Dana, vol. 9, pp. 45-56, 1991

The spatial distribution of cod (*Gadus morhua* L.) in the Baltic Sea

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Abstract

The spatial distribution of cod in the Baltic Sea is estimated on the basis of catch rates in bottom trawl surveys. Data from the period 1982-1989 are used. The surveys are conducted by several vessels which differ in towing speed and gear used. The catch rates by these vessels can therefore not be compared directly and a general linear model (GLM) has been applied to overcome this difficulty. The spatial distribution is given by age group 1, 2, and 3+ and by quarter of the year as mean values over the time period covered.

Introduction

Knowledge of the spatial distribution of cod (*Gadus morhua* L.) in the Baltic is important for various kinds of modelling of the biological system in this sea area. It is needed for the development of the ICES Multi-Species Virtual Population Analysis (MSVPA) model for the Baltic Sea (see e.g. Sparholt, 1991) in order to compile the cod stomach data, because data from each quarter of the year and each sub-division should be weighted according to the amount of cod present in that sub-division and quarter. If the aim is to model the migration of the cod stock within the Baltic it is necessary to know the amount of cod present in a given area at a particular time to describe the net migration. Also for a proper use of effort data in an assessment of the cod stock a knowledge of the spatial distribution of cod is important, because the fleets of the Baltic countries are restricted to national fishing zones, and the effort is therefore not evenly distributed over the area.

There seems to be three possibilities for obtaining estimates of the spatial distribution of cod:

1. From commercial catch statistics assuming that the catch in a given area at a specific time is proportional to the amount of cod in that area at that time.
2. From commercial catch per unit of effort (CPUE) data, assuming that the CPUE values are proportional to the density of cod in each area at a specific

time. The estimates of the amount can then be obtained by multiplying the density with the area.
3. From trawl survey data, which can be treated as CPUE data.

Method 1 is unlikely to give reliable estimates because the basic assumption is not fulfilled in the Baltic, due to the uneven distribution of fishing effort between areas. Method 2 is also unlikely to give reliable estimates because the commercial fishery is not evenly distributed over the entire area of a reporting unit and because misreporting as regards fishing areas frequently has occurred.

This leaves us with method 3 for the present analysis. This method has the advantage that a) the effort is known very precisely for each country, because the gear used, the rigging and the towing speed have been constant in time for each country, b) because the fishing position as well as the depth are known, and c) because detailed information on the catch of each haul such as the number caught by age is available.

All countries surrounding the Baltic Sea conduct trawl surveys, but mainly within their own fishing zone. As the surveys are not standardized between countries with regards to fishing gear etc., the fishing power differs between the countries. Therefore, the catch rates obtained by one country can not be compared directly with those obtained by another country. Only methods which take the difference in fishing power between vessels into account are therefore relevant in this context. In the present paper Generalized Linear Models (GLM) have been used on logarithmic transformated catch rates.

Material

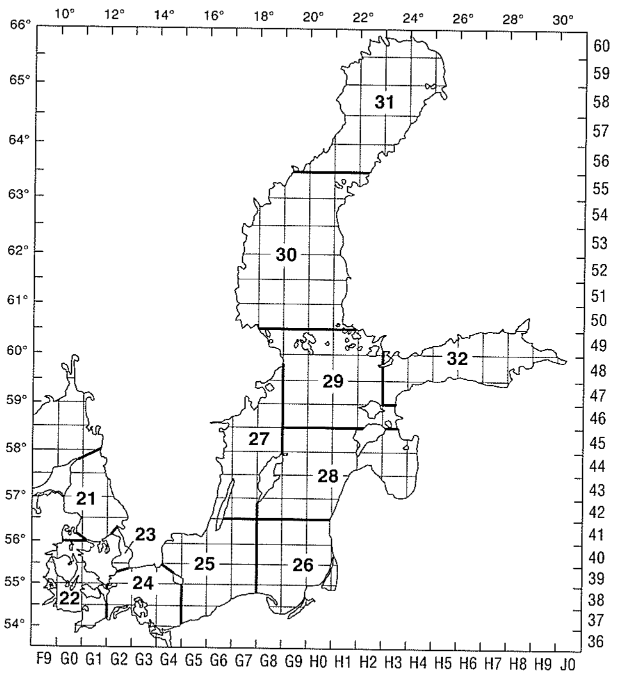
Trawl surveys have been carried out by Denmark, Federal Republic of Germany, the former German Democratic Republic, Poland, Sweden, and USSR in the Baltic proper, here defined as the ICES Sub-divisions 25, 26, and 28 (Figure 1). Data from these surveys were computerized by Anon. (1988) for the years 1980-1987, and by Anon. (1989) for the years 1988-1989. Table 1 summarizes the data used in the present analysis. Data from 1980 and 1981 were not used due to uncertainties in the quality of these data and because only few hauls were made in these two years. Figure 2 shows the number of hauls by statistical square for each country. For Denmark 30 hauls were only given by sub-division and these hauls are not represented in the figure.

