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3M cod possible technical measures: spatial / temporal closures

by

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Abstract

In 2019, the NAFO Commission requested the NAFO Scientific Council (SC) advice on possible technical measures to protect and improve the productivity of the 3M stock of Atlantic cod, *Gadus morhua*. The objective of this paper is to study possible protection measures related to the temporal and spatial closures of fishing activity.

Analysis of historical maturity data indicates that the spawning time of 3M cod occurs during the first quarter of the year and that it is when 65% of the annual cod catch is made. The catch per unit of effort (CPUE) has generally higher values in this season than in the rest of the year and the mean length of caught cod in that season is generally above the length at maturity (L50). During this first quarter, trawl fishery activities are concentrated in a small area at the Southwest of the fishing ground, but, as our data comes from the fishery, we cannot conclude that this is the only spawning area as we have not information about cod activity in the rest of the area in that season.

For all these reasons, it is concluded that a spawning closure of Flemish Cap cod fishery during the first quarter of the year may be a suitable measure to protect and improve the productivity of 3M cod stock.

Introduction

The Flemish Cap is a traditional cod fishing area in Division 3M of the NAFO Regulatory Area. The cod fishery on Flemish Cap in the second half of the 20th century consisted of Portuguese trawlers and gillnetters, Spanish pair trawlers and Faroese longliners. The fishery was closed in 1999 and cod stock had been under fishing moratorium since then to 2009. Since its reopening in 2010 until now, the fishery has been composed mainly by trawlers from Portugal, Spain, Russia, Estonia, United Kingdom and Norway (in odd years) and since 2014 longliners from Faroe Islands (Denmark) and Norway (in even years) joined the fishery.

The main current measures for managing the cod fishery are a gear mesh size of 130 mm codend, a Minimum Landing Size (MLS) of 41 cm fork length and the annual TACs. In recent years the NAFO Commission requested the NAFO Scientific Council (SC) new measures to improve cod stock management.

Thus, in 2015 the Commission requested the SC to analyze and provide advice on management measures that could improve selectivity in the cod and redfish Division 3M fisheries in order to reduce possible by-catches and discards. The SC responded that the implementation of sorting grids in the Div. 3M cod fishery gear would reduce the catches of small and immature individuals of cod (below the MLS of 41 cm) reducing at the same time redfish by-catches and thereby discards. This measure would also increase the current F_{msy} value and the equilibrium yield (catches) with a small impact in the equilibrium Spawning Stock Biomass (SSB). To quantify these improvements selectivity experiments with the modified gears need to be performed in the Flemish Cap. Although the implementation of sorting grids was already analyzed in 2015 by NAFO Scientific Council (SC) (González-Costas *et al.*, 2015 and NAFO, 2015) this measure has not yet been taken.

In 2019, the Commission requested the SC advice on gear, including sorting grids, area and time-based measures that can be used to protect and improve the productivity of the 3M cod stock.

Atlantic cod, *Gadus morhua*, is a broadcast spawner species (Hutchings *et al.*, 1999) that aggregate in large numbers to spawn (Rose, 1993; Rose and Kulka, 1999; Wright *et al.*, 2006a; Siceloff and Howell, 2013). Aggregations are persistent from year to year and are formed in specific locations for set periods of time. Cod exhibits a diversity of migratory behavior associated with differing degrees of reproductive isolation among spawning aggregations (Knutsen *et al.*, 2003; Wright *et al.*, 2006b; Skjaeraasen *et al.*, 2011). These cod spawning characteristics described above make spawning closures, that have been applied to many stocks of this species, particularly appropriate (Murawski et al., 2000; Hu and Wroblewski, 2009; Armstrong et al., 2013).

In response to the Commission´s request, this document considers possible area/season closures to protect and improve the productivity of the 3M cod stock.

Material and methods

Biological data and length at maturity

Biological data collected on board by the IEO Scientific Observer Program between 2010 and 2018 were used for maturity estimations. The percentage of spawning females by haul has been calculated using data from macroscopic observation of gonads collected by these observers. Macroscopic maturity staging follows the common maturity scale proposed in the WKMSGAD (ICES, 2013), with the following stages: Immature (1), Maturing (2), Spawning (3), Regressing (4a), Regenerating (4b), Omitted spawning (5), and Abnormal (6). Although macroscopic observation is not as accurate as histology in some of the maturity stages, the spawning stage is easy to identify by eye because the gonad has increased in size and the hydrated oocytes are visible even to the naked eye. The macroscopic visualization of the spawning is therefore a reliable indicator of the season of spawning. The spatial-temporal distribution of the data taken by observers depends on the activity of the commercial fleet and the covering is not homogeneous. Thus, in order to cover all months and the whole area, female biological data from 2010 to 2018 were pooled (Table 1).

The length at first maturity (L50) has also been calculated, using in this case the microscopic (histological based) maturity data from ovaries collected in the EU Flemish Cap survey, carried out every summer since 1988, during the same period (2010-2018). For this estimation, maturity data is required to be accurate and to cover the whole length range. The method to estimate the L50 was similar to that used by Sampedro *et al.* (2018): Generalized Linear Models (GLMs) with a binomial error distribution and a logit link were fitted to the proportion of fish mature by length class. Estimated L50 was derived from the model parameters.

Haul by haul data (Catch, effort and CPUE)

NAFO Secretariat has compiled since 2016 the haul by haul data of all fleets fishing in the NRA. From the haul by haul database, the hauls corresponding to Div. 3M with cod catches in the period 2016-2018 were selected. From this set of hauls, the data with complete information (position, effort, etc.) were used and analyzed.

Understanding as directed hauls those where the percentage of the cod catch over the total catch was the highest of all the species caught, CPUE (kg/h) has been calculated in the directed hauls. Point out that the CPUE units chosen (kg / hour) may not be the most suitable for longline gears, but it is the most appropriate one available in the haul by haul database. In the directed trawl fishery in the 2016-2018 period there are 59 sets with otter twin trawls out of a total of 3148 general trawl. To estimate the CPUE of hauls with otter twin trawls sets, the total catch was divided by two.

Catch length distributions

Length distribution samples by haul of the 3M cod directed trawl fishery, carried out by scientific observers from Spain and Portugal in the period 2010-2018, have been analyzed. The length distribution samples of the catches of the Faroese (Ridao, personal communication) and Norwegian (Nedreaas, personal communication) longliners for the same period have also been analyzed. These length samples were carried out on board taking a random sample of the total cod catch of each sampled haul. Table 2 shows the number of hauls targeting cod with cod length distribution samples carried out in the trawl fishery by Portuguese and Spanish observers and in the longline fishery by Faroese and Norwegian observers in the period 2010-2018.

