means of identifying important fishing areas for individual vessels, as well as for entire fleets. Current methods could be refined to generate fishing grounds for a fleet by merging those delineated for individual vessels. This could ensure that all vessels were represented in the resulting outputs.

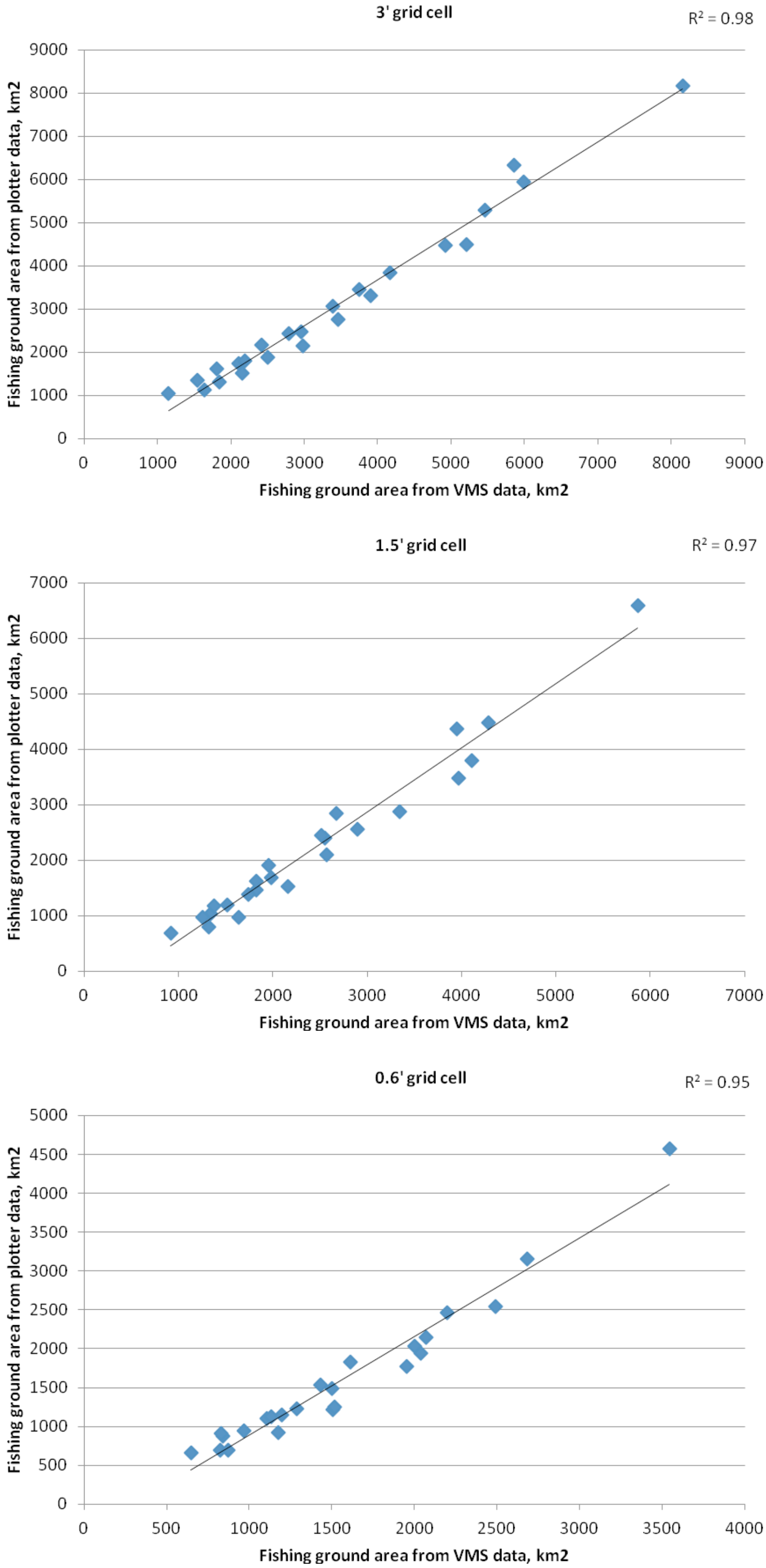


Figure 16: Correlation between estimates of the area of fishing grounds derived from plotter data and all VMS data

