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Some aspects of planning of acoustic stock estimations

by

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Abstract

The method of acoustic stock assessment has been used since some years in the institute of Deep Sea Fishery and Fish Processing. In this paper some aspects of planning are analysed by means of the results of springs cruises in years 1982, 1983 and 1984, which were carried out in cooperation with the Balt-NIIPCH Riga in the Baltic Sea. A detailed description of the first results is given in Oeberst (1985). This paper shows some selectet parts of this publication.

Introduction

Since some years it has been worked out problems of planning of acoustic assessments in the Baltic Sea. In this short report only some results are given. The aim of this investigation is to find criterious that make if possible to improve the cruise in the ICES-Sub-divisions 26, 25 and 24 in May and June. Sprat is the main fish species. Herring and cod are not fully represented.

The allocation of the research time to the ICES Sub-divisions 26, 25 and 24

In the years 1982 until 1984 several methods of stratification of the ICES Sub-divisions 26, 25 and 24 were used to give the best assessment.

The allocation of the integration steps were proportional to the surface of the Sub-divisions. The results show great differences of the accuracy of the assessments between the ICES areas. Using the theory of stratified sampling, Cochran (1972), formula (1) gives the best allocation.

$$n_i = n \cdot \frac{B_i \, s_i}{\sum_{i=1}^{K} B_i \, s_i} \qquad (1)$$

where

- n = number of the planned integration steps
- B_i = biomass in the i-th strata
- s_i = standard deviation of the integrator values in the i-th strata
- k = number of the strata

In the following table the estimations of n_i are given for the years 1982 and 1984 if n = 1000. In 1983 RV "Eisbär" worked only in the ICES Sub-divisions 25 and 24.

	1982			1983		
ICES Sub-divisions	26	25	24	26	25	24
integration steps during the working period	437	441	122	426	476	98
n_i	191	671	138	225	636	139

The results will show that this allocation gives the best accuracy of the assessment.

The defination of accuracy of the sprat stock assessment

In the last chapter the best allocation is given for a fixed research time. The next problem is to estimate the research time needed if a special accuracy of the assessment is demanded. The calculation of the confiddnce interval for the sprat stock estimations is the first step. For that it is necessary to estimate the variance of the random variable Bs.

$$Bs_j = \frac{A_j}{C} \cdot 3.43 \cdot 10^6 \cdot \frac{h_{s_j} \cdot M_j}{sm_j}$$

Bs_j mean biomass of the sprat stock in the j-th Sub-division

C constant of the equipment

h_{s_j} mean proportion of the sprat biomass

sm_j mean target strength in m^2/kg

M_j mean integrator value per n.m. of the j-th area.

By means of the propagation of error of functions of random variables (Rasch 1968) follows

$$VAR\left(\frac{h_{s_{ji}} M_{ji}}{sm_{ji}}\right) \sim \left(\frac{M_j}{sm_j}\right)^2 VAR\left(h_{s_{ji}}\right) + \left(\frac{h_{s_j}}{sm_j}\right)^2 VAR\left(M_{ji}\right) + \left(\frac{h_{s_j} M_j}{sm_j^2}\right)^2 VAR\left(sm_{ji}\right)$$

$$+ 2\left[\left(\frac{M_j h_{s_j}}{sm_j^2}\right) cov\left(h_{s_{ji}}, M_{ji}\right) - \left(\frac{M_j^2 h_{s_j}}{sm_j^3}\right) cov\left(h_{s_{ji}}, sm_{ji}\right)\right.$$

$$\left. - \left(\frac{h_{s_j}^2 M_j}{sm_j^3}\right) cov\left(M_{ji}, sm_{ji}\right)\right]$$

The values VAR ($h_{s_{ji}}$), VAR (sm_{ji}), cov ($h_{s_{ji}}$, M_{ji}), cov ($h_{s_{ji}}$, sm_{ji}), and cov (M_{ji}, sm_{ji}) are unknown or can only be estimated with a great unaccuracy for the j-th area. In this case it is possible to give an assessment for the confidence intervall $[\underline{Bs}, \bar{Bs}]$ by means of the interval arithmetic (Kiesewetter, Maess 1974).

$$\underline{Bs}_j = \frac{A_j}{C} \cdot 3.43 \cdot 10^6 \left[\frac{\left(M_j - d_{Mj}\right)\left(h_{s_j} - d_{h_{sj}}\right)}{\left(sm_j + d_{smj}\right)}\right]$$

$$\bar{Bs}_j = \frac{A_j}{C} \cdot 3.43 \cdot 10^6 \left[\frac{\left(M_j + d_{Mj}\right)\left(h_{s_j} + d_{h_{sj}}\right)}{\left(sm_j - d_{smj}\right)}\right]$$

$[M_j - d_{Mj}, M_j + d_{Mj}]$ is the confidence intervall of M_j on the basis of the normal distribution of $_{ji}$.

