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Joint Swedish and Danish survey for cod in the Kattegat November-December 2015

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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 by four commercial trawlers from Denmark and Sweden. The survey design has been largely unchanged during the years, but a fourth strata representing the closed area in Southern Kattegat was added year 2014. The total swept area biomass of cod was 9477 tonnes in 2015 which is the highest since the survey commenced and an over 700 % increase since 2008. The abundance (numbers) however decreased from and 8.9 mill. individuals in 2014 to 5.8 mill. in 2015, representing lower recruitment of young age classes in the recent years. Length distribution showed a strong increase in individuals over 50 cm, which are for the first time in the study dominating the abundance measured as biomass.

Introduction

Cod fishermen in Kattegat has, 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 ACFM/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 other factors such as migration, non reported landings and re-allocation of catches also could be 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 implies that also 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 index and distribution of cod. The results should be used to strengthen the scientific advice on the cod stock in Kattegat. Due to it's 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 four 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 design

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, the two fjords Laholmsbugten and Skældervigen 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 2008-2013 stratified in three strata: a stratum with expected high density of cod, a stratum with medium density and a stratum with low density of cod based on information from the fishers. In 2010 and 2011 there were a minor re-stratification to adopt the areas to the catch information collected during the former years. In 2014 was a fourth strata 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-b) and table 1.

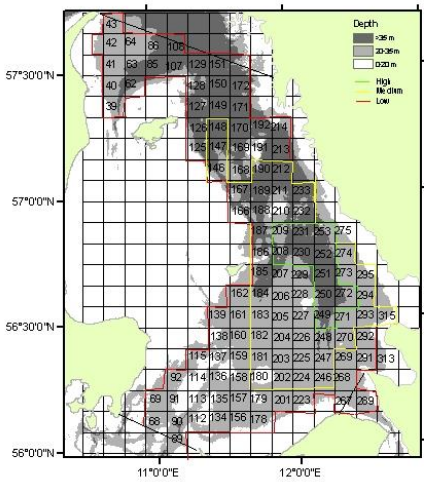


Figure 1a. The stratified survey area (2008-2009) with section numbers. Green High density of cod. Yellow Medium density. Red Low density.

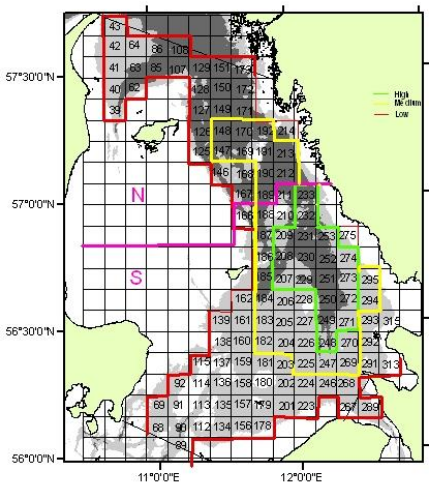


Figure 1b. The stratified survey area (2011) with section numbers. Green High density of cod. Yellow Medium density. Red Low density. N and S Northern and southern area, respectively.