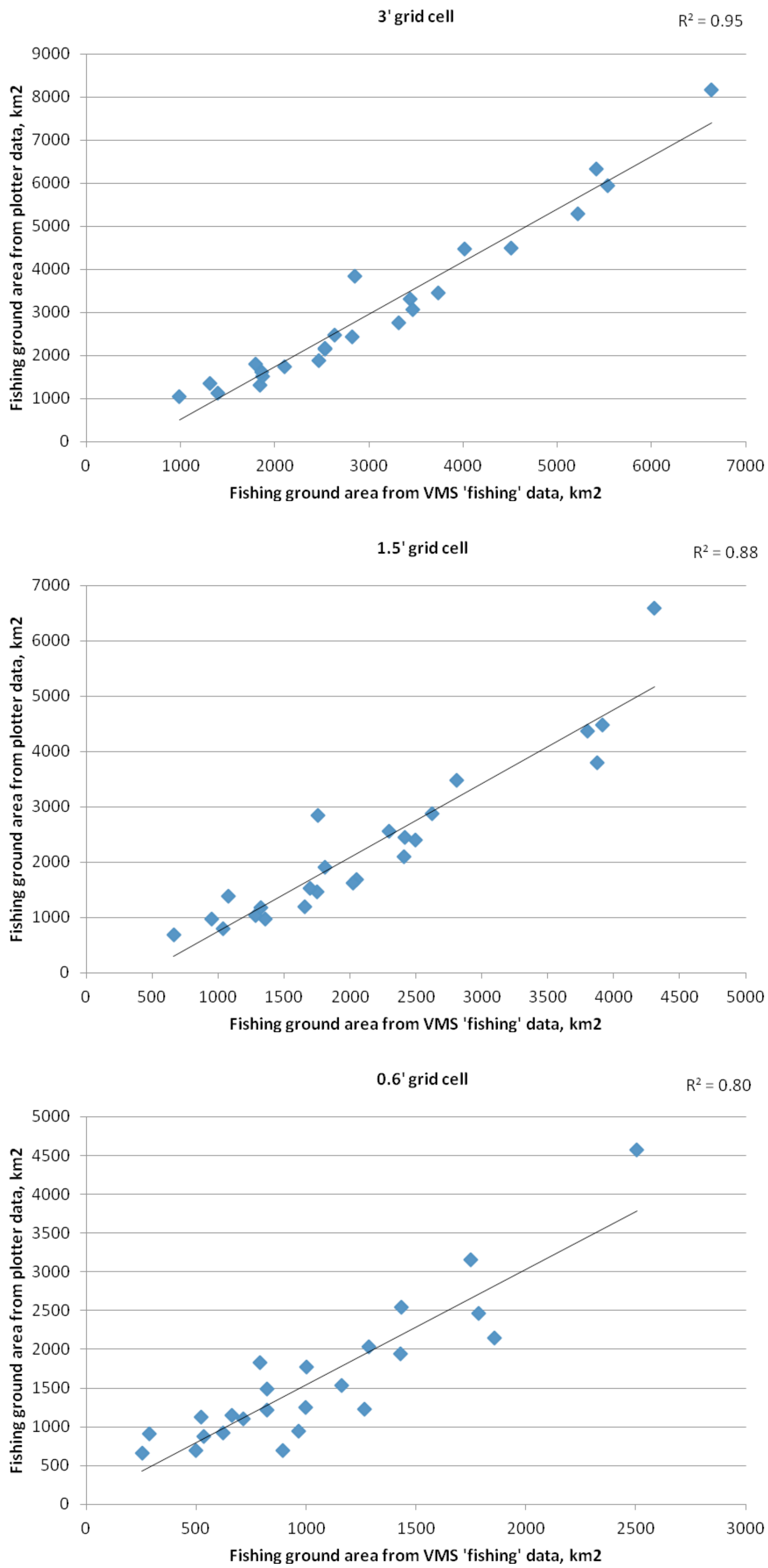


Figure 17: Correlation between estimates of the area of fishing grounds derived from plotter data and VMS 'fishing' data

