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ABUNDANCE AND DISTRIBUTION OF LARVAE OF COMMERCIALLY IMPORTANT FISH SPECIES IN THE WESTERN BALTIC SEA DURING THE PERIOD 1993-I 998

by

Birgitt Klenz

Federal Research Centre for Fisheries Hamburg
institute for Baltic Sea Fishery Rostock
An der Jägerbäk 2
D-18069 Rostock, Germany

ABSTRACT

The distribution and abundance of larvae and juveniles of the western Baltic Sea fish species of commercial importance are described. The results are based on five ichthyoplankton surveys carried out in May/June on a standard station grid in ICES Subdivisions 22 and 24 during the period 1993-1998. The number of larvae caught varied throughout the time series. In 1994 the largest mean abundance [larvae/m^2] was estimated.
The time series derived from the Bongo-Net samples shows a very slight increase in larval abundances of the western Baltic cod stock. But the values are below the mean abundance of cod larvae in the Bornholm Basin.
The influence of the varying plankton survey time and the direct wind-induced drift of cod early life stages from the main area of investigation towards the east are discussed.
An increasing trend in herring larvae abundances was observed during the period 1993-1998. In three years regional spawning activities along the German coast were ascertained in accordance with previous results from literature - especially on stations in the Kiel Fjord, in the Eckernforde Bight, and in the north of the River Schlei.
Species assemblage correlations are investigated for the larvae sampled during the period 1993-1998. The statistical analysis of the data shows no general relationship between the larvae of the commercially Important western Baltic Sea fish species. The species assemblage varies through the years investigated.

Key words: western Baltic Sea, fish larvae, abundance, distribution, species assemblage correlations

I. Introduction

Ichthyoplankton samples provide the material necessary to study many aspects of marine and fishery biology. The distribution and abundance of fish eggs and larvae in North Sea and Baltic Sea have been topics of fishery research since over 100 years. The early life stages Can be observed over a period of approximately two to three months as part of the plankton communities and can be sampled during ichthyoplankton surveys. The collections of marine fish species in their larval phase and the observation of the environmental conditions during these surveys additionally offer the possibility to investigate factors influencing the reproduction of the target fish species. This gives a piece of information on plankton communities and diversity of fish species in the area investigated,

Surveys on the occurrence of cod eggs and larvae in the Baltic Sea have frequently been carried out at different times of the year since the beginning of this century (Anon. 1998). Since 1993 these studies in the western Baltic Sea (ICES Subdivisions 22 and 24) have been intensified by the Institute for Baltic Sea Fishery Rostock. Every year one cruise aboard Fishery Research Vessel "Solea" has been performed in May/June. The multiple objectives of these surveys were investigations on the reproduction of the western Baltic cod stock *Gadus* morhua *morhua*, and on the species composition and diversity of fish larvae in the area of investigation.

The economically important fish species in the western Baltic Sea are the herrings *Clupea harengus* and *Sprattus sprattus*, the cod *Gadus morhua* morhua as well as the flatfishes *Limanda limanda*, *Pleuronectes platessa* and *Platichthys flesus*. They-are species with a high fecundity and a long developmental phase in the plankton community. Their reproduction success is determined very essentially by environmental conditions in this phase (Schnack 1993). The development of the adult stock is influenced mainly by fishery activities. Herring and sprat have a central position in the Baltic Sea ecosystem. They are the dominant part of the fish biomass. And they are important prey items for many predators including cod. In the first half of this century autumn spawning herring and spring spawning herring still appeared in a relatively balanced relationship in the Baltic Sea. At present the herring, which is spawning during the spring onshore in shallow estuaries, bights and haffs, prevails in the western Baltic Sea (Rechlin and Bagge 1996). In these shallow areas the early developmental stages grow up after hatching. Thus the Kiel Fjord, the River Schlei and the inshore Bay of the River Trave play an important role for the recruitment of the spring spawning herring of the Kiel Bay (Kändler 1952). Including of inshore stations and stations in such shallow estuaries into a station grid of an ichthyoplankton survey will bring Small Or newly hatched herring larvae into the catches of the plankton gear.

This paper gives an account of the larvae and juveniles of herring, sprat, cod, Common dab, European plaice and flounder. It describes the mean abundances and distributions of these larvae and juveniles. Investigations are presented, if cod for example co-occur with other species more than simply by chance.

