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QUANTITATIVE ANALYSIS OF RÜGEN SPRING SPAWNING HERRING LARVAE SURVEYS WITH REGARD TO THE RECRUITMENT OF THE WESTERN BALTIC AND DIVISION IIIa STOCK

by

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ABSTRACT

The larvae data of the Rügen spring-spawning herring sampled during the surveys in the Greifswalder Bodden and Strelasund (ICES Sub-division 24) in 1991,1992, and 1993 were analyzed.

This paper describes in detail the method for estimating the number of larvae with a total length TL>=30 mm which can be related to the number of age group 0 of the herring stock in Sub-divisions 22-24 and Division IIIa. Eight to ten cruises per survey were carried out, and for each cruise the number of larvae per length-class of the total area was estimated. These polymodal length compositions were splitted into normally distributed components by the BHATTACHARYA method where each component belongs to a definite cohort. For each cohort growth (G) and mortality (M) per day from one cruise to the next one were estimated and tested for differences between cruises and components. The dependence of growth and mortality on mean length,abundance and No. of the time interval was investigated.

During the period investigated the grand means of growth were nearly the same (G=0.477 - G=0.531 mm d-1). But the mortality rates which amounted to M=0.094, M=0.241 and M=0.147 were significant different. Dependences of G and M could only be proved on mean length and abundance, and only irregularly.

The high mortality rates caused a great loss of larvae in 1992 and also in 1993 when a great many larvae were hatched. The total number of larvae amounted to 236, 18 and 199 million after metamorphosis (TL>=30 mm). These values taken as index correspond well with other estimates of year-class strength for the total spring spawning herring stock. Therefore it seems that the method presented here is suitable for calculating the larvae abundance at TL>=30 mm.

INTRODUCTION

The Greifswalder Bodden (GB) (area: 510.2 km² ,volume: 2960 $*10^6$ m^3, mean depth: 5.8 m, greatest depth: 13.5m) and the adjacent waters are the main spawning grounds of the spring spawning herring in the Western Baltic (BIESTER 1991). Here the eggs are deposited on water plants, the larvae hatch and grow up.

BRIELMANN (1981, 1986, 1989) showed that the abundance of larvae (total length TL>=30 mm) reaching the juvenile stage in the GB and Strelasund (ST) is a good indicator for the year-class strength of the spring spawning herring in ICES Sub-divisions 22+24. It can be used to estimate the number of the 0-group herring by regression. In order to get the number of larvae that survive up to TL>=30 mm, it is first necessary to make growth and mortality investigations. These can only be done when several cruises are carried out during a spawning season. BRIELMANN (1981) estimated the growth and mortality rates by tracing the modes of a length composition through several cruises. With our analysis the polymodal length compositions were splitted into a variabel number of normally distributed components using the BHATTACHARYA method (BHATTACHARYA 1967). The number of larvae and the mean length of a component could then be taken to estimate the growth and mortality per day of a cohort from one cruise to the next one and finally the abundance of larvae that would survive.

This paper demonstrates the new procedure of the quantitative larvae analysis on data of 1991, 1992, and 1993.

MATERIAL AND METHODS

The German herring larvae monitoring which started in 1977 takes place every year from March/April to June. Since then the same sampling method, sampling strategy and station grid have been used. Usually during 10 consecutive cruises 35 standard stations are sampled with r/v Clupea in broad daylight: 5 stations in the ST and 30 stations in the GB .

The station grid and the sub-areas for the estimation of the total number of larvae that could be in the GB and ST during a cruise can be seen in Figure 1. The division of the total area into sub-areas is necessary because of the different distribution of spawning herring schools and different conditions for the deposition of the eggs.

At each station herring samples were taken with a MARMAP-Bongo (diameter: 600 mm, mesh size of both nets: 0.315 mm) by parallel double oblique tows at a speed of 3 knots. The towing of the Bongo nets were limited to 1 m distance from the bottom. The volume strained was recorded by means of flow meters which were attached in the centre of the net aperture. All plankton samples were preserved in a 4% buffered formaldehyde/seawater solution. In the lab the herring larvae were picked out from the samples, and the total length (TL) was measured to 1 mm below. The TL was not corrected for a possible shrinkage.

Table 1 gives a summary of the dates of all cruises carried out from 1991-1993 and the corresponding number of stations, the total number of larvae caught, the mean number per m² of the stations sampled during a cruise and its standard deviation and coefficient of variation.