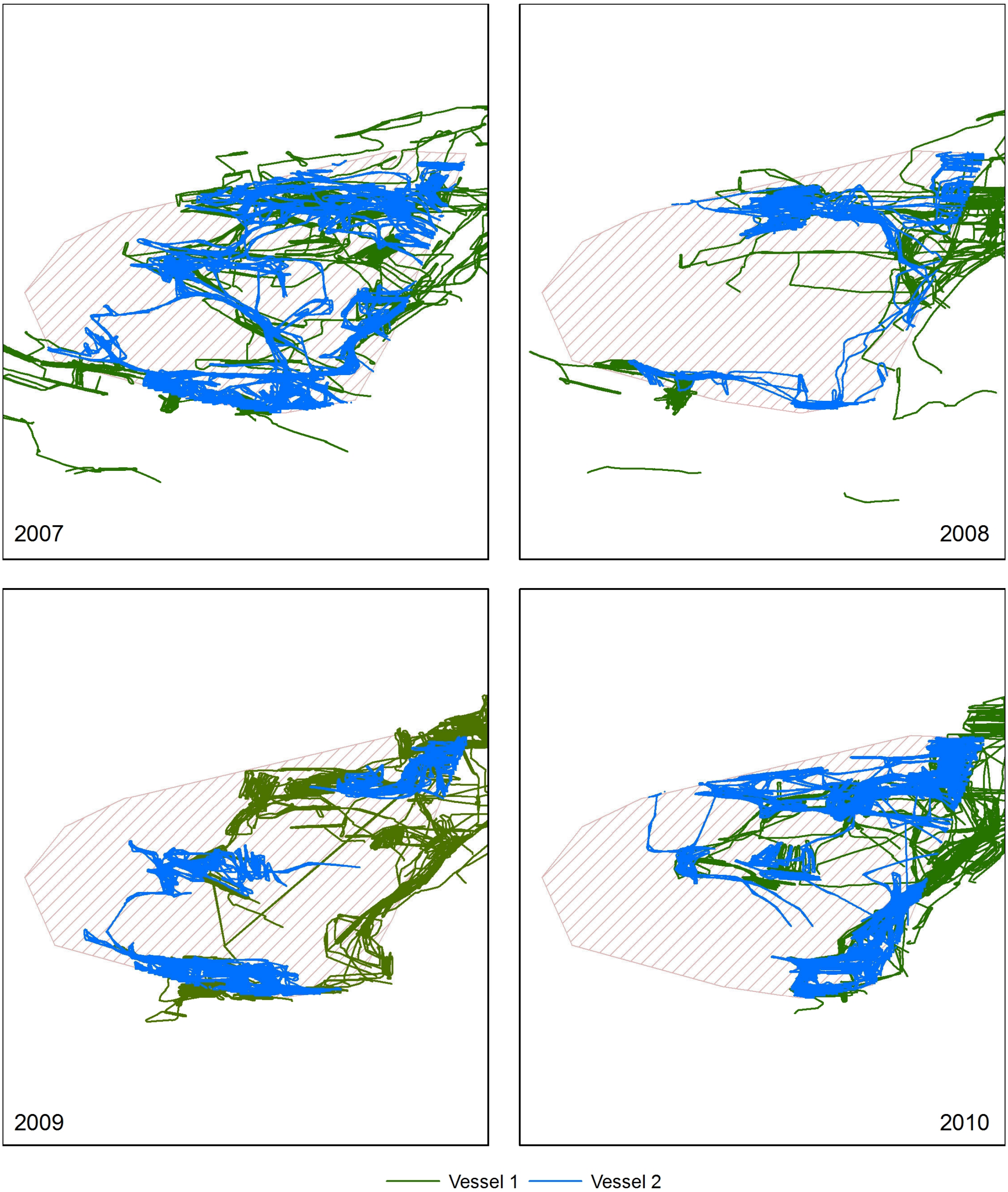


Figure 18: Plotter tracks within area of interest
showing some evidence of the inclusion of steaming activity

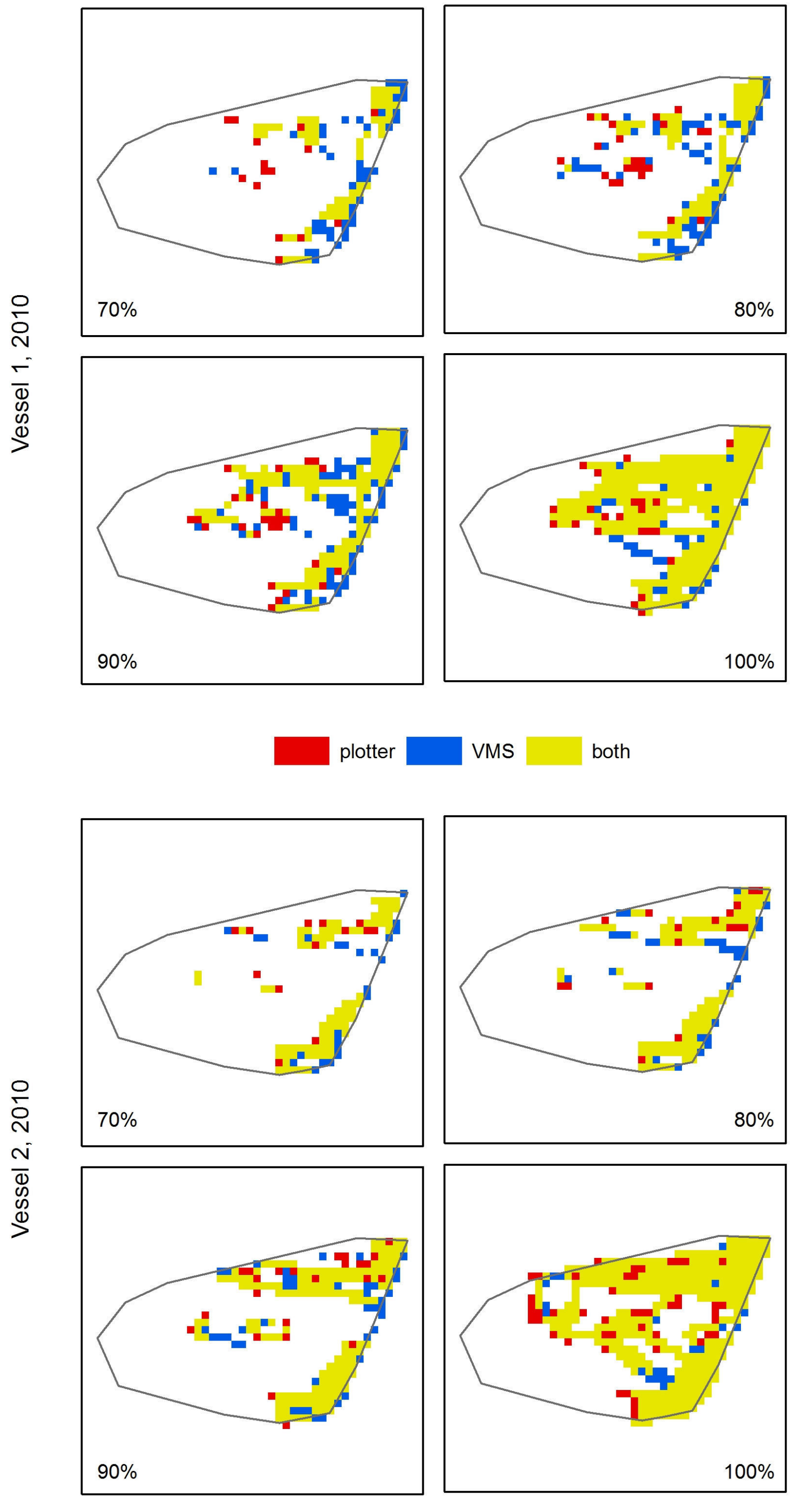


Figure 19: Similarity of fishing grounds,
2010 at 3’ resolution

6.22 Using the data for Vessel 1, which contained date and time information, data for four representative time periods were identified and the plotter data matched with the corresponding VMS data. The data are shown in Figure 20. The time periods selected were 24-26 August 2009, 20-23 October 2009, 29-30 March 2010 and 8-10 June 2010. The two hourly pings from the standard VMS system are highlighted in red. These data were used to investigate speed profiles and logging frequency.

