

# Joint Swedish and Danish survey for cod in the Kattegat November-December 2019

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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 551 tonnes in 2019. This corresponds to a reduction of more than 94% compared to 2015 when the highest biomass was estimated and represents the lowest estimated biomass in the whole time series of the survey. At the same time the abundance increased from an estimated 0.88 million individuals in 2018 to 2.04 million in 2019. The length distribution was dominated by young individuals, around 20 cm and the number of age class zero cod was the highest observed since the start of the survey in 2008.

## Introduction

Cod fishermen operating in the Kattegat has been restricted by steadily decreasing quotas since 2003 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 poor 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 monitoring trends in 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 survey improves the knowledge of spatial distribution of cod by size/age-groups and provides valuable information for monitoring the effect of the closed areas established in the Kattegat from January 1st 2009. Furthermore, although the survey is primarily designed for cod, data for all species is collected and survey products can be generated for other species and/or purposes.

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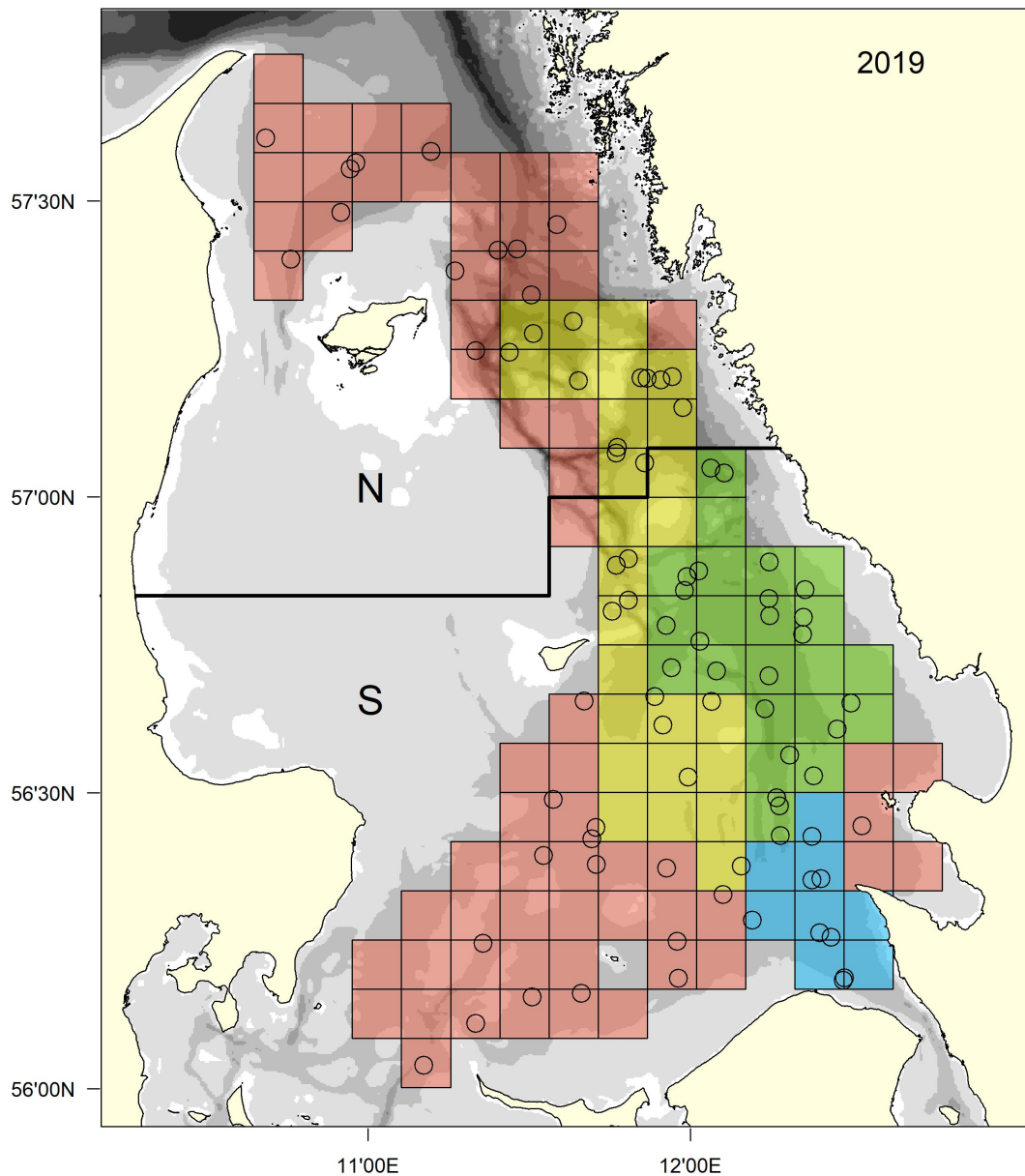
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## Materials and Methods