In table 1 the intervals of Bs are given for several stratas of 1982, 1983 and 1984.

The results show that the accuracy of the sprat stock assessments is very dependent on the variability of the proportion of sprat in the hauls. Besides it can be derived that the variance of Bs does not go to zero if the number of integration values go to infinity.

The results of a regular trawl station in the year 1983

The results of a regular trawl station carried out in June of 1983 will be given without discussion in this chapter. In figure 1 the positions of hauls are shown. In figure 2 the catch and the proportions of sprat and herring are given. The high variability of the proportion of sprat in the catches is remarkable.

The length of an integration step

In practice of the international acoustic stock estimations integrations steps with a length of 1 n.m., 2,5 n.m. and 5 n.m. are used. This problem is discussed in the literature (Shotton, Bodigss 1982).

In 1984 on RV "Eisbär" an integration step of one n.m. was used. In table 2 the standard deviations of the mean integrator values $s_{\bar{x}}$ and the half confidence interval $d_{\bar{x}}$ are given for the integration step of one n.m. as well as for two, three and five n.m. The autocorrelation values $r_{x_i, x_{i+k}}$ are given too. The relation between $s_{\bar{y}}$ (k =) and $r_{x_i, x_{i+1}}$ is shown in figure 3.

The mathematical relation is given by

$$s^2_{y_i} \sim s^2_{x_i} + 2 \sum_{k=1}^{m-1} \frac{m-k}{m} \operatorname{cov}(x_i, x_{i+k}) \quad (2)$$

where m is the number of connected nautical miles and cov x_i, x_{i+k} is the covarianz between x_i and x_{i+k}.

With other words the variability of the integrator values grows with the length of the integrations steps depending on the autocorrelation between the single echo values.

In the publication of Oeberst (1985) the following problems are also discussed too:

- The influence of the position of the haul and of the variability of the proportion of the fish species on the confidence intervall of Bs.
- The stratification of the area searched into divisions with the same proportions of fish species.
- Estimation of the influence of large fish density patchiness on the stock assessment.
- The connection between the catch per half an hour and the proportion of sprat.

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Table 1: Confidence interval of biomass estimation $\bar{B}$ and sprat stock biomass estimation for several stratas of 1982, 1983 and 1984

strata	M	d_M	sm	d_{sm}	h_s	d_{hs}	biomass $\bar{B}$	confidence interval $\underline{B}$	$\bar{B}$	sprat biomass B_s	confidence intervall $\underline{B}_s$	$\bar{B}_s$	$\frac{\bar{B}-B}{B}$	$\frac{\bar{B}s-Bs}{B_s}$
1982														
A	2.26	0.174	1.14	0.043	0.393	0.272	35 100	31 217	39 287	13 794	3 777	26 126	0.12	0.89
B	2.55	0.287	1.30	0.030	0.950	0.080	43 100	37 382	49 090	41 026	32 596	50 650	0.14	0.24
G	5.89	0.446	1.28	0.208	0.510	0.420	134 700	107096	173 015	68 698	41 095	133 302	0.28	0.94
1983														
A	0.52	0.117	0.63	0.234	0.16	0.339	19 013	10 744	37 054	3 042	0	18 490	0.95	5.08
D	0.57	0.110	0.89	0.115	0.61	0.187	21 147	15 174	29 122	12 958	6 416	23 210	0.38	0.79
H	0.29	0.037	1.11	0.322	0.81	0.451	8 324	5 667	13 141	6 658	4 001	16 439	0.58	1.47
1984														
6140	2.08	0.562	1.08	0.377	0.62	0.647	16 215	8 772	31 641	10 053	0	40 088	0.95	2.99
6038	2.41	0.610	1.35	0.277	0.99	0.027	20 694	12 825	32 626	20 487	12 350	33 181	0.58	0.62
ICES 24	1.45	0.360	1.18	0.402	0.51	0.973	23 602	13 234	44 685	12 037	0	66 267	0.89	4.51