Data from bottom trawls were used in the GLM models and data from pelagic trawls were only used to evaluate the results.

Hauls taken on depths less than 20 m were excluded from the analysis because the catches were very small (only about 1/10 of the catch rate on deeper water) and because very few hauls were done on shallow water.

Data were available as catch rates in number/hr of cod of age 1, age 2, and age 3+.

From Table 2 it can be seen that the data were unevenly distributed between sub-divisions and quarters, especially the material from the second quarter in all sub-divisions and from the fourth quarter in Sub-divisions 26 and 28 were limited and no data at all were available from the third quarter.



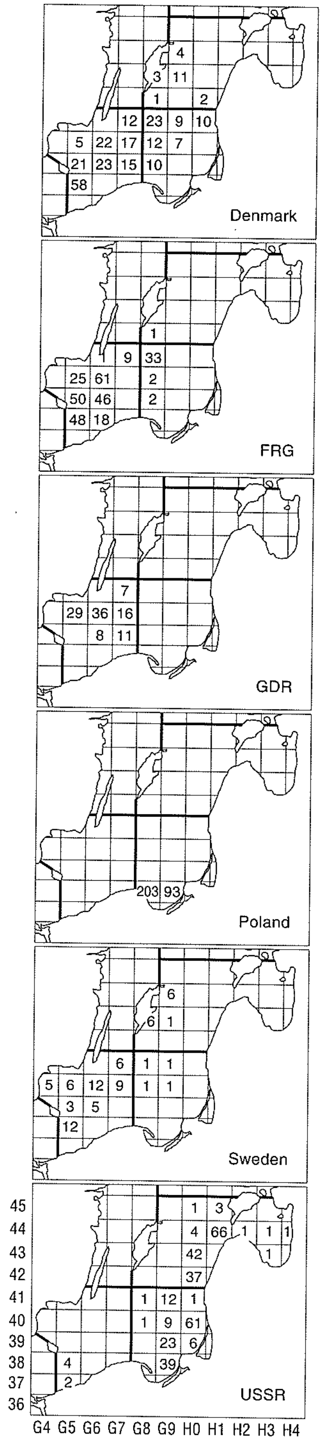


Fig. 1 (above). The sub-divisions in the Baltic Sea.
Fig. 2 (right). The number of trawl hauls by statistical square and country in Sub-divisions 25, 26, and 28 in 1982-1989.

Table 1. The number of demersal trawl hauls by country, year, sub-division, and quarter.

Country	Year	Sub-division	Quarter	No. of hauls
Denmark	1982-1989	25,26,28	1	298
FRG	1982-1989	25,26,28	1,2,4	296
GDR	1983-1986 and 1989	25	1,4	107
Poland	1982-85 and 1987-89	26	1	296
Sweden	1986-1989	25,26,28	1	76
USSR	1982-1989	25,26,28	1,2,4	313
Total				1386

Table 2. The number of demersal trawl hauls by sub-division and quarter for 1982-1989.