The mean length per sampled haul has been calculated. The total mean length per year and per month has been calculated as the mean of the observed mean length of each sample of that year and month.

Results

Maturity

In Table 1 it can be seen that in the period 2010-2018 there are no maturity data available in November and December and that in January and February the individuals observed are not many. It can also be seen that, especially in the first quarter, the specimens analyzed below 40 cm are a small amount. Note that these samples are only collected in the Spanish trawl fishery by the Spanish scientific observers.

Table 3 shows the estimated L50 per year with the Flemish Cap survey data. The minimum is found in 2013, when the 50% of females are mature at a length of 43 cm, while the maximum is found in 2011 and 2018, with a value of 58 and 56 respectively. The average value for the period (2010-2018) is 53.

Table 4 presents the percentage of spawning female cod (stage 3 of the common maturity scale proposed in the WKMSGAD ICES, 2013) by month in Div. 3M for the 2010-2018 period. These results clearly show that the main spawning season for the 3M cod is the first quarter of the year, where more than the 60% of the observed cod females each month were spawning. From then on, the percentage of spawning females drastically decreases.

Figure 1 shows the position and percentage of spawning females in every haul where maturity biological samples were recorded in the period 2010-2018 by quarter. Most of the observed sets where the percentage of spawning females is greater than 60% are concentrated in the first quarter and in a very specific area in the Southwest of Flemish Cap. Outside the first quarter, only a few sets where the percentage is greater than 60% are observed in the third quarter.

Haul by haul data

Catches

Figure 2 presents the 3M cod catch from the haul by haul data, by year and month, for the period 2016-2018. The black line in the plots represents the total catches of all sets where cod has been caught, while the areas show the catch of hauls directed to cod for the longline and trawl fisheries. Table 5 presents the 3M cod catches in this period by year, month and fishery as well as the percentage of the total catches by fishery and month. Figure 3 shows the distribution of sets with cod catches in Div. 3M by type of fishery, quarter and year for the analyzed period.

In these figures and tables it can be clearly seen that there are different fisheries that catch cod in Flemish Cap. There are two fisheries targeting cod that carry out more than the 90% of the annual total catches, the first with trawlers (around 65%) and the second with longliners (around 30%). There is another fishery (mainly redfish fishery) that catches cod as by-catch (around 5%). The main part of the annual total catches of cod in Div. 3M takes place in the first quarter (around 65%). Catches of the second (around 20%) and third quarters (around 10%) are considerably smaller and practically residual in the fourth quarter (around 5%).

Effort and Catch Per Unit Effort (CPUE)

The catch information shows that most of the cod catches are made in the directed fishery. Due to the problems in interpreting the CPUEs of the non-directed fisheries, it was decided to analyze only the CPUEs of the directed fisheries to cod in Div. 3M.

Table 6 presents the effort (number of sets and hours) of the cod directed fishery by gear, year and quarter. It can be observed that in the trawl directed fishery the main part of the total effort in hours takes place in the first and second quarters (around 65%-70%). Generally, effort in the third quarter is smaller (around 20%), and much less in the fourth quarter (around 10%). In the longline fishery, most of the total annual effort is made in the first quarter, with much less effort in the second and third quarters. Effort in the fourth quarter is null.

Figure 4 shows the position and CPUE value of sets targeting cod made in the 2016-2018 period by quarter and year. The circles represent the sets made with trawl and the triangles the sets made with longliners. Colors represent CPUEs levels (Kg / hour). To establish the color ranges, it was decided to use the percentiles of 20% of the distribution of the CPUEs of each year and gear; so each of the ranges contains 20% of the sets made that year with each gear.

Analysis of the haul by haul data shows quite constant annual spatial-temporal patterns of the fisheries catching cod in Div. 3M in the period 2016-2018. The trawl fishery targeting cod in the first quarter, when most of the catches of this fishery are taken, is concentrated in a small area of the Southwest quadrant of Flemish Cap at depths greater than 350 meters and the hauls made in this area and quarter have significantly higher CPUEs than those made in the other quarters. In the rest of the quarters the sets are more dispersed in the South central part of the Flemish Cap at different depths and their CPUEs are generally lower than those observed in the first quarter. The directed longline fishery in the first quarter of the year, when most of the effort of this fishery is performed, is not as concentrated in a small area as the trawl fishery. Normally it is carried out in the central Western part of the bank at depths between 150-350 meters. Hauls with by-catch occur mainly in the first and third quarter, especially in July, of each year. In the first quarter they are mainly conducted in the Northwest quadrant of Flemish Cap between the 400-500 meter isobaths and in the third quarter they are located throughout the Western half of the bank at slightly shallower depths, between the 300-400 meter isobaths.

Catch length distributions

Table 2 indicates that the monthly sampling coverage, mainly in the case of trawl fishery, is not closely related to the level of monthly fishing effort done (Table 5). Table 7 presents the cod mean length (cm) of these samples by gear, year and month, showing that the mean lengths per month of the longline fishery are higher than those observed in the trawl fishery. It can also be observed that the month mean length has no a clear trend in both fisheries, while the annual mean length shows a growing trend since 2013, mostly in the trawl fishery.

The position of the length samples is only available in the samples of the trawl fishery carried out by Spanish and Portuguese scientific observers. Figure 5 shows the position and mean size of these samples by quarter in the period 2010-2018. The range of colors has been decided taking into account the L50 estimated in Table 2. It can be generally interpreted that the range of blue colors are samples whose average size is less than the L50 and that they possibly have a large number of individuals below the Minimum Landing Size (MLS, 41 cm to fork), whites are samples where the average size is around the L50 and reds are samples where the average size is clearly above the L50. The spatial/temporal pattern observed in these samples is quite similar to that observed in the general trawl fishery in Figure 4, therefore it could be assumed that they are representative of the trawl fishery in general.

Highlight in Figure 5 the number of sets in the trawl fishery targeting cod that have an average size of around 40 cm or less, especially in the third quarter.