### *Survey area*

The survey area cover depths exceeding 20 m in the Kattegat Sea (FAO area 27.3.a.21); bounded to the north by a line from Skagen to Tistlarna; to the southeast by a line between Gilleleje and Kullen; and to the southwest by a line between Griben and Hassensør on Djursland. The total survey area is 10204 km<sup>2</sup> (Figure 1).



**Figure 1.** Survey stratification and sampled stations in 2019. Green represents the high-density stratum; yellow the medium-density stratum and red the low-density stratum. In 2013 a fourth stratum was added (marked in blue) to ensure sufficient sampling in the closed area. N (north) and S (south) identifies the two domains used for biological sampling.

*Survey method and stratification*

The survey has a stratified random design with 80 hauls distributed within a survey grid of  $5 \times 5$  nm squares. The grid was initially stratified into three geographical strata based on the information from commercial fishers on expected densities of cod; one stratum with expected high density of cod, one stratum with medium density and one stratum with low density. In 2010 and 2011, changes were made to align the stratification with the catch information collected during the earlier years. A fourth stratum was added in 2013 to ensure the collection of data from the closed area in southeastern Kattegat (Figure 1 and Annex 1).

The effort allocation varies between strata with relatively more hauls allocated to the high-density, the medium-density and the closed area strata than to the low-density stratum (table 1 & 2).

Table 1: Number of survey squares by strata and year.

Year	High density	Medium density	Low density	Closed area	Total
2008-2009	10	44	65		119
2010	15	32	72		119
2011	18	31	70		119
2012					
2013-2017	21	26	65	8	120
2018-2019	21	26	64	8	119

Table 2: Number of squares by vessel and strata. In 2013 only Swedish vessels participated in the survey.

Year	N vessels	High density	Medium density	Low density	Closed area	Total
2008-2010	4	6	8	6		20
2011	4	9	6	5		20
2012						
2013	2	15	10	10	5	40
2014-2015	4	6	5	7	2	20
2016-2019	3	6/12	5/10	7/14	2/4	20/40

*Survey period*

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

**Vessels and Fishing gear**

The original design was to be conducted by four chartered commercial trawlers, two covering the northern part and two covering the southern part of the survey area. The vessels were selected based on similarity in engine power, length and applicability for scientific investigations; two Swedish and two Danish vessels were chartered for each survey. In 2013 however, only Swedish vessels participated in the survey, and from 2016 and onwards Denmark has used R/V Havfisker instead of chartered trawlers, thus two Swedish vessels and one Danish vessel currently participate in the survey. R/V Havfisker fish twice as many hauls as the Swedish vessels keeping the total number of hauls at the same level as previous years. Participating vessels are shown in table 3. Each vessel is assigned 20 or 40 stratified randomly selected survey squares, i.e., all vessels are assigned the same proportion of hauls from each strata. In the closed area, and the high and medium density strata, several vessels are allowed to fish in the same survey square resulting in an overlap between vessels. In the low-density stratum, only one vessel is allowed in each square.

Within each survey square, the skipper decides on the best way to fish at the location, e.g. set position and tow direction. The survey gear is a 112 feet commercial bottom trawl with 70 mm liner in the cod-end (see Annex 2). The ground gear is of rockhopper type with 4 thumps rubber discs at 10 cm. The otter boards are 64-66" Thyborøn with a warp diameter of 15 mm. The sweep lengths have varied over time, but since 2016 been consistent within vessel (90 m, 108 m and 135.5 m). The hauls starts when the trawl is considered stable on the bottom, roughly 5-7 minutes after wires are connected. The tow duration is 1 hour

Table 3: Vessels participating in the survey.