Table 2: Standard deviations ($s_{\bar{x}}$, $s_{\bar{y}}$), the half breadth of confidence intervalls ($d_{\bar{x}}$, $d_{\bar{y}}$) and the autoroccelation coefficients (r_{xy}) for two, three and five nautical miles for some areas om 1984

Area	$s_{\bar{x}}$	$d_{\bar{x}}$	K = 1			K = 2			K = 4		
			r_{xy}	$s_{\bar{y}}$	$d_{\bar{y}}$	r_{xy}	$s_{\bar{y}}$	$d_{\bar{y}}$	r_{xy}	$s_{\bar{y}}$	$d_{\bar{y}}$
ICES 24 (2)	0.41	0.82	0.61	0.52	1.06	0.39	0.61	1.27	0.00	0.73	2.03
ICES 24 (1)	0.08	0.16	0.26	0.11	0.22	0.18	0.12	0.25	0.10	0.13	0.28
6038	0.31	0.62	0.56	0.41	0.83	0.38	0.45	0.92	0.32	0.61	1.29
6140	0.29	0.58	0.68	0.38	0.77	0.49	0.41	0.84	0.20	0.54	1.14
6239	0.34	0.65	0.53	0.41	0.83	0.27	0.45	0.92	0.29	0.57	1.20
6341 (1)	0.22	0.45	0.37	0.29	0.62	0.54	0.34	0.77	0.44	0.47	1.21
6341 (2)	0.17	0.35	0.35	0.23	0.49	0.33	0.29	0.64	0.26	0.38	0.93
6441 (2)	0.15	0.31	0.35	0.22	0.46	0.33	0.27	0.59	0.31	0.35	0.86
6240 (2)	0.11	0.22	0.29	0.15	0.32	0.24	0.18	0.41	0.14	0.23	0.59
6240 (1)	0.16	0.33	0.17	0.19	0.42	0.11	0.23	0.56	0.21	0.34	1.08
6441 (1)	0.10	0.20	0.13	0.14	0.30	0.11	0.17	0.37	0.07	0.20	0.49
6340 (1)	0.11	0.22	0.05	0.13	0.28	0.03	0.16	0.36	0.08	0.19	0.49
6340 (2)	0.06	0.12	-0.02	0.06	0.13	0.03	0.06	0.13	-0.03	0.07	0.17
6339 (1)	0.09	0.18	-0.01	0.08	0.17	-0.03	0.08	0.18	-0.01	0.08	0.20
6339 (2)	0.11	0.22	0.01	0.12	0.25	0.01	0.13	0.28	0.05	0.15	0.37
6338	0.04	0.08	0.04	0.05	0.10	0.04	0.06	0.13	0.01	0.07	0.17

