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Joint Swedish and Danish survey for cod in the Kattegat December 2009

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Abstract

In 2008 was a new survey targeting cod in Kattegat initiated. The survey was conducted in December by four commercial trawlers from Denmark and Sweden. In total were 80 trawl hauls made. The survey was repeated in 2009 with the same design, number of hauls and participating vessels. The catches were generally low and the total swept area biomass and abundance was estimated as 776.2 tons compared to 1008.4 tons in 2008. The trawlable abundance was estimated at 2.10 mill compared to 1.55 mill individuals in 2008. The over all CPUE was 20.3 specimens and 8.9 kg per hour, respectively compared to 14.2 specimens and 14.1 kg per hour, respectively, in 2008. In 2009 age 1 totally dominated the catches, while there was a reduction in CPUE for most age classes > 1, especially ages >= 3.

Introduction

Since 2003 the cod fishery in Kattegat has 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 at present in the Kattegat area are 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 the available surveys are relatively noisy, especially for older ages. In 2008 a joint Swedish – Danish survey directly aimed at cod and with better coverage of the area was conducted.

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 1 January 2009.

Restrictions

The 4 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 og 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. The survey area is 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. Each stratum is further subdivided in 5*5 nm squares (sections). The high density stratum has been allocated relatively more stations than the other strata (Fig 1).

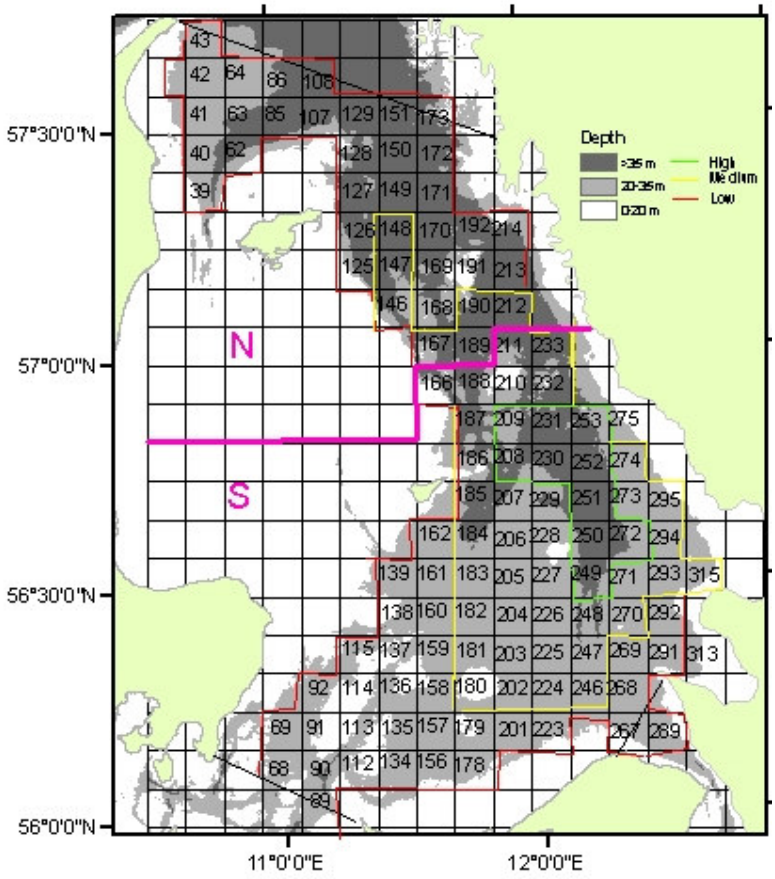


Fig 1. Stratification of survey area with section numbers. Green High density of cod. Yellow Medium density. Red Low density. N and S Northern and southern area, respectively.

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 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, Northern, Eastern and Western area. The 2 Danish ships fish in the Western low density area and the two Swedish vessel fish in the 2 Eastern areas.

Numbers of stations by vessel, stratum and area

Ship	High density	Medium density	Low density (South)	Low density (North)	Total
Den_1	6	8	6		20
Den_2	6	8		6	20
Swe_1	6	8	6		20
Swe_2	6	8		6	20

Target species

The survey is directed to demersale species in Kattegat, but designed for cod. The catch of all species is, however, recorded.

Survey period

The survey took place during December 2 - December 17 2009.

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.

DK-Vessel 1

Danish participant	1 (H210 – Søren Kanne)
Engine (KW):	368 kW
Tonnage (BRT):	69.2
Length (m):	20.7
Owner	Flemming Christensen

DK-Vessel 2

Danish participant	2 (FN370- Susanne H)
Engine (KW):	220 kW
Tonnage (BRT):	52.6
Length (m):	18.4
Owner	Hans Jørgen Hansen

SW-Vessel 1

Swedish participant	1 (GG 1195 – Otseco)
Engine (KW):	175 kW
Tonnage (BRT):	28
Length (m):	15.3
Owner	Peter Bihl

SW-Vessel 2

Swedish participant	2 (VG 47 – Yvonne II)
Engine (KW):	294 kW
Tonnage (BRT):	88
Length (m):	21.2
Owner	Johnny Nilsson

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 Fiskeriverket (Swedish vessels), on board each vessel who were responsible for processing the catch.