	Quarter			
Sub-div.	1	2	4	Total
25	478	17	121	616
26	504	34	38	576
28	103	36	55	194
Total	1085	87	214	1386

Methods

A GLM was used on logarithmic transformed catch rates. The model was given by the equation:

$$\log(\text{catch rate}) = Y + C + S + D + Q + D{\cdot}Q + D{\cdot}S + S{\cdot}Q + \epsilon, \qquad (1)$$

where

Y = Year
C = Country
S = Sub-division
D = Depth
Q = Quarter of the year
ϵ = Epsilon, the error term.

$D{\cdot}Q$, $D{\cdot}S$, and $S{\cdot}Q$ represents interaction terms. The reasons for using the above main effect terms were:

Year:	Because the cod stock and year-classes vary by year.
Country:	Because countries have used different vessels, gear, rigging, towing speed etc., and therefore were expected to differ in fishing power.
Sub-division:	Because this is one of the two main parameters for describing the spatial distribution of cod.
Depth:	Because this is the other main parameter in describing the spatial distribution.
Quarter:	Because the spatial distribution probably varies over the year.

The three interaction terms were included of the following reasons:

Depth · quarter:	Because the depth distribution of cod probably varies over the year, for instance 1-group cod move to deeper water during the year as they become larger.
Depth · sub-division:	Because the depth distribution of cod is expected to vary by area, for instance due to the oxygen depletion in some areas which cod then avoid.
Sub-division · quarter:	Because cod are expected to undertake seasonal migrations between sub-divisions.

The three-factor interaction term of depth, quarter, and sub-division was not included because the analysis then would contain so called 'empty cells', which means that for some combinations of depth, quarter, and sub-division no observations were available. For instance no hauls were made in Sub-division 25 in the fourth quarter on depths greater than 100 m in any of the years. Therefore, no parameter could be estimated for this cell and this would prevent an estimation of the overall spatial distribution in that quarter.

The country effect was not included in interactions with other terms because the vessel for each country was expected to have constant fishing power throughout the time period, in all quarters, in all depth ranges, and in all sub-divisions.

The year should ideally have been included in interaction with sub-division, depth and quarter because the spatial distribution of cod might change from year to year (Aro, 1989). However, the analysis would then contain empty cells and as mentioned above this would prevent an estimation of the spatial distribution.

The depth ranges used were 21-40 m, 41-60 m, 61-70 m, 71-100 m, >100 m.

The GLM was done separately on 1-group, 2-group, and 3+-group cod.

The computer procedure GLM from the statistical computer package SAS (Anon., 1985) was used, because this procedure can handle unbalanced data, i.e. where the number of observations vary by cells. This procedure gives the descriptive statistics as well as estimates of the parameters. The parameters were used to calculate the median catch rate by sub-division, quarter, and depth. The mean catch rate was not calculated because the errors terms of the estimated parameters, which would then be needed, were difficult to obtain from the computer procedure. In the present study it is only the relation between the catch rates in the various sub-divisions which is of interest, and the use of the medians instead of the means is unlikely to influence the outcome of the analysis significantly.

To avoid taking the logarithm of zero 0.5 cod/hr was added to all the catch rates.

The variance structure was analysed by looking at the mean and standard deviations of the catch rates of age 3+ for each particular combination of year, country, sub-division, quarter, and depth. The standard deviations were plotted against the mean and a strong positive slope (0.93 ± 0.10, 95% confidence level) was estimated by regression analysis. On logarithmic transformed catch rates the slope was negative but close to zero (-0.15 ± 0.04) indicating that it was reasonable to assume equal variances on all logarithmic transformed observations as is implicitly done by using the above GLM procedure. A negative slope indicates that the coefficient of variation decreases with increasing size of the observation, and it is interesting that a comparable small decrease in the coefficient of variation with increasing size of the observation has also been observed by Sparholt (1989) and Sparholt (1990) when dealing with commercial catch-at-age data, hydroacoustic stock number estimates and young fish survey data for herring in the Skagerrak-Kattegat area and in the central Baltic.