Year	DK1	DK2	SWE1	SWE2
2008	Søren Kanne	Susanne H	Otseco	Yvonne II
2009	H210	Susanne H	Otseco	Yvonne II
2010	Havfisken	Susanne H	Ganler	Tärnan
2011	H292	Susanne H	Cindy Vester	Tärnan
2012				
2013			Cindy Vester	Tärnan
2014	Tiki	Stjerne	Cindy Vester	Tärnan
2015	Annie Holm	Stjerne	Cindy Vester	Tärnan
2016-2019	Havfisken		Cindy Vester	Tärnan

(down to 20 minutes accepted) at a speed of 3 knots over ground (2.7 to 3.4 knots accepted but should not vary within station). The haul ends when hauling the net back in starts. The trawled distance is estimated from GPS-positions or from the mean towing speed, recorded every 10 minutes and the tow duration. A maximum of 5 minutes of the tow duration are allowed outside the assigned survey square. If the 5 minutes are exceeded the haul should be terminated. Trawling is only carried out during daylight (15 minutes before sunrise to 15 minutes after sun set). 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.

#### *Sampling of catch*

Two technicians/scientists from DTU-Aqua (Danish vessels) or SLU-Aqua (Swedish vessels), on board each vessel are responsible for processing the catch. The catch is processed in accordance with IBTS standard operating procedures (ICES 2020). After each haul the catch is sorted by species and weighted to nearest 0.1 kg and the number of specimens is recorded. All fish species are measured as total length (TL) to 1.0 cm below. Norwegian lobster is measured to 0.1 mm below. Biological sampling is presently only carried out for cod. Two otoliths per 1-cm length class and domain (north and south) are to be collected. The Swedish protocol for biological sampling changed in 2016 and otoliths are collected from every haul. The number of age samples samples by haul is one per length class for cod sizes 10-40 cm, two per length class for cod sizes 41-60 cm and three per length class for cod larger than 60 cm. Individual weights are measured for all specimens for which age data are collected, but sex and maturity is not routinely reported. Besides the biological sampling of cod have campaigns for other purposes been conducted; for example genetic sampling of cod, thorny skate and thornback ray; and sampling of individual weights for establishing local weight-length relations for some species.

#### *Data management*

All trawl data (set/haul positions, doorspread, towing speed etc.) and catch and length frequency data on cod is screened for unrealistic figures before further estimations. Data is stored in national data bases but could be uploaded to the ICES DATRAS system.

#### **Biomass and abundance**

The catch in each tow (in kg and numbers) is standardized by swept area (in km<sup>2</sup>) prior to further calculations. Swept area is calculated using recorded tow distance and estimated wingspread based on door spread and trawl dimensions (Anon. 2006) (Annex 1). Weight-at-length is estimated from calculated weight-length regressions and age-at-length from an age-length-key generated from the sample data. Missing age-length data is imputed using the multinomial approach by Gerritsen et al (2006). To date, the age-length-key have been based on Swedish samples only and age samples have been pooled from the entire area.

#### *Estimation of stock indices*

The calculations of biomass and abundance indices are based on the stratified random design, using inverse probability weighting. The probability for a square to be included in the sample depends primarily on the

proportion sampled squares to strata size, but also on whether overlapping is allowed and the number of overlapping vessels. From 2013 to 2017 the survey grid contained 120  $5 \times 5$  Nm survey squares, but for consistency, biomass and abundance was estimated for 119 squares throughout the period. The catchability coefficient is assumed to be 1.0. All calculations were carried out in R, using the R-survey package for the design based index estimation (Lumley 2020).