For the primary analysis of the data, that means to get the number of larvae per station and m² the methods of SMITH and RICHARDSON (1977) and KLENZ (1993) were used and extended to length-classes. In order to get the number of larvae per length -class and cruise the following calculations were carried out. The notations are also valid for the calculations of the number of larvae that could reach TL=30 mm.

Notations

Indices

a indicates the net outside
c indicates a component
C indicates a cohort
i indicates the net on the shipside
k indicates the number of sub-areas
L indicates a length-class
l indicates the number of length-classes
m indicates the number of stations per sub-area
n indicates the number of cohorts identified
p indicates the last component of a cohort
S indicates a station
s indicates a cruise
v indicates the number of cruises
y indicates a sub-area

Quantities

A Area of a sub-area [10^{-6} m²]
D Depth of the tow [m]
G Growth per day [mm]
M Instantaneous natural mortality rate
N Number of larvae
t Time [days]
T Middle date of a cruise (with two days the first date)
TL Total length [mm]
V Volume of water filtered [m^3]
Z Instantaneous total mortality rate

1. Mean number of larvae per per m² and station

Number per length-class:

$$N_{S,L} = [D_S(N_{S,a,L} + N_{S,i,L})]/(V_{S,a} + V_{S,i}) \qquad (1)$$

When there was trouble with a flow meter or sample glass, only the value of one net was used.

Total number:

$$N_S = \sum_{L=1}^{l} N_{S,L} \tag{2}$$

The result of equation (2) is not in all cases the same as when the total was calculated from all larvae picked out because sometimes larvae were damaged and could not be measured.

2. Number of larvae per sub-area of the GB and ST

Number per length-class:

$$N_{L,y} = [(\sum_{S=1}^{m} N_{S,L})/m]\, A_y \tag{3}$$

Total number:

$$N_y = \sum_{L=1}^{l} N_{L,y} \tag{4}$$

If there was no station sampled in a sub-area, neighbouring stations of other sub-areas were used to calculate the mean number of that sub-area.

3. Number per length-class and cruise

$$N_L = \sum_{y=1}^{k} N_{L,y} \tag{5}$$

In most cases the number of larvae per length-class resulted in a polymodal length composition per cruise. This was resolved into normally distributed components by the log-difference method of BHATTACHARYA (1967). This method is also described in SPARRE (1987). For this approach the software package ELEFAN from ICLARM (GAYANILO et al. 1989) was used. In each case several runs were carried out taking different combinations of length-classes into consideration. The option with the highest separation index and the lowest χ^2 value from comparing the observed and resulting length compositions were chosen. In this way the number of larvae and the mean length of each component were obtained. These are the basic values for calculating the growth and mortality rates per day of each cohort by tracing the cohort through all cruises. Both the quantities are necessary in order to calculate the number of larvae of a cohort when they have reached a length of 30 mm on an average.

The following calculations were carried out for each cohort from one cruise to the next one.

1. Growth in length per day

$$G_{s,c} = (TL_{s+1,c+1} - TL_{s,c})/(T_{s+1} - T_s) \quad (6)$$

2. Instantaneous natural mortality rate

$$M_{s,c} = - [\ln(N_{s+1,c+1}/N_{s,c})/(T_{s+1} - T_s)] \quad (7)$$

This equation was derived from

$$N_t/N_0 = \exp-(Zt) \quad (8)$$

(RICKER 1975) where Z was replaced by M.

3. Time that is necessary for the last component of a cohort to reach the mean length of 30 mm

$$t_{30,s,p} = (30 - TL_{s,p})/G \quad (9)$$

4. Number of larvae when the mean length of 30 mm of a cohort is reached

$$N_{30,C} = N_{s,p} \exp -(Mt_{30,s,p}) \quad (10)$$

5. Total number of larvae after metamorphosis (TL>=30 mm)

$$N = \sum_{C=1}^{n} N_{30,C} + \sum_{s=1}^{v} N_{31+,s} \quad (11)$$

An important question was what growth rate (G) and natural mortality (M) should be taken when using equations (9) and (10), respectively. There is the possibility to take the corresponding mean values of the component and of the cruise, respectively, or the grand mean. In order to answer this question, an ANOVA was carried out to test the effect of the component and cruise on G and M. Moreover the dependence of G and M on larvae abundance, mean length of a component at the beginning of the time interval, on the time interval No. as indication for the date, and of G on M were investigated by regression analysis. When significance was found, M was calculated and G of the corresponding cruise or component was used to estimate t_{30}. The grand means were only taken when the ANOVA showed no significant effects, and the correlations were not significant or there were reasons to neglect the significant correlation.