Strictly spoken, the distribution of the catch rates is not log-normal because there are zero observations in the data, and a delta-distribution (e.g. Pennington, 1983) would probably be more realistic, especially for 1- and 2-group cod with many zero catches. For age group 3+ the problem is minor because the catch was zero in only 5.6% of the hauls. The problem is, however, that GLMs for delta-distributions have not yet been developed.

No major differences in the variance structure were detected between years, countries, sub-divisions, quarters, or depths.

Results

Table 3 shows the calculated statistics for the GLMs for each of the age groups 1, 2, 3+. For age 1 the model explained 27% of the variation in the data and the main contributors to this were the year effect, the country effect, and the depth·quarter effect. The year effect was the result of fluctuating year-class strengths and the

Table 3. The descriptive statistics of the GLMs. The sum of squared deviations (s. of sq.) for the various effects are of type III s. of sq. (Anon., 1985), which are independent of the order of the effects in the model.

	Error source	d.f.	s. of sq.	*F*	Probability	r^2
Age 1	Model	40	1437	12.56	0.01%	0.27
	Error	1345	3849			
	Corrected total	5287				
	Error source	d.f.	s. of sq.	*F*	Probability > *F*	
	Year	7	227	11.32	0.01%	
	Country	5	130	9.08	0.01%	
	Sub-division	2	4	0.69	50.04%	
	Depth	4	80	7.02	0.01%	
	Quarter	2	41	7.24	0.07%	
	Depth · quarter	8	246	10.74	0.01%	
	Sub-div. · quarter	4	39	3.41	0.87%	
	Sub-div. · depth	8	93	4.07	0.01%	
Age 2	Error source	d.f.	s. of sq.	*F*	Probability	r^2
	Model	40	1920	16.02	0.00%	0.32
	Error	1345	4031			
	Corrected total	5951				
	Error source	d.f.	s. of sq.	*F*	Probability > *F*	
	Year	7	682	32.52	0.00%	
	Country	5	250	16.67	0.01%	
	Sub-division	2	49	8.20	0.03%	
	Depth	4	60	4.96	0.06%	
	Quarter	2	11	1.76	17.20%	
	Depth · quarter	8	152	6.35	0.01%	
	Sub-div. · quarter	4	58	4.88	0.07%	
	Sub-div. · depth	8	69	2.86	0.37%	
Age 3+	Error source	d.f.	s. of sq.	*F*	Probability	r^2
	Model	40	2544	30.86	<0.00%	0.48
	Error	1345	277			
	Corrected total	5317				
	Error source	d.f.	s. of sq.	*F*	Probability > *F*	
	Year	7	474	32.88	0.00%	
	Country	5	580	56.31	0.00%	
	Sub-division	2	12	2.89	5.56%	
	Depth	4	13	1.53	19.22%	
	Quarter	2	11	2.67	6.96%	
	Depth · quarter	8	205	12.45	0.01%	
	Sub-div. · quarter	4	28	3.43	0.85%	
	Sub-div. · depth	8	124	7.51	0.01%	

Table 4. Estimated parameters from the ANOVA.

