

Joint Swedish and Danish survey for cod in the Kattegat November-December 2018

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Abstract

An annual survey targeting cod in Kattegat was initiated in 2008 and has then been continued every year with the exemption of 2012. The survey is conducted in November-December in cooperation with commercial trawlers from Denmark and Sweden. The survey design has been largely unchanged during the years, but a fourth stratum representing the closed area in Southern Kattegat was added in 2013. The total swept area biomass of cod was estimated to 647 tonnes in 2018. This corresponds to a reduction of more than 90% compared to 2015 when the highest biomass was estimated and represents the lowest estimated biomass in the whole time series of the survey. The abundance decreased from an estimated 3.52 million individuals in 2017 to 0.88 million in 2018 which is also the lowest number ever estimated in the survey. The estimated numbers of fish five years and older is still higher than in 2009-2011, but the potential recruitment observed in 2017 data can no longer be detected in the survey.

Introduction

Cod fishermen in Kattegat have, since 2003, been restricted by steadily decreasing quotas due to low abundance of cod estimated from the cod assessment. ICES consider, however, the cod assessment in Kattegat uncertain due to the catch data quality and the analytic assessment has not been accepted by ACOM in recent years. The assessment has shown a discrepancy between the reported landings and total removals from the stock and ICES assumed that the majority of the unallocated mortality was caused by discard, but at the benchmark 2016 it was concluded that other factors, primarily migration of cod from the North Sea/Skagerrak was a major part of the problem. Therefore, the assessment has to be largely based on available fisheries independent survey information. The surveys conducted previously in the Kattegat area were however not well suited for estimation of total cod abundance mainly due to the way they are designed, as well as limited coverage and sampling intensity. This also implies that the relative abundance indices obtained from these surveys were relatively noisy, especially for older ages. In 2008 a joint Swedish – Danish survey series directly aimed at cod and with better coverage of the area was initiated.

The goal of the Kattegat cod survey is to provide fisheries independent data for estimating the abundance, biomass, recruitment and distribution of cod. The results should be used to strengthen the scientific advice on the cod stock in Kattegat. Due to considerably better coverage compared to hitherto available surveys, the joint Swedish and Danish Kattegat cod survey improves the knowledge of spatial distribution of cod by size/age-groups and provides valuable information for monitoring the effect of the closed area established in the Kattegat from January 1. 2009.

Restrictions

The commercial trawlers participating in the survey conduct the survey without any restrictions in the vessels quota, days at sea regulation and with dispensation from all by-catch regulations.

Materials and Methods

Survey area

The survey area is covering Kattegat area restricted northward by a line from Skagen to the Tistlarna lighthouse and south-eastward by a line between Gilleleje and Kullen and south-westward by a line between Gniben and Hassensør on Djursland. Further, the area is restricted by the 20 m depth contour line and the area is split in areas “North” and “South”. However, parts of Laholmsbukten and Skælderviken are also included in the survey area despite that the depth is shallower than 20 meter

Survey method and stratification

The survey is designed as a stratified random bottom trawl survey. Data is raised by strata allowing for re-stratification between years if necessary. The survey area where during 2008-2011 stratified in three strata based on information from commercial fishers on expected densities of cod: a stratum with expected high density of cod, a stratum with medium density and a stratum with low density. In 2010 and 2011 there was a minor re-stratification to adopt the areas to the catch information collected during the former years. In 2013 a fourth strata was added to better assure data from the area closed for fisheries.

Each stratum is further subdivided in 5*5 nm squares (sections). The high density, medium density and closed area stratum has been allocated relatively more stations than the other strata (Fig 1a-c) and table 1.