The catch was processed in accordance with BITS 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.

In total 813 cod otoliths were sampled for age determination.

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.

Estimation of stock indices
CPUE
CPUE is estimated as mean catch (kg or number at age) per hour.

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 and LOW. The total survey area is 10119 km^2 (Table 1).

Table 1. Areas distributed on strata.

High density	Medium density	Low density	All
10 squares	44 squares	64 squares	118 squares
857.5 km^2	3773 km^2	5488 km^2	10119 km^2

Biomass and abundance

Two different approaches were used in the biomass and abundance estimation. 1) A traditional Swept area calculation multiplied with the strata area and a 2) GRASP (General Regression model for spatial predictions).

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.

Over all S.E. is estimated using the stratum area as weighting factor.

2) GRASP is a general method for making spatial predictions of a response variables using point surveys of the response variables and spatial coverage of predictor variables. We used GRASP to estimate the total fishable biomass of Kattegat cod using the swept area method based on survey data. GRAPS allows integrating data on bottom complexity, hydrographic variables, and all other kind of predictor variables that are spatially referenced and to use such models to produce predictions of biomass and abundance. GRASP models will produce estimates of stock size that are independent on catch based VPA kind of modeling and thus provide alternative stock estimates compared to traditional assessment models.

For obtaining absolute estimates of cod biomass, we included a length based logistic model of cod catchability as estimated by Haley and Myers (2001) derived from IBTS surveys for the summer/autumn period in the North Sea and Skagerrak. The 50^{th} and the 5^{th} percentiles of the estimated parameters of the catchability models (Haley and Myers (2001) were used to calculate the length specific catchability of cod. For comparison, a model where catchability coefficient is assumed to be 1.0 for all length classes was also used.

Results

All 80 planned stations were covered. Only results on cod are presented although information on a number of other species was collected.

Cod

Cod was caught at all 80 stations. The catches were, however, generally low (Annex 3) but with the highest catches in the High Density Area and lowest in the Low Density Area.

The distribution of cod catches in numbers and weight is given in fig 2.

Biomass and abundance by method 1.

The trawlable biomass of cod was estimated at 776.2 (S.E. 86,8) tons (Table 2) compared to 1008.4 tons (S.E. 125.9) in 2008. The highest density was found in the High Density Area (0.15 ton per km^2), while the highest biomass was found in Medium Density Area (332.4 tons). The decrease in biomass was observed in all Areas and is caused by a reduction in cod > 40 cm (Fig 3).

The trawlable abundance was estimated at 2.10 mill (S.E 0.30) (Table 3) compared to 1.55 (S.E. 0.12 specimens in 2008. The highest density was observed in the High Density Area, 280.5

specimens per km^2 , while the largest abundance, 1.20 mill was found in the Low Density Area (Table 3). The increase in abundance between 2008 and 2009 was seen in all Areas.