Parameters	Age 1	Age 2	Age 3+
Intercept	0.1019	−0.9112	1.5596
Year			
1982	0.5145	2.7542	1.5820
1983	0.6303	1.7440	1.9849
1984	0.9346	1.4509	1.5480
1985	0.3035	1.3167	1.1146
1986	0.0330	0.4006	0.4136
1987	−0.0801	1.3460	0.5460
1988	−0.4761	1.3655	0.6538
1989	0.0000	0.0000	0.0000
Country			
Denmark	0.2752	−0.2088	0.6008
FRG	0.1404	0.0944	0.9786
GDR	−0.0439	−0.5751	−0.8823
Poland	1.1161	−1.5660	−1.6948
Sweden	0.8468	0.0058	0.7755
USSR	0.0000	0.0000	0.0000
Sub-division			
25	0.3191	−1.1416	−1.6667
26	−1.4229	−1.6207	−1.3485
28	0.0000	0.0000	0.0000
Depth			
21-40 m	2.2028	3.8585	2.2136
41-60 m	3.0692	4.0215	2.1095
61-70 m	3.1513	4.3126	2.4213
71-100 m	0.9345	2.8710	0.9624
>100 m	0.0000	0.0000	0.0000
Quarter			
1	0.2845	2.4981	1.9331
2	−0.4978	2.6699	2.2527
4	0.0000	0.0000	0.0000
Depth · quarter			
21-40 m 1	−3.9464	−4.0754	−2.8882
21-40 m 2	0.0662	−2.6572	−3.0737
21-40 m 4	0.0000	0.0000	0.0000
41-60 m 1	−3.4392	−3.4686	−2.5888
Depth · quarter (continued)			
41-60 m 2	−3.1100	−3.9996	−5.0870
41-60 m 4	0.0000	0.0000	0.0000
61-70 m 1	−2.9499	−3.1580	−2.7896
61-70 m 2	−1.7988	−2.1970	−4.1295
61-70 m 4	0.0000	0.0000	0.0000
71-100 m 1	−0.6154	−1.2981	−0.2496
71-100 m 2	0.1132	−1.1102	−1.2139
71-100 m 4	0.0000	0.0000	0.0000
>100 m 1	0.0000	0.0000	0.0000
>100 m 2	0.0000	0.0000	0.0000
>100 m 4	0.0000	0.0000	0.0000
Sub-division · quarter			
25 1	0.9274	0.6766	0.7678
25 2	2.2030	1.5694	1.8269
25 4	0.0000	0.0000	0.0000
26 1	0.6769	0.5345	0.5371
26 2	0.3144	−0.8500	0.1691
26 4	0.0000	0.0000	0.0000
28 1	0.0000	0.0000	0.0000
28 2	0.0000	0.0000	0.0000
28 4	0.0000	0.0000	0.0000
Sub-division · depth			
25 21-40 m	−0.4967	−0.8090	−0.1623
25 41-60 m	−0.9817	0.4529	1.1268
25 61-70 m	−1.3908	−0.3800	0.8048
25 71-100 m	−1.4897	−1.3116	−0.4743
25 >100 m	0.0000	0.0000	0.0000
26 21-40 m	2.3471	1.2392	0.2012
26 41-60 m	1.7651	1.5298	0.9901
26 61-70 m	0.9641	0.9483	1.3530
26 71-100 m	0.2034	0.3095	0.8318
26 >100 m	0.0000	0.0000	0.0000
28 21-40 m	0.0000	0.0000	0.0000
28 41-60 m	0.0000	0.0000	0.0000
28 61-70 m	0.0000	0.0000	0.0000
28 71-100 m	0.0000	0.0000	0.0000
28 >100 m	0.0000	0.0000	0.0000

depth·quarter effect was due to a relatively low catch in the first quarter compared to other quarters on depths less than 71 m while on greater depths the differences between quarters were minor as judged from the estimated parameters given in Table 4. For age 2 the model explained 32% of the variation in the data and the main contributors were the year, country, and the depth·quarter effects. The country effect can be interpreted as differences in fishing power of the various research vessels. The same reason for the depth·quarter effect as for age 1 can be given for age 2. For age 3+ the model explained as much as 48% of the variation in the data and the main contributors were year, country, depth·quarter, and sub-division·depth. The sub-division·depth effect seemed to be due to a relatively higher concentration of cod in the depth interval 41-70 m in Sub-division 25 and 26 compared to Sub-division 28. It can also be seen that the quarter effect explains about twice as much of the variation in the distribution by depth than the sub-division effect for all three age-groups.

The estimated parameters from the GLM (Table 4) were used to estimate the mean density of cod in the period 1982-1989 by sub-division, quarter, and depth stratum.

The area of each depth stratum (Table 5) was then multiplied by the density to obtain the amount of cod by sub-division, quarter, and depth stratum. It was assumed that no cod were found at depths greater than 120 m.