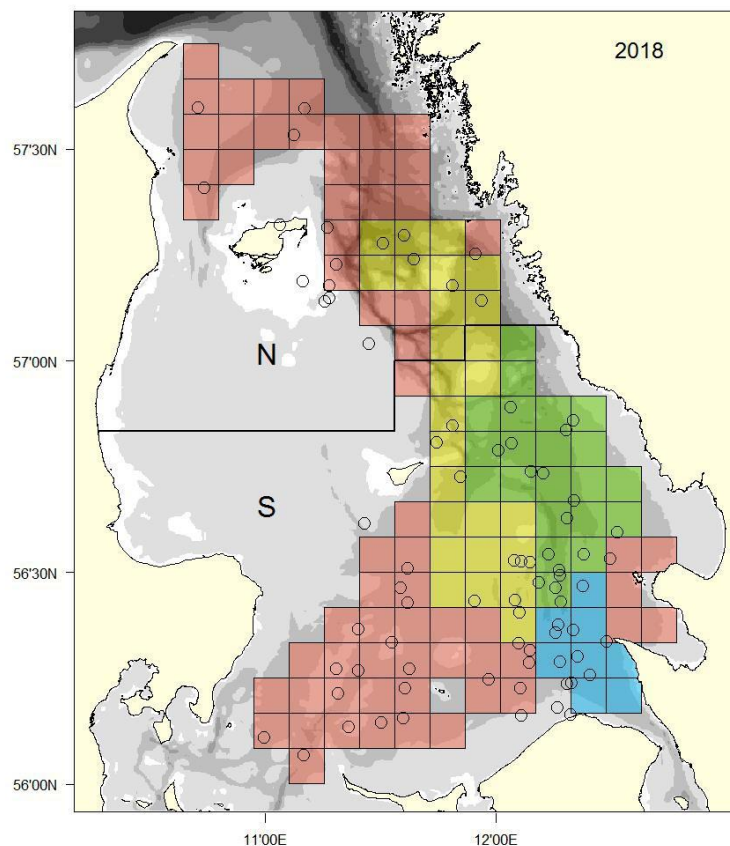


Figure 1. Survey stratification and sampled stations in 2018. Green represents high density areas; yellow medium density areas and red low density areas. From 2013 the fourth (blue) stratum was added to ensure sufficient sampling in the closed areas. N (north) and S (south) identifies the two domains used for age sampling.

Table 1: Showing number of survey squares by strata and year.

Year	High density	Medium density	Low density	Closed area	Total
2008	10	44	65		119
2009	10	44	65		119
2010	15	32	72		119
2011	18	31	70		119
2012					
2013	21	26	65	8	120
2014	21	26	65	8	120
2015	21	26	65	8	120
2016	21	26	65	8	120
2017	21	26	65	8	120
2018	21	26	65	8	120

Station (tow) location

The survey is planned with in average 3 to 4 trawl hauls per day in 6 days for each of the 4 vessels, i.e. in total 80 trawl hauls. Each vessel is assigned 20 randomly selected 5*5 nm survey squares. Probability for a square to be selected differ between strata (see table 1 and table 2). The skipper of the vessel decides on the best way to fish at the square and hence the exact position of the haul. In the closed area, high and medium density strata several vessels are allowed to fish in the same square. In the low density stratum only one haul is allowed in each square. Furthermore the low density area is divided in a Southern and Northern area. 1 Danish and 1 Swedish vessel are fishing in the south area and the other vessels are fishing in the north.

Table 2: Showing number of stations by vessel, stratum and area. In 2013 only Swedish vessels participated in the survey.

Year	Number of vessels	High density	Medium density	Low density	Closed area	Total
2008	4	6	8	6	20	80
2009	4	6	8	6	20	80
2010	4	6	8	6	20	80
2011	4	9	6	5	20	80
2012					20	80
2013	2	15	10	10	20	80
2014	4	6	5	7	20	80
2015	4	6	5	7	20	80
2016	3	6/12	5/10	7/14	20	80
2017	3	6/12	5/10	7/14	20	80
2018	3	6/12	5/10	7/14	20	80

Target species

The survey design is optimised to get estimates on cod. All species are recorded and the survey can be used for other species as well.

Survey period

The survey takes place during second half of November - first half of December.

Vessels and Fishing gear*Vessels*

The survey is conducted by four commercial chartered trawlers, two covering the northern and two the southern area, respectively. Two vessels are Swedish and the other two are Danish. The vessels have been appointed due to the similarity in engine power, length and applicability for scientific investigations. From 2016 and onwards Denmark has used R/V Havfisken instead of chartered trawlers, thus 2 Swedish vessels and 1 Danish vessel participate in the survey. The Danish vessel fish twice as many hauls as the Swedish vessels keeping the total fished hauls at the same level as previous years. Participating vessels are shown in table 3.

Table 3: Vessels participating in the survey.