## Results

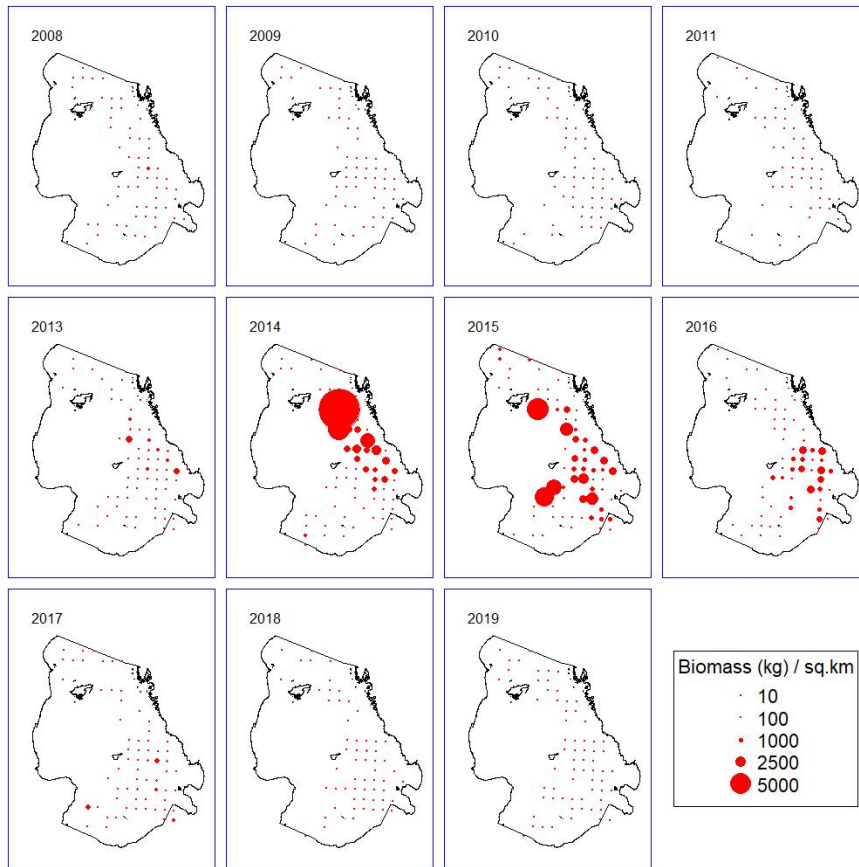
### *Biomass and abundance*

Annual distribution of cod biomass and abundance 2008-2019 is presented in Figure 2 a & b. For biomass, 2014 and 2015 stands out with quantities high above the levels before and after. 2014 is also the year with the highest abundance in the time series.

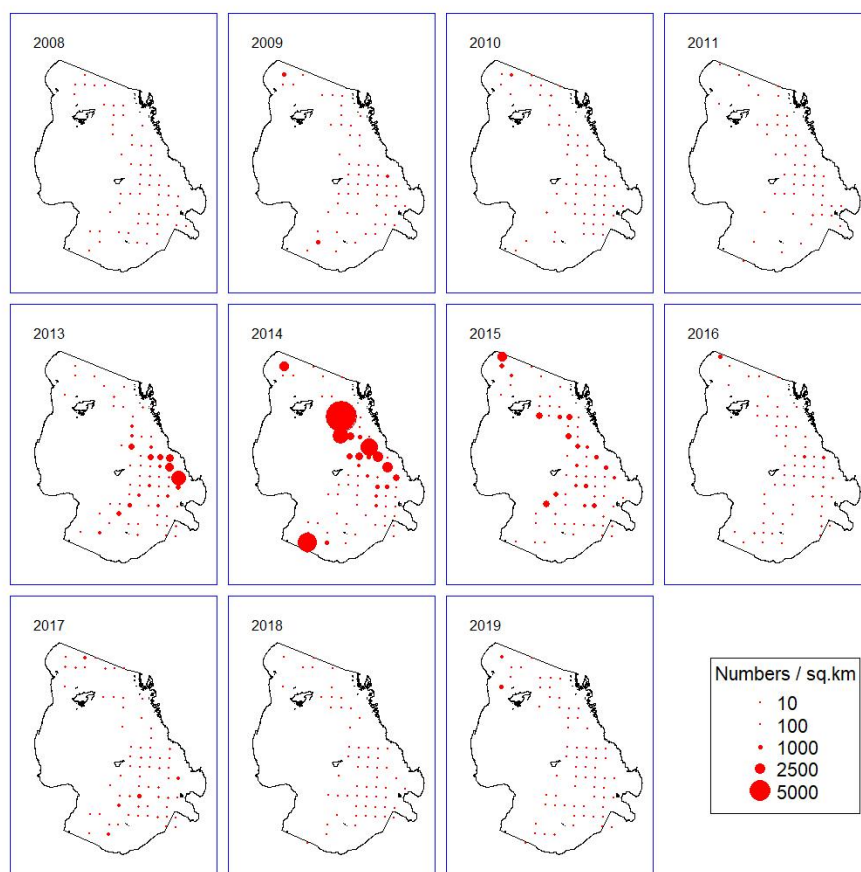
The trawlable biomass of cod in 2019 was estimated to 551 tons, compared to 649 tons in 2018 and 2255 tons in 2017 (Table 4). This corresponds to a reduction in biomass with 16% the last year and approximately 87% in two years. The estimated biomass 2019 is the lowest since the survey started in 2008. The trawlable abundance in 2019 was estimated to 2.08 million, which is a significant increase from last year, albeit from very low numbers (0.88 million in 2018) (Table 4).