RESULTS

Abundance

In 1991 the highest mean abundance per station and cruise were found from 8 April to 10 April and on 27/28 May as well from 3 June to 5 June (Table 1).This finding corresponds with the total number of larvae calculated for the total area (Table 2). Early in April only few larvae were caught, and mostly they measured TL>26 mm. Therefore the first and the incomplete third and fifth cruise were excluded from further investigations. The number of larvae per component estimated by the BHATTACHARYA method can be seen in Table 3. Because the two cohorts represented by the first and second component of the second cruise can't be traced through further cruises, they were also excluded from the growth and mortality investigations. It is also to be mentioned that the same component No. belonged to the same cohort on "17.06.91" and "24.06.91". That means that during the last cruise in 1991 no larvae newly hatched, i.e. no new cohort was found. This conclusion could be drawn from growth estimations. As a rule the component No. of a cruise is the component No. of a cohort, too. That means a cohort can be traced on the diagonal to the right downward in Tables 3 and 4.

For 1992 the highest mean abundance of the stations and of the total area was estimated for the period 21 April to 14 May (Tables 1 and 2). The resulting number of larvae of the components can be seen in Table 3. The incomplete cruises were leaved out.

During the survey of 1993 a great many larvae were caught during the cruises from 13 April to 21 May where from 22 April to 19 May there was a gap of investigations for technical reasons. Many larvae were still found during the next two cruises. But at the beginning of the survey from 6 April to 8 April only few larvae were caught (Table 1). The corresponding larvae per length-class calculated for the total area are given in Table 2, and the number of larvae of the main components estimated from them can be seen in Table 3. Because of the negligible number of larvae estimated for the first cruise and the fact that most larvae had already a length of TL>26 mm, the first cruise was omitted from the growth and mortality investigations. The second cruise was excluded from these investigations because the cohort couldn't be traced to its next component. Looking at the mean length per component on "20.05.93" and "24.05.93" (Table 3) and taking growth (Table 4) into consideration, it is obvious that the same component No. belongs to the same cohort in each case. This is also valid for "07.06.93" and "15.06.93". As in 1991 it means that during the last cruise no new cohort of larvae was found.

Growth

Table 4 shows the mean length per component and Table 5 the growth per day of a cohort from one component to the next one, i.e. the growth rates between the cruises. The cruises which were included can be looked up in the chapter "Abundance". Besides in this place it should be mentioned again that in some cases of 1991 and 1993 the same component No. belongs to the same cohort with consecutive cruises. If the growth rates were calculated from one component to the next one as it can be done usually, they would amount to G>1 mm d^{-1} and that wouldn't be plausible in comparison to the other results.

From Table 5 it can be seen that the grand mean is nearly the same in 1991 and 1992 (G=0.477 and G=0.476) and somewhat higher in 1993 (G=0.531) where the difference is not significant as estimated by the SCHEFFE test procedure. For herring larvae of other areas a summary of previous growth estimates is given by PELTONEN (1988).They ranged from 0.14 to 0.69 mm d^{-1}.That means that in the GB and ST the growth rates fall into this range. CHRISTENSEN and MUNK (1989) estimated G=0.3 mm d^{-1} for the North Sea. The results of the ANOVA show that there were no significant differences between the dates of the cruises as well as between the components with all surveys (Table 7).

Only for 1992 a significant positive correlation between the mean length of a component and growth rate could be proved whereas a significant dependence of growth on the time interval representing the date and on the mean length of a component couldn't be found for all surveys considered (Table 7).

Mortality

The mortality rates (M) per day are given in Table 6. For the estimations the cohorts were traced through the cruises as for the growth investigation. Great differences could be found between the surveys. The grand mean amounted to M=0.094, M=0.241, and M=0.147 in 1991, 1992 and 1993, respectively. Only the difference between the mortality rates of 1991 and 1992 are statistically significant using the SCHEFFE test . For herring larvae of different areas (Georges Bank, North Sea, Baltic Sea) the mortality estimates of other scientists using different methods varied between 0.011 and 0.177, mostly they were below 0.1 (KARASJEVA, 1988; LOUGH et al., 1985;PELTONEN, 1990). That means that the mortality of the larvae was very high in the GB and ST compared with the other regions.

Within a survey there were no significant differences between the cruises as well as between the components (Table 7).

The regression analyses showed that there was only a significant dependence of the mortality rate on the mean length of a component in 1993 and on the mean abundance of a component in 1992 (Table 7).