Year	DK1	DK2	SWE1	SWE2
2008	Sören Kanne	Susanne H	Otseco	Yvonne II
2009	H210	Susanne H	Otseco	Yvonne II
2010	Havfisker	Susanne H	Ganler	Tärnan
2011	H292	Susanne H	Cindy Wester	Tärnan
2012				
2013			Cindy Wester	Tärnan
2014	Tiki	Stjerne	Cindy Wester	Tärnan
2015	Annie Holm	Stjerne	Cindy Wester	Tärnan
2016	Havfisker	Havfisker	Cindy Wester	Tärnan
2017	Havfisker	Havfisker	Cindy Wester	Tärnan
2018	Havfisker	Havfisker	Cindy Wester	Tärnan

Gear

The trawl is a commercial bottom trawl.

Trawl (see Annex 1): A Swedish TV-trawl 112 ft. 24-464 mounted with 13 8" balls and 16 6" balls. Ground gear: Rock hopper type with 4 thumps rubber discs at 10 cm Mesh size in cod end: 70 mm stretch mesh. Otter boards: 64"-66" "Thyborøn" Warp: 15 mm.

The trawls are checked continuously during the survey.

Fishing operation

Within each square the skipper decides on the best way to fish at the location (e.g. exact position and tow direction). Maximum 5 min of the total trawling time should be outside the allocated square. If the 5 minutes are exceeded the haul should be terminated.

Trawling was restricted to 15 min. before sunrise to 15 min. after sun set.

Trawl procedure

Towing time: 60 min (towing time down to 20 min is accepted). Towing speed: Between 2.7 kn. and 3.4 over the seabed, but speed should not vary within a station. Hauls start: when the trawl is considered going stable on the bottom, roughly 5-7 min after wires are connected. Haul end: when hauling back starts. Trawled distance: is estimated from the plotter or by the mean of the towing speed recorded every 10 min. and the total towing time.

Sampling of catch

There were two technicians/scientists from DTU-Aqua (Danish vessels) or SLU-Aqua (Swedish vessels), on board each vessel who were responsible for processing the catch.

The catch was processed in accordance with IBTS standard operating procedures for trawl surveys. After each haul the catch was sorted by species and weighed to nearest 0.1 kg and the number of specimens recorded. All fish species are measured as total length (TL) to 1.0 cm below. Norwegian lobster was measured in mm.

For cod are two otoliths per cm class and area (north and south) collected. The Swedish sampling protocol for age changed in 2016 and otoliths were taken from every haul. The number of individuals sampled for age by haul was 1 individual per length class for cod size 10-40 cm, 2 individuals per length class for cod size 41-60 cm and 3 individuals per length class for cod larger than 60 cm.

Screening of data

All trawl data (position, wingspread, towing speed etc.) and catch and length frequency data on cod were screened for unrealistic figures before further estimations.

Data

Data are stored in a standard data base and could, if the survey continues, be uploaded to the ICES DATRAS system.

Survey area

Hence no stations are deeper than 100 m, biomass and abundance is estimated for depths between 20 and 100 m (including the two shallow areas Laholmsbukten and Skælderviken). The survey area is stratified in four strata: HIGH, MEDIUM, LOW and CLOSED AREA. The total survey area is 10204 km².

Biomass and abundance

Biomass and abundance was estimated through a traditional Swept area calculation where mean catch km⁻² is multiplied with the stratum area.

- 1) Biomass and abundance estimates are obtained by applying the swept area method using the recorded towed distance and wing spread and the stratum area as weighting factor (Cohran, 1977).

Wing spread is estimated as:

$$\text{Wing spread} = \frac{\text{Ground gear length} \times \text{Door spread}}{\text{Bridle length} + \text{Ground gear length}}$$

Door spread is estimated for the single hauls, using a warp divergence method (Anon. 2006) (Annex 1).

Swept area = (distance towed (nm) x 1.852) x (wing spread (m))/1000

The catchability coefficient is assumed to be 1.0.

All catches are standardized to 1 km² swept prior to further calculations.

Estimation of stock indices

Calculation of biomass and abundance indices was based on the stratified random design, assuming sampling with replacement. Age at length was estimated from Swedish samples only. From 2013 the survey area contained 120 5×5 Nm squares, but for consistency, biomass and abundance was estimated for 119 squares throughout the period. All calculations were carried out in R, using the R-survey package (Lumley 2012).

