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Application of some statistical methods to results of groundfish surveys in the Mecklenburg Bay and in the Arkona Basin in November 1978 and 1979

by

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Abstract

Stratified mean catch per tow, variance, and coefficient of variation were calculated for cod, herring, plaice, and flounder from GDR research vessel autumn bottom trawl surveys in 1978 and 1979. The catch frequence distributions were examined and found to be positive skewed. The logarithmic transformation of the individual catches was made in order to normalize the frequency distributions of survey catches and to reduce the variance of catches. Year class abundance indices of cod and herring were determined by applying relative age compositions to the mean catch per tow in number.

Introduction

In 1977 GDR started a series of bottom trawl surveys in the Mecklenburg Bay, the Arkona Basin and the Bornholm Basin (Schulz and Kästner, 1978). The major objective of these surveys is to provide relative estimates of the abundance and recruiting year class strength of fish populations in these areas. Such informations are essential for assessing the current status of stocks and particularly for predicting total allowable catches.

This paper presents indices of abundance expressed in terms of mean weight (or number) of fish caught per standard tow in the Mecklenburg Bay as well as the Arkona Basin in 1978 and 1979. In addition, the level of precision of the calculated abundance indices is considered in a preliminary analysis. This paper also provides estimates of the mean catch per tow in number of 0, 1 and 2 year old cod and herring in these two areas.

Material and methods

All basic data were collected during the GDR bottom trawl surveys in November 1978 and 1979.

These surveys were conducted by the R/V "Eisbär" (1 200 h.p.). The gear used was a Polish herring bottom trawl HG 20/25 with a mesh size of 11 mm in the cod end. Each tow was made of a 30-minute duration at a mean trawling speed of 3.5 knots.

In the Mecklenburg Bay the depth range of 15-25 m was included in the surveys. This area was not further subdivided and 19 tows were made at randomly scattered points in 1978 as well as 1979.

The Arkona Basin area investigated during the surveys was divided into four depth strata of 10-19 m, 20-29 m, 30-39 m and 40-49 m. Station selection was performed stratum by stratum using random numbers. In this area 24 tows were carried out in November 1978 and 31 tows in November 1979.

Further informations about the methods used in the surveys are given in Schulz 1978, Schulz and Kästner 1979.

Abundance indices as mean catch per standard tow both in weight and number were estimated for cod, herring, plaice and flounder. According to the survey design in the Mecklenburg Bay formulare for simple random sampling were used to calculate mean catch

per tow and its variance. Because of the stratification employed in the Arkona Basin, the theory of stratified sampling could be used. For calculating stratified mean catch per tow and its variance the applied formulare are:

$$\bar{x}_{st} = \frac{1}{A} \sum_{h} A_h \bar{x}_h$$

$$v(\bar{x}_{st}) = \frac{1}{A^2} \sum_{h} \frac{A_h^2 s_h^2}{n_h}$$

where:

$\bar{x}_{st}$ = stratified mean catch per tow

A = total strata area

A_h = area of the h-th stratum

$\bar{x}_h$ = mean catch per tow in the h-th stratum

$v(\bar{x}_{st})$ = variance of the stratified mean catch per tow

s_h^2 = variance of catches in the h-th stratum

n_h = number of tows in the h-th stratum

Further details on theory of stratified sampling are given in Cochran 1972.

Furthermore the coefficient of variation (CV) was calculated as ratio of standard deviation to the mean.