Table 4: Weight in kg/km<sup>2</sup> and total biomass in tonnes. Numbers per km<sup>2</sup> and total abundance in 1000's.

Year	Weight km2	Stdev	Biomass	Number km2	Stdev	Abundance
2008	129.2	216.1	1318.1	156.8	94.0	1600.1
2009	80.6	78.3	822.4	212.0	203.0	2162.9
2010	75.7	84.1	772.2	211.7	193.6	2160.1
2011	119.6	187.2	1220.0	224.1	175.9	2287.0
2013	232.8	330.8	2375.0	540.7	493.4	5517.1
2014	776.6	1450.1	7924.5	855.6	1299.1	8730.4
2015	919.1	1119.5	9378.6	563.3	495.8	5747.4
2016	487.8	562.3	4977.0	303.4	250.1	3095.6
2017	221.0	290.9	2255.0	344.9	244.9	3519.1
2018	63.4	99.6	646.8	86.3	86.0	880.2
2019	54.0	69.6	550.9	199.5	190.4	2035.9



**Figur 2a.** Biomass of cod per km<sup>2</sup>, calculated as an average from all vessels per square.



**Figur 2b.** Abundance of cod per  $\text{km}^2$ , calculated as an average from all vessels per square.

Table 5: Stratum area ( $\text{km}^2$ ), hauls, mean biomass and Stdev ( $\text{kg}/\text{km}^2$ ) and total biomass (t).

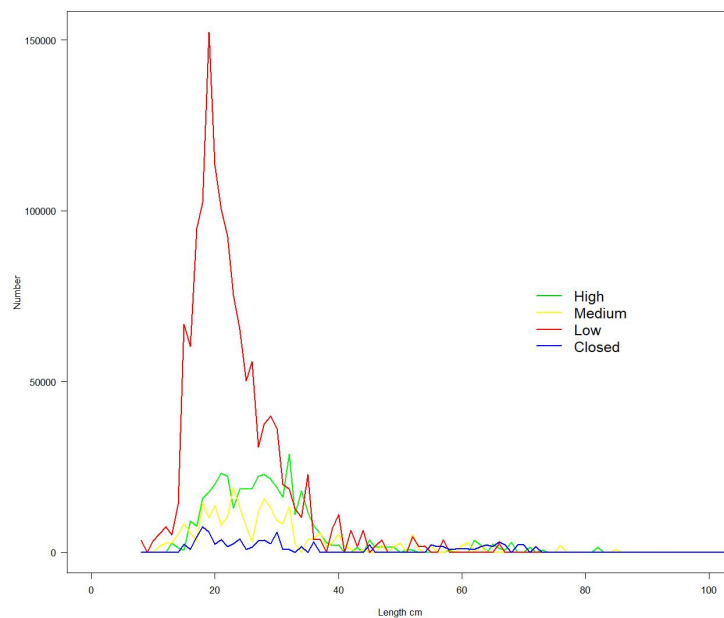
Strata	Area	Hauls	Mean_biomass_km2	Stdev	Biomass
Closed	686.00	8	116.50	168.00	79.90
High	1801.00	24	77.90	75.90	140.30
Medium	2229.00	21	42.50	47.60	94.60
Low	5488.00	28	37.00	30.40	203.20

Table 6: Stratum area ( $\text{km}^2$ ), hauls, mean number and Stdev ( $\text{N}/\text{km}^2$ ), and total abundance (1000's).