Ref T. Lumley (2012) “survey: analysis of complex survey samples”. R package version 3.28-2.

Results

Biomass and abundance

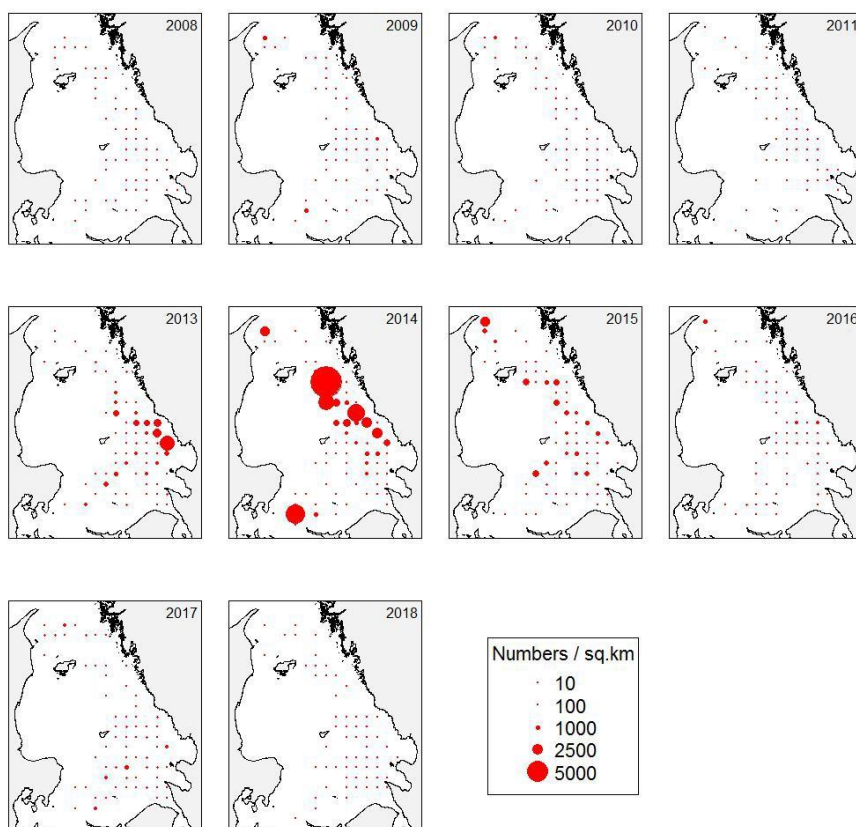
Annual data on cod abundance and distribution for 2008-2018 is given in Figure 2ab. For biomass, 2014 and 2015 stand out with quantities high above the level for 2008-2011. For numbers, year 2014 was the highest in the timeseries.

The trawlable biomass of cod in 2018 was estimated to 647 tons, compared to 2255 tons in 2017 and 4977 tons in 2016 (Table 4). This corresponds to a reduction in biomass with approximately 87% in two years. The trawlable abundance in 2018 was estimated to 0.88 million which corresponds to a 75% decrease compared to 2017 (3.52 million) and more than 90% decrease from the estimate of 8.73 million in 2014 (Table 4).

The highest densities in biomass (133 kg per km²) and numbers (112 specimens per km²) were found in high stratum (Table 5 and 6). This was also the case in 2016 & 2017 but differs from 2015 when the highest biomass was found in the mid-density stratum. Catch per unit effort, measured as weight per trawl hour and numbers per hour was highest in the high density area (Table 8).

Table 4: Biomass (t) and abundance of cod with Stdev together with weight and number km2 by year.