The catch frequency distributions were examined and a test of skewness (Snedecor and Cochran 1976) was used to check the assumption of normality. In addition, the relationship between population variance (s^2) and mean ($\bar{x}$) was analysed using Tailor's

power law (Taylor 1961, Sissenwine 1976):

$$s^2 = a\,\bar{x}^b$$

$$\log \quad s^2 = \log a + b \log \bar{x}$$

The parameter a is a sampling factor. The exponent b is an index of dispersion and can describe a variety of distributions; $b > 1$ indicates a contiguous distribution. Estimates of b for different species were derived from the slope of a linear log-log relationship between strata variance and strata means of all available data. Once b is estimated an appropriate transformation can be derived in order to stabilize the catch variance and normalize the frequency distribution. For the exact transformation the catch from each tow (x) is to replace by x^p where $p = 1 - \frac{b}{2}$. When $p = 0$, then a logarithmic transformation was recommended (Snedecor and Cochran 1976). Based on the "Powerlaw" analysis, a $\ln (x + 1)$ transformation was applied to individual catches. A logarithmis transformation has also the advantage that it reduces the effect of exceptionally large catches on the mean catch per tow and its variance.

Abundance indices with variance and coefficient of variation were also calculated for log-transformed data.

Estimates of year class abundance indices of cod and herring were determined by applying relative age composition to the mean catch per tow in number.

Results

Mean catches per tow calculated on the linear scale with variance and coefficient of variation for the Mecklenburg Bay are presented in tables 1 and 2. The abundance indices in terms of weight as well as number show an increase for

cod, herring, plaice and flounder from 1978 to 1979. The same trend can be observed from indices calculated on the logarithmic scale (tables 5 and 6). Coefficients of variation were in the order of 0.13 - 0.41 for data on the linear scale and 0.04 - 0.31 for log transformed data.

Stratified mean catches per tow in weight and in number for the Arkona Basin together with variance and coefficient of variation are given in tables 3 and 4. It can be seen that the index of weight abundance increased for cod and herring from 1978 to 1979. Stratified mean catch per tow in number for herring also went up but for cod this index declined.

Indices of abundance for cod and herring on the transformed scale show the same trend but the changes are more moderate (tables 7 and 8). For plaice and flounder a decrease of the stratified mean catch per tow was observed from 1978 to 1979.

Coefficients of variation for untransformed data range from 0.14 to 0.24 except for herring where values between 0.26 and 0.77 were obtained. Mean catches in number per age group are presented for cod and herring both in the Mecklenburg Bay and the Arkona Basin in tables 9 and 10. These indices of year class abundance were also calculated on the linear scale and the logarithmic scale. A very high mean catch per tow of the herring year class 1979 as 0-group was observed in the Mecklenburg Bay and the Arkona Basin. For cod the 0-group catch appears to be low in the Arkona Basin.

The statistical test on normality of the catch frequency distribution confirmed a positive skewness for all species considered in this paper. The results of the calculated log-log regressions between strata variances and strata means are presented in tables 11 and 12. It can be seen that the variance stabilizing parameter p approaches 0 and therefore a logarithmic transformation of the data is indicated.

Discussion

The results of the bottom trawl surveys indicate that the stock biomass and the stock size in number for cod in the Mecklenburg Bay increased from 1978 to 1979. It seems also that in this area the strength of the 1979 year class can be expected above the level of the 1978 year class.

According to the abundance indices from the trawl surveys in the Arkona Basin the biomass of cod increased slightly from 1978 to 1979. On the other hand it seems that the stock size in number has declined during these two years.

One reason for this different trend might be that according to the trawl surveys both year classes 1978 and 1979 appear to be weak and they could cause a reduction of the mean catch per tow in number. The small increase of the stratified mean catch per tow in weight could be explained probably by the growth of the year classes 1976 and 1977.

An improvement of stock abundance is indicated for herring by the results of the trawl surveys in the Mecklenburg Bay and in the Arkona Basin because the mean catch per tow in terms of weight and number increased from 1978 to 1979.

According to the 0-group catch of herring a strong year class 1979 can be expected.

In evaluating the verbal estimates of stock abundance and year class strength it must be pointed out that these are based only on the results from two years. It seems very important to prolong the time series of these surveys with the aim to establish a correlation between the actual year class strength as calculated from the Virtual Population Analysis (VPA) and the observations in the surveys. Furthermore a longer series of mean catch per tow in weight could be also very helpful for estimating terminal fishing mortality in the VPA.