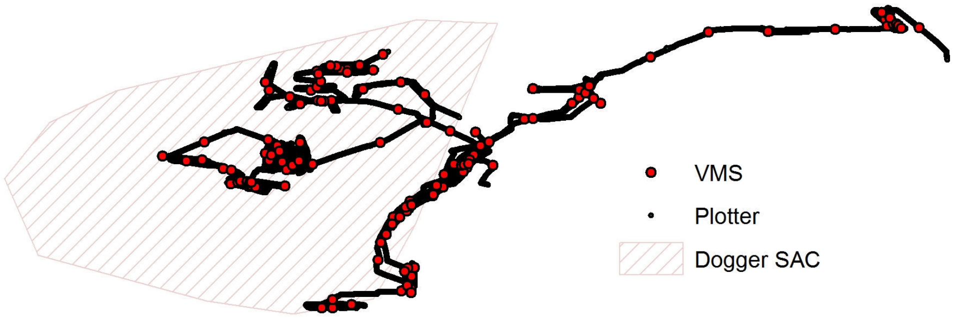


Figure 20: Data used to investigate speed profiles and logging frequency

Discussion: speed profiles

6.23 Speed profiles were created for both sets of data. The distance and time interval between successive data points was used to calculate a speed. The average speed recorded in the VMS data was 5.9 knots with a minimum of zero and a maximum of 9 knots. The calculated speeds for the plotter data averaged 5.5 knots with a minimum of zero and a maximum of 15 knots. The speed profiles are shown in Figure 21.

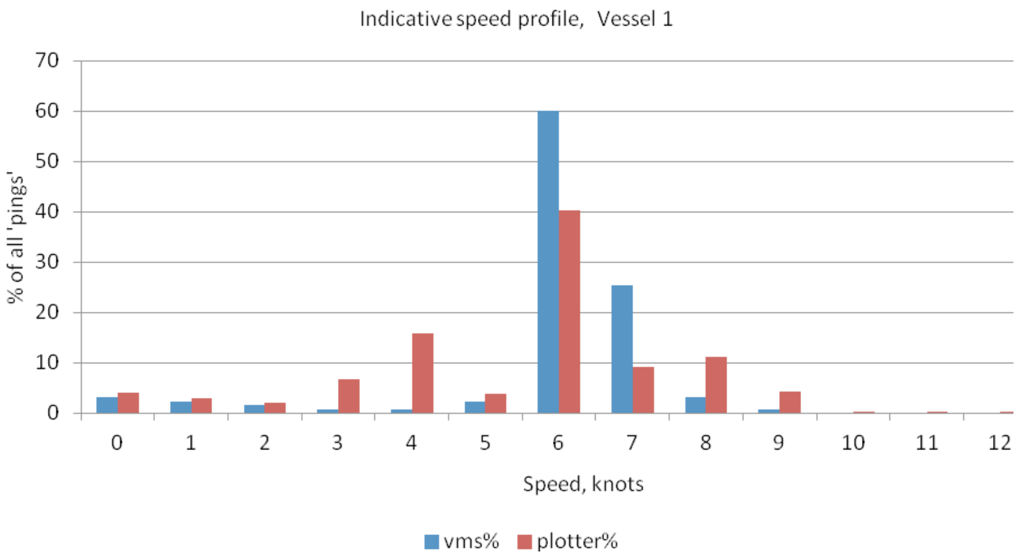


Figure 21: Speed profiles from selected VMS and plotter data

6.24 The standard VMS data as processed using the method proposed by Lee *et al.* (2010) would indicate 163 hours of fishing and 79 hours of non-fishing during these 4 sample periods while the plotter data, processed using a similar speed rule, would indicate 187 hours of fishing and 60 hours of non-fishing. The infrequent sampling of standard VMS may fail to capture some periods of fishing activity. The speed profile derived from the VMS data, while not fully representative of the actual speed profile, provides a reasonable indication of the expected profile with 67.7% of the pings falling within the 1-6 knot speed bands compared to 71.5% of the plotter points.

Discussion: logging frequency and track length

6.25 The ping interval of the plotter data for Vessel 1 is probably higher than it need be with an average frequency of approximately 25 seconds across the four sample periods. The logging frequency requires a balance to be achieved between the quantity of data gathered (36,541 plotter points compared with 130 VMS for these sample periods) and the additional benefit of gathering those data. For VMS systems introduced under EU legislation, the European Commission has recommended a 30 minute ping interval (Lambert et al., 2012) which should greatly assist in understanding of vessel movements.

6.26 The VMS tracks for Vessel 1 for the four sample periods varied in length from 135km to 355km with a total of approximately 1,084km. The tracks derived from the plotter for Vessel 1 varied from 417km to 946km and totalled 2,642km with the VMS tracks capturing, on average, just 41% of the true (plotter) track length (Table 11).

Table 11. Track length from plotter data at different sampling frequencies

Track length (km)						
Sample	**VMS** (% of plotter)	**All plotter**	**Plotter** every 3rd ping)	**Plotter** every 15th ping)	**Plotter** every 50th ping	**Plotter** every 100th ping
1	306 (48%)	643	639 (99%)	604 (94%)	511 (79%)	365 (57%)
2	355 (38%)	946	940 (99%)	893 (94%)	770 (81%)	621 (66%)
3	135 (32%)	417	408 (98%)	388 (93%)	346 (83%)	250 (60%)
4	288 (45%)	636	632 (99%)	595 (94%)	490 (77%)	479 (75%)
Total	1084 (41%)	2642	2619 (99%)	2480 (94%)	2117 (80%)	1715 (65%)

6.27 The plotter data were sub-sampled by selecting every 3rd, 15th, 50th and 100th point from each track equating to approximately 1-minute, 5-minute, 15-minute and 30-minute intervals. Tracks were created for each of the subsets of points and total lengths recorded (Table 11).