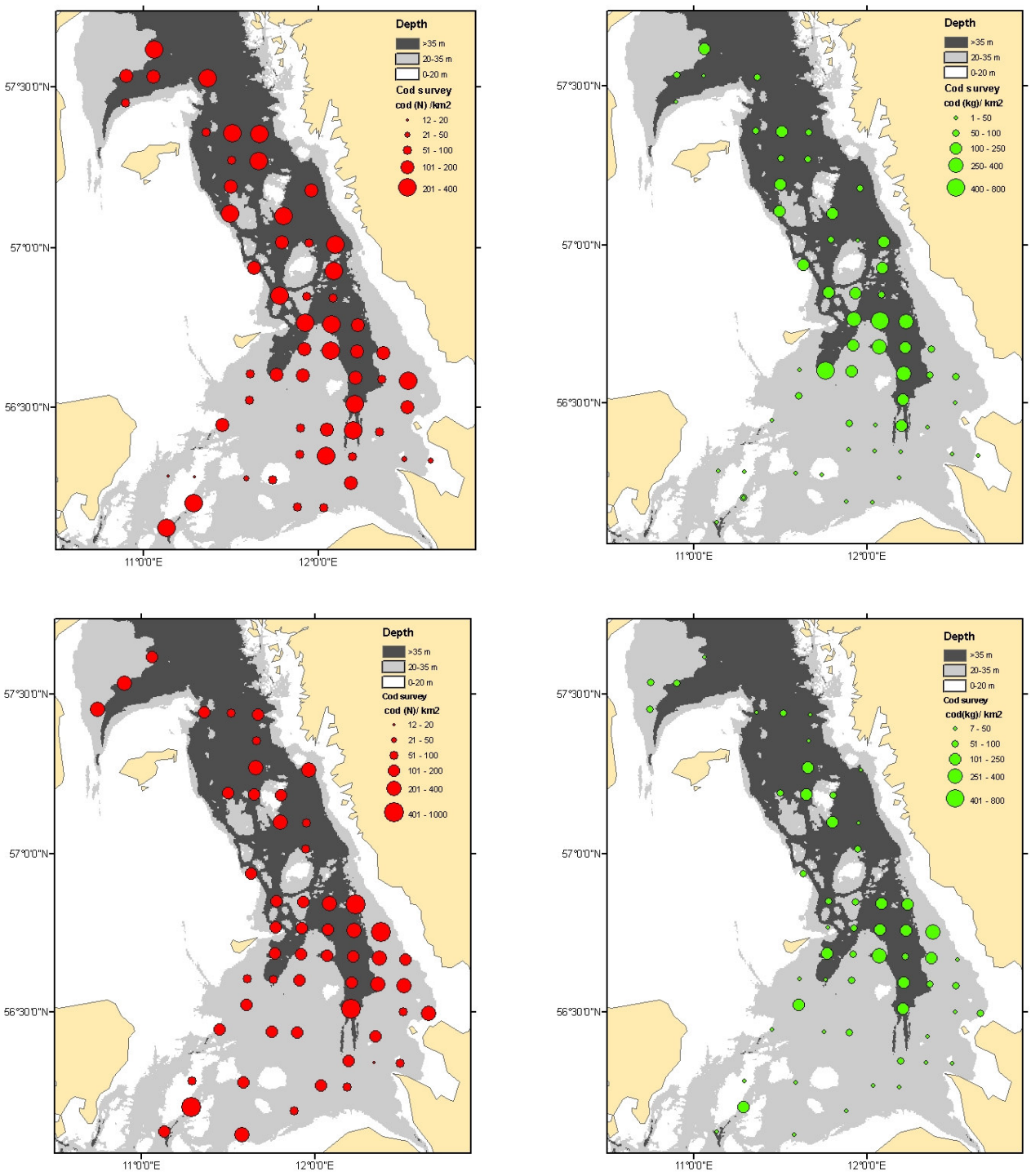


Figure 2. Abundance (left) and biomass (right) of cod per km^2 calculated as an average from all vessels per square. Upper panel 2008 lower panel 2009

Table 2. Cod 2009. Area, number of hauls, mean biomass per km^2 (tons), biomass (tons) and Standard Error distributed on Density Strata (Div.).

Div.	Area	Hauls	Mean sq. km	Biomass	S.E.
High	858	24	0.1464	125.6	14.9
Low	5488	24	0.0580	318.3	61.8
Medium	3773	32	0.0881	332.4	59.0
All		80	0.0767	776.3	86.8

Table 3. Cod 2009. Area, number of hauls, mean abundance per km^2, abundance and Standard Error distributed on Density Strata (Div.).

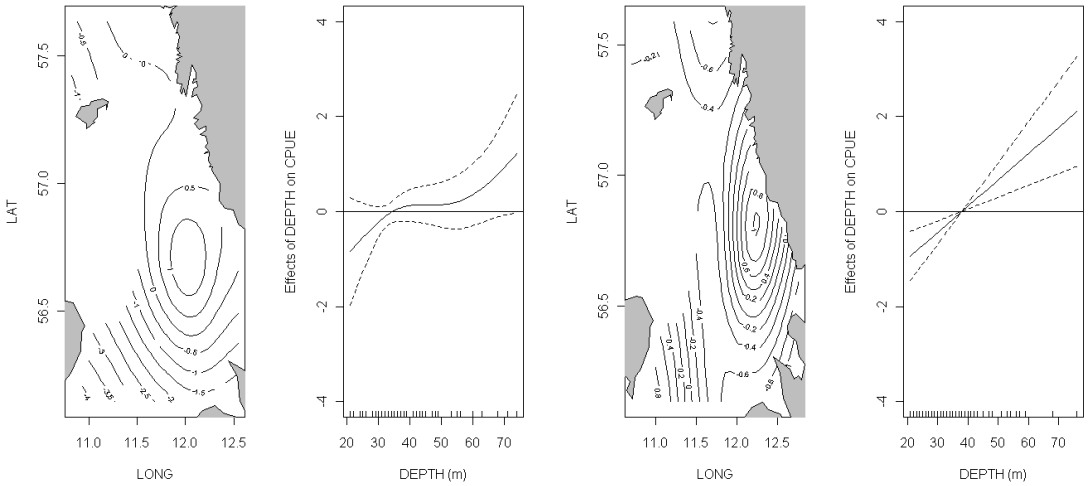
Div.	Area	Hauls	Mean sq. km	Abundance	S.E.
High	858	24	280.5	240687.2	32346.9
Low	5488	24	218.9	1201141.7	282099.5
Medium	3773	32	175.1	660658.0	91303.9
All		80	207.9	2102486.9	298266.4

Biomass calculated with GRASP

The final model, after backward stepwise selection based on significance included only the interaction between LAT:LONG and DEPTH as significant terms. The model was able to significantly reduce the total deviance explaining about 60% of the total deviance 2008 and 50% 2009. The plot of the LAT:LONG on CPUE showed the highest concentrations of cod larger than 39 cm are found in the central part of the Kattegat both in 2008 and 2009 (Figure 3a,b), while depth has a positive effect on CPUE with the highest cod biomass located in area deeper than 40 meters both 2008 and 2009 (Figure 3 a,b). The spatial model predictions for the Kattegat area for cod larger than 39 cm are presented in Figure 4.