II. Material and methods

The area under investigation is shown in Figure 1.

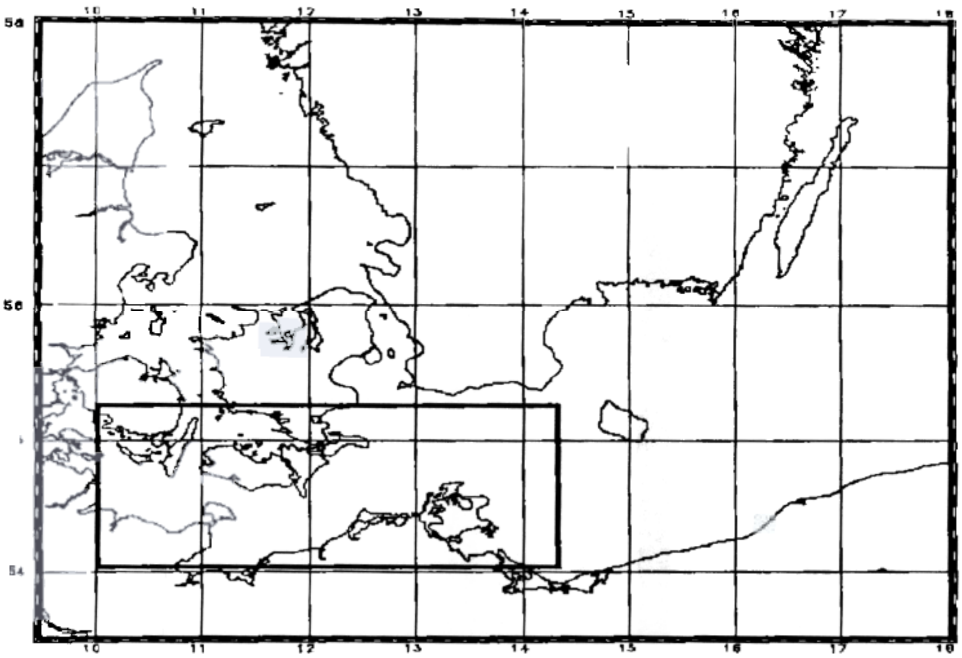


Fig. 1. Area under investigation in the western Baltic Sea, ichthyoplankton surveys May/June 1993-1998.

The studies are based on a standard station grid representing the Kiel Bay, Liibeck Bay, Mecklenburg Bay and parts of the Arkona Sea. A total of five ichthyoplankton surveys were carried out aboard Fishery Research Vessel „Solea" during the period 1993-1998. The gear used was a Bongo-Net (net opening: 60 cm diameter, 0.5 mm and 0.335 mm mesh size), which was towed at a constant towing speed of three knots obliquely from the surface down to 2 m above the bottom. The volume of water strained was calculated by means of attached digital flow meters with back-run stop. Tow depth was monitored on board with a deck command unit according to the multi plankton sampler of HYORO-BIOS. On board the samples were preserved in 4 % buffered formaldehyde and sea water solution for analysis in the laboratory. Fish larvae were sorted from the samples and examined.

At present it is internationally usual to look back from the characters of a young **fish to the** larva to identify species or the lowest achievable **taxonomic level. This** method is also applicated in the Institute for Baltic Sea Fishery Rostock. Length measurement of each fish **larva** is designated as the total length (TL) to 0.5 mm below. Shrinking of larvae caused by preservation was not considered.

Kühn (1998) investigated growth, development and mortality of cod **larvae** (*Gadus morhua* L.) under defined conditions in the marine aquaculture hatchery „Butt" in Strande near Kiel. The author described the size ranges in which hatching, yolk-sac resorbtion, flexing of urostyle and metamorphosis of the larvae of the western **Baltic cod** stock *Gadus morhua morhua* occur at mean **water** temperatures of 10" C. Therefore for our investigations on the abundance and distribution of larvae of commercially important western Baltic Sea fish species the distinction between cod larva and juvenile stage was chosen in accordance with Kuhn (1998).

The numbers of larvae per m^2 are estimated according to the „FAO standard techniques for pelagic fish egg and larva surveys" (Smith and Richardson 1977, Klenz 1994).