6.28 There is a decline in the amount of the total track captured as the time interval increases. However the reduction in data quantity to 1/15th of the original size (achieved by sub-sampling at approximately 5 minute time intervals) only reduces the accuracy of the track generated by approximately 6%. Based on the data from the vessel considered here, plotter logging at 5 minute intervals could therefore provide a useful balance between the needs of the skipper and the utility of the data for other purposes.

6.29 For their assessment of fishing pressure, Eastwood *et al.* (2007) and Piet *et al.* (2007) made use of an approach which required an indication of the area of the seabed swept by fishing gear. Using VMS data for such assessments would significantly have underestimated the area swept. The first pass of fishing gear is often considered the most damaging (Hiddink *et al.,* 2006) and to discriminate initial and repeated impacts it is necessary to accurately assess the area impacted. Based on the findings from the plotter data used in this study, a ping interval of between 1 and 5 minutes would allow the capture of between 94% and 99% of the length of the true vessel track.

Discussion: impact on seabed habitats

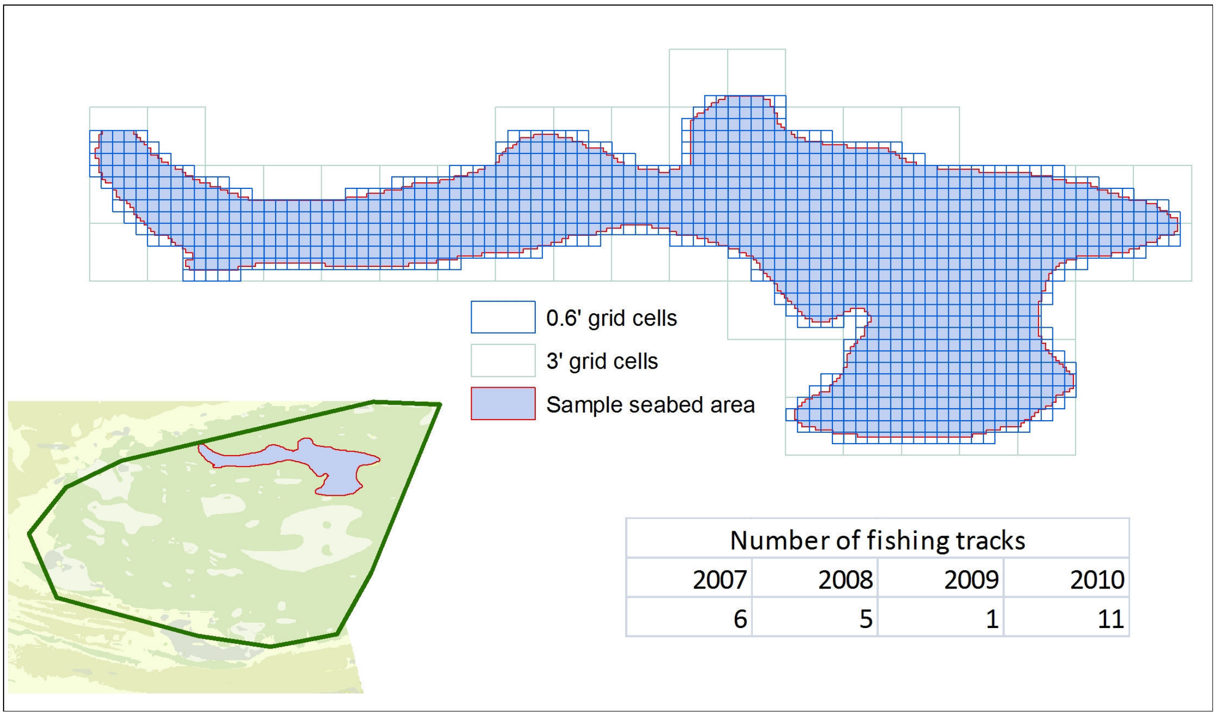
6.30 Tracks from plotter data can be analysed in relation to seabed sediment types. This could provide useful information in determining whether particular features or areas of interest are impacted by fishing activity.

6.31 As an example, an area of infra-littoral coarse sediment was selected from the central area of the Dogger SAC and the number of tracks crossing this area was calculated for Vessel 2 for each year. This provides some information on the potential seabed impact of trawling by this vessel. The area of interest was subdivided into smaller units (in this case grids of 3’ and 0.6m resolution were used) to demonstrate the finer scale at which these determinations can be made when high quality plotter data are available (Figure 22).

6.32 Fishing tracks may pass over the same area many times. For studies on benthic impacts an appreciation of the areas subjected to single passes and multiple passes of trawled gear, and the frequency of those passes, can be useful.

6.33 By using a combination of track length and gear characteristics the plotter data can be analysed to determine area swept and associated physical effects. Vessel 2 employed beam trawl gear. The gear dimensions have been taken from Lart (2012) where the two beams (with shoes) that are deployed are 24m wide in total, the shoes 2.88m, and the tickler chains (excluding the width of the shoes) and footrope 21.12m in total.

6.34 Impact area calculations were undertaken for the various gear components for each of the four years. Results for footrope are shown but have been found to have little additional effect following the impact from the tickler chains.