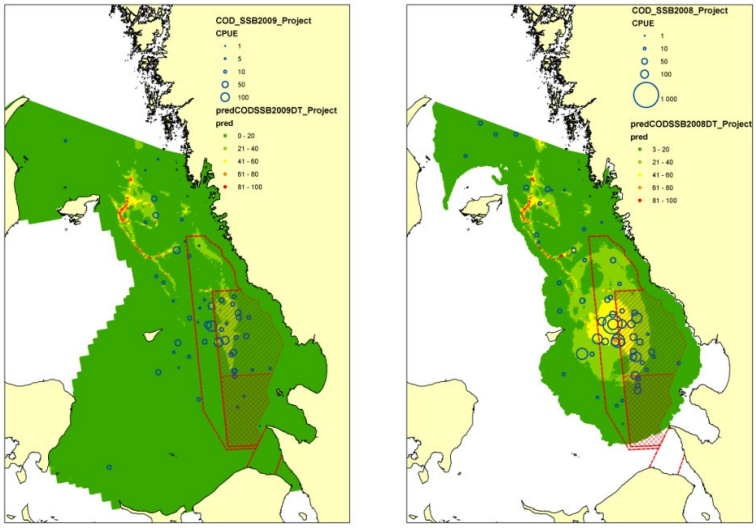
The trawlable cod biomass (cod >39 cm) ranged between 947 and 1457 tones with 50^{th} percentiles and 5^{th} percentile respectively. Assuming that the catchability (q) of the sweeps is 50% of catchability of the trawl (q=1). These estimates are lower than 2008 were the trawlable cod biomass was estimated to be 1289 and 2454 tones 50^{th} percentiles and 5^{th} percentile respectively.

A GRASP model for cod less than 39 cm was also produced on survey data for 2008 and 2009 using the same interactions(LAT:LONG and DEPTH) as in the model for cod larger than 39 cm. The model was able to significantly reduce the total deviance explaining about 60 % 2008 and 55 % 2009. The highest concentrations of cod less than 39 cm was found in the central part of Kattegatt in 2009, there was also a considerable overall higher density 2009 than in 2008. (Figure 5 a,b)



a) b)

Figure 3 a and b. Plots of the predictor effects (LAT:LONG, depth) as estimated by the final GAM models on CPUE (kg•h^{-1}) for Cod larger than 39 cm. a) 2008 and b) 2009.



a) b)

Figure 4. Spatial distribution of CPUE in kg•h-1 of cod in the Kattegat estimated for Cod >39 cm in a) 2008 and b)2009. Colours indicate modeled results while bubbleplots show results from different hauls. Note the differences in scale of the bubbleplots.

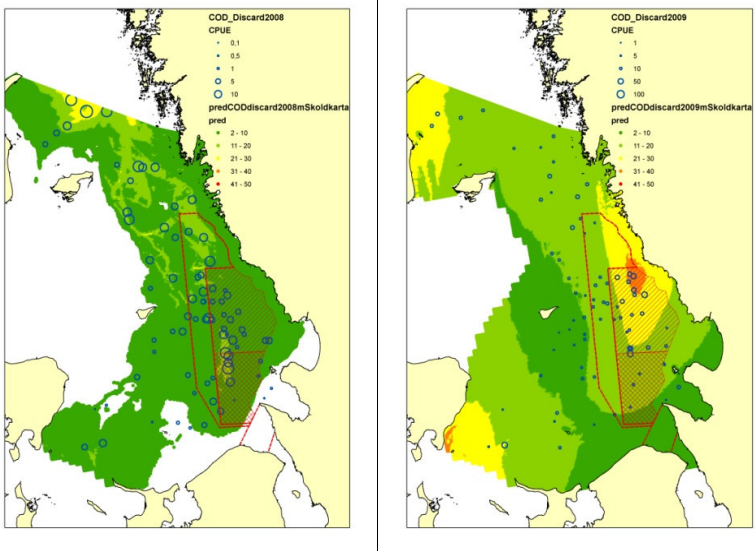


Figure 5. Spatial distribution of CPUE in kg•h-1 of cod in the Kattegat estimated for Cod <39 cm in a) 2008 and b)2009. Colours indicate modeled results while bubbleplots show results from different hauls.Note the differences in scale of the bubbleplots.

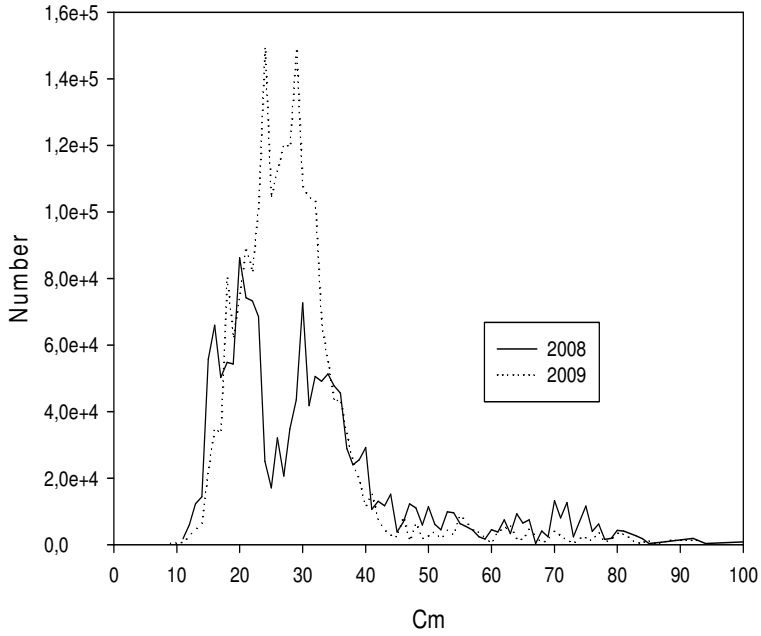


Fig. 6. Length distribution in number of cod in the total survey area.