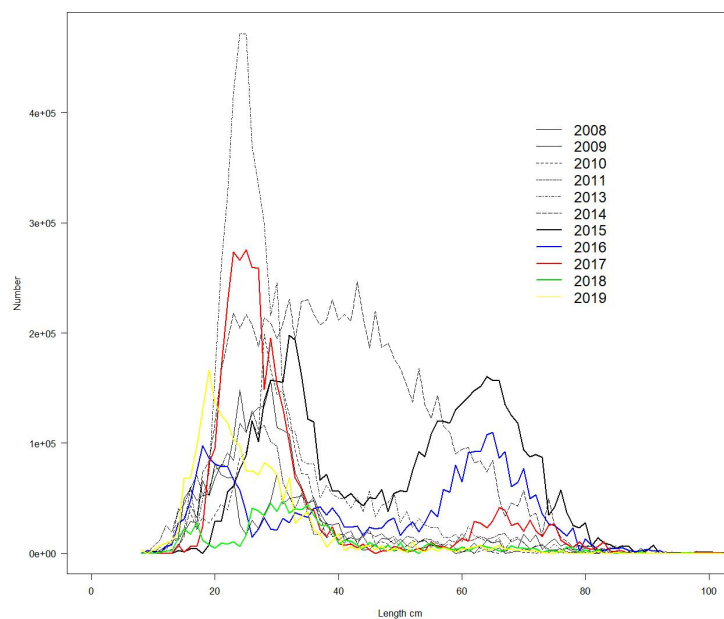
Strata	Area	Hauls	Mean_number_km2	Stdev	Abundance
Closed	686.00	8	128.30	120.00	88.00
High	1801.00	24	227.10	143.50	409.00
Medium	2229.00	21	114.40	82.10	255.10
Low	5488.00	28	247.20	243.70	1356.50

*Length distribution*

In 2019, the overall length distribution (weighted by stratum area) ranged from 8 to 85 cm with a distinct peak around 20 cm (young of the year cod). The highest densities of cod were found in the low density stratum (Figure 5). Raised length distributions for the entire survey period are shown in figure 6.



**Figure 5.** Cod length distribution by strata in 2019.



**Figure 6.** Cod length distributions in the total survey area by year, 2008-2019.



## Age distribution

From 2008 to 2013 was the age distribution dominated by age class 1-4. The proportion of older fish (age 5 and 6+) increased in the catches from 2013 and peaked in 2015. Older fish continued to make up a relatively high proportion of the catches during 2016-2017 but decreased in 2018 even though they still made up a significant proportion of the biomass. In 2019 the older fish was virtually absent from the catches, decreasing to the lowest observed values since 2011. The number of recruits (age 0 and 1) which in 2018 was the lowest in the entire time series increased in 2019 and the number of age 0 cod is the highest observed since the start of the survey (table 7 & 8).

Table 7: Estimated numbers at age (in 1000's) in the survey area by year.

yy	a0	a1	a2	a3	a4	a5	a6
2008	621.9	538.7	181.7	115.5	74.6	44.3	23.5
2009	308.9	1696.8	83.6	20.9	20.1	22.7	9.8
2010	314.8	1155.1	655.7	24.2	4.4	4.6	1.2
2011	494.9	930.0	550.6	249.0	51.9	8.3	2.2
2013	240.4	2121.4	2138.2	643.9	309.8	54.8	8.6
2014	503.9	1474.7	2829.8	2364.2	955.4	421.6	180.8
2015	56.8	944.4	1293.3	1278.0	1077.3	702.9	394.7
2016	254.6	587.1	378.6	498.5	497.0	437.8	442.0
2017	31.5	1128.3	1138.3	732.8	160.5	149.7	178.0
2018	85.7	247.4	311.2	166.1	8.0	25.8	36.1
2019	704.5	673.8	387.9	199.3	58.1	8.8	3.5

Table 8: Estimated biomass at age (in tonnes) in the survey area by year.

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
2019	51.56	133.49	127.82	148.01	56.53	24.66	8.81	550.87

*CPUE*

The survey swept area index from 2008 to 2019, estimated as the weighted mean catch in numbers at age per km<sup>2</sup> are shown in table 9.

Table 9: CPUE at age (N/km<sup>2</sup>)

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
2019	69.04	66.03	38.02	19.53	5.69	0.86	0.34	199.52