Number of fishing tracks			
2007	2008	2009	2010
6	5	1	11

Figure 22: Location of site for demonstration of swept area calculations

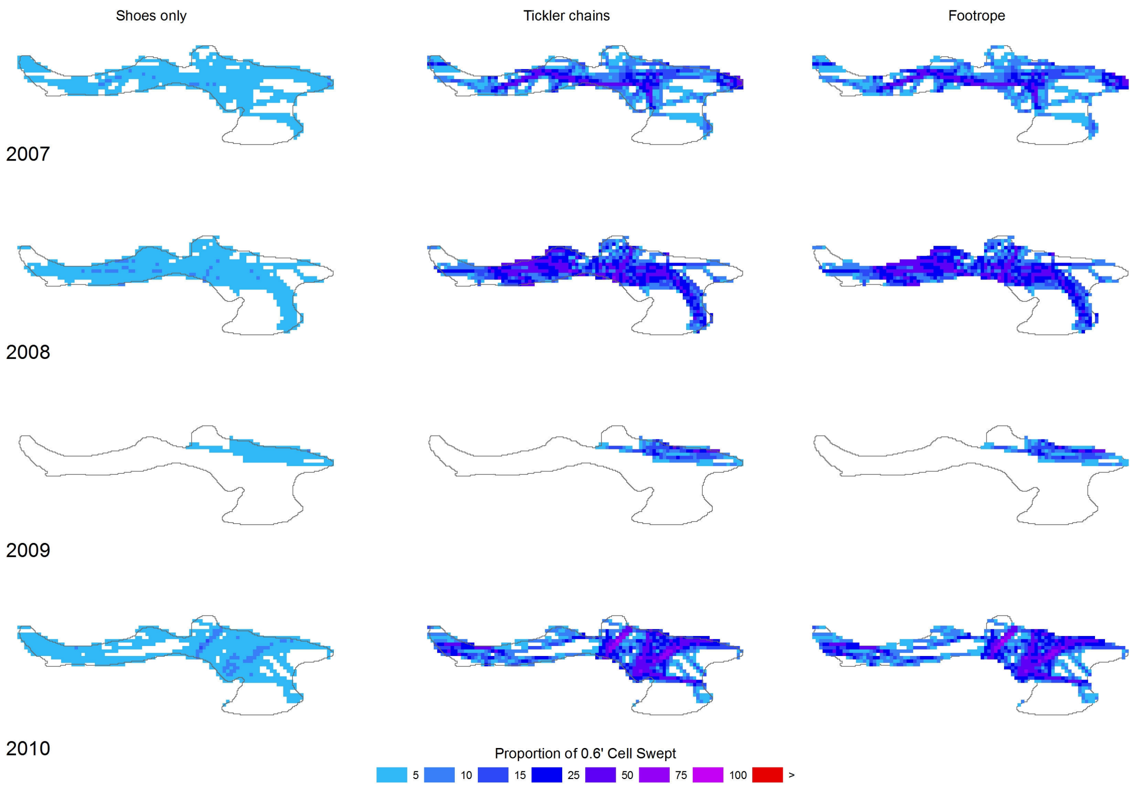


Figure 23: Proportion of cell impacted by gear components

6.35 Beam shoes, tickler chains and footrope all contribute to both ploughing and sweeping impacts and it is possible to determine total impacts e.g. for ploughing, by summarising the swept area of the contributing components. The footrope has been found to contribute little additional impact following the pass of the tickler chains and so the impact of the whole gear can best be represented by combining the impact of the beam shoes and the tickler chains.

6.36 While a similar approach can be carried out using the VMS data, the 3' grid resolution appropriate to the temporal resolution of VMS data (Lee *et al*, 2010) can present a potentially misleading impression of the extent of area impacted. The use of higher resolution plotter data provides a more accurate, and more precise, representation of the area being impacted. As an example, Figure 24 illustrates the total ploughing impact determined at a 3' and a 0.6' grid cell resolution. The 3' grid uses the swept area determined from the VMS-derived tracks while the 0.6' grid uses that from the plotter data. Note that while the same legend colours have been used, the legend values have been scaled to reflect the fact that each 0.6' grid is 1/25th of the size of a 3' grid cell.

6.37 Figure 25 illustrates this same data on total ploughing impact determined at both the 3' and 0.6' grid cell resolution. In this case the figure shows relative patterns which can be directly compared across the two grid sizes. Values have been coloured according to their variation from the mean value. The lightest coloured cells, in the middle of the colour range, are those which have values close to (within 0.25 standard deviations to either side of) the mean value. Cells coloured purple have *below* average proportions of cell impacted with darker hues indicating lower values (i.e. further away from the mean value). Cells coloured green have *above* average proportions of cell impacted with darker hues indicating higher values and showing the cells with the greatest proportion of cell impacted.

6.38 This means the same colour represents the same relative position along the range of values for each grid size and allows a more easy interpretation of the data at the two resolutions

6.39 The higher resolution plotter data, supporting analysis at a finer resolution, clearly shows (white) areas not subject to impact which are not ascertainable at the coarser resolution. Combining such impact metrics with high resolution information on seabed characteristics could provide increased understanding of pressures from fishing activity within sensitive or managed areas.

6.40 Were suitable data available to support automation of these processes, the scaling of this approach for multiple vessels, and at an appropriate resolution, could facilitate reporting of such MSFD metrics as 'percentage of seabed not impacted'. The additional data requirements, and the associated processing time for those data, may prove prohibitive.