Year	Weight km2	Stdev	Biomass	Number km2	Stdev	Abundance
2008	129.20	216.10	1318.10	156.80	94.00	1.60e+06
2009	80.60	78.30	822.40	212.00	203.00	2.16e+06
2010	75.70	84.10	772.20	211.70	193.60	2.16e+06
2011	119.60	187.20	1220.00	224.10	175.90	2.29e+06
2013	232.80	330.80	2375.00	540.70	493.40	5.52e+06
2014	776.60	1450.10	7924.50	855.60	1299.10	8.73e+06
2015	919.10	1119.50	9378.60	563.30	495.80	5.75e+06
2016	487.80	562.30	4977.00	303.40	250.10	3.10e+06
2017	221.00	290.90	2255.00	344.90	244.90	3.52e+06
2018	63.40	99.60	646.80	86.30	86.00	8.80e+05

**Figure 2a.** Abundance of cod per km2, calculated as an average from all vessels per square.

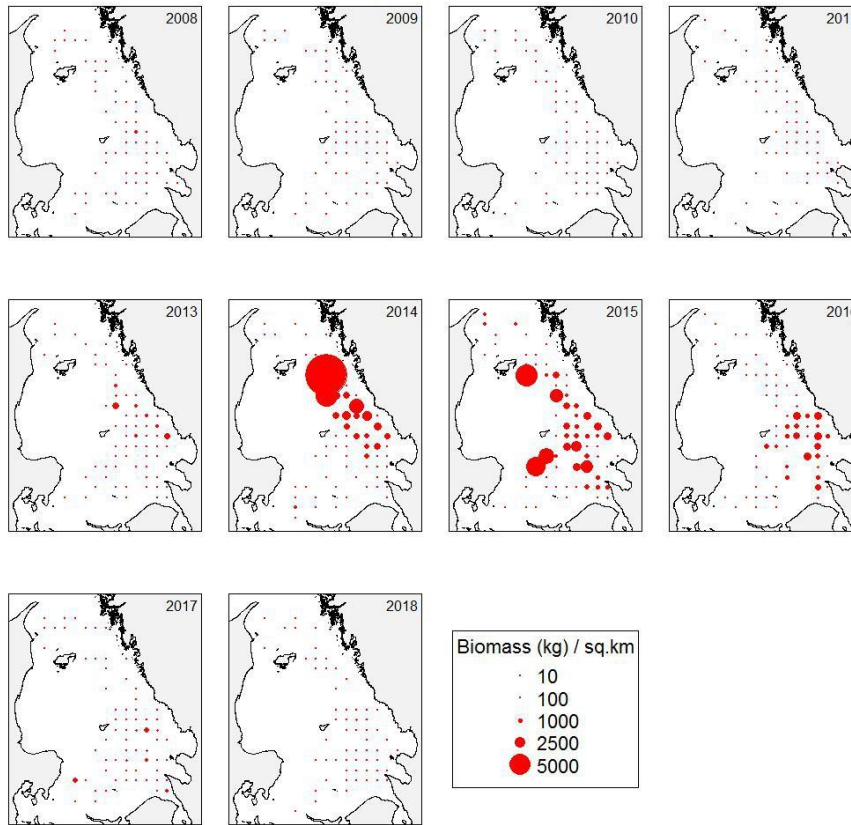


Figure 2b. Biomass of cod per km², calculated as an average from all vessels per square.

Table 5: Stratum area (km), number of hauls, mean biomass per km² (tons), Stdev and total biomass (tons).

Strata	Area	Hauls	Mean_biomass_km2	Stdev	Biomass
Closed	686.00	8	60.70	55.80	41.70
High	1801.00	25	133.00	89.60	239.50
Medium	2229.00	20	58.50	42.00	130.50
Low	5574.00	25	21.30	105.00	118.40

Table 6: Cod 2018, Stratum area (km), number of hauls, number per km² (tons), Stdev and abundance

Strata	Area	Hauls	Mean_number_km2	Stdev	Abundance
Closed	686.00	8	88.80	55.80	6.09e+04
High	1801.00	25	112.20	89.60	2.02e+05
Medium	2229.00	20	71.30	42.00	1.59e+05
Low	5574.00	25	78.70	105.00	4.39e+05

Length distribution The length ranged from 10 to 85 cm. The overall length distribution (weighted by stratum area) showed modes at 18 and 30 cm in 2018 (Figure 5 and 6). Most small cod were found in the low and medium density areas, while large individuals (over 50 cm) were more common in the medium and high density areas (Figure 6).