Discussion

The analysis of the data suggests that the catches of the cod directed fisheries in Div. 3M are made mainly in the first quarter and that these catches are mainly composed by spawning fish, as indicated by the fish maturity and length distributions. It can also be concluded that the trawl fishery in the first quarter is concentrated in a fairly small area that may be one of the main spawning areas since the catches made in this area have higher CPUEs and larger size individuals with a high percentage of spawning cods. This concentration of catches in a given area is less clear in the longline fishery.

Spawning aggregations often occur at times and places that are predictable making them vulnerable to exploitation (Sadovy and Domeier, 2005). Aggregative behaviour can cause localized increases in catchability which can lead to higher fishing mortality (Halliday, 1988; van Overzee and Rijnsdorp, 2015). High catch rates during spawning can mask overall stock declines as the aggregation fisheries exhibit catch per unit effort (CPUE) hyperstability (Rose and Kulka, 1999; Erisman *et al.*, 2011). High fishing mortality on spawning individuals will lead to a size and age truncation, which can affect the viability of offspring produced and the timing of spawning (Birkeland and Dayton, 2005; Wright and Trippel, 2009). Ultimately, the removal of larger individuals during spawning may also create a strong selection pressure for fish that mature at a smaller size and younger ages and so may have evolutionary consequences (Law, 2007; Devine *et al.*, 2012). Therefore, the cessation of fishing of spawning aggregations can lead to a recovery of demographic structure (Wright and Trippel, 2009), sex ratios (Beets and Friedlander, 1998), prevent the extirpation of distinct spawning components (Ames, 2004; Armstrong *et al.*, 2013) and reduce negative selection pressures (Law, 2007).

Area/season closures have been suggested as a tool to support fisheries management, particularly for areas/seasons where key life history stages congregate (Halliday, 1988; Murawski *et al.*, 2000; Pickett *et al.*, 2004), such as spawning aggregations. The application of spawning closures as part of a multidisciplinary approach to fisheries management is advocated to prevent the disruption of spawning activity and the extirpation of semi discrete spawning components. Integrating information on Atlantic cod spawning dynamics into fisheries management plans will better account for reproductive processes, which is expected to promote rebuilding and decrease the risk of further collapses of population structure (Zemeckis *et al.*, 2014). Therefore,

the introduction of a spawning area/time closure to the period when fish aggregate to spawn can reduce fishing mortality directly, while permitting sustainable exploitation outside of the spawning period (Murawski *et al.*, 2000).

Despite theoretical models predicting potential benefits of spawning area closures for fish conservation (Sadovy and Domeier, 2005; Gruss *et al.*, 2014), this management approach remains controversial due to the frequent lack of clear objectives, monitoring and empirical impact studies (Sadovy and Domeier, 2005; STECF, 2007; Gruss *et al.*, 2014). Although many spawning area closures have been established, the effectiveness of this approach has rarely been evaluated (van Overzee and Rijnsdorp, 2015). Spawning closures may be of benefit if they: (1) reduce the fishing mortality of the large and older spawners; (2) avoid negative effects on spawning habitats; (3) reduce the risk of over-exploitation in species which form large spawning aggregations; (4) reduce the evolutionary effects on maturation and reproductive investment; and (5) reduce the risk of over-exploitation of specific spawning components. The contribution of spawning closures to sustainable fisheries will differ among species and depends on the complexity of the spawning system, the level of aggregation during spawning and the vulnerability of the spawning habitat (van Overzee and Rijnsdorp, 2015).

The STECF subgroup on Management of Stocks (STECF, 2007) conducted comprehensive analyses of available relevant information about the existing closed areas within EU waters. The subgroup was not in position to draw full conclusions on the efficiency of any of the closures evaluated. The available data and information did in general not allow a separation of possible effects of the closures from effects of other management measures affecting the stocks and fisheries concerned. Despite the difficulty in measuring the effectiveness of the closures mentioned above, the STECF Mixed Fisheries Group recognized that the closure would not be sufficient by itself to protect cod, but that its removal would not help to improve cod recovery measures.

Then, there are different opinions on the best type of closure to consider: temporary, area or area / temporary. Although it seems that the closure of a wide area is the one that has the most support. This is what ICES (2019) recommends for the advises for Eastern Baltic cod for 2020. If spawning closures are chosen to be applied as a supplementary management measure, closures covering most of the distribution area of the stock during its main spawning time is preferable to small area closures. Eero *et al.* (2019) also conclude that designing relatively small area closures appropriately is highly complex and data demanding, and may involve tradeoffs between positive and negative impacts on the stock. Seasonal closures covering most of the stock distribution during the spawning time are more robust to data limitations, and less likely to be counterproductive if suboptimally designed.

Conclusions

In the case of 3M cod, it seems clear that the spawning season is the first quarter of the year. Regarding the spawning areas, it is difficult to know the total existing spawning areas within Flemish Cap, since the analyzed data for the first quarter of the year is quite concentrated in a small part of the Flemish Cap bank, which does not allow us to have information about what is happening elsewhere. Taking into account the existing problems to define the spawning areas, the small spatial distribution of this stock (Flemish Cap), the need to protect the Spawning Stock Biomass (SSB) as a whole and the simplicity of implementation and control of this management measure, it seems much more appropriate to close all Flemish Cap to the fishery targeting cod during the spawning season than close small areas.

Although the objective of this document is to study the possible implementation of spatial / temporal closures in the Flemish Cap cod fishery for spawning protection, it has also been observed that in the trawl fishery, with the current regulation, several individuals are caught below the Minimum Landing Size (MLS). It suggests the need of implementing other types of technical measures to avoid the capture of large amounts of individuals

below the MLS that have to be discarded following NAFO rules. Technical measures can be grouped into a) those that regulate the design characteristics of the gears that are deployed, such as the regulation of mesh size; b) those that regulate the operation of the gear such as setting maximum limits on how long or what type of gear can be deployed; c) those that set spatial and temporal controls such as closed/limited entry areas and seasonal closures; and d) those that define minimum sizes of fish and specify catch composition. NAFO SC proposed to solve this problem with the implementation of the 55 mm sorting grids in the current gear or the increase of the current codend mesh size around 20 mm (NAFO, 2015). This measure would have the advantage of minimizing redfish catches in the 3M cod fishery and to catch bigger cod, minimizing the discards in the cod fishery.

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Table 1. Number of cod females sampled by length range and month and number of fishing hauls sampled by month in Div. 3M by the Spanish Scientific Observers Onboard during the years 2010-2018.