Length distribution

The length ranged from 9 to 93 cm. The overall length distribution (weighted by stratum area) showed two modes at 24 an 29 cm, respectively. Further the number of cod > 40 cm was reduced compared to 2008 (Fig 6).

Most small cod were found in the Low density area, while the largest cod were found in the High density area (Fig 7).

Age distribution
The over all age distribution (weighted by stratum area) showed a very clear dominance of age 1 and very few fish older than 2 years (Fig 8). The increase in numbers of the 2008 year class between 2008 and 2009 may be caused by trawl selectivity. Number by age and year is given in Table 4.

Table 4. Number at age of Cod by year in the survey area

age	2008	2009
0	512281.9	260350.0
1	591938.0	1559905.6
2	249683.8	209152.7
3	94205.0	27316.6
4	59493.5	17424.3
5	28791.3	20352.0
6	6823.6	6838.6
7	1859.7	0
8	0.0	1147.1
9	1277.7	0

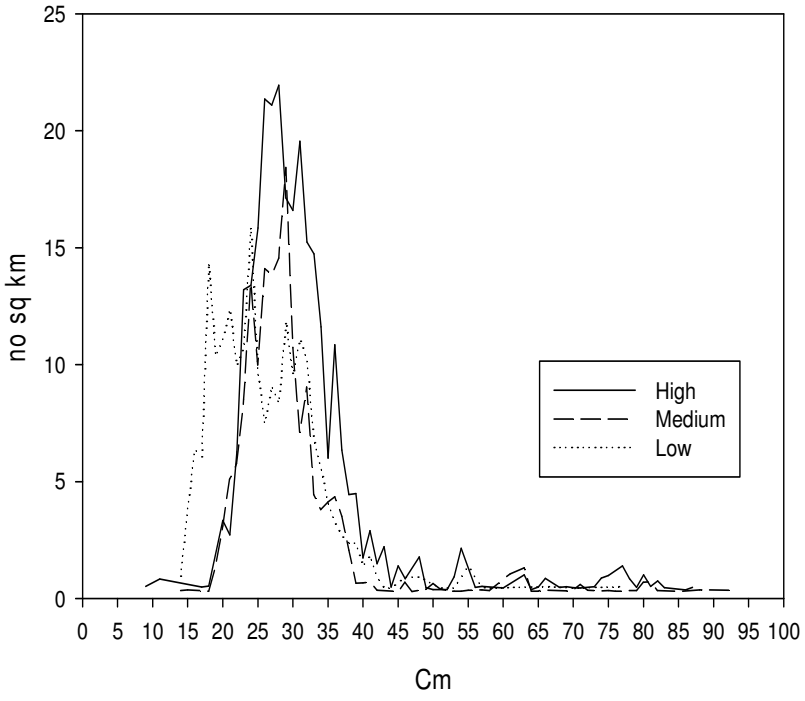


Fig. 7. Length distribution of cod in number per km^2 in the three strata.

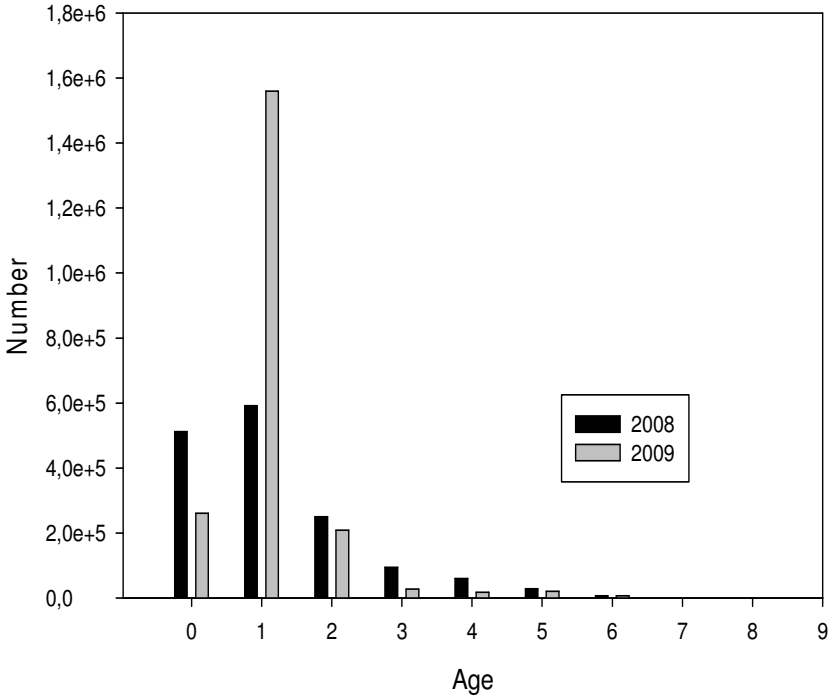


Fig 8. Over all age distribution (weighted by stratum area) of cod in total number in the survey area.