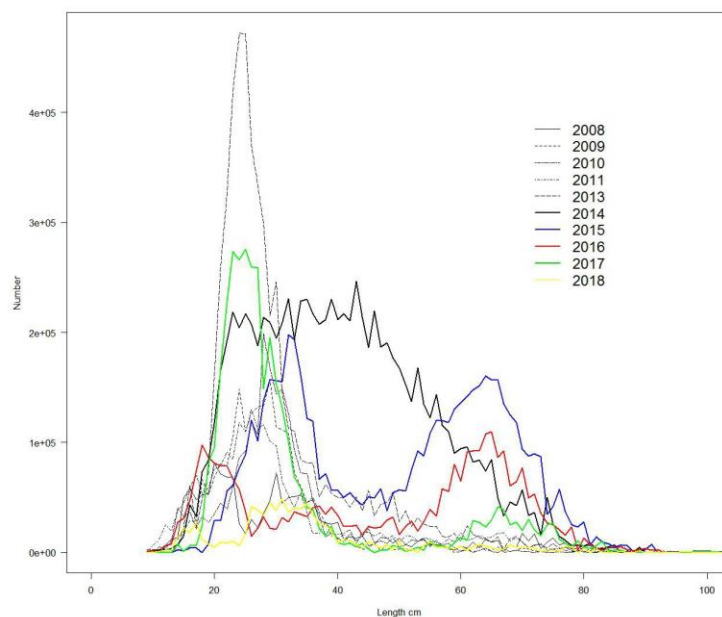


Figure 5. Length distribution in total number of cod weighted by stratum area by year in the total survey area.

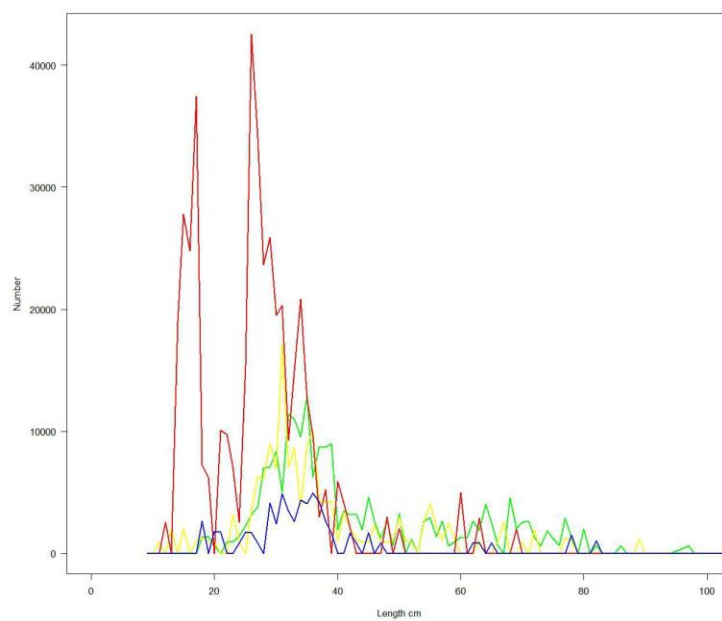


Figure 6. Length distribution of cod in 2018.

Age distribution

From 2008 to 2013 was the age distribution dominated by age class 1-4. In 2014 did the contribution of older fish (age 5 and 6) increase in the catches. This relatively higher contribution of older fish in the catches continued between 2015-2017. In 2018 were there however not many old fish left (table 7), even if they proportionally contributes to the biomass (table 8). The number of age 1 cod was in 2018 the lowest in the entire time series (table 7).

Table 7: Number at age of cod by year in the survey area.

yy	a0	a1	a2	a3	a4	a5	a6
2008	621.90	538.70	181.70	115.50	74.60	44.30	23.50
2009	308.90	1696.80	83.60	20.90	20.10	22.70	9.80
2010	314.80	1155.10	655.70	24.20	4.40	4.60	1.20
2011	494.90	930.00	550.60	249.00	51.90	8.30	2.20
2013	240.40	2121.40	2138.20	643.90	309.80	54.80	8.60
2014	503.90	1474.70	2829.80	2364.20	955.40	421.60	180.80
2015	56.80	944.40	1293.30	1278.00	1077.30	702.90	394.70
2016	254.60	587.10	378.60	498.50	497.00	437.80	442.00
2017	31.50	1128.30	1138.30	732.80	160.50	149.70	178.00
2018	85.70	247.40	311.20	166.10	8.00	25.80	36.10