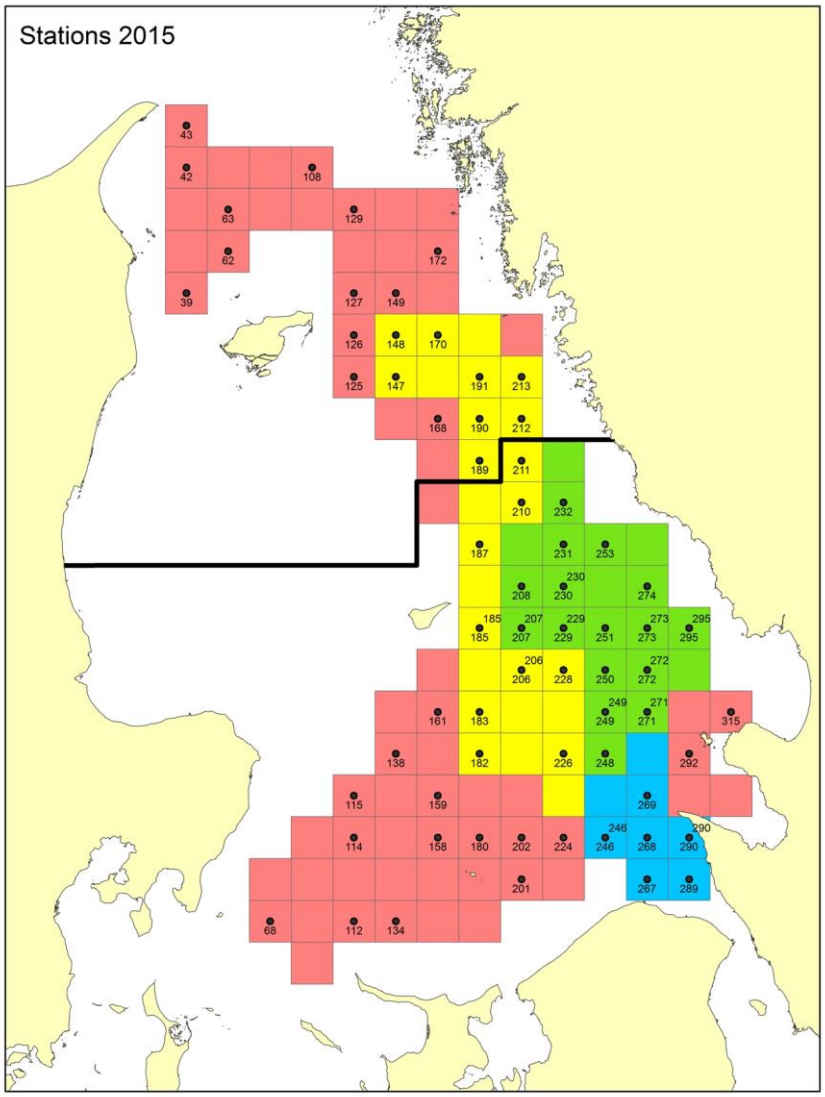


Figure 1c. The stratified survey area (2013-2015) with section numbers. Green High density of cod. Yellow Medium density. Red Low density. Blue Closed area.

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**
2013	21	26	65	8	**120**
2014	21	26	65	8	**120**
2015	21	26	65	8	**120**

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

Station (tow) location
The survey is planned with in average 3.3 trawl hauls per day in 6 days for each of the 4 vessels, i.e in total 80 trawl hauls. The hauls are allocated randomly to the 5*5 nm squares and each vessel will fish in 20 different squares. 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 is fishing in the south area and the other vessels are fishing in the north.

Year	No of vessels	high density	medium density	low density	closed area	**total hauls by vessel**	**total haul survey**
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**
2013	2	15	10	10	5	**40**	**80**
2014	4	6	5	7	2	**20**	**80**
2015	4	6	5	7	2	**20**	**80**

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

Target species
The survey is directed against and designed for cod, but the catch of all species is, however, recorded.

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. Participating vessels are shown in table 3.

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

Table 3. Vessels participating in the survey

Gear
The trawl is a commercial bottom trawl provided by the EC LOT 3 project.

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 recoded 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.

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 fjords Laholmsbugten and Skældervigen). The survey area is stratified in three density strata: HIGH, MEDIUM, LOW and CLOSED AREA. The total survey area is 10204 km^2 .

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:

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

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

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

The catchability coefficient is assumed to be 1.0.

All catches are standardized to 1 km^2 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 2008-2015 is given in Figure 2A-B. For biomass, the two last years stand out with quantities high above the level for 2008-2011. For numbers, year 2014 was the highest in the time series.

The trawlable biomass of cod was in 2015 estimated at 9477.5 tons, compared to 7255.7 tons in 2014 (Table 2). The trawlable abundance was in 2015 estimated at 5.86 millions compared to an estimated at 8.92 mill. in 2014 (Table 2). The increase in biomass compared to year 2008 was over 700 %. The highest biomass in 2015 (1.23 ton per km^2) and numbers (720 specimen per km^2) was found in mid-density stratum (Table 3 and 4). Catch per effort, as measured by specimen and weight per hour trawl time was however highest in the high density area (Table 7).

Commented [JHS1]: Why this difference in pattern between CPUE and calculated abundance? Interpretation needed.