	Month										
Length range	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	**n**
19-29	0	0	0	3	8	3	16	56	9	8	103
30-39	0	0	14	38	73	101	78	59	78	23	464
40-49	1	1	124	106	167	282	116	198	119	43	1157
50-59	2	7	386	237	101	244	166	179	108	46	1476
60-69	6	3	413	299	112	227	197	157	126	86	1626
70-79	25	5	237	261	50	47	190	46	35	34	930
80-89	36	10	139	326	24	30	83	14	17	8	687
90-99	16	4	99	266	15	11	41	10	7	7	476
100-109	3	1	33	113	6	5	22	7	3	2	195
110-119	0	2	8	37	0	0	9	2	1	0	59
120-129	1	0	3	9	1	0	2	0	3	0	19
130-139	0	0	1	0	0	0	1	0	0	0	2
Total	90	33	1457	1695	557	950	921	728	506	257	7194
Hauls sampled	7	3	62	74	20	20	48	28	20	8	290

Table 2. Number of hauls with cod length distribution samples by gear, year and month, of the 3M cod directed fishery, 2010-2018.

Number of trawlers length distribution samples

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2010	3		10	29	17	18	5	4	8	13	8	12	127
2011		6	17	14	15	11		8	14	20			105
2012				30	6	17	9		4	8			74
2013		9	12	7	20	9	6	16	13	1	1		94
2014		10	44	22	12	3	10	12	8	1	2		124
2015	4	14	20	4	20	23	15	12	14	9	4		139
2016	1	13	9		9	14	9	2	10		4		71
2017	8	18			1	18	2	15	20	15			97
2018	3	10	9	13	7	9	7	7	8	16			89
Total	19	80	121	119	107	122	63	76	99	83	19	12	920

Number of longliners length distribution samples

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2010													
2011													
2012													
2013													
2014										1			1
2015	2	3											5
2016	19	12											31
2017	36	19											55
2018	34			9	32								75
Total	91	34		9	32					1			167

Table 3. Cod female length at maturity (L50) in cm estimated with microscopic maturity data obtained in the Flemish Cap surveys from 2010 to 2018. The mean length at maturity is also showed.

Year	L50 (cm)
2010	54
2011	58
2012	53
2013	47
2014	50
2015	50
2016	54
2017	52
2018	56
Mean(2010-2018)	53

Table 4. Percentage of spawning female cod by month in Div. 3M for the 2010-2018 period.

Month	Spawning %	Not Spawning %	**n**
Jan	88.89	11.11	90
Feb	72.73	27.27	33
Mar	60.12	39.88	1457
Apr	18.35	81.65	1695
May	1.80	98.20	557
Jun	0.11	99.89	950
Jul	8.14	91.86	921
Aug	0.27	99.73	728
Sep	0.40	99.60	506
Oct	0.78	99.22	257

Table 5. 3M cod catches (tons) by fishery, year and month as well as the percentage of the total catches by month and fishery for each year based on the haul by haul data in the period 2016-2018.

		Month													
Year	**Fishery**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**	**%**
2016	**By_Catch**	38	79	0	6	0	0	156	0	0	1	0	0	279	3%
	LL	2181	883	0	417	0	1	22	0	0	0	0	0	3504	34%
	OTB	29	2867	835	40	480	816	378	180	666	91	114	22	6517	63%
Total 2016		2248	3828	835	463	480	817	555	180	666	92	114	22	10300	100%
%		22%	37%	8%	4%	5%	8%	5%	2%	6%	1%	1%	0%		
2017	**By_Catch**	33	56	0	0	2	0	99	0	0	0	0	0	190	2%
	LL	959	331	0	0	0	0	0	0	0	0	0	0	1290	17%
	OTB	577	1891	1325	368	628	561	26	281	229	423	3	17	6329	81%
Total 2017		1569	2278	1325	368	630	562	124	281	229	423	3	17	7809	100%
%		20%	29%	17%	5%	8%	7%	2%	4%	3%	5%	0%	0%		
2018	**By_Catch**	67	193	66	0	8	0	92	19	0	0	0	0	446	5%
	LL	2193	0	0	22	675	0	0	0	2	0	0	0	2892	31%
	OTB	833	890	1074	441	534	644	273	219	411	183	63	351	5914	64%
Total 2018		3093	1083	1140	463	1218	644	364	238	412	183	63	351	9253	100%
%		33%	12%	12%	5%	13%	7%	4%	3%	4%	2%	1%	4%		
Total 2016-2018		6910	7189	3300	1293	2328	2023	1044	700	1307	699	180	390	27362	
% 2016-2018		25%	26%	12%	5%	9%	7%	4%	3%	5%	3%	1%	1%	100%	

Table 6. Directed 3M cod fisheries effort (number of hauls and hours) by fishery, year and quarter for the 2016-2018 period as well as the percentage of the effort (hours) by quarter and year.

		2016				2017				2018			
		Q 1	Q2	Q3	Q4	Q 1	Q2	Q3	Q4	Q 1	Q2	Q3	Q4
Trawl	Hauls	320	303	191	56	430	299	105	57	535	396	259	197
	Effort (hours)	942	1506	1015	272	1453	1220	601	302	2086	1698	1158	594
	Effort % Year	25%	40%	27%	7%	41%	34%	17%	8%	38%	31%	21%	11%
Longliners	Hauls	134	29	15		66				94	60	2	
	Effort (hours)	2484	294	35		1490				1841	721	16	
	Effort % Year	88%	10%	1%		100%				71%	28%	1%	

Table 7. Cod mean length (cm) of the targeting length distributions samples in the period 2010-2018 by gear, year and month.