From Table 6 it can be seen that in the first quarter of the year the largest amount of cod was found in Sub-division 26, and for age 2 and older cod the amount in Sub-division 28 was higher than in Sub-division 25. The differences between sub-divisions were larger in the second quarter than in the first. In the fourth quarter the amount of all three age groups was rather similar in the three sub-divisions.

The mean catch rate by depth and age has also been calculated on the basis of the parameters given in Table 4 (Table 7). It can be seen that few fish are found below a depth of 100 m, and that young cod prefer more shallow water than adult cod.

Table 5. The area ('000' km^2) of each depth stratum by sub-division.

	Sub-division		
Depth	25	26	28
21-40 m	11.5	6.4	6.1
41-60 m	10.6	5.5	5.4
61-70 m	5.7	2.9	1.6
71-100 m	8.6	13.2	6.0
101-120 m	0.0	6.8	4.6
>120 m	0.0	0.0	11.4

Table 7. The catch rates of cod by depth stratum and age as estimated by the GLM models.

Depth	Age 1	Age 2	Age 3+
21-40 m	0.32	0.16	0.17
41-60 m	0.22	0.25	0.17
61-70 m	0.29	0.41	0.30
71-100 m	0.10	0.16	0.24
>100 m	0.07	0.03	0.13
Total	1.00	1.01	1.01

Table 6. The estimated amount of cod in relative number (arbitrary unit) by age, sub-division, quarter, and depth.

		Quarter		
Age	Sub-div.	1	2	4
1	25	0.35	0.75	0.30
	26	0.41	0.18	0.43
	28	0.23	0.07	0.27
	Total	0.99	1.00	1.00
2	25	0.24	0.55	0.25
	26	0.41	0.10	0.34
	28	0.35	0.35	0.42
	Total	1.00	1.00	1.01
3+	25	0.22	0.38	0.29
	26	0.48	0.30	0.31
	28	0.29	0.32	0.40
	Total	0.99	1.00	1.00

Table 8. Statistics for various GLM models of log catch rates of cod of age 3+.

Models	Sum of squares	Total s. of sq.	d.f.	*F*	Probability
Year	493	5317	7	20.10	0.01%
" Country	1837	"	12	60.42	0.00%
" " Sub-div.	1918	"	14	55.30	0.00%
" " Square	2116	"	62	14.1	0.00%
" " Depth	2015	"	16	52.24	0.00%
" " Sub-div. depth	2103	"	18	49.69	0.00%
" " " " Quart.	2115	"	20	45.08	0.00%
" " " " " Depth·quart.	2401	"	28	39.91	0.00%
" " " " " Sub-div.·quart.	2141	"	24	38.24	0.00%
" " " " " Year·sub-div.	2265	"	34	29.52	0.00%
" " " " " Year·quart.	2234	"	31	31.65	0.00%
" " " " " Depth·quart. sub-div.·quart.	2420	"	32	35.33	0.00%
" " " " " Depth·quart. sub-div.·quart. sub-div.·depth	2544	"	40	30.86	0.00%
" " " " " " " " Sub-div.·depth·quart.	2644	"	52	25.37	0.00%

Evaluation of the model

Table 8 shows the statistics for various other GLM models for the logarithm of the catch rate of age group 3+. In a model including year as the only effect the model explained only a small fraction of the total error, as the model s. of sq. is only 493 out of a total s. of sq. of 5317. When a country effect was added the explanation became much better. Including sub-division, square, depth, sub-division·depth, and sub-division·depth·quarter did not individually improve the explanation very much. However, all these parameters together with the interaction terms used in model (1): depth·quarter, sub-division·quarter, and sub-division·depth, improved the explanation from 34 to 48%. The interaction terms between year and sub-division and between year and quarter did not improve the model substantially, neither did the inclusion of the interaction term sub-division·depth·quarter.

The same array of models was also applied to the logarithmic catch rates of age 1 and 2, with similar results, except that the quarter of the year had a higher effect on the catch rate of 1 group cod and that the year effect had a higher effect on both ages than on age 3+ probably reflecting the fluctuations in the yearclass strengths, which are larger in single cohorts than in aggregations of cohorts such as a 3+ group.

