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ANALYSIS OF BALTIC HERRING YEAR-CLASS STRENGTH IN THE GULF OF RIGA

by

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The year-class strength of Baltic herring in the Gulf of Riga is analysed in relation to different abiotic and biotic factors. The recruitment differs rather significantly between years and as the intensity of herring fishery in the Gulf of Riga is one of the highest in the Baltic sea it causes remarkable fluctuations of the stock size. Therefore it is important to reveal relationships with predictable value. The results show that the success of reproduction is mainly determined by the water temperature in prespawning period (April) that defines the beginning, length and course of the spawn as well as the feeding conditions for larvae. In years when cod is abundant in the Central Baltic and it enters the Gulf of Riga the recruitment of herring could be significantly influenced by predation. The results are compared with analysis made in previous decades taking into consideration the ecological changes in the Gulf of Riga. The year-class strength of herring in the Gulf of Riga is compared with that of herring stocks from other regions of the Baltic sea. The similarity between regions decreases with the increase of distance between them.

Introduction

Herring is the main commercial fish in the Gulf of Riga constituing about 80% of the total catch. The difference of year-class strength between years is rather significant at least it is more expressed than in the Baltic Proper (Komilovs, 1994), therefore the size of recruitment strongly influences the stock size and the level of the catches. The attempts to predict the year-class strength and to evaluate the factors which affect it have been made since 1950s. In 1950s and 1960s the prevailing opinion was that recruitment depends on feeding conditions of larvae especially in the period of transition from internal to external feeding (Lisivnenko, 1957). Rich year-classes appeared in years with early and abundant development of feeding zooplankton, when the coincidence of beginning of external feeding of hatched larvae and maximum of zooplankton was the largest (Ojaveer, Simm, 1975). Some authors have noted the dependence of recruitment from spawning stock size (Rannak, 1975), although the influence of meteorological and hydrological conditions was also considered. Rich year-classes appeared in years with warm an early spring and cool beginning of summer (Rannak, 1971). Beginning with 1980s the success of reproduction was connected with the conditions on the spawning grounds because it was stated that important changes have taken place in the ecological situation in the Gulf of Riga. The investigations on the spawning grounds showed that the space of the spawning grounds has strongly diminished and the embryonal mortality has significantly increased (Komilovs, 1993). Thus it was considered that it was the main reason why from the mid 1970s a series of poor year-classes appeared and the stock size decreased. The studies on the spawning grounds in 1983-1992 showed that during this period the conditions there and success of embryonal development were stable and did not worsen. From the mid-1980s the success of reproduction increased. At present the enlargement of long-term observations of conditions during the reproduction period allow to make new analysis.

Materials and methods

The year-class strength of gulf herring was estimated as relative values of herring abundance at the age of 1 year. The values were taken from the report of the Working Group on Assessment of Pelagic Stocks in the Baltic (Anon, 1994b). The recruitment values of herring in the Central Baltic (SD 25-29, 32 and the Gulf of Riga), in the Bothnian sea and the Gulf of Bothnia were taken from the same Report (Anon, 1994b). As the assesment of herring in the Gulf of Finland and of coastal herring in the Southern Baltic is not carried out since 1990 the recruitment

values for these stocks were taken from the Report of the Working Group on Assessment of Pelagic stocks in the Baltic in 1990 (Anon, 1990). The regression analysis were made to evaluate the influence of different factors on the recruitment (table 1). The severity of winter that was characterized by the sum of negative temperatures in Riga and the mean water temperature in April when the spawn usually begins in the Gulf of Riga were chosen as the main factors which affected the hydrological conditions during the spawn. The feeding conditions of larvae were characterized by data on zooplankton abundance in May and August (time of standard surveys). Since the feeding of herring larvae is selective for the estimation of feeding conditions the abundance of two *Copepoda* species *Acartia bifilosa* and *Eurytemora hirundoides* was used. Regular surveys of herring larvae were performed in July in 1976-1992. The mean number per $1000m^3$ in the Gulf of Riga were calculated. To evaluate the predation pressure on young herring the values of spawning stock biomass of cod in the Central Baltic were used for the analysis. These values were taken from the Report of the Working Group on Assessment of Demersal Stocks in the Baltic (Anon, 1994a).