Most age 0 were found in the Low density are while most age 1 cod together with most old cod were found in the High density area (Fig 9).

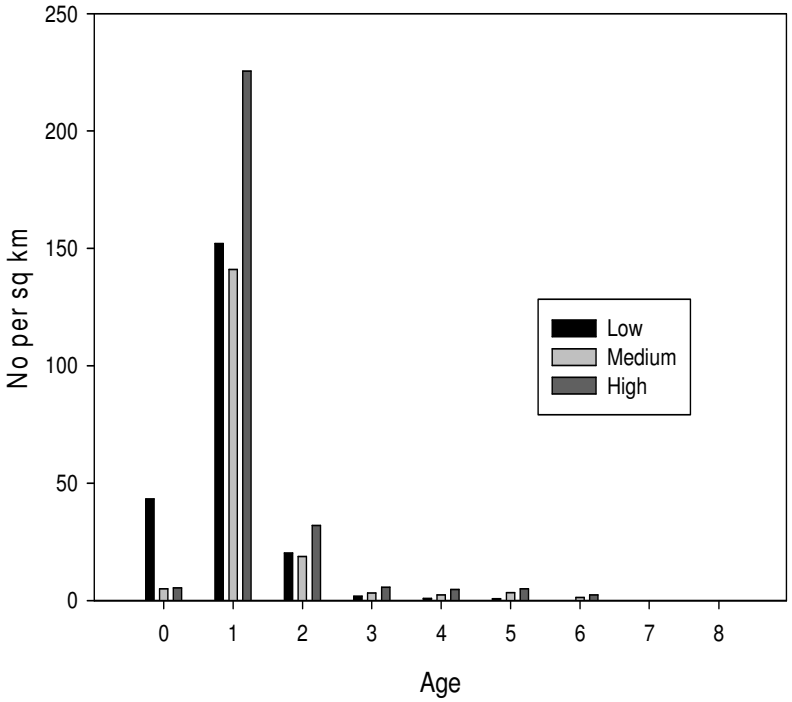


Fig. 9. Age distribution of cod in number per km^2 distributed on density areas.

CPUE.

CPUE in number and weight per hour was highest in the High density area while the CPUE in numbers were lowest in the Medium density area and CPUE in weight was lowest in the Low density area (Table 5). The CPUE in numbers increased in all Areas, while CPUE in weight decreased in the High and Medium density area, but increased in the Low density area compared to 2008.

Table 5. CPUE of cod in number and kg per hour with SE distributed on density areas.

Division	Number	Weight	SE Number	SE Weight	n
High	26.4	13.6	3.6	1.6	24
Low	19.6	5.4	4.5	1.0	24
Medium	16.1	8.1	2.2	1.4	32
All	20.3	8.9	2.0	0.9	80

The over all CPUE was 20.3 specimens and 8.9 kg, respectively compared to 14.2 specimens and 14.1 kg per hour, respectively, in 2008. The over all CPUE in number by age and year is given in Table 6. In 2009 age 1 totally dominated the catches, while there was a reduction in CPUE for most age classes > 1, especially ages 2 and 3.

Table 6. CPUE of cod in number by year and age per hour.

Age	0	1	2	3	4	5	6	7	8	9
2008	4.72	5.45	2.30	0.87	0.55	0.27	0.06	0.02	0.00	0.01
2009	1.42	15.57	2.12	0.32	0.24	0.27	0.01	0	0.01	0