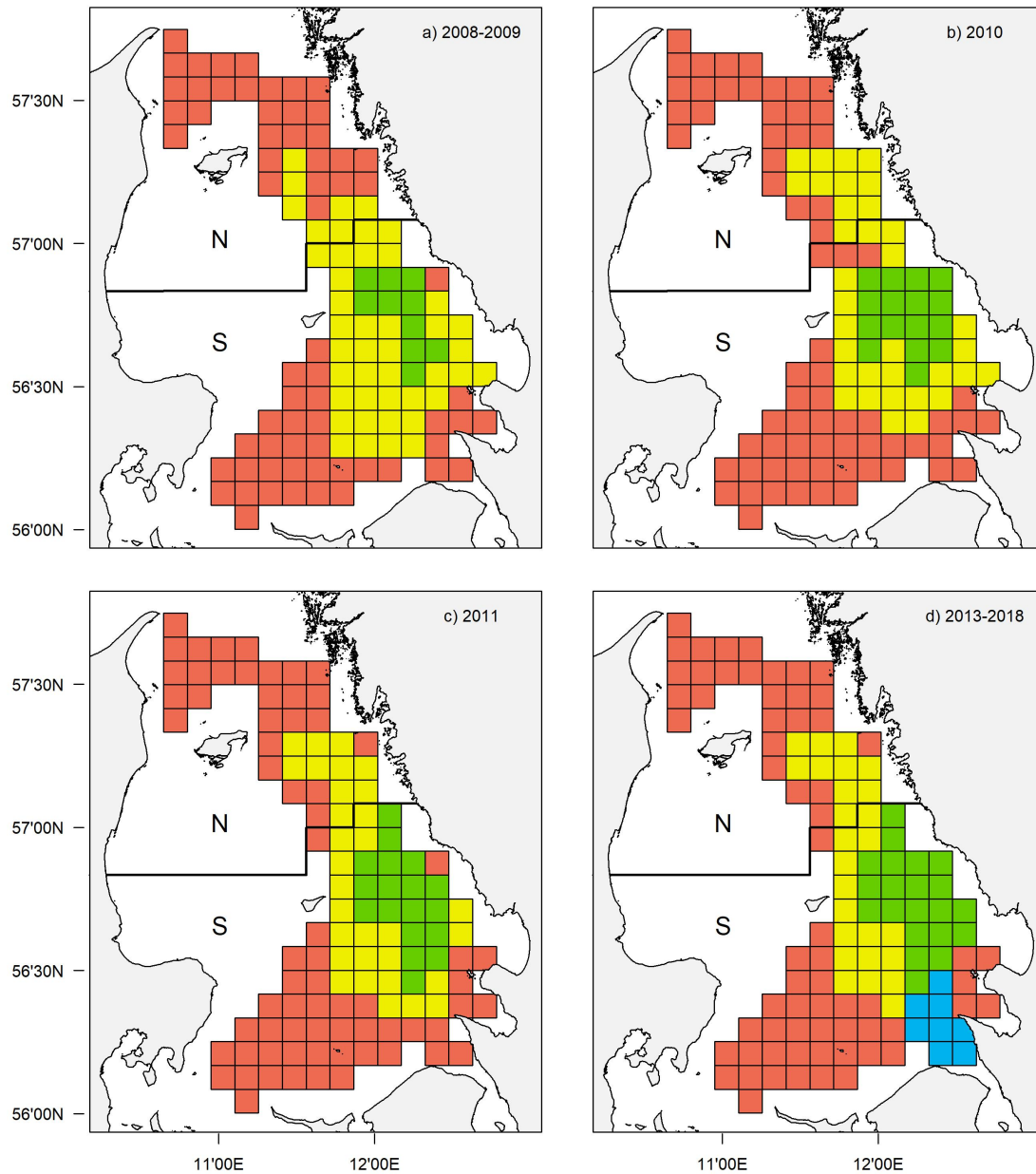
**References**

Gerritsen H, Mcgrath D, Lordan C, 2006. A simple method for comparing age - length keys reveals significant regional differences within a single stock of haddock (*Melanogrammus aeglefinus*). ICES J Mar Sci. 63:6 1096-1100.

ICES 2020. Manual for the North Sea International Bottom Trawl Surveys. Series of ICES Survey Protocols SISP x-IBTS X. 84 pp

Lumley T, 2020. Survey: analysis of complex survey samples. R package version 4.0.