Trawlers catches mean length (cm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2010	81.0		57.5	64.0	61.8	59.5	54.1	59.7	53.1	51.8	60.8	55.4	59.5
2011		57.2	53.8	79.3	49.4	53.3		53.5	51.5	51.3			55.9
2012				72.7	72.8	54.1	48.9		50.6	48.1			61.7
2013		50.7	57.1	46.5	47.4	43.5	43.1	40.9	41.8	42.5	45.6		46.3
2014		48.8	57.3	58.3	44.0	43.8	47.9	49.5	46.1	50.4	50.8		52.8
2015	48.6	50.7	64.8	69.7	52.1	51.4	50.8	47.4	49.4	50.2	67.3		53.6
2016	47.8	54.1	60.5		47.0	54.5	56.4	50.2	58.7		68.9		55.7
2017	63.5	64.7			57.1	63.0	61.8	56.4	65.9	65.4			63.2
2018	62.0	66.6	63.0	60.2	64.1	64.9	55.2	56.9	64.1	64.3			62.5
Total	62.1	56.6	58.7	65.7	53.0	55.4	51.2	50.4	54.2	55.9	62.0	55.4	

Longliners catches mean length (cm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2010													
2011													
2012													
2013													
2014										68.5			68.5
2015	72.1	71.7											71.9
2016	67.2	65.6											66.6
2017	75.3	79.9											76.9
2018	71.1			72.5	77.0								73.8
Total	72.0	74.1		72.5	77.0					68.52			

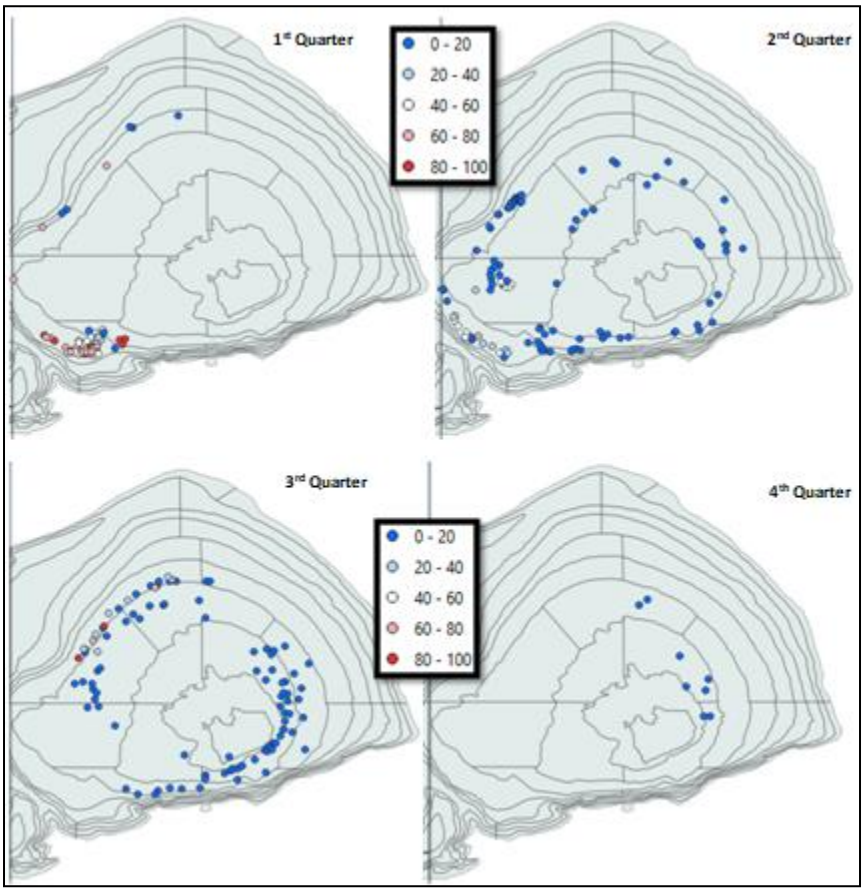


Figure 1. Location by quarter of commercial hauls where biological maturity sampling of cod in Div. 3M was carried out by Spanish scientific observers in the period 2010-2018. Each point represents a sampled haul and the colors represent the percentage of spawning females over the total females.