Results

The highest correlation for recruitment of the Gulf of Riga herring was found with water temperature in April (r=0.78) that determined the conditions in the prespawning and beginning of the spawning periods (Table 2). The investigations on the spawning grounds showed that the beginning of spawn was determined by the water temperature. In years with early springs when the water temperature was comparatively high the spawning was not only earlier but also longer, the space of the spawning grounds was used more widely and the eggs were layed more evenly. The water temperature in April is chiefly determined by the severity of winter therefore the correlation coefficient between these two parameters is - r=0.79, as well as between the severity of winter and recruitment is - r=0.64. Certainly the conditions in spring also have their influence. The second highest correlation was found with the abundance of zooplankton (food for larvae) in May (r= 0.76). May is the period when hatching of larvae begins. The abundance of zooplankton is strongly determined by the hydrological and meteorological conditions in spring and severity of winter. The correlation coefficients of zooplankton abundance in May with severity of winter and water temperature in April are correspondingly - r= 0.59 and r =0.68. Thus severity of winter determined not only hydrological conditions in spring, but also spawning conditions and abundance of food in the first half of the hatching period. The third significant correlation for recruitment was found with the spawning stock biomass of herring

(r=0.47), although it is strongly influenced by the increase of herring stock size and rich year-classes in the last years. If we exclude the values of two last years then the correlation coefficient for period 1971-1990 diminishes and is only - r=0.27. The correlations of recruitment with abundance of larvae, spawning stock biomass of cod in the Central Baltic (SD 25-32) and abundance of zooplankton in August were not significant, correspondingly (r=0.39, r=0.42, r=0.41). The larval surveys in the Gulf of Riga were carried out in July 1976-1992. It seems that the correlation coefficient is low because the surveys did not cover a significant area of larval distribution namely coastal area and were performed on depths of 10 m and deeper. In some regions a significant correlation was found between abundance of larvae and herring year-class strength and it was increasing with the size of larvae (Raid, 1985). The abundance of zooplankton in summer that is characterized by August surveys seems isn't a limiting factor because the abundance of zooplankton in summer usually is rather high and sufficient.

To estimate the similarity of stock-recruitment relationships in different regions of the Central and Northeastern Baltic the regression analysis between recruitment values of different herring stocks was made (Table 3). For the herring in the Southern Baltic (coastal herring) and the Gulf of Finland the assessments were stopped after 1990, therefore the recruitment values were taken till 1988. The highest correlation was found between the herring stocks of the gulfs, namely The Gulf of Riga (1), the Gulf of Finland(2) and the Bothnian sea(3): r_{12}= 0.82, r_{13}=0.67, r_{23}=0.58. The correlation between recruitments of the Bothnian sea and the Gulf of Bothnia is also rather high (r=0.60). Other correlations were not significant.

Discussion

The ecological changes that have taken place in the Gulf of Riga are essential. These changes are manifested in increase of biogenes and primary production, the alteration of abundance and species composition of phytoplankton, zooplankton and fish community. Herring spawning grounds in the gulf of Riga are broad and important because there spawns the local population as well as the herring from the Baltic Proper. The investigations of the spawning grounds (1983-1992) revealed that the space of the spawning grounds had decreased due to disappearance of vegetation from deeper places and the mortality during the embryonal development had increased (Komilovs, 1993). Although during the last decade the surveys on the spawning grounds were carried out rather intensively it is difficult to estimate the average embryonal mortality for the whole gulf because it

is almost imposible to state all depositions of eggs in prolonged and tied to different and hardly predictable places spawning. Besides it would be necessary to estimate the hatching success of larvae for all these depositions because the mortality rates are very different not only between spawning grounds but also on one spawning ground during the spawning period. Nevertheless taking into account experience of 10 years long investigations the embryonal mortality could be estimated on the average at the level of 30% for the whole Gulf of Riga. In 1950s and 1960s the average mortality during the embryonal development was estimated at the level of 5-10%. Thus it means that the embryonal mortality has incresed approximately 3-6 times, therefore it is not surprising that in the end of 1970s and in 1980s when the stock size of gulf herring diminished it was considered that the main reason for that was the unfavourable conditions for the development of eggs. Further appearance of continued rich year-classes and the increase of stock size in stable but unfavourable conditions on the spawning grounds shows that although the embryonal mortality has essentially increased the number of hatched larvae is still sufficient to create a rich year-class. It is known that during the larval phase the mortality is very high therefore it is still the main stage at which the success of reproduction is determined. It is confirmed also by this analysis that has given high correlation between the recruitment of herring and abundance of zooplankton in May. The advantage of early beginning of the spawn when water temperature is higher than on the average is also connected with the feeding of larvae. In early and warm springs the abundance of zooplankton is higher than on the average, the spawning and hatching periods are longer that diminishes the competition of different generations of larvae for feeding because with the growth of the larvae they pass over to new bigger food items. Thus the statements made 20-30 years ago that rich year-classes appear in years with early springs, when herring larvae is provided with sufficient amount of food are still in strength. The insignificant correlation between year-class strength and abundance of zooplankton in summer (August) indicates that the amount of food is sufficient and confirms that the most vulnerable is the stage when the transition of larvae from internal to external feeding takes place: mainly May-June.