Table 2. Total biomass (tons) and abundance for 2008-2015

Year	Biomass	S.E	Weight km^{-2}	Abundance	S.E.	Number km^{-2}
2008	1080.8	137.5	0.1059	$1.64*10^6$	144.8	161.2
2009	747.9	86.8	0.0733	$2.13*10^6$	309.4	209.2
2010	813.6	112.8	0.0797	$2.34*10^6$	299.0	229.7
2011	953.7	125.7	0.0935	$2.07*10^6$	195.0	203.2
2012	NA	NA	NA	NA	NA	NA
2013	2167.8	286.9	0.2124	$5.34*10^6$	472.7	523.7
2014	7255.7	1625.2	0.7111	$8.92*10^6$	1731.0	874.5
2015	9477.8	1687.1	0.9288	$5.86*10^6$	737.5	574.7

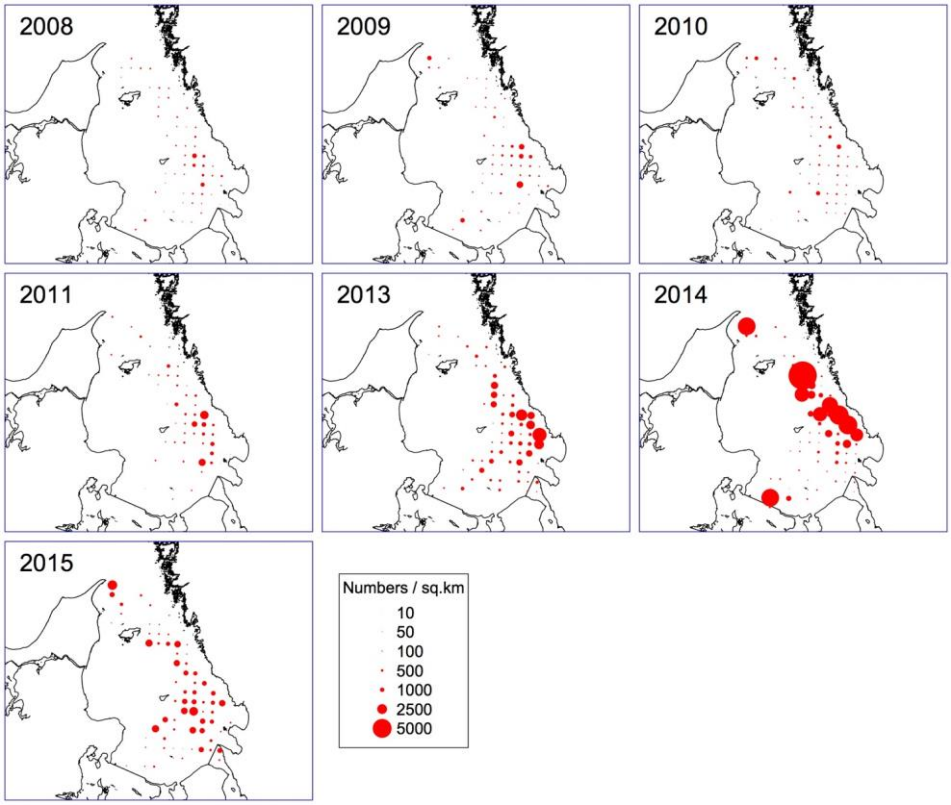


Figure 2A. Abundance of cod measured as CPUE per km^2, calculated as an average from all vessels per square.