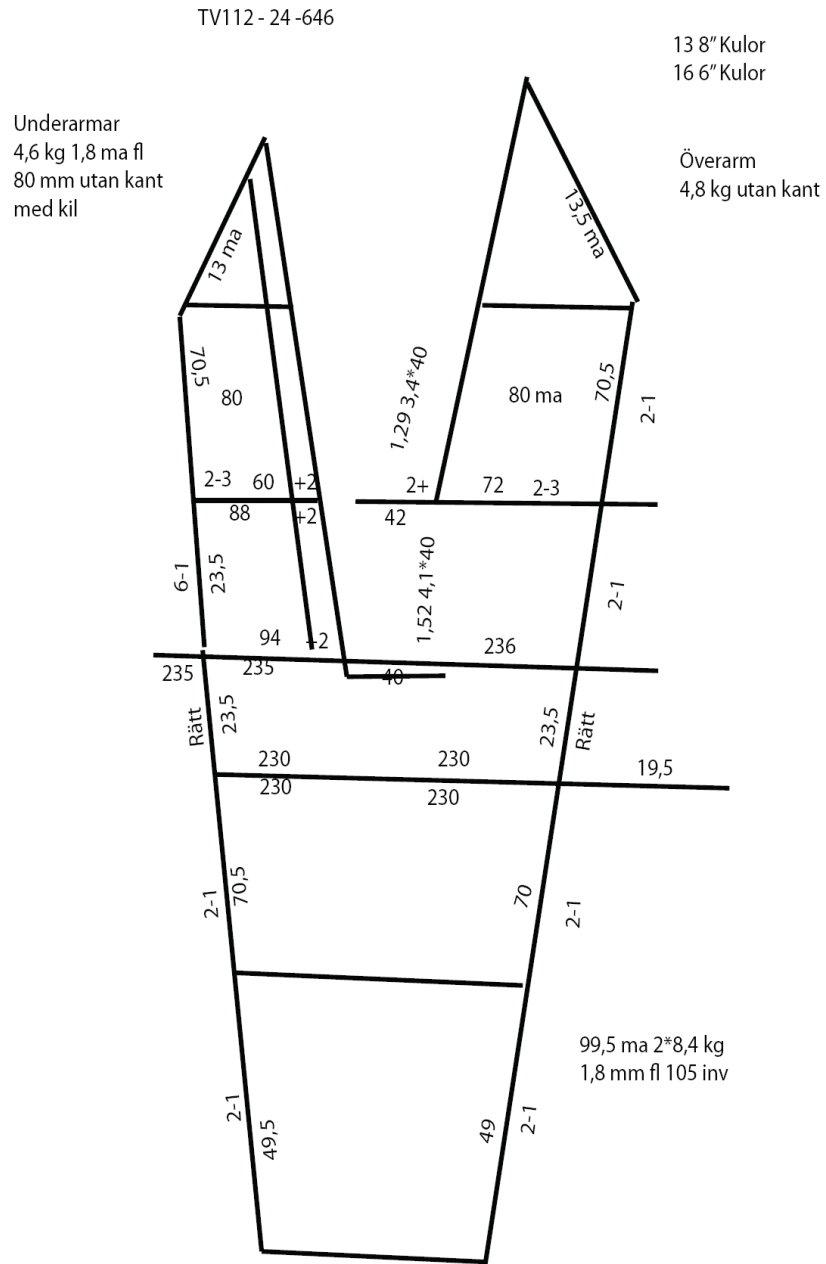
## Annex 1. Survey stratification 2008 - 2019



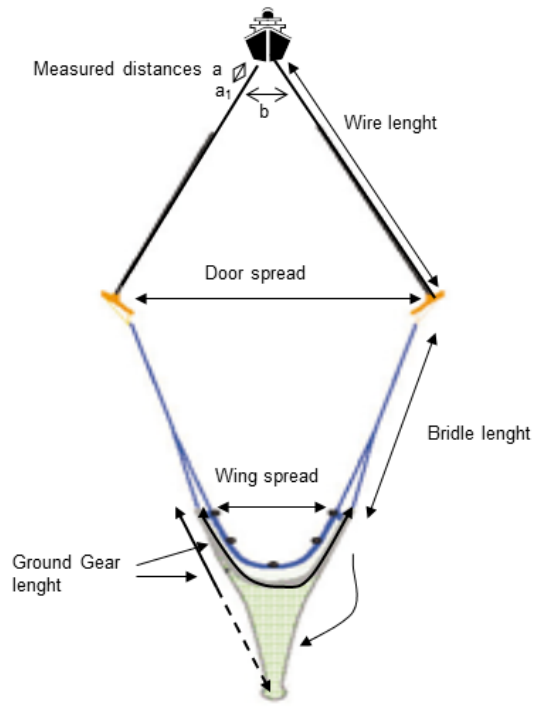
**Figur 1a-d.** The survey stratification 2008-2019. Green represents the high-density stratum; yellow the medium-density stratum and red the low-density stratum. In 2013 a fourth (blue) stratum was added to ensure sufficient sampling in the closed areas.

clearpage

## Annex 2. TV112 trawl



## 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 a<sub>1</sub> (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