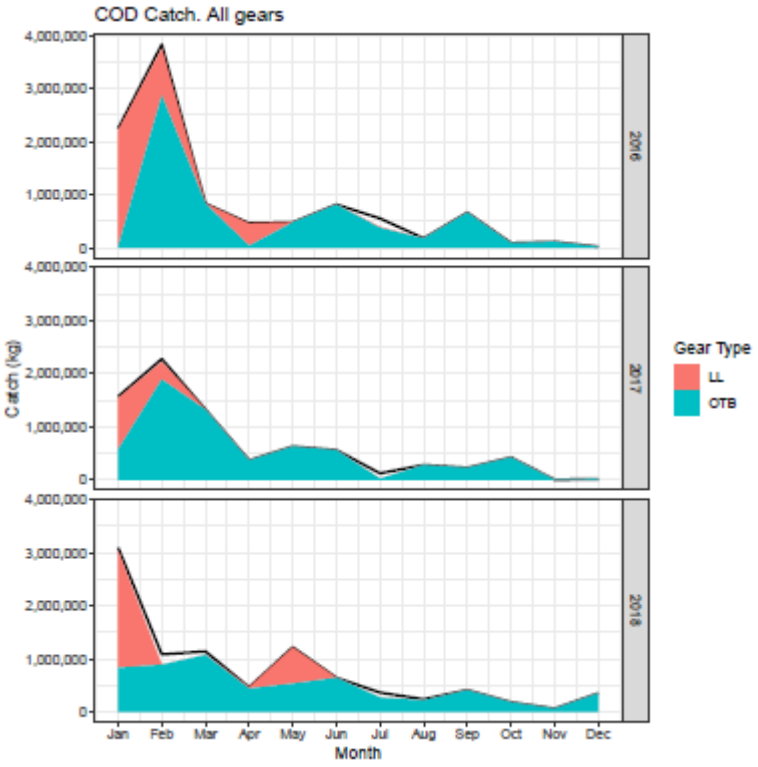
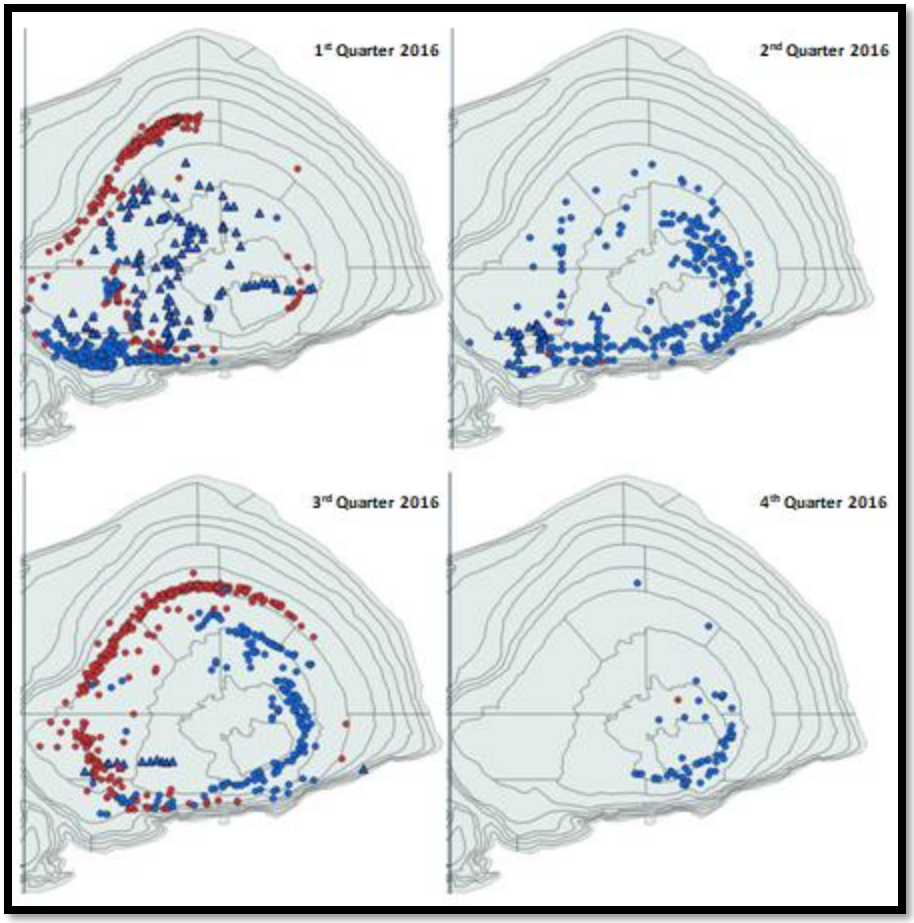
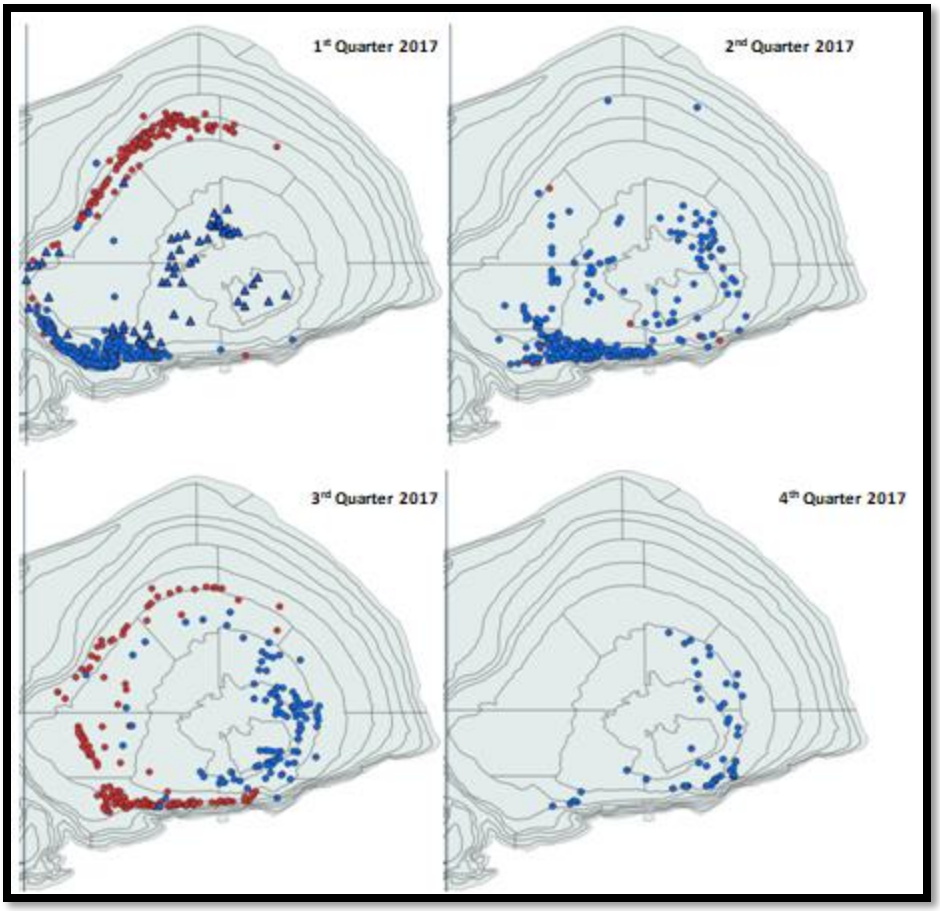


Figure 2. 3M cod catches (Kg) by year and month based on the haul by haul data in the 2016-2018 period. The black line shows the total 3M cod catches, while the areas show the catch of hauls directed to cod for the longline (LL) and trawl fishery (OTB).