All statistical analyses were performed by using the software package STATGRAPHICS version 5 of the Statistical Graphics Corporation. The effect of the parameter year on the mean larval abundances was investigated by ANOVA. Possible significant differences between the survey averages by species and year were analysed using the multiple range analysis. The multiple variable analysis was used to examine possible species assemblage correlations.

The analyses include **samples** of five ichthyoplankton surveys in the western Baltic Sea in May/June 1993, 1994 ,and 1998-1998. For 1995 no data are available.

III. Results

111.1. Mean abundances of larvae and juveniles of commercially important fish species in the western Baltic Sea

III. 1.1. Total *catches of* **larvae and juveniles**

Table I shows the mean abundances per m^2 of fish larvae **and juveniles** averaged over all stations in the Belt Sea and the Arkona Sea and the total number of all taxonomic levels identified. It also gives **a** general account of the larvae and juveniles of the commercially **important** western **Baltic** Sea fish species [No.] as well **as** of their mean abundances in number per m^2 [$\bar{N}/m^2$].

Table I. Fish larvae and juveniles in the western Baltic Sea (ICES Subdivisions 22 and 24) in May/June 19931998.

	1993		1994		1996		1997		1998	
No. of sampled stations per survey	57		47		30		54		57	
Total number of fish larvae and juveniles in the Bongo-Net catches	331		3,194		649		4,259		3,354	
Mean abundance of fish larvae and juveniles (number per m^2)	0.9		5.4		1.2		2.8		2.8	
Total number of taxonomic levels identified	20		22		12		16		18	
	No. of larvae	Mean abundance $\bar{N}m^{-2}$	No of larvae	Mean abundance $\bar{N}m^{-2}$	No. of larvae	Mean abundance $\bar{N}m^{-2}$	No of larvae	Mean abundance $\bar{N}m^{-2}$	No. of	Mean abundance
'Larvae and juveniles of commercially 'Important fish species	58		237		513		2,104		2,320	
Scientific name (Common name)										
Clupea harengus (Herring)	45	0.10	182	0.30	404	0.70	1,746	1.30	1,837	1.50
Sprattus sprattus (Sprat)		-	-	-	-	.	1	0.95×10^{-3}	1	0.87 x [illegible]
Gadus morhua morhua (Cod)	-	-	29	0.05	28	0.05	84	0.07	150	0.13
Limanda limanda (Common dab)	8	0.02	26	0.04	81	0.20	9	0.01	32	0.03
Pleuronectes platessa (European plaice)	5	0.01	-	-	-		21	0.02	149	0.13
Platichthys flesus (European flounder)							243	0.20	151	0.15

Figure 2 does not show a trend in larval and juvenile abundances in the given time series derived from the Bongo-Net samples. With variations up to the numeral 6 the samplings yielded only low mean abundances during the period 1993-1998.

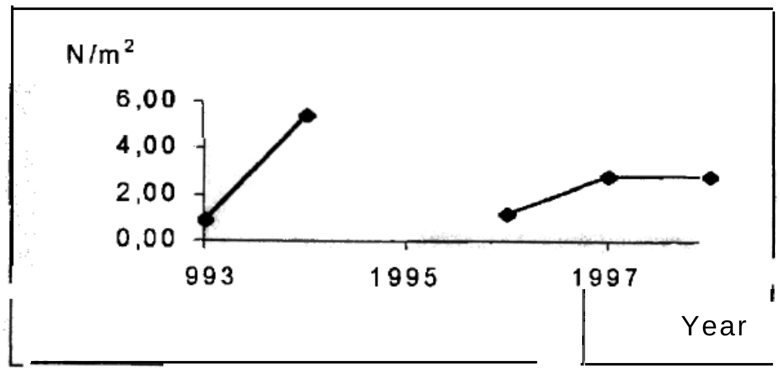


Fig. 2. Mean larval and juvenile abundances of the ichthyopiankton surveys in the western Baltic Sea, **May/June 1993-1998.**

For the mean larval and juvenile abundances the analysis of variance denoted an essentially larger variability between the years than within a year.

Using the multiple range analysis Table II shows that the mean abundance of the total catches in 1994 was the significant largest.