The coefficients of variation in the order of 0.13-0.41 for untransformed data are considered reasonable and not unusual for trawl surveys. On the other hand, however, the coefficient of variation for herring in 1979 ranging from 0,61 to 0.77, is fairly high. These values arise from the variability of catches, which is probably caused by the distributional characteristics of the species herring.

The examination of catch frequency distributions as well as the observed relationship between the variance and the mean make it clear that a logarithmic transformation of the original catch data is appropriate. Therefore more confidence should be putted in the abundance indices derived from transformed data.

Finally it should be pointed out that this paper only deals with the results of the bottom trawl surveys conducted in the last two years and their inherent precision. It is possible that gain in precision could be achieved by increasing the number of tows or by an inprovement of the stratification scheme. Such questions should be considered in a future analysis.

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Table 1: Mean catch per tow (kg, linear scale) with variance and coefficient of variation, Mecklenburg Bay (ICES 22)

Species	Survey	Mean	Variance	CV
Cod	Nov 1978	30.14	70.56	0.28
	Nov 1979	74.07	99.20	0.13
Herring	Nov 1978	42.85	173.71	0.31
	Nov 1979	86.91	357.97	0.22
Plaice	Nov 1978	1.50	0.28	0.35
	Nov 1979	4.62	0.59	0.17
Flounder	Nov 1978	0.45	0.03	0.38
	Nov 1979	1.41	0.08	0.20

Table 2: Mean catch per tow (number, linear scale) with variance and coefficient of variation Mecklenburg Bay (ICES 22)

Species	Survey	Mean	Variance	CV
Cod	Nov 1978	56.95	270.60	0.29
	Nov 1979	178.68	529.46	0.13
Herring	Nov 1978	1819.53	377217.07	0.34
	Nov 1979	5069.95	1119596.77	0.21
Plaice	Nov 1978	2.89	1.04	0.35
	Nov 1979	8.84	2.50	0.18
Flounder	Nov 1978	1.16	0.22	0.41
	Nov 1979	3.58	0.56	0.21

Table 3: Stratified mean catch per tow (kg, linear scale) with variance and coefficient of variation, Arkona Basin(ICES 2

Species	Survey	Mean	Variance	CV
Cod	Nov 1978	116.17	469.82	0.19
	Nov 1979	149.91	766.39	0.18
Herring	Nov 1978	13.58	12.69	0.26
	Nov 1979	89.61	3005.50	0.61
Plaice	Nov 1978	19.86	9.71	0.16
	Nov 1979	19.01	14.40	0.20
Flounder	Nov 1978	3.27	0.61	0.24
	Nov 1979	1.76	0.11	0.19

Table 4: Stratified mean catch per tow (number, linear scale) with variance and coefficient of variation, Arkona Basin (ICES 24)

Species	Survey	Mean	Variance	CV
Cod	Nov 1978	404.93	3159.54	0.14
	Nov 1979	270.76	2000.25	0.17
Herring	Nov 1978	687.58	52578.92	0.33
	Nov 1979	9020.22	48706666.00	0.77
Plaice	Nov 1978	80.88	161.38	0.16
	Nov 1979	45.35	84.45	0.20
Flounder	Nov 1978	8.11	3.03	0.21
	Nov 1979	4.35	0.53	0.17

Table 5: Mean catch per tow (kg, ln scale) with variance and coefficient of variation, Mecklenburg Bay (ICES 22)

Species	Survey	Mean	Variance	CV
Cod	Nov 1978	2.76	0.10	0.11
	Nov 1979	4.10	0.03	0.04
Herring	Nov 1978	2.81	0.13	0.13
	Nov 1979	3.72	0.14	0.10
Plaice	Nov 1978	0.65	0.02	0.23
	Nov 1979	1.57	0.02	0.09
Flounder	Nov 1978	0.29	0.01	0.31
	Nov 1979	0.75	0.01	0.16

Table 6: Mean catch per tow (number, ln scale) with variance and coefficient of variation, Mecklenburg Bay (ICES 22)