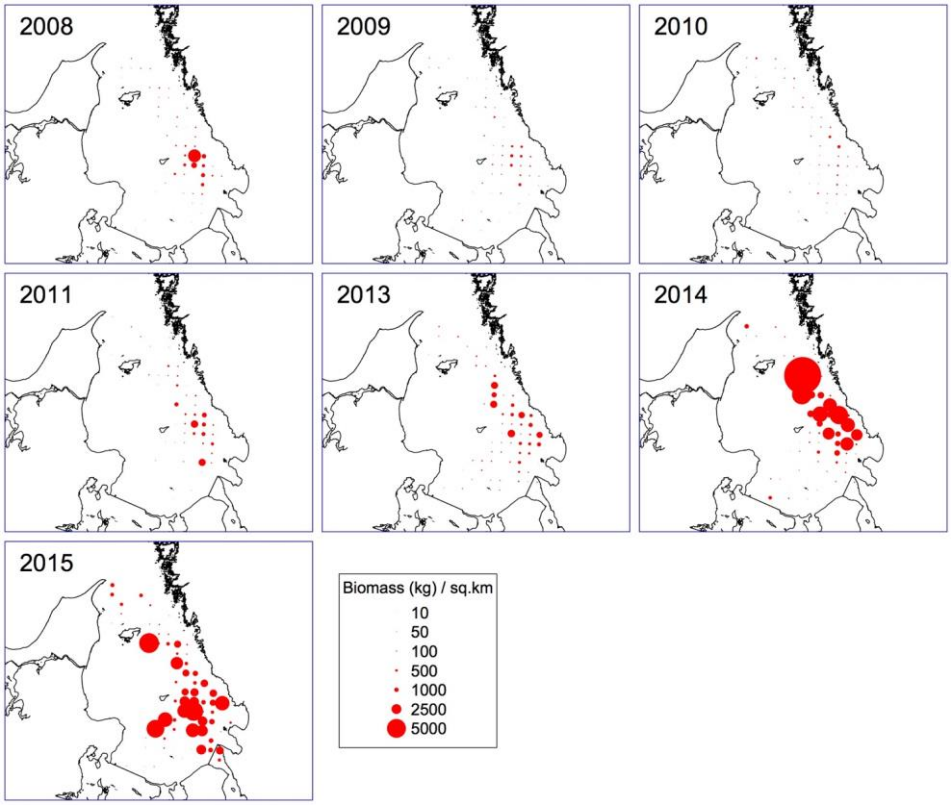


Figure 2B. Biomass of cod measured as CPUE per km^2, calculated as an average from all vessels per square.

Table 3. Cod 2015. Total biomass (tons), area, number of hauls, mean biomass per km^2 (tons), and Standard Error by density strata (Div.).

Stratum	Area km^2	No. Hauls	Mean biomass per km^2	Tot. Biomass	S.E tot biomass
Closed	686	8	0.919	630.7	160.8
High	1801	24	1.191	2144.9	261
Medium	2229	20	1.231	2744.9	666.3
Low	5574	27	0.724	4037	1535.1

Table 4. Cod 2011. Total abundance (numbers), area, number of hauls, mean abundance per km^2 and Standard Error distributed on by density strata (Div.).

Stratum	Area km^2	No. Hauls	Mean number per km^2	Tot. numbers	S.E tot numbers
Closed	686	8	476.773	3.27E+05	160796
High	1801	24	627.218	1.13E+06	261032.6
Medium	2229	20	720.548	1.61E+06	666339.1
Low	5574	27	511.421	2.85E+06	1535089.6

Length distribution
The length ranged from 10 to 85 cm. The overall length distribution (weighted by stratum area) showed modes at 36 and 65 cm in 2015 (Figure 5 and 6).

Most small cod were found in the low density area, while large individuals (over 50 cm) dominated in the medium and high density areas (Figure 6).

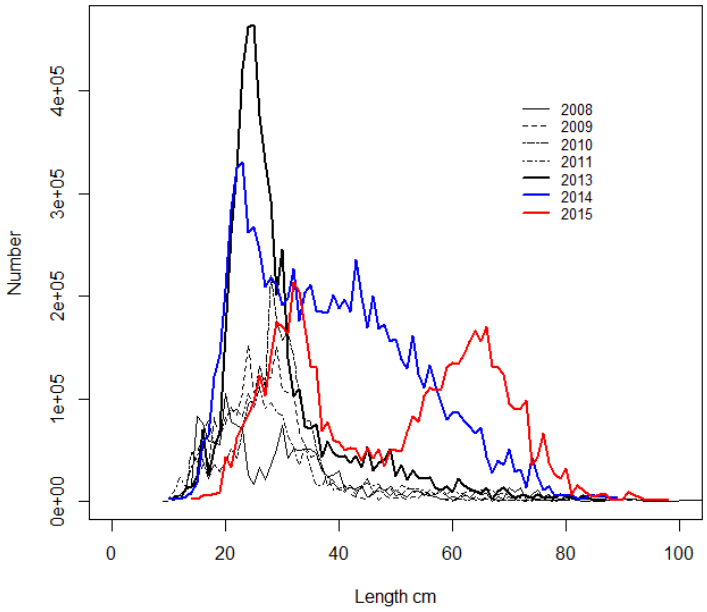


Figure 5. Length distribution in total number of cod weighted by stratum area by year in the total survey area.