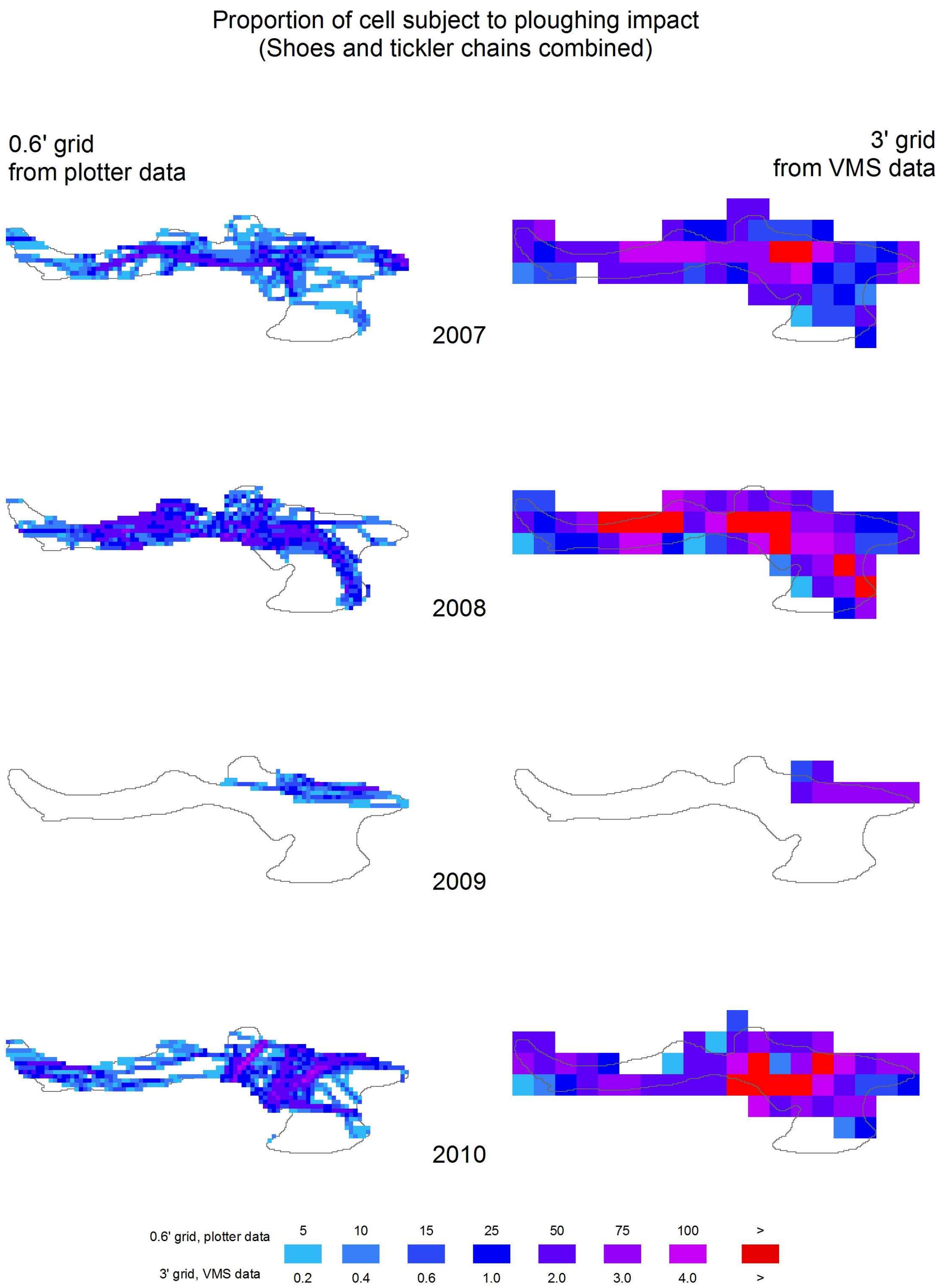


Figure 24: Improved resolution of analysis supported by plotter data

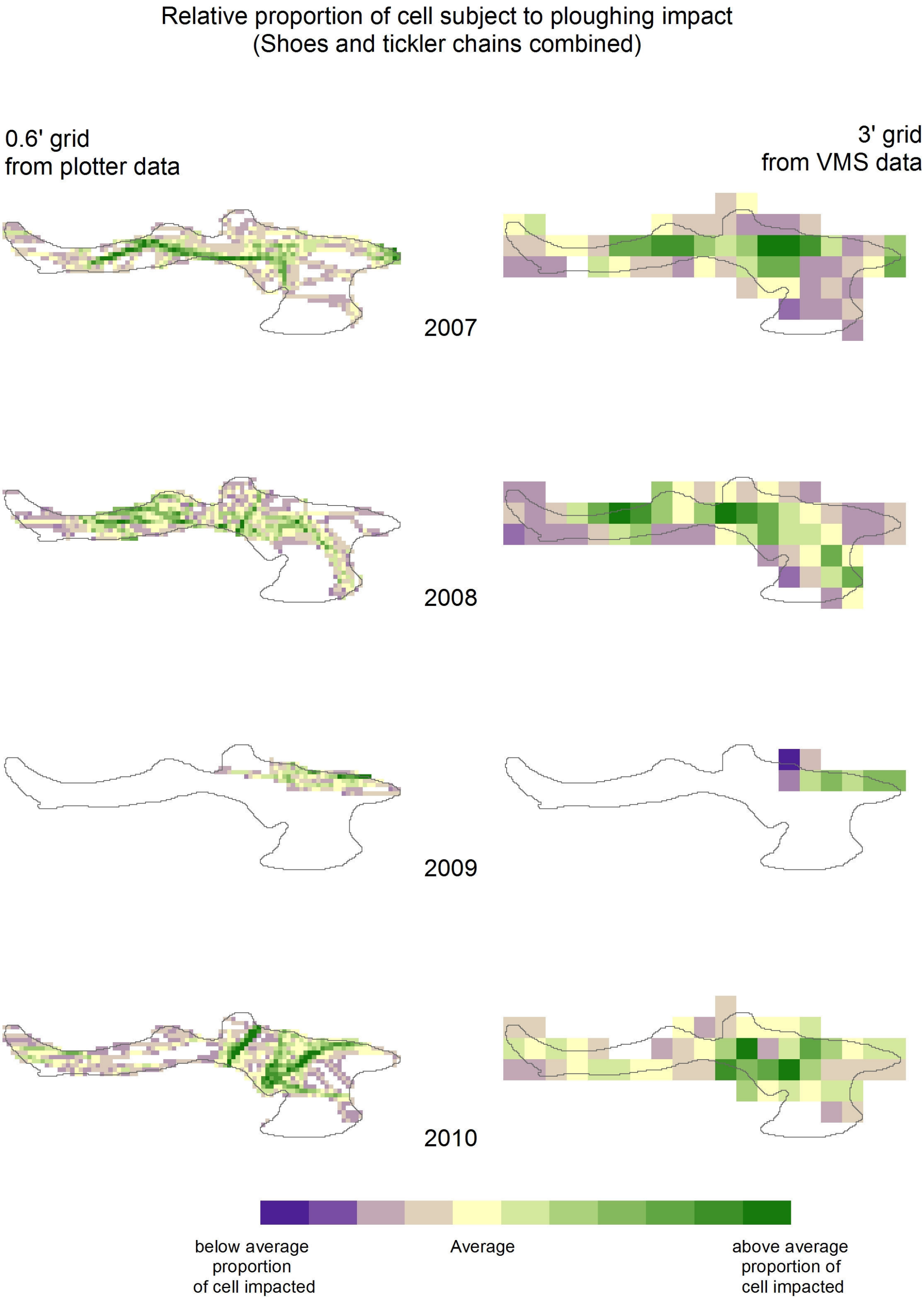


Figure 25: Relative proportion of cell subject to 'ploughing' impact

7. Summary and recommendations

7.1 The analysis has helped to identify the strengths and limitations of the plotter data supplied with additional attribution. The bulk plotter data was of limited utility as, without information identifying the time and date, the data can only indicate potential fishing locations.

7.2 None of the data as provided permit any analysis of the effectiveness of the fishing undertaken as no information on landings was supplied.

7.3 No control can be imposed regarding how skippers of fishing vessel make use of their on-board plotters. However, consistency in the use of such equipment would greatly assist in any subsequent use of those data. A series of targeted questions asked of the skipper at the time the data are collected could greatly aid interpretation of the data. Date and time information, where available, still contained many errors and required significant pre-processing prior to their inclusion in any analysis. This would make it difficult to automate routines for the importing of those data into other systems for subsequent analysis.

7.4 Detailed plotter data were only available for two vessels and therefore any conclusions drawn would be strengthened by the analysis being extended to a greater number of vessel and across differing fleets.

7.5 One set of the detailed plotter data was supplied with date and time information making it possible to easily analyse alongside corresponding VMS data. Analysis based on track length, speed, and fishing ground delineation was possible using these data and the results could be directly compared with those derived from VMS data.

7.6 The second set of detailed plotter data, while not being attributed with date and time information, were well-referenced by the skipper and organised in such a way as to indicate the week, month and year to which the data applied. Speed-based analysis was not possible using these data, and they could not be integrated with VMS data without manual intervention. However they still provided useful track length information which facilitated the delineation of fishing grounds. These data, if well organised, would support monthly, seasonal, annual or longer term identification of core fishing grounds.

7.7 Little variation was found in the fishing grounds delineated using the detailed plotter data with those created using VMS data. This reinforces the value of the methods of Jennings and Lee (2012) for identifying areas of importance for fishing. This work has shown that the method can be applied successfully at the level of the individual vessel as well as at the fleet scale. Further refinement of these methods could derive fleet fishing grounds based on an amalgamation of the grounds identified for individual vessels.