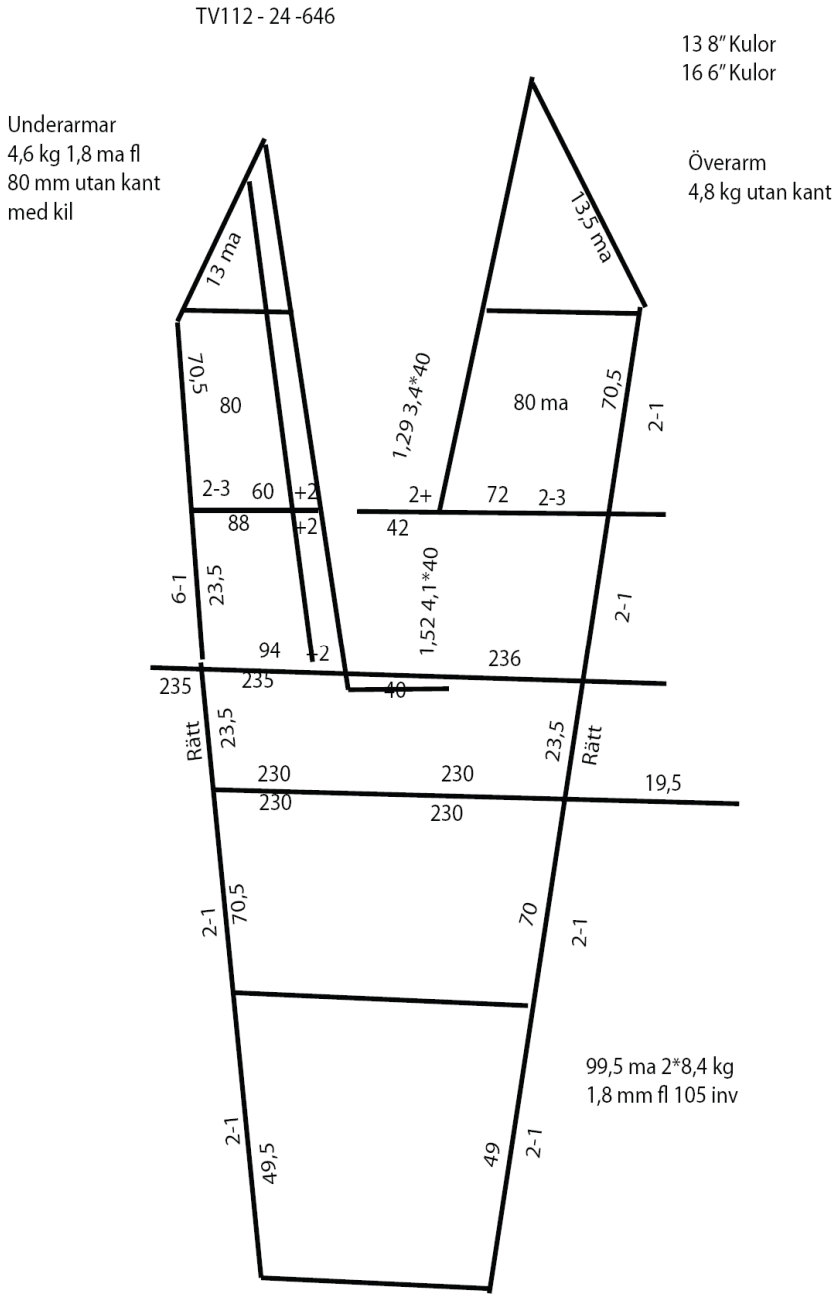
The CPUE in kg varied between vessels (7.4 - 10.7 kg and 26.5 -14.7 specimens per hour) but there is no statistical difference in catch rates between the vessels. In should be noted that the vessels covered different areas with little over lap.

Table 7. CPUE of cod in number and weight with S.E. by vessel.

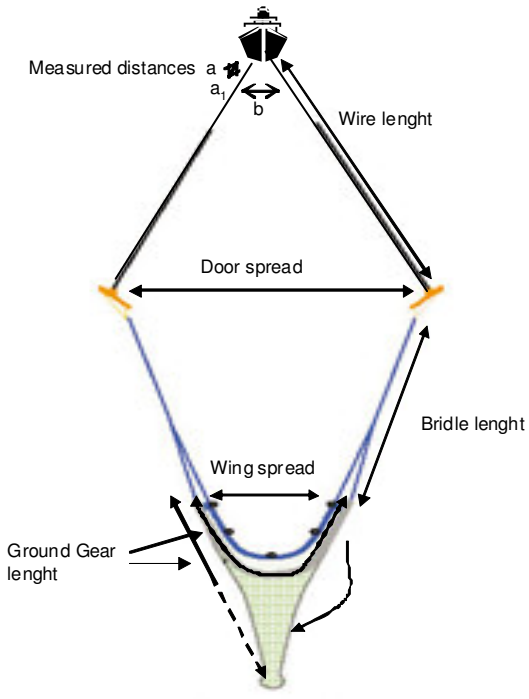
Vessel	Number	Weight	SE Number	SE Weight	n
FN370	23.9	10.7	4.4	2.0	20
H210	26.5	9.2	5.0	1.9	20
SDUO	16.0	8.3	1.9	1.6	20
SFEC	14.7	7.4	3.4	1.5	20

All four vessels made six hauls in the high density areas where the CPUE ranged between 11.9 and 15.9 kg and 21.0 and 36.5 specimens, respectively, but there was no statistical difference (5% level) in CPUE between the vessels.

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

Annex 3. Haul by haul information. Time in min. Swept area in km^2 catch weight of cod in kg