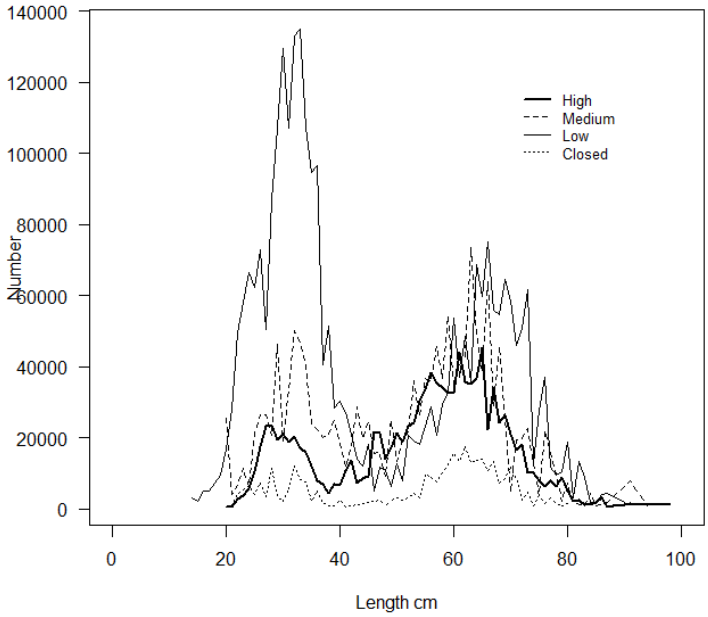


Figure 6. Length distribution of cod in total number by stratum.

Age distribution

The overall age distribution (weighted by stratum area) was dominated by ages 1-4, with significantly fewer age-0 in 2015 compared to the other years (Table 6). Overall the numbers in the younger age classes decreased in 2015 but increased for the higher ages indicating lower recruitment in recent years but higher abundance of adult fish.

Table 6. Number at age of cod by year in the survey area.

Age	2008	2009	2010	2011	2012	2013	2014	2015
0	732155	351047	352597	504594	NA	254085	795973	67282
1	538811	1643483	1258797	850573	NA	2089987	1697964	1022025
2	172594	78554	697915	486692	NA	2068786	2820567	1310094
3	93880	18491	23796	190124	NA	599471	2201943	1271977
4	57008	16595	4663	34824	NA	276193	859079	1059178
5	32995	18479	4719	5523	NA	46947	377145	697371
6	12386	7507	914	1557	NA	6925	158639	374652
7	2908	0	0	0	NA	1719	11904	53925
8	0	480	0	0	NA	0	0	7665
9	1295.1	0	0	0	NA	0	0	0

CPUE

CPUE in both weight and number per hour was highest in the high density area (Table 7). The overall CPUE in 2015 was 55.6 specimen and 92.2 kg per hour, compared to 16.1 specimens and 6.6 kg, respectively, in 2010 (Comparable data in 2011 report).

Table 7. CPUE of cod in number and kg per hour 2015 with SE distributed on density areas.

Division	Number	Weight	SE Number	SE Weight	N
High	62.1	117.0	6.72	15.3	24
Low	46.6	67.0	9.74	24.9	27
Medium	61.3	92.8	10.7	22.6	20
Closed	52.4	101.6	11.8	28.0	8
All	55.6	92.2	6.37	15.1	79