Total number of larvae after metamorphosis (TL>=30 mm)

Very different numbers of larvae were estimated by equation (11). The following text table gives the results

Year	1991	1992	1993
N [millions]	236	18	199

In this place it should be mentioned which values were taken for growth (G) and mortality (M) for the calculation of the time necessary for the last component of a cohort to reach the mean length of 30 mm (Eq.9) and of the number of larvae that had survived in this time (Eq.10), respectively. In dependence on the results of the ANOVA and the regression analysis the following procedures were used. For 1991 the grand means of G and M were taken. For 1992 M was calculated by the regression equation, and for G the mean values of the corresponding component were used. For 1993 the grand means of G and M were used although for M a sinificant positive correlation between the mean length of a component and M was found. This decision was made because in reality the mortality decreases with age(HOUDE, 1990) what means with length, and because net avoidance could occur with larger larvae by daylight (LOUGH et al., 1985) what could cause the higher mortality.

DISCUSSION

The objective of the herring larvae surveys in the Greifswalder Bodden and Strelasund (ICES Sub-division 24) has been to find an index that can be used to estimate the number of recruits for the spring spawning herring stock in ICES Sub-divisions 22-24 and Division IIIa. As it is demonstrated in this paper(Table 6) and taken into account by BRIELMANN (1981, 1986, and 1989), the natural mortality can be very different comparing the different spawning seasons. Therefore the abundance of larvae caught during a survey couldn't be the right indicator for the year-class strength, but the number of larvae reached the metamorphosis could it be.

To get this number it was to estimate , when do the larvae reach the length of TL>=30 mm in dependence of growth, and how many larvae survive up to that date. Because it has been known that during the larval ages and length ranges, respectively, growth is not constant (BRIELMANN, 1981; RAID, 1986; SAILA and LOUGH, 1981) and survival increases and mortality decreases, respectively, (HOUDE, 1990; LOUGH et al.; 1985; SAILA and LOUGH, 1981), it was decided to estimate the growth and the mortality in dependence on time and age, and because in the Greifswalder Bodden and Strelasund the hatching of larvae takes place on several dates in dependence on the arrival of the spawner schools, the calculations had to be carried out by cohorts and from one cruise to the next one. Other methods, i.e. the use of growth equations or regression analysis, seemed to be not suitable for our purpose.

For evaluating the method used for estimating the number of larvae TL>=30 mm the results were compared with the trend of other independent estimates of the abundance of age groups 0 and 1 of the corresponding year-classes (Figure 2). In order to make the trend clearer, the time series were prolonged backward up to 1977 when the first larvae index was available. The data puplished by BRIELMANN (1989) cover only the spawning seasons from 1977-1987. Therefore there is a gap from 1988-1990. The number of recruits (age group 0) estimated by VPA for the spring spawning herring stock in Sub-divisions 22-24 and Division IIIa were taken from ANON. (1993). In 1994 the Assessment Working Group for the Area South of 62°N "found it difficult to accept the unexpected results of the assessment, and it was decided not to present any assessment". Therefore for year-class 1993 a comparison is not possible. In addition to the VPA results the estimates of the acoustic surveys in Sub-divisions 22-24 for age group 1 of the year-classes 1988-1992 and of the German bottom trawl surveys in Sub-dision 24 for age group 0 are presented. For age group 0 of the acoustic surveys the values seemed to be biased, and therefore they are not shown. For age group 1 of the trawl surveys the values were leaved out because the level was too low to demonstrate the fluctuations.

Comparing the order of magnitude of the indices of 1991-1993 with those estimated by BRIELMANN (1989) for 1977-1987 and looking at the trends of the other estimates from 1991-1993, it can be concluded that the method presented in this paper is valid for estimating the number of larvae survived up to a length of TL>=30 mm in the Greifswalder Bodden and Strelasund as an index for the year-class strength of the spring spawning herring stock migrating in the ICES Sub-divisions 22-24 and Division IIIa. Thus this index can be used to predict the number of recruits as 0-group for the VPA by regression. To discuss the deviations in the fluctuations between the larvae indices and the other estimates for 1977-1987 is not the matter of this paper. But it should be mentioned that the number of 0-group herring estimated only for Sub-divisions 22-24 correspond better with the larvae index (BRIELMANN, 1989), and that there are some deficiencies with the input data for the assessment of the total stock (ANON., 1994).

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Table 1. Herring larvae surveys in the Greifswalder Bodden and Strelasund: Dates of the cruises, number of stations, total catch in number and mean abundance per station with standard deviation and coefficient of variation by cruise.