Haul	Vessel	Sweptwing	LatStart	LonStart	Time	Number	Weight
1	FN370	0,0931	56.45.583	11.56.826	60	12	3,1
2	FN370	0,0947	56.51.322	12.00.372	61	14	5,0
3	FN370	0,0893	56.44.839	12.01.461	60	17	22,7
4	FN370	0,0893	56.51.048	12.08.532	60	37	18,9
5	FN370	0,0880	56.41.258	12.14.606	60	17	11,5
6	FN370	0,0906	56.44.851	12.10.345	60	32	10,4
7	FN370	0,0995	56.57.896	11.37.921	60	17	7,5
8	FN370	0,0934	56.47.487	11.48.433	61	16	3,2
9	FN370	0,0893	56.36.828	11.51.902	60	12	12,7
10	FN370	0,0908	56.40.261	12.06.187	61	15	33,5
11	FN370	0,0880	57.04.383	11.48.196	60	35	25,8
12	FN370	0,0908	56.26.009	12.16.955	61	11	2,7
13	FN370	0,0908	56.46.259	12.21.048	61	70	23,2
14	FN370	0,0931	56.37.458	12.30.817	60	10	1,3
15	FN370	0,0882	57.31.712	10.42.143	61	31	5,4
16	FN370	0,0893	57.35.359	11.07.235	60	15	4,5
17	FN370	0,0851	57.25.292	11.34.462	58	8	4,4
18	FN370	0,0816	57.34.750	10.45.081	60	82	7,3
19	FN370	0,0893	57.33.592	10.56.350	60	19	7,5
20	FN370	0,0863	57.25.300	11.21.576	58	10	3,5
41	H210	0,0903	56.43.769	11.56.473	51	13	2,6
42	H210	0,1131	56.43.472	12.07.954	60	13	11,0
43	H210	0,1096	56.32.656	12.13.049	60	69	29,7
44	H210	0,1096	56.46.376	12.16.356	60	40	22,9
45	H210	0,1096	56.51.775	12.14.459	60	46	18,7
46	H210	0,1096	56.32.651	12.21.591	60	36	10,0
47	H210	0,1062	56.34.160	11.46.825	60	10	2,8
48	H210	0,1006	57.06.564	11.52.268	60	10	4,8
49	H210	0,1028	56.25.745	11.55.633	60	21	9,0
50	H210	0,0994	56.35.520	11.51.873	60	18	3,1
51	H210	0,1073	57.02.731	11.53.974	60	8	6,6
52	H210	0,1028	56.41.452	12.19.517	60	35	19,8
53	H210	0,0908	56.28.320	12.28.678	60	8	1,9
54	H210	0,0960	56.22.093	12.34.996	60	36	6,8
55	H210	0,0886	56.08.820	11.04.992	60	12	1,8
56	H210	0,0942	56.18.270	11.12.109	57	6	1,2
57	H210	0,0960	56.14.728	11.36.132	60	9	1,8
58	H210	0,0879	56.09.116	11.12.514	57	87	20,9
59	H210	0,0938	56.07.954	11.38.236	60	25	3,4
60	H210	0,1062	56.26.680	11.30.455	60	20	3,8
1	Otseco	0,0932	57.28.02	11.40.84	60	15	3,5
2	Otseco	0,0932	56.51.14	12.16.26	60	43	10,5
3	Otseco	0,0798	56.647.6	12.16.05	60	29	14,0
4	Otseco	0,0932	56.41.17	12.45.37	60	6	2,9
5	Otseco	0,0932	56.37.43	12.13.06	60	12	14,0
6	Otseco	0,1119	56.32.67	12.13.09	50	14	8,0
7	Otseco	0,0784	56.17.56	12.11.85	60	5	1,1
8	Otseco	0,0858	56.15.86	12.04.38	60	12	2,6
9	Otseco	0,0967	57.21.43	11.40.37	60	7	2,3
10	Otseco	0,0932	57.17.82	11.38.24	60	22	14,2
11	Otseco	0,0932	57.713.6	11.38.75	60	11	11,0
12	Otseco	0,0932	57.11.86	11.33.65	60	14	6,5
13	Otseco	0,0967	57.12.22	11.51.26	60	19	6,7

14	Otseco	0,0932	57.15.32	11.56.12	60	19	3,3
15	Otseco	0,0858	56.28.31	11.49.86	60	9	1,6
16	Otseco	0,0890	56.25.45	11.50.04	60	16	3,1
17	Otseco	0,0969	56.40.65	12.09.28	60	16	20,2
18	Otseco	0,0867	56.40.53	11.159.7	55	12	7,3
19	Otseco	0,0969	56.41.15	11.52.07	60	17	2,8
20	Otseco	0,0858	56.44.47	12.03.28	60	19	28,0
1	Yvonne II	0,0859	56.56.18	11.41.23	60	10	7,0
2	Yvonne II	0,0781	56.51.38	11.45.52	60	13	4,8
3	Yvonne II	0,0803	56.46.77	11.52.98	60	12	9,9
4	Yvonne II	0,0805	57.05.31	11.58.95	63	5	3,5
5	Yvonne II	0,0781	56.49.26	11.58.04	60	15	5,5
6	Yvonne II	0,0818	56.49.64	12.03.58	62	17	18,8
7	Yvonne II	0,0856	56.40.52	11.46.95	57	8	15,5
8	Yvonne II	0,0907	56.38.17	11.44.81	58	7	4,5
9	Yvonne II	0,0845	56.37.54	11.39.88	60	6	0,9
10	Yvonne II	0,0831	56.33.13	11.37.11	61	10	11,0
11	Yvonne II	0,0818	56.18.14	12.23.71	62	1	0,6
12	Yvonne II	0,0862	56.18.97	12.28.75	61	5	1,1
13	Yvonne II	0,0877	56.28.04	12.28.85	60	6	1,6
14	Yvonne II	0,0877	56.32.84	12.30.00	60	21	7,2
15	Yvonne II	0,0841	56.49.82	12.13.86	60	35	13,5
16	Yvonne II	0,0841	56.36.89	12.11.91	60	12	9,0
17	Yvonne II	0,0841	56.31.28	12.13.02	60	70	24,5
18	Yvonne II	0,0841	56.23.35	12.213.8	60	14	5,0
19	Yvonne II	0,0811	56.13.48	11.54.69	60	8	0,9
20	Yvonne II	0,0859	56.16.87	11.37.47	60	19	3,7

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