1st Quarter 2016
2nd Quarter 2016
3rd Quarter 2016
4th Quarter 2016


1st Quarter 2017
2nd Quarter 2017
3rd Quarter 2017
4th Quarter 2017

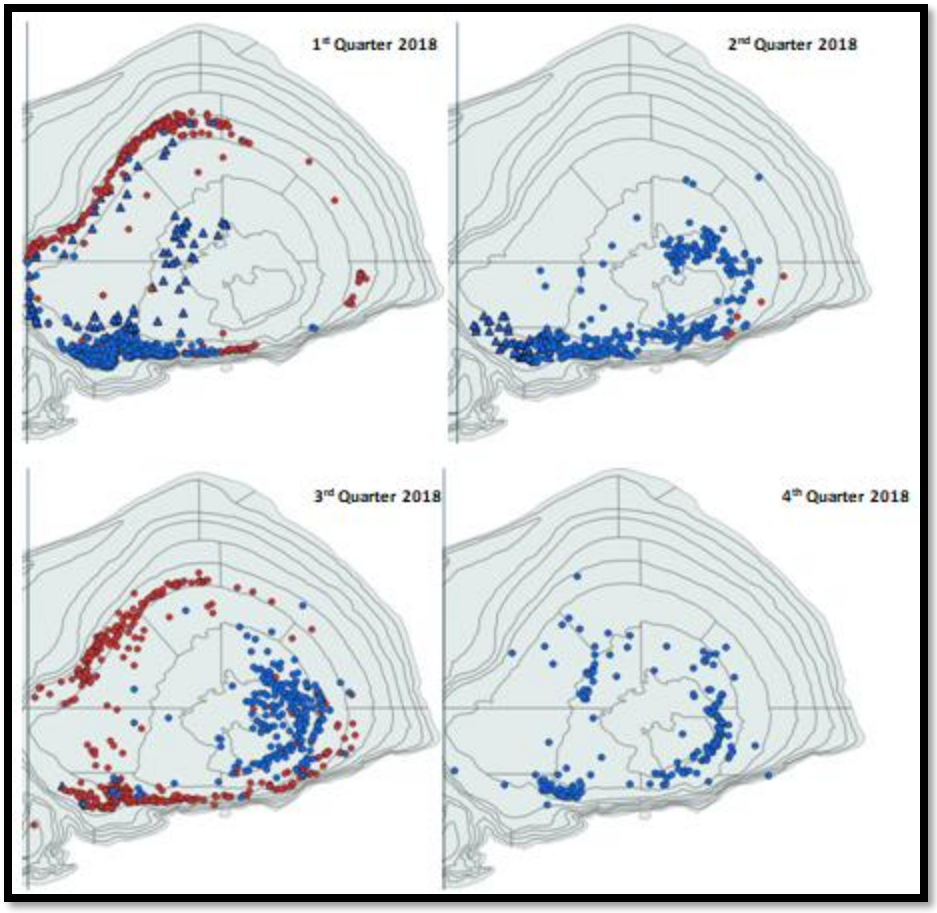
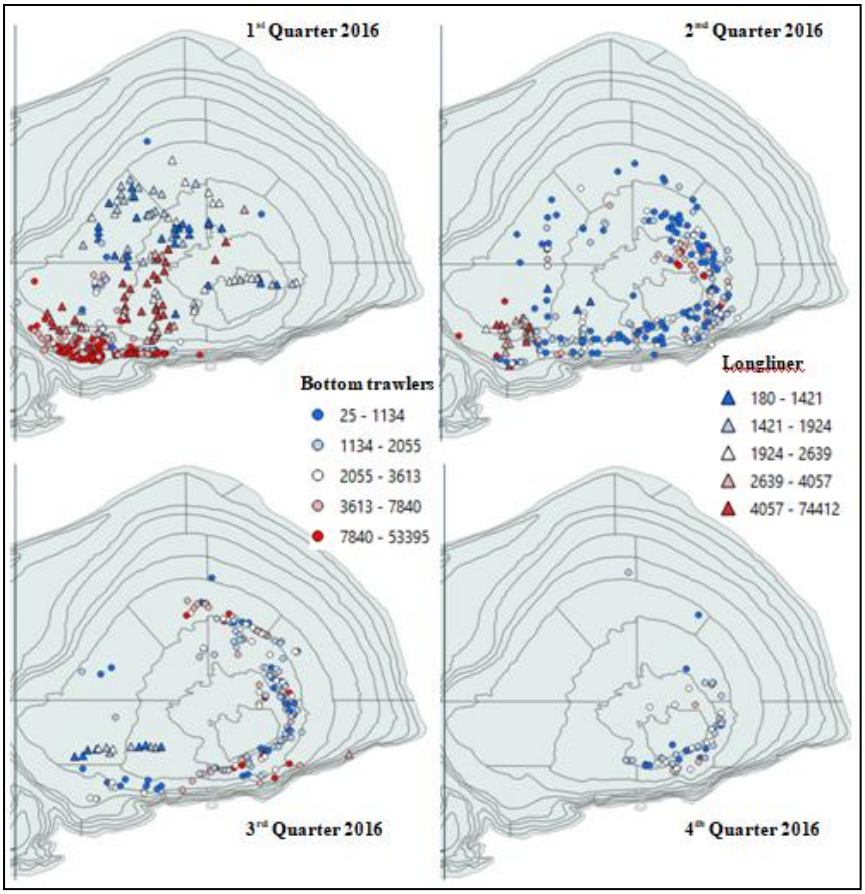
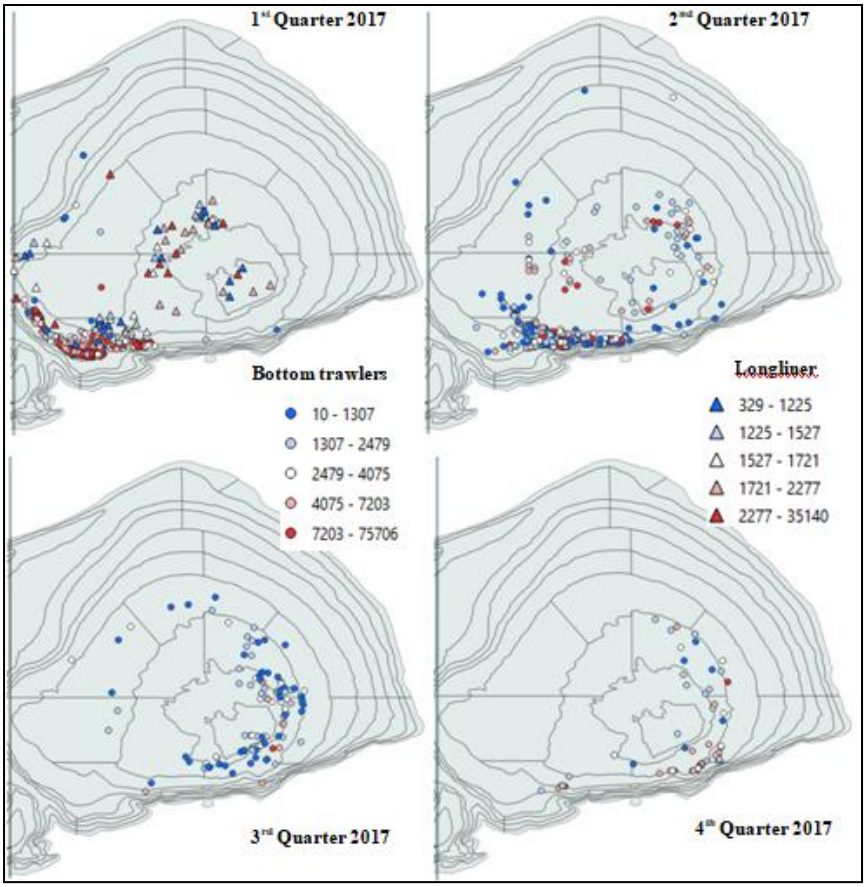


Figure 3. Position of sets with cod catches in Div. 3M by year. The circles represent the trawlers sets and the triangles the longliners sets. The red color indicates the sets with cod by-catch and the blue color represents the sets directed to cod.