No. of cruise	Date	Number of stations	Total number of larvae caught	Mean abundance per station N m^{-2}	Stnd. dev.	C.V.
1	02.04.-03.04.91	30	25	0.40	0.2	0.500
2	08.04.-10.04.91	35	21 489	15.27	76.524	5.011
3	15.04.91	11	295	0.73	0.608	0.833
4	30.04.-02.05.91	35	2 368	1.70	3.079	1.811
5	06.05.91	5	253			
6	13.05.-14.05.91	33	2 483	1.40	2.349	1.678
7	27.05.-28.05.91	35	24 377	17.72	15.488	0.874
8	03.06.-05.06.91	35	16 414	12.63	11.336	0.898
9	17.06.-18.06.91	33	6 510	4.90	3.912	0.798
10	24.06.-25.06.91	35	4 583	3.36	2.498	0.743
Total		287	78 797	7.47	29.549	3.956
1	08.04.-10.04.92	35	1 109	0.90	1.825	2.028
2	13.04.-15.04.92	9	2 323	6.83	8.574	1.255
3	21.04.-22.04.92	34	13 645	10.45	9.413	0.901
4	27.04.-28.04.92	35	10 552	7.66	9.556	1.248
5	04.05.-06.05.92	35	15 481	11.77	48.216	4.097
6	11.05.-14.05.92	35	10 694	8.32	17.139	2.060
7	18.05.-19.05.92	35	6 976	5.56	19.094	3.434
8	25.05.-26.05.92	35	2 650	1.97	2.454	1.246
9	09.06.92	5	1 361	7.52	3.682	0.490
Total		258	64 791	6.60	21.027	3.186
1	06.04.-08.04.93	35	103	0.08	0.100	1.250
2	13.04.-14.04.93	35	39 918	27.53	47.480	1.725
3	20.04.-21.04.93	35	36 472	24.23	27.378	1.130
4	20.05.-21.05.93	35	37 059	24.52	25.704	1.048
5	24.05.-25.05.93	35	25 214	17.32	16.070	0.928
6	01.06.-02.06.93	35	14 628	10.20	8.510	0.834
7	07.06.-08.06.93	35	7 465	5.36	4.570	0.853
8	14.06.-17.06.93	28	2 447	2.11	1.530	0.725
Total		273	163 306	14.35	24.850	1.732

Table 2. Herring larvae surveys in the Greifswalder Bodden and Strelasund, 1991-1993: Number of larvae [millions] in the total area by length-class [mm] and cruise.

1991

Cruise	Total	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31+
		Length-class																										
1	8.385		0.572		0.541	0.246						0.280												1.526	0.878	1.361		2.982
2	6 043.398	60.129	1 111.915	3 340.558	1 315.318	67.456	0.647			71.160	41.004	31.116				0.332										0.932	0.346	2.486
3	124.193		4.229	24.253	61.100	26.464	5.949	1.382	0.277															0.273		0.267		
4	795.764		11.651	58.035	100.628	148.528	219.673	196.185	60.472	0.356	0.236																	
5	65.550		2.027	10.660	22.438	8.986	3.138	5.250	8.378	3.682	0.991																	
6	886.511	3.950	146.406	283.846	193.852	84.472	14.768	10.302	32.286	45.149	41.237	25.879	2.847	0.970		0.547												
7	9 297.787	6.766	159.734	1 305.640	3 437.873	3 271.892	850.919	89.472	50.637	42.511	30.625	11.452	6.879	0.633	10.199	6.810	4.362	0.991	1.460		0.693				0.239			
8	5 278.983	1.049	144.890	863.597	729.143	276.840	255.348	459.788	743.156	823.829	546.409	259.445	72.390	34.272	22.871	14.694	10.755	6.344	3.306	3.673	3.825	2.115	0.658		0.346			0.241
9	2 372.609	0.672	69.874	215.480	148.959	94.741	94.333	108.371	176.021	213.259	197.203	203.711	166.718	111.720	75.720	104.899	161.840	122.043	66.030	24.475	5.774	3.698	1.896	2.691	0.677	0.352	0.835	0.616
10	1 636.506	0.741	7.491	18.067	73.575	171.152	169.316	87.762	71.877	47.937	35.717	54.545	85.829	135.138	129.540	103.496	78.161	35.134	45.726	70.258	68.811	64.703	40.687	27.327	5.569	4.113	2.244	1.591

(Cruise 3 and 5 were sampled incompletely)