Because the area unit used, i.e. sub-division, is rather large the country effect estimated might be due to a systematic difference in trawling stations between two or more countries and the country effect would then be confounded with a difference in spatial distribution. In order to check this a special GLM model was run with year, country, statistical square, and depth as the class variables. Because statistical squares (approximately 30 nm × 30 nm) is much smaller than sub-divisions it is less likely that the country effect will be confounded with the spatial effect in this GLM model than in model (1). This analysis showed that the country effect was not sig-

Table 9. Comparison between VPA stock number estimates and the year effects estimated by the GLM. SE is the standard error.

	Age 2			Age 3+		
Year	VPA	GLM	SE	VPA	GLM	SE
1982	642	2.75	0.26	889	1.58	0.22
1983	426	1.74	0.24	958	1.98	0.20
1984	272	1.45	0.25	824	1.55	0.21
1985	209	1.32	0.24	552	1.11	0.20
1986	217	0.40	0.26	390	0.41	0.21
1987	364	1.35	0.26	317	0.55	0.21
1988	224	1.37	0.25	392	0.65	0.21
1989	–	0.00	0.25	330	0.00	0.21
Correlation coefficient VPA log transformed r^2		0.70			0.92	

nificantly influenced by this change in the area-unit used in the GLM models and, thus, that there is no serious confounding between the country and the area effect.

The model can be evaluated against the VPA stock number estimates from the ICES Report of the Baltic Demersal Working Group (Anon., 1989). The year effect estimated by the model should be positively correlated with the VPA estimates. Table 9 gives the VPA estimates and the estimated year effects from the GLM. As can be seen the correlation coefficient r^2 is 0.92 for age 3+ and 0.70 for age 2. This, thus, confirmed that the model was able to estimate the year effect fairly precisely. VPA estimates of age 1 was not given by Anon.(1989).

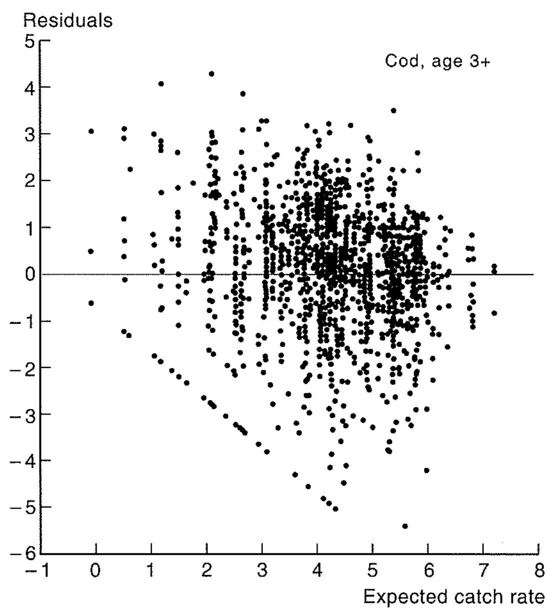


Fig. 3. Residuals plotted against the expected values of logarithmic transformed catch rates of age 3+ cod.

The better correlation between the GLM and the 3+-group than between the GLM and the 2-group is in accordance with the difference of the standard errors of the estimated year effects of age 2 and age 3+.

The residuals from the model plotted against the expected value (Figure 3) showed a slightly negative correlation, thus indicating, that the logarithmic transformation was not completely satisfying. This was also observed in the 'Methods' section, but the bias introduced in this way is probably small and certainly smaller than in a non-transformed analysis.

The residuals were also plotted against the year and quarter by each country and no trends over the time period were detected.

Discussion

The present GLM analysis is based on demersal trawl data. As cod in the Baltic are often pelagic this could bias the results of the spatial distribution of cod. A few pelagic trawl hauls have, however, been done in the period 1982-1989. Table 10 shows the catch rates of cod by sub-division in the demersal trawls hauls compared to the pelagic trawls hauls. As can be seen the catch rates in the two types of hauls are rather similar and the above mentioned bias is, therefore, not expected to be of major importance.