Table II. Multiple range **analysis** for mean larval and juvenile abundances [$\bar{N}\ m^{-2}$] by year.

Year	No. of stations	$\bar{N}\ m^{-2}$	Homoaeneous Groups
1993	53	0.8641509	x
1996	30	1.1866667	x
1998	57	2.7649123	x
1997	52	2.8000000	x
1994	45	5.3866667	

Contrast	Difference	+/- Limits
1993- 1994	-4.52252	1.01071 •
1993- [illegible]	-0.32252	1.13920
1993-l 997	-1.93585	[illegible] •
1993-1998	-1.90076	[illegible] *
[illegible]	4.20000	1.17523 •
[illegible]	2.58667	101516 *

1994-1998	2.62175	0.99429	•
1996-l 997	-1.61333	1.14315	•
1996- [illegible]	-1 57825	1.12466	*
1997- 1998	0 03509	0.95616	

denotes a statistically significant difference for $\alpha=0.05$

This includes the abundances of larvae and juveniles of different commercially important fish species as follows:

III. 7.2. Cod

The performed plankton gear samplings in the western Baltic Sea yielded only very low numbers of cod larvae and juveniles (see Table I). 291 early life stages of cod were sampled during the five ichthyoplankton surveys. Until 1997 in the Bongo-Net catches a total of only 29 larvae was identified. Most individuals were in stages after the transformation to a juvenite. In contrast 77 newly hatched larvae could be found in the samples of 1998. That was for the first time in the available time series. These small cod larvae had a portion of 58 % of the total cod numbers and were concentrated especially on stations in the southern Little Belt. 20 % of the cod individuals sampled in 1998 were in developmental stages of the metamorphosis. 11 % of cods had reached already the stages after the transformation to a young fish.

The time series denoted a very slight increase in cod abundances (mean values between 0 and 0.13 larvae and juveniles per m^2). Figure 3 presents the trend line of the mean larval and juvenile abundances of the western Baltic cod stock during the period 1993-1998.

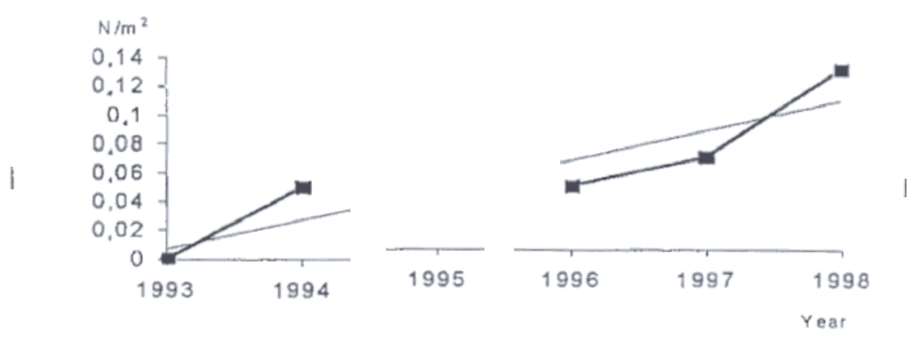


Fig. 3. Trend line of mean larval and juvenile abundances of the western Baltic cod stock, ichthyoplankton surveys, May/June 1993-l 998.

There is a larger variance of the cod abundances [$\bar{N}/m^2$] between the years than within a year denoted by ANOVA. Table III shows the following significant range for the mean cod larvae abundances using the muttiple range analysis:

$\bar{N}/m^2_{1993} < \bar{N}/m^2_{1997} < \bar{N}/m^2_{1998}$ and $\bar{N}/m^2_{1994} < \bar{N}/m^2_{1998}$.

Table III. Multiple range analysis for mean larval and juvenile cod abundances [$\bar{N}$ m^{-2}] by year.