1992

Cruise	Total	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31+
		Length-class																										
1	359.992		8.158	39.067	191.749	112.046	0.870		0.361		0.296	0.296			0.384		0.260	0.275			0.323		0.275				1.078	4.553
2	3 188.156	11.626	214.453	1 684.468	1 204.013	62.859	9.657									0.540			0.270									0.270
3	5 476.124	11.852	491.397	2 223.737	2 164.711	415.504	103.483	47.276	15.164	0.553	0.246							0.330							0.347			1.522
4	3 298.436	1.056	55.185	417.638	1 606.633	817.138	242.233	83.772	49.287	20.757	2.734	0.527															0.671	0.804
5	5 256.370		705.768	2 690.558	968.375	246.404	323.587	193.786	60.668	29.539	16.653	12.210	6.477	2.061														0.284
6	3 502.877	7.911	279.036	1 438.695	1 188.954	203.803	87.741	69.022	46.487	58.976	60.087	27.158	11.115	4.865	6.646	4.941	3.070	1.864	1.937	0.284	0.284							
7	1 914.522	2.610	86.994	538.713	570.761	260.338	153.438	83.441	36.958	30.867	30.964	30.347	17.888	22.301	22.902	13.398	4.826	3.857	2.807	0.829				0.281				
8	910.635	0.272	33.587	250.163	250.731	101.216	70.340	31.341	17.770	20.890	41.968	38.742	24.483	11.226	7.861	2.482	1.613	1.393	2.859	0.500	0.272	0.927						
9	360.999		0.245	1.327	5.845	16.942	31.709	33.558	54.302	76.727	53.489	23.903	12.338	7.741	9.331	7.019	7.166	5.065	5.072	2.123	1.903	1.630	1.362	1.090	0.551	0.561		

(Cruise 2 was sampled incompletely, cruise 9 only Strelasund)

1993

Cruise	Total	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31+
		Length-class																										
1	32.657			1.079	2.732	0.563								0.266	0.282			0.334	0.258		0.731	0.345	0.540	1.470	2.764	1.389	2.086	17.819
2	10 462.495	18.789	853.924	3 789.775	4 291.617	1 471.580	14.073	0.252			0.331						0.233				0.305	0.233		0.247	0.288	1.376	2.109	17.363
3	10 297.836	14.812	931.121	3 978.945	4 420.835	903.742	37.456	0.656												0.236			0.336		0.854	1.140	1.343	6.361
4	13 049.233	39.256	548.530	2 174.410	1 042.347	837.615	2 281.778	3 096.672	1 354.323	265.446	250.764	269.215	206.866	169.297	160.551	148.924	107.250	54.396	26.311	8.424	3.966	2.278		0.617				
5	8 295.049	18.142	178.861	1 040.558	2 191.526	1 357.901	401.106	217.017	370.882	726.606	780.439	429.456	124.947	49.103	83.359	81.956	69.576	65.978	54.317	30.269	16.497	5.240	0.786	0.255	0.272			
6	4 584.843	1.113	74.794	363.913	748.669	859.588	515.876	325.607	414.779	390.347	254.167	110.022	66.397	71.698	111.263	106.480	88.872	39.080	14.161	4.948	5.841	4.377	1.227	2.698	3.872	2.120	2.444	0.492
7	2 447.190		13.507	117.762	151.925	146.098	205.916	291.616	345.751	192.665	134.029	149.220	173.611	138.381	73.317	56.171	50.996	48.246	52.426	52.122	25.368	11.043	5.921	3.205	2.634	12.119	2.126	0.487
8	1 035.315		0.875	11.325	15.237	27.948	36.844	49.611	49.101	46.121	46.821	59.221	85.806	90.296	87.042	57.612	61.819	55.893	41.769	28.370	27.753	35.922	27.137	31.955	35.090	16.247	5.603	5.898

Table 3. Herring larvae surveys, 1991-1993: Number of larvae of the main components of the length compositions estimated by the BHATTACHARYA method.

Middle date of cruise	Component 1.	2.	3.	4.	5.
09.04.91	5896.04	125.77			
01.05.91	795.54				
13.05.91	716.95	161.66	7.37		
27.05.91	9125.48	130.32	38.18		
04.06.91	2023.78	3070.80	114.73	12.92	
17.06.91	440.98	1468.91	449.89	11.20	
24.06.91	567.82	737.66	288.40	38.81	
09.04.92	351.90				2.24
21.04.92	5319.48	146.76			
27.04.92	3014.30	277.18			
05.05.92	4397.72	797.05	57.29		
12.05.92	3104.66	181.55	189.92	23.26	3.22
18.05.92	1336.90	385.41	131.41	53.71	6.82
25.05.92	554.60	191.23	148.76	8.59	6.26
13.04.93	10440.01				
20.04.93	10287.42				
20.05.93	3913.27	7736.30	736.96	599.06	59.54
24.05.93	5231.09	2586.61	350.94	121.68	4.30
01.06.93	2634.20	1458.55	449.20	31.48	8.50
07.06.93	467.91	1077.86	617.45	131.54	130.39
15.06.93	292.84	358.37	190.08	117.74	64.77

Table 4. Herring larvae surveys, 1991-1993: Mean lengths of the main components of the length compositions estimated by the BHATTACHARYA method.