Species	Survey	Mean	Variance	CV
Cod	Nov 1978	3.23	0.12	0.11
	Nov 1979	4.94	0.04	0.04
Herring	Nov 1978	6.23	0.21	0.07
	Nov 1979	7.56	0.26	0.07
Plaice	Nov 1978	0.96	0.04	0.21
	Nov 1979	2.06	0.03	0.08
Flounder	Nov 1978	0.53	0.02	0.26
	Nov 1979	1.24	0.04	0.15

Table 7: Stratified mean catch per tow (kg, ln scale) with variance and coefficient of variation, Arkona Basin (ICES 24)

Species	Survey	Mean	Variance	CV
Cod	Nov 1978	4.15	0.04	0.05
	Nov 1979	4.33	0.05	0.05
Herring	Nov 1978	1.73	0.07	0.15
	Nov 1979	2.07	0.13	0.17
Plaice	Nov 1978	2.72	0.02	0.05
	Nov 1979	2.35	0.06	0.11
Flounder	Nov 1978	1.04	0.02	0.14
	Nov 1979	0.71	0.01	0.15

Table 8: Stratified mean catch per tow (number, ln scale) with variance and coefficient of variation, Arkona Basin (ICES 24)

Species	Survey	Mean	Variance	CV
Cod	Nov 1978	5.38	0.04	0.04
	Nov 1979	4.81	0.05	0.05
Herring	Nov 1978	4.17	0.26	0.12
	Nov 1979	4.65	0.33	0.12
Plaice	Nov 1978	4.06	0.03	0.04
	Nov 1979	3.06	0.09	0.10
Flounder	Nov 1978	1.71	0.04	0.11
	Nov 1979	1.11	0.02	0.14

Table 9: Mean catch per tow in number by age groups in the Mecklenburg Bay (ICES 22)

Species		Survey	Age-group 0	1	2	3+	total
Cod	linear scale	Nov 1978	1.48	37.02	14.47	3.98	56.95
		Nov 1979	71.47	64.50	28.06	14.65	178.68
	ln scale	Nov 1978	0.08	2.10	0.82	0.23	3.23
		Nov 1979	1.98	1.78	0.78	0.41	4.95
Herring	linear scale	Nov 1978	1266.27	471.21	60.04	22.01	1819.53
		Nov 1979	3584.46	1330.86	145.76	8.87	5069.95
	ln scale	Nov 1978	4.34	1.61	0.21	0.07	6.23
		Nov 1979	5.34	1.99	0.22	0.01	7.56

Table 10: Statified mean catch per tow in number by age groups in the Arkona Basin (ICES 24)

Species		Survey	Age-group 0	1	2	3+	total
Cod	linear scale	Nov 1978	110.06	222.27	59.04	13.56	404.93
		Nov 1979	29.65	112.12	93.55	35.44	207.76
	ln scale	Nov 1978	1.47	2.95	0.78	0.18	5.38
		Nov 1979	0.53	1.99	1.66	0.63	4.81
Herring	linear scale	Nov 1978	478.83	64.27	108.29	36.19	687.58
		Nov 1979	8610.70	273.31	124.48	11.73	9020.22
	ln scale	Nov 1978	2.90	0.39	0.66	0.22	4.17
		Nov 1979	4.44	0.14	0.06	0.01	4.65

Table 11: Parameters from power low regressions calculated for catch data in weight with correlation coefficient (r) and variance stabilizing exponent (p)

Species	r	a	b	p
Cod	0.98	1.56	1.84	0.08
Herring	0.98	3.82	1.84	0.08
Plaice	0.95	0.21	2.42	-0.21
Flounder	0.97	1.57	1.60	0.20

Table 12: Parameters from power low regressions calculated for catch data in number with correlation coefficient (r) and variance stabilizing exponent (p)

Species	r	a	b	p
Cod	0.98	3.13	1.74	0.13
Herring	0.99	2.82	1.90	0.05
Plaice	0.88	0.25	2.24	-0.12
Flounder	0.97	2.22	1.52	0.24