Table 8: WECA, weight at age in tonnes

yy	a0	a1	a2	a3	a4	a5	a6	total
2008	49.87	198.18	164.66	294.44	245.03	230.74	135.18	1318.10
2009	22.97	426.67	90.84	57.46	66.21	99.32	58.93	822.40
2010	17.97	277.30	380.30	51.92	25.28	14.99	4.43	772.19
2011	27.14	171.47	293.74	499.70	180.62	37.10	10.20	1219.96
2013	14.59	404.84	728.35	529.89	448.51	207.39	41.41	2374.99
2014	41.42	370.45	2039.16	2312.11	1616.10	1040.36	504.93	7924.54
2015	5.22	268.62	1106.28	2146.13	2416.09	2123.87	1312.39	9378.61
2016	12.32	84.53	290.55	761.84	1213.49	1253.85	1360.47	4977.05
2017	1.34	209.92	238.67	306.83	396.91	470.62	630.68	2254.97
2018	4.14	58.14	182.79	131.18	20.87	85.29	164.41	646.83

CPUE

CPUE in both weight and number per hour was highest in the high density area (Table 8). The overall CPUE in 2018 was 9.0 individuals per hour (compared to 33.5 in 2017) and 5.8 kg per hour (compared to 18.7 kg in 2017).

Table 9: CPUE (h) in 2018. Number, Stdev Number, Weigh, Stdev weight, by Strata and overall.

Strata	Number	Stdev Number	weight	Stdev Weight
High	12.10	18.70	12.50	18.70
Medium	7.50	4.50	5.70	4.50
Low	7.90	1.60	1.80	1.60
Closed	8.70	3.10	4.70	3.10
All	9.00	9.00	5.80	10.40

Table 10: CPUE per age and km2 (swept area)

yy	a0	a1	a2	a3	a4	a5	a6	total
2008	60.94	52.79	17.80	11.32	7.31	4.34	2.31	156.81
2009	30.27	166.29	8.19	2.05	1.97	2.23	0.96	211.96
2010	30.85	113.20	64.26	2.37	0.43	0.45	0.11	211.69
2011	48.50	91.14	53.96	24.40	5.09	0.81	0.22	224.12
2013	23.56	207.90	209.55	63.10	30.36	5.37	0.85	540.68
2014	49.38	144.52	277.32	231.69	93.63	41.31	17.72	855.59
2015	5.57	92.55	126.74	125.25	105.57	68.88	38.69	563.25
2016	24.95	57.53	37.10	48.85	48.70	42.91	43.32	303.37
2017	3.09	110.58	111.55	71.82	15.73	14.67	17.44	344.88
2018	8.40	24.24	30.50	16.28	0.78	2.53	3.54	86.26