Year	No. of stations	$\bar{N}$ m^{-2}	Homoneneous Groups
1993	53	0.0000000	x
1994	44	0.5000000	xx
1996	26	0.0615385	xxx
1997	49	0.0673469	xxx
1998	49	0.1387755	x x

Contrast	Difference +/-	Limits	
1993-1994	-0.05000	0.06586	
1993-1996	-0.06154	0.07732	
1993-1997	-0.06735	0.06400	*
1993-1998	-0.13878	0.06400	*
1994-1996	-0.01154	0.07988	
1994-1997	-0.01735	0.06707	
1994- 1998	-0.08878	0.06707	*
1996- 1997	-0.00581	0.07835	
1996-1998	-0.07724	0.07835	
1997-1998	-0.07143	0.06524	*

* denotes a statistically significant difference for $\alpha=0.05$

III. 7.3. Herring

Herring larvae could be caught with the plankton gear during each ichthyoplankton survey. They were predominant among the commercially important fish species with a mean abundance between 0.1 and 1.5 individuals/m’ (see Table I). Figure 4 presents a positive trend in the mean herring larvae abundances of the ichthyoplankton surveys 1993-1998.

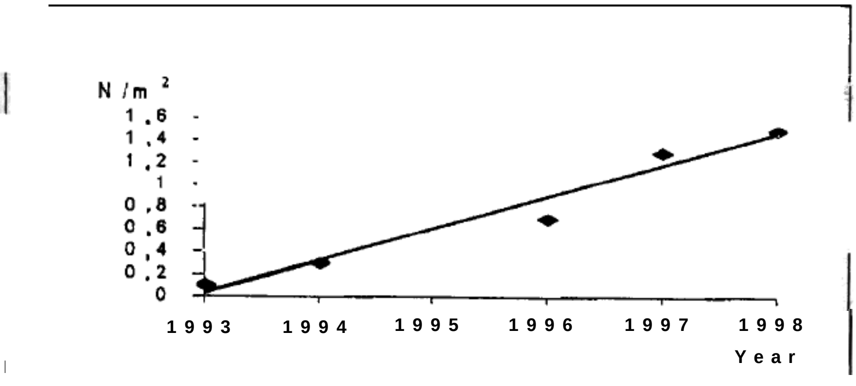


Fig. 4. Trend line of mean larval herring abundances, ichthyoplankton surveys in the western Baltic Sea, May/June 1993-1998.

Table IV (analysis of variance) denotes no significant differences between the herring larvae abundances of 1993 and 1994, of 1994 and 1996 as well as of 1997 and 1998.

Table IV. Multiple range analysis for mean larval and juvenile herring abundances [$\bar{N}\ m^{-2}$] by year.

Year	No. of stations	$\bar{N}\ m^{-2}$	Homooeneous Groups
1993	53	0.1207547	x
1994	45	0.3333333	xx
1996	30	0.7066667	x
1997	52	1.2961538	x
1998	57	1.5035088	x

Contrast	Difference +/-	Limits
1993-I 994	-0.21258	0.38932
1993-1996	-0.58591	0.43882 •
[illegible]	-1.17540	0.37488 *
1993- 1998	-1.38275	0.36649 *

1994-1996	-0.37333	0.45270	
1994-1997	-0.96282	0.39104	*
1994-1998	-1.17018	0.38300	*
1996-I 997	-0.58949	0.44034	*
1996-1998	-0.79684	0.43322	*
1997-1 998	-0.20735	0.36831	

* denotes a statistically significant difference for $\alpha=0.05$

According to Rechlin and Bagge (1996) herring, which is spawning during the spring onshore in shallow estuaries, bights and haffs, prevails in the western Baltic Sea. In these shallow areas the early developmental stages grow up after hatching.

In the standard station grid of the ichthyoplankton surveys inshore stations and stations in the estuaries are included. Small or newly hatched herring larvae were to be expected in the catches of the plankton gear. The Figures 5-7 show that larvae of the length groups 5-7 mm were present in the Bongo-Net samples of the surveys 1996 to 1998.