Figure 1: The positions of catches of the regular trawl station 1983

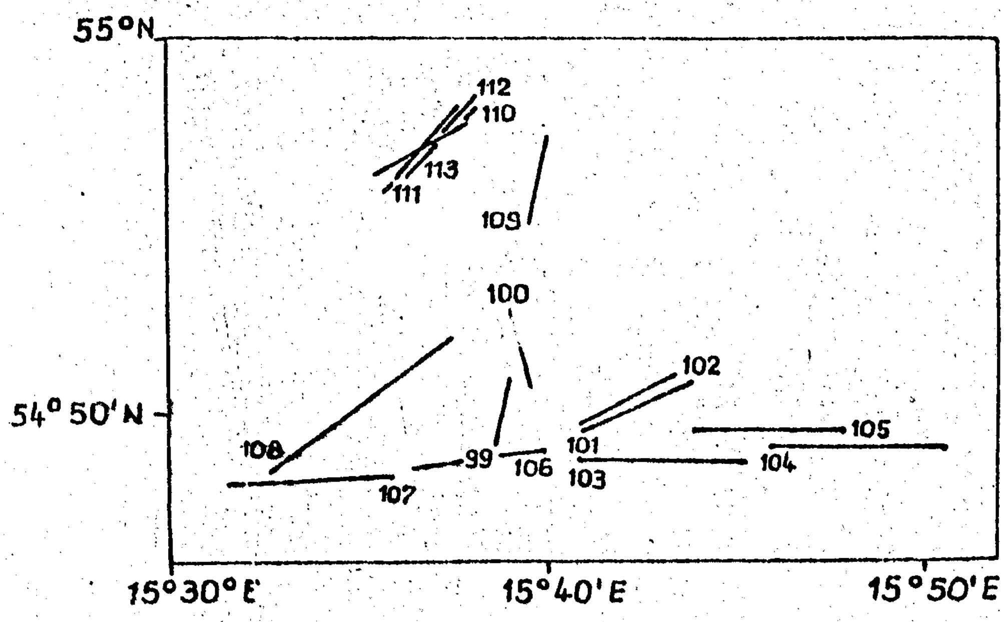

Figure 2: The catch and the proportion of sprat and herring (1983 regular trawl station)

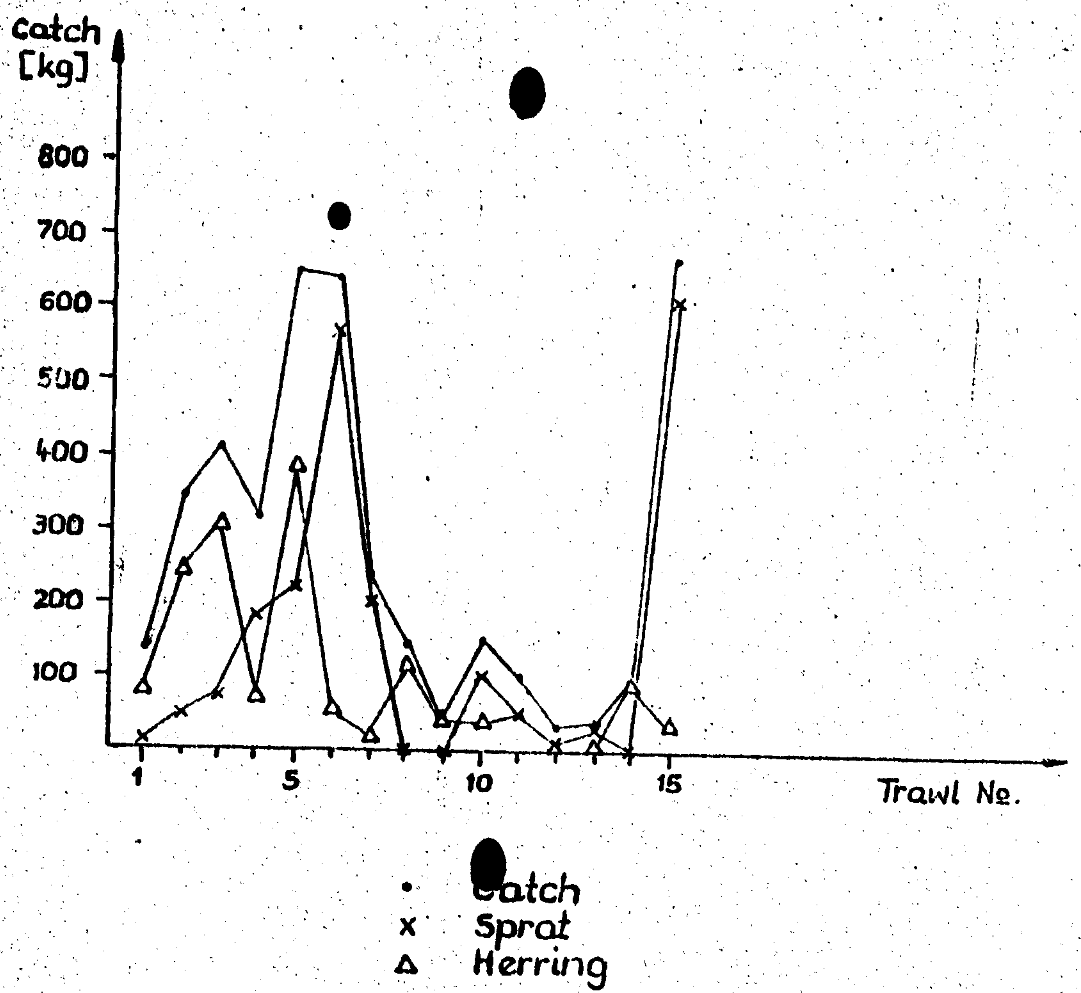

Figure 3: Relation between $s_{\bar{y}} - s_{\bar{x}}$ for $k=1$ and the Autokorrelation $r_{x_i, x_{i+1}}$