Table 10. The arithmetic mean (1982-1989) catch rates (kg/hr) of cod age 3+ by sub-division in demersal and pelagic trawls in trawl surveys. N is number of hauls.

Subdivision	Demersal	N	Pelagic	N
25	253.26	616	271.17	55
26	150.45	576	110.61	93
28	248.46	193	288.84	27
Total		1386		177

Table 11. The mean annual commercial catch (tonnes) in 1980-1988 (Anon., 1989, Table 1.2) of cod in the central Baltic by sub-division. A Danish mean annual catch of 73 137 tonnes in Sub-divisions 25, 26, and 28 was impossible to split into sub-division and was therefore excluded.

Subdivision	Catch
25	65689
26	86453
27	6560
28	40669
29	8590
30	3231
31	36
32	9580
Total	220807

The cod stock is distributed all over the Sub-divisions 25-32, but the main part of cod is found in the three Sub-divisions 25, 26, and 28 considered here. Table 11 shows the commercial catch in all sub-divisions and it can be seen that 90% of the commercial catch has been taken in Sub-divisions 25, 26 and 28 in 1980-1988.

The database used does not contain information about haul position on a finer scale than statistical squares. This is too crude a scale if one wants to take into account the correlation between stations situated close to each other. Geostatistical analysis of cod catches in bottom trawl surveys in the North Sea indicates that hauls separated by more than about 5 nm is not correlated at all (K.P. Andersen, pers. comm.).

The large difference between sub-divisions in the second quarter of the year should be considered with caution, because these estimates are based on a rather limited number of trawl hauls.

It can be concluded that the GLM models of the catch rates of cod in bottom trawl surveys in the Baltic Sea give estimates of the spatial distribution of cod in the Central Baltic, which 1) can not be rejected due to known gaps or biasis in the basic data, 2) appear sensible as regards the parameters considered in the GLM model and the variance structure in the data, and 3) are able to compensate for the large difference in fishing power between the research vessels from the various countries. A comparison of the annual fluctuations in cod abundance as estimated by the GLM models with those from VPA was the only possible evaluation of the models against independent data. This comparison showed that there was a good agreement between these fluctuations.

Finally, it should be mentioned that the parameters given in Table 4 can be used to obtain other details about the spatial distribution of cod in the Baltic than extracted in the present paper.

Acknowledgement

We would like to thank the General Secretary of ICES for permission to use data from the ICES Working Group Reports, and for allowing us to use the database of the ICES Study Group on Young Fish Surveys in the Baltic (Anon., 1988).

References

Anon., 1985: SAS User's Guide Statistics, Version 5 Edition. – SAS Institute Inc., Cary, NC, USA.

Anon., 1988: Report of the Study Group on Young Fish Surveys in the Baltic. – ICES C.M. 1988/J:27.

Anon., 1989: Report of the Working Group on the Assessment of Demersal Stocks in the Baltic. – ICES C.M. 1989/Assess: 17.

Aro, E., 1989: A review of fish migration pattern in the Baltic. – Rapp. P.-v. Réun. Cons. int. Explor. Mer *190*: 72-96.

Pennington, M., 1983: Efficient Estimators of Abundance, for Fish and Plankton Surveys. – Biometrics *39*: 281-286.

Sparholt, H., 1989: A model for estimating natural mortality rate, stock size, and emigration of the Skagerrak-Kattegat and Western Baltic herring stocks, based on catch-at-age, acoustic, and young fish survey data. – Rapp. P.-v. Réun. Cons. int. Explor. Mer *190*: 261-270.

Sparholt, H., 1990: A stochastic integrated VPA for herring in the Baltic Sea using acoustic estimates as auxiliary information for estimating natural mortality. – J. Cons. int. Explor. Mer *46*: 325-332.

Sparholt, H., 1991: Multispecies assessment of Baltic fish stocks. – ICES mar. Sci. Symp. *193*: 64-79.