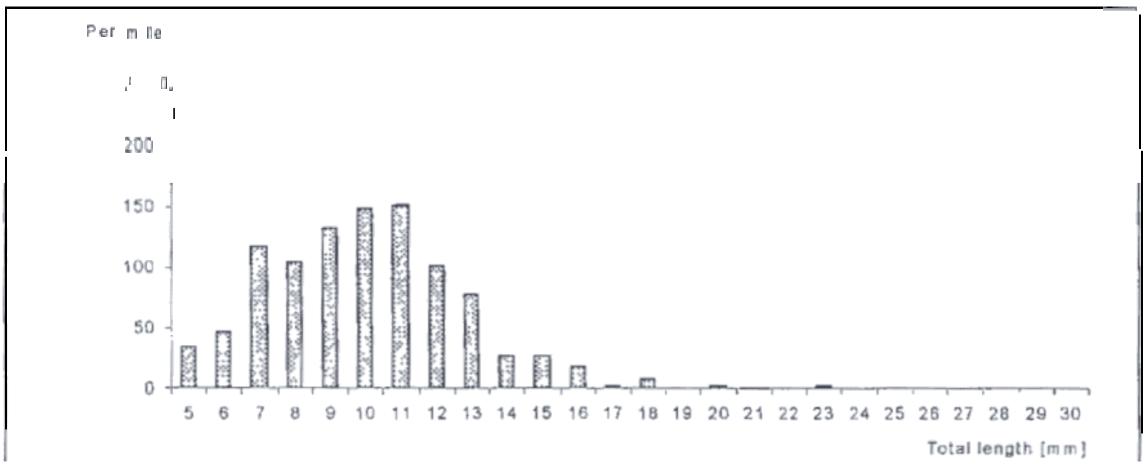
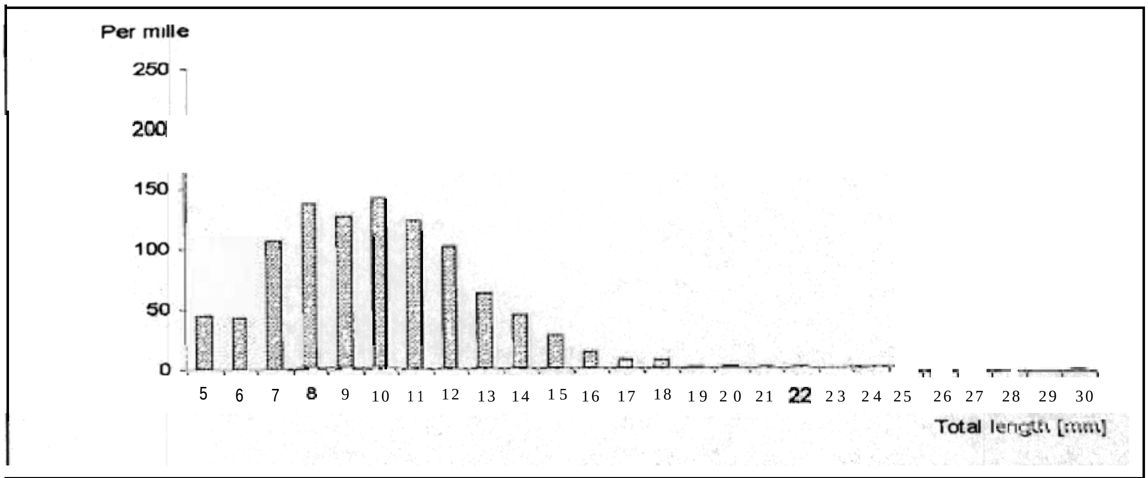


Fig. 5. Length composition of herring larvae of all stations in the are8 of investigation in 1996

In 1996 the newly hatched herring larvae were concentrated especially on a station off Wamemunde as well as on a station in the Lübeck Bay.



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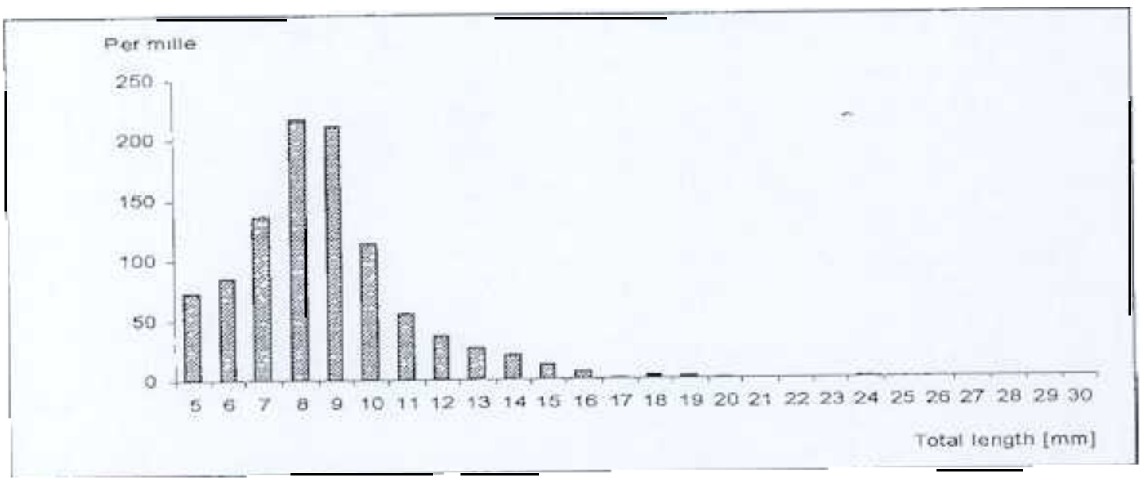