1st Quarter 2016
2nd Quarter 2016
3rd Quarter 2016
4th Quarter 2016
Bottom trawlers
25 - 1134
1134 - 2055
2055 - 3613
3613 - 7840
7840 - 53395
Longliner
180 - 1421
1421 - 1924
1924 - 2639
2639 - 4057
4057 - 74412


1st Quarter 2017
2nd Quarter 2017
Bottom trawlers
10 - 1307
1307 - 2479
2479 - 4075
4075 - 7203
7203 - 75706
Longliner
329 - 1225
1225 - 1527
1527 - 1721
1721 - 2277
2277 - 35140
3rd Quarter 2017
4th Quarter 2017

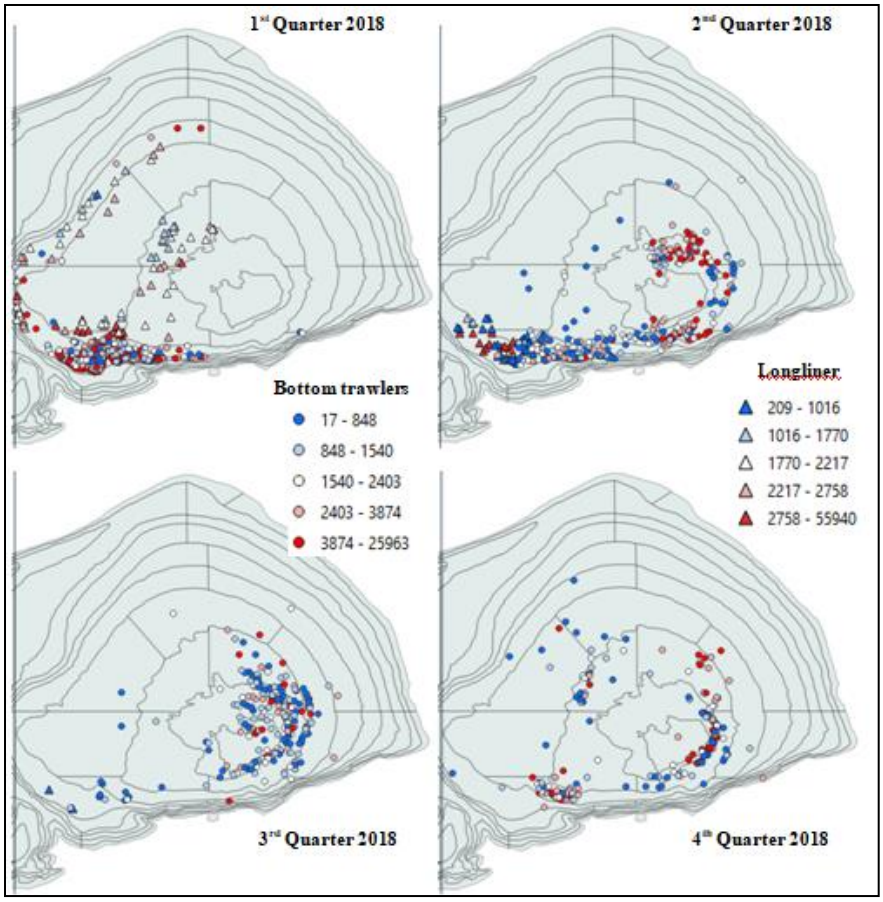


Figure 4. Position of sets targeting cod. The circles represent the sets of the trawlers and the triangles the longliners sets. The color indicates the CPUEs levels. Each of the ranges contains 20% of the sets made in a year with each gear.

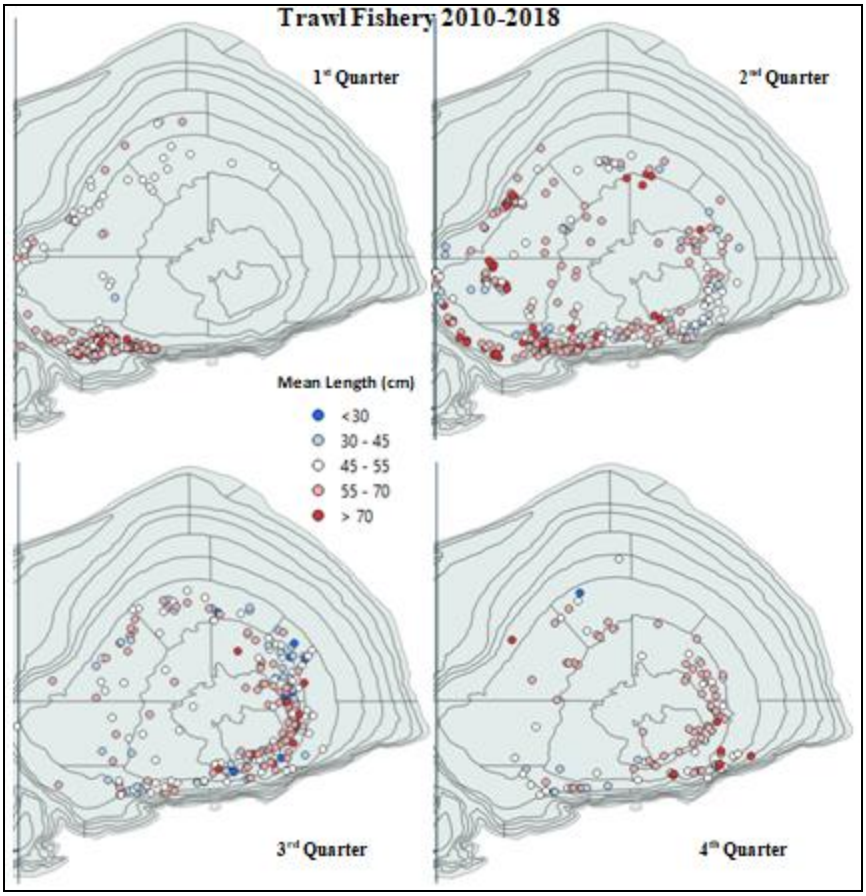


Figure 5. Position of the length distribution samples carried out by the Spanish and Portuguese scientific observers in the 3M cod trawl fishery in the period 2010-2018 by quarter. The colors represent the mean length ranges of each sample.