Middle date of cruise	Component 1.	2.	3.	4.	5.
09.04.91	7.53	13.00			
01.05.91	10.10				
13.05.91	7.75	13.96	15.74		
27.05.91	8.89	12.91	18.56		
04.06.91	8.21	12.97	17.34	22.16	
17.06.91	7.72	14.53	21.26	26.24	
24.06.91	10.04	18.35	24.79	28.74	
09.04.92	8.61				21.50
21.04.92	8.00	10.27			
27.04.92	8.64	11.54			
05.05.92	7.57	10.47	14.76		
12.05.92	7.96	10.89	13.86	18.84	21.96
18.05.92	8.08	10.20	14.66	18.45	22.23
25.05.92	7.94	9.77	15.21	18.62	22.29
13.04.93	8.07				
20.04.93	8.18				
20.05.93	7.65	11.23	15.59	18.48	21.47
24.05.93	8.67	14.16	19.42	22.55	24.13
01.06.93	9.13	13.00	19.30	24.47	28.42
07.06.93	8.72	12.07	16.54	20.75	23.12
15.06.93	12.10	17.48	21.48	25.55	28.48

Table 5. Herring larvae surveys, 1991-1993: Growth per day between the cruises for the cohorts.

Year	Time between cruises [d]	Components of the cohorts 1/2	2/3	3/4	Mean
1991	12	0.322			0.322
	14	0.369	0.329		0.349
	8	0.510	0.554	0.450	0.505
	13	0.486	0.638	0.685	0.603
	7	0.331	0.546	0.504	0.460
	Mean	0.404	0.516	0.546	0.477
1992	12	0.138			0.138
	6	0.590			0.590
	8	0.229	0.403		0.316
	7	0.474	0.484	0.583	0.514
	6	0.373	0.628	0.765	0.589
	7	0.241	0.716	0.566	0.508
	Mean	0.341	0.558	0.638	0.476
1993	30	0.102			0.102
	4	0.255	0.733	0.958	0.648
	8	0.541	0.643	0.631	0.605
	6	0.490	0.590	0.242	0.441
	8	0.422	0.676	0.618	0.572
	Mean	0.362	0.660	0.612	0.531

Table 6. Herring larvae surveys, 1991-1993: Mortality per day between the cruises for the cohorts.

Year	Time between cruises [d]	Components of the cohorts 1/2	2/3	3/4	Mean
1991	12	0.133			0.133
	14	0.122	0.103		0.112
	8	0.136	0.016	0.135	0.096
	13	0.025	0.148	0.179	0.117
	7	-0.036	0.098	0.064	0.042
	Mean	0.076	0.091	0.126	0.094
1992	12	0.073			0.073
	6	0.492			0.492
	8	0.166	0.197		0.182
	7	0.455	0.205	0.129	0.263
	6	0.348	0.054	0.211	0.204
	7	0.278	0.136	0.390	0.268
	Mean	0.302	0.148	0.243	0.241
1993	30	0.009			0.009
	4	-0.073	0.274	0.185	0.129
	8	0.160	0.219	0.301	0.227
	6	0.149	0.143	0.205	0.166
	8	0.059	0.138	0.147	0.114
	Mean	0.061	0.193	0.210	0.147

Table 7. Herring larvae surveys in the Greifswalder Bodden and Strelasund: Results of the ANOVA and regression analysis for growth and mortality rates.

	1991	1992	1993
ANOVA for growth per day			
Effect of cruise	P=0.14	P=0.19	P=0.49
Effect of component	P=0.32	P=0.06	P=0.30
ANOVA for Mortality (M)			
Effect of cruise	P=0.53	P=0.34	P=0.47
Effect of component	P=0.43	P=0.28	P=0.10
REGRESSION ANALYSIS			
Growth on time interval No.	r=0.48	r=0.45	r=0.13
on mean length of a component	r=0.42	r=0.56*	r=0.35
on abundance	r=0.20	r=-0.17	r=-0.37
Mortality on growth per day	r=0.33	r=0.45	r=0.63*
on time interval No.	r=-0.39	r=0.06	r=0.12
on mean length of a component	r=0.30	r=-0.27	r=0.68*
on abundance	r=0.23	r=0.73*	r=-0.26