7.8 The speed profile of the plotter data, which are predominantly capturing fishing activity, indicate that the speed rules employed by Lee *et al.* (2011) are appropriate for capturing fishing activity of larger beam trawl vessels.

7.9 The polling frequency of the plotters can lead to high data volumes which increase the processing times required to obtained useful information from those data. Data collected at frequencies of less than 1 minute provide little additional spatial or temporal value but increase data volumes significantly. A sampling interval of between 1 and 5 minutes would appear to adequately support the re-creation of vessel tracks.

7.10 While plotter data, requiring significant pre-processing, may be of value for ad hoc analyses of particular areas, the results from this project indicate that any reduction in reporting interval helps to support more accurate representations of the distribution of fishing activity and more reliable assessments of fishing impacts. A reduction to 30 minutes from the existing 120 minutes would provide significant benefits, although higher frequencies would be needed for accurate representation of the fishing tracks of individual vessels.

7.11 The implementation of a system of 'geo-fences' whereby, within pre-determined areas of interest, the VMS reporting interval could automatically be altered could bring significant benefits to the management of controlled areas. The reporting interval could be modified according to the extent of the area enclosed within each 'geo-fence'.

7.12 Detailed plotter data, if collected in a consistent way and linked to data and time information, could assist in the analysis of seabed impacts and inform such good environmental status (GES) metrics as 'proportion of seabed not impacted'.

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Customer focus

With our unique facilities and our breadth of expertise in environmental and fisheries management, we can rapidly put together a multi-disciplinary team of experienced specialists, fully supported by our comprehensive in-house resources.

Our existing customers are drawn from a broad spectrum with wide ranging interests. Clients include:

- international and UK government departments
- the European Commission
- the World Bank
- Food and Agriculture Organisation of the United Nations (FAO)
- oil, water, chemical, pharmaceutical, agro-chemical, aggregate and marine industries
- non-governmental and environmental organisations
- regulators and enforcement agencies
- local authorities and other public bodies

We also work successfully in partnership with other organisations, operate in international consortia and have several joint ventures commercialising our intellectual property

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