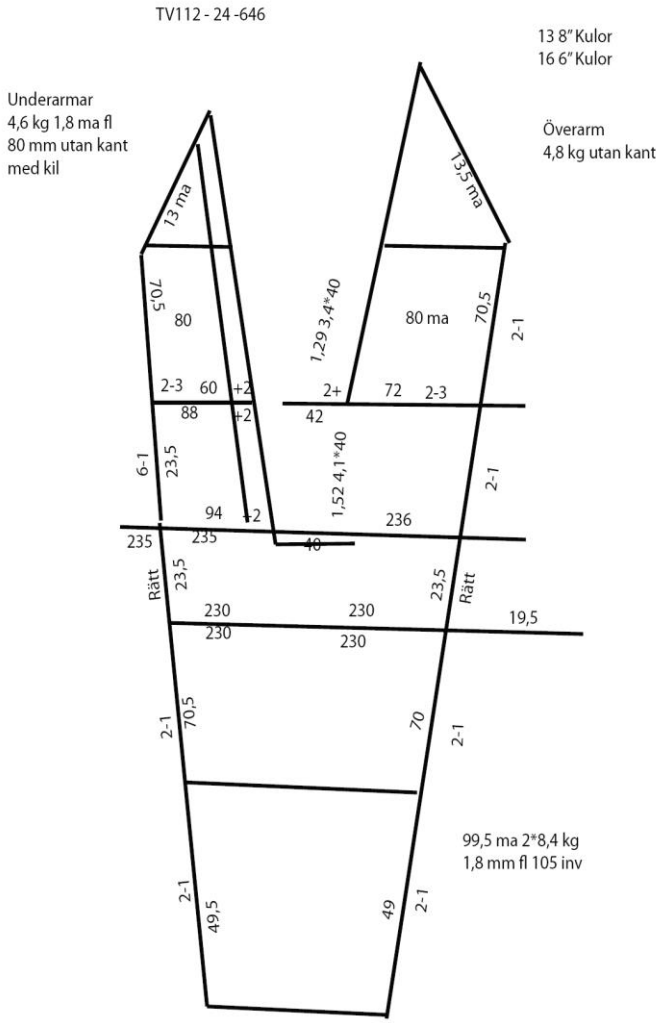
Table. 8. CPUE (km2) calculated from No at length ((km2 (wingspread) and h) using an age length key based on Swedish age readings

Year	a0	a1	a2	a3	a4	a5	a6	total
2008	71.752058	52.80415	16.914333	9.200585	5.5867691	3.2331734	1.62636336	161.1174
2009	34.403085	161.06315	7.698348	1.812071	1.6265593	1.8124457	0.78101770	209.1967
2010	34.554937	123.36357	68.395594	2.331682	0.4575705	0.4622471	0.09031694	229.6559
2011	49.450740	83.35711	47.690200	18.632856	3.4136667	0.5403959	0.15201845	203.2370
2012	NA	NA	NA	NA	NA	NA	NA	NA
2013	24.900597	204.82111	202.743403	58.748873	27.1233370	4.6471993	0.73485387	523.7194
2014	77.996435	166.40242	276.418777	216.002883	84.5373057	37.2240206	15.89340230	874.4752
2015	6.593589	100.15967	128.390728	125.297372	104.9937081	69.5680162	39.69212497	574.6952

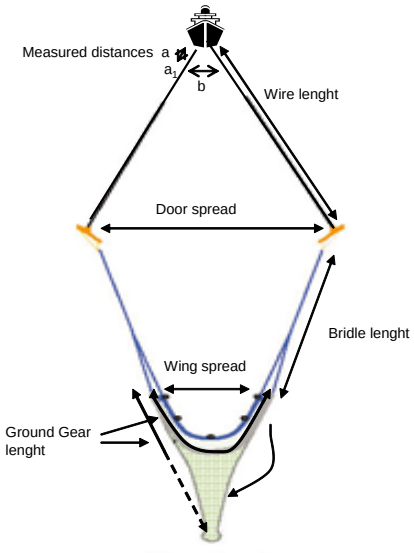
Table 9. WECA calculated from weight at length ((km2 (wingspread) and h) using an age length key based on Swedish age readings. For consistency, the biomass estimates was based on 119 survey squares (despite 120 squares in 2013-2015)

Year	a0	a1	a2	a3	a4	a5	a6	total
2008	56513.871	197613.3	152051.23	228569.14	178114.47	169982.64	97930.964	1080775.7
2009	25471.448	406020.3	86431.54	48295.03	53967.18	79185.60	48496.149	747867.2
2010	19953.607	301562.6	397186.32	49286.65	27020.71	15152.60	3483.560	813646.1
2011	28160.976	154242.1	257713.66	359473.77	122089.04	24914.97	7072.518	953667.0
2012	NA	NA	NA	NA	NA	NA	NA	NA
2013	14987.220	390289.8	678452.63	474099.27	394502.38	179109.50	36340.316	2167781.2
2014	64818.312	375190.4	1887035.02	2093325.88	1456081.42	929602.30	449626.668	7255680.0
2015	6165.261	285404.7	1075192.22	2131280.98	2444032.71	2178244.63	1357528.164	9477848.7

Annex 1. TV112 trawl



Annex 2. 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

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

For every haul, a length on the wire (distance a) and the length between the wires measured at a_1 (distance b) have been recorded.

Wing spread is estimated as:

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

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

NOTE: Figure not according to scale