* denotes significance at α=0.05
P denotes sgnificance level
r denotes correlation coefficient

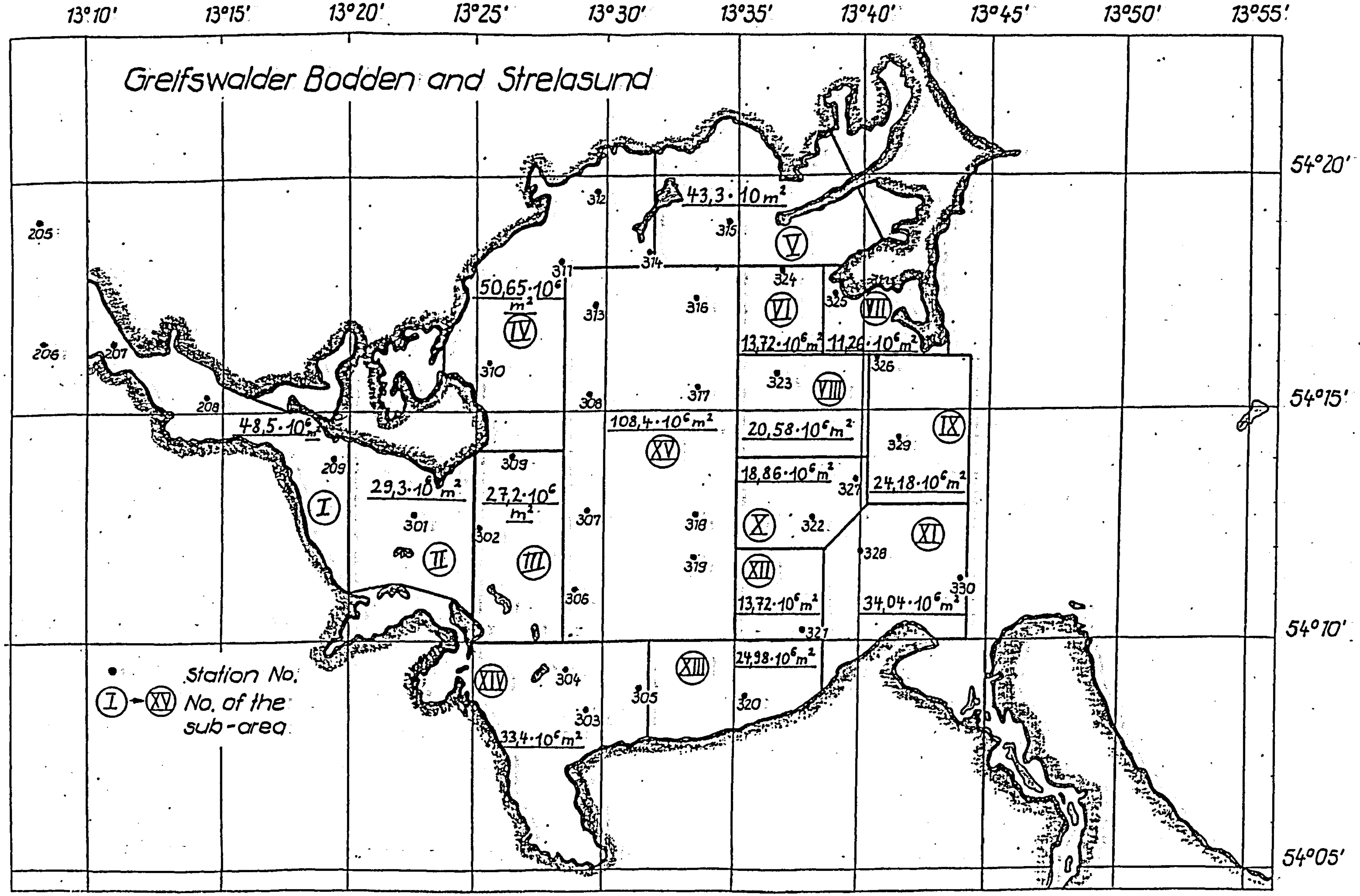

Figure 1. Station grid of the herring larvae surveys and sub-areas representing different spawning conditions.

Figure 2. Time series of herring larvae(10^{-9}) survived up to TL>=30 mm in the Greifswalder Bodden and Strelasund (——), number of age group 0 and 1 of spring spawning herring (10^{-9}) in ICES Sub-divisions 22-24 and Division IIIa estimated by VPA (---) and acoustic surveys (····), respectively, and the 0-group index estimated during the German bottom trawl surveys(-·-). For sources see DISCUSSION.