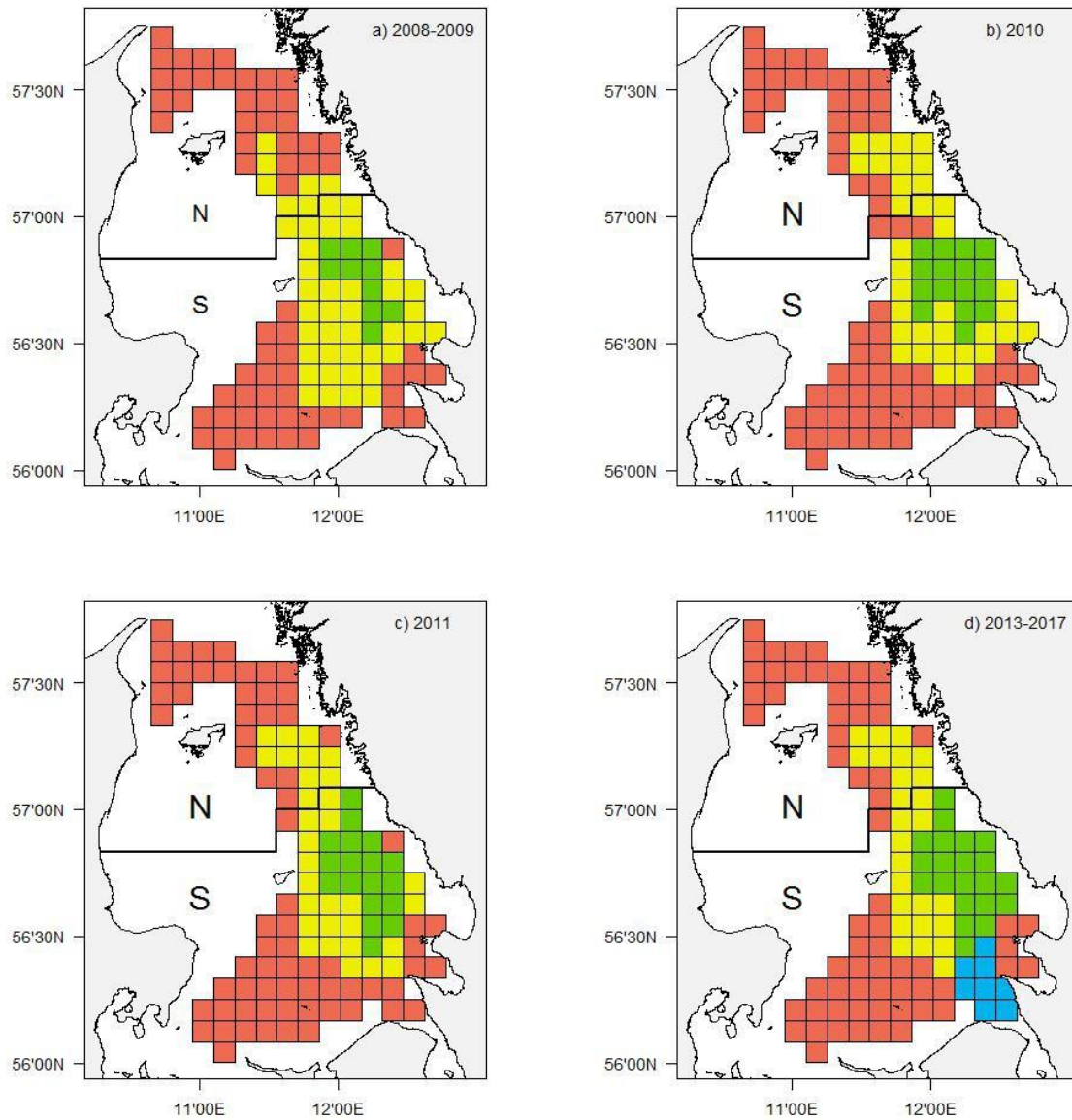
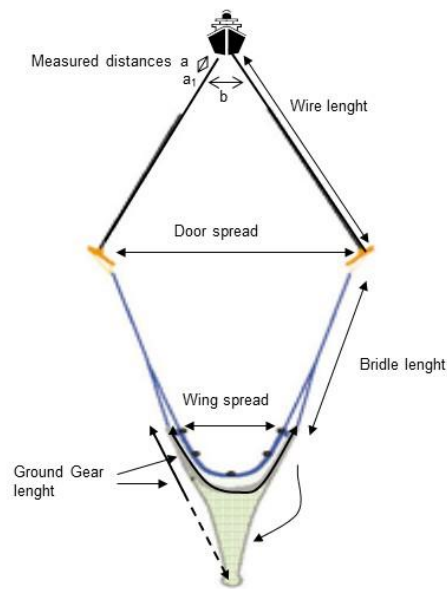
Annex 1. Survey stratification 2008 - 2018

Figure 1a-d. The survey stratification 2008-2018. Green represents high density areas; yellow medium density areas and red low density areas. From 2013 the fourth (blue) stratum was added to ensure sufficient sampling in the closed areas.

Annex 3. Calculation of wing spread.



Calculations of door spread and wing spread

Assuming that the distance between the trawl doors and the wires form an equilateral triangle, the door spread have been calculated as

$$\text{Door spread} = \frac{\text{Wire length} \times \text{measured distance } b}{\text{measured distance } a}$$

For every haul, a length on the wire (distance a) and the length between the wires measured at a₁ (distance b) have been recorded.

Wing spread is estimated as:

$$\text{Wing spread} = \frac{\text{Ground gear length} \times \text{Door spread}}{\text{Bridle length} + \text{Ground gear length}}$$

(Calculation from "Course in Trawl Gear Technology", May 2006, SeaFish Flume Tank, Hull, UK)

NOTE: Figure not according to scale