It seems that in the end of 1970s and the first half of 1980s the reproduction success was strongly influenced by cod which was very abundant in this period in the Gulf of Riga and fed intensively with the young herring that had resulted in several poor year-classes. At present when cod is absolutely absent in the gulf the influence of this factor is missing.

The comparison of year-class strength in different regions of the Central and Northeastern Baltic shows that a high similarity exists between herring stocks in the gulfs: the Gulf of Riga, the Gulf of Finland and the Bothnian sea that could

be as assertion of similar factors which affect the year-class strength and indicate the exlstance of separate stocks there as well. The recruitment of joint herring stock of the Central Baltic has the highest value of correlation coefficient with recruitment of the Gulf of Finland probably because the latter is the most opened from the gulfs. The lowlest values of correlation coefficients has the recruitment of coastal herring that indicates the importance of other factors determining reproduction success in the Southern Baltic. Generally the similarity between year-class strength of the examined regions decreased with the increase of distance between them.

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Table 1

The main parameters used for the regression analysis of the Gulf of Riga herring year-class strength

Year	Relative values of recruitment	Spawning stock biomass	Sum of negative temperatures in winter	Mean water temperature in April	Abundance of zooplankton in May	Abundance of zooplankton in August	Spawning stock biomass of cod in SD 25-32	Average number of larva in July
1971	0.76	34391	357	0.8	7.4	19.8	237	
1972	0.71	63859	469	0.7	10.5	21.1	259	
1973	1.06	64102	213	2.0	12.4	19.8	276	
1974	0.45	55318	255	1.8	16.3	18.2	342	
1975	1.94	50576	72	2.7	16.5	26.9	426	
1976	0.47	36454	543	0.5	7.0	20.8	424	72
1977	0.57	50164	457	0.4	6.1	18.2	399	97
1978	0.54	46038	429	0.6	9.3	18.2	487	-
1979	0.61	44444	849	0.3	5.3	15.6	727	522
1980	0.52	43948	647	0.5	6.6	37.9	828	431
1981	0.97	45403	386	0.7	6.1	41.6	780	595
1982	0.72	41516	442	1.0	8.6	43.8	805	87
1983	1.27	50923	199	1.4	12.9	34.4	783	292
1984	0.65	40916	314	0.9	7.6	24.1	759	58
1985	0.56	56112	854	0.1	4.2	19.7	615	5
1986	1.92	66859	532	0.9	21.0	46.9	451	1453
1987	0.27	51993	849	-0.2	4.0	14.7	372	2
1988	0.60	92383	268	0.4	4.7	31.1	354	102
1989	1.70	59590	158	3.1	7.9	29.2	283	92
1990	1.85	68070	159	3.8	20.3	35.4	215	276
1991	1.93	68639	200	1.7	13.3	30.2	143	181
1992	1.95	86645	102	2.7	19.5	20.3	64	206
units	-	tonnes	-T°C	T°C	thousands/ m^3	thousands/ m^3	tonnesx10^3	number/ $1000m^3$

Table 2

The correlation coefficients between recruitment of the Gulf of Riga herring and different factors

Factors	Correlation coefficient
Mean number of herring larvae in July	0.39
Spawning stock biomass of gulf herring	0.47
Sum of negative temperatures in winter	-0.64
Mean water temperature in April	0.78
Abundance of zooplankton in May	0.76
Abundance of zooplankton in August	0.41
Spawning stock biomass of cod in SD 25-32	-0.42

Table 3

Correlation coefficients between year-class strength of different populations of the Baltic sea herring

Region	Gulf of Riga	Gulf of Finland	Bothnian Sea	Gulf of Bothnia	Baltic Proper	Southern Baltic
Gulf of Riga	1	0.82	0.67	0.27	0.13	0.06
Gulf of Finland	0.82	1	0.58	0.44	0.51	0.16
Bothnian sea	0.67	0.58	1	0.60	0.08	0.01
Gulf of Bothnia	0.27	0.44	0.60	1	0.20	0.15
Baltic Proper	0.13	0.51	0.08	0.20	1	0.38
Southern Baltic	0.06	0.16	0.01	0.15	0.38	1