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These **data ascertain** spawning activities on small regional grounds along the German coast during the three years investigated – especially at the stations in the Kiel Fjord, in the Eckernförde Bight **and** north of the River Schlei mouth.

III. 7.4. *Sprat*

Larvae of sprat were not present in the plankton gear samples. Only two juveniles could be observed in the material of 1997 and 1998 For this reason the fish species sprat **was not** considered at the following statistical analyses.

III. 1.5. *Flatfishes*

Plaice larvae **were caught** only in May/June 1993, 1997, and 1998. The mean abundances were between 0.01 and 0.13 individuals per m^2 (see Table I). In 1998 97 % of plaice larvae were in yolk-sac stages.

Larvae of Common dab were represented in all years in the Bongo-Net catches. But up to now samplings yielded only low mean abundances between 0.01 and 0.2 larvae per m^2.

Flounder larvae could be caught only in 1997 and 1998. They rank second in the mean abundance of commercially important species (see Table I). The main length range of the larvae sampled was between 5 and 8 mm TL. All individuals were postlarvae after the completed resorbtion of the yolk.

111.2. **Species assemblage correlations**

Statistical analyses were performed with all data sets of the time series. Possible correlations between the occurrence of the different fish species in the years of investigation were studied by the multiple variable analysis.

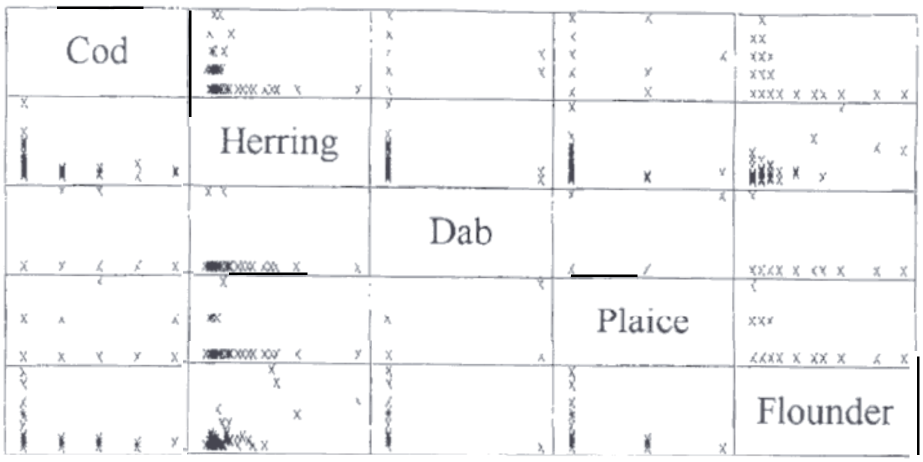
The results in connection with herring were strongly influenced by the abundances of some stations northern the River Schlei mouth. Here patches limited in space with high abundances of small herring larvae (length groups 4-7 mm) could be observed. The herring larvae of these length groups were eliminated from the data sets of the time series to get rid of the strong influence of these patches on the correlations of herring with other species in further analysis.

Only for 1997 (Figure 8 and Table V) and 1998 (Figure 9 **and** Table VI) sufficient data sets were available for the investigation, if cod co-occur with other commercially important fish species **of** the western Baltic Sea more than simply by chance.

Figure 8 shows the x-y plots of the larvae abundances per station for the combination of different fish species in 1997.

Fig. 8. X-Y plots of larvae abundances (n m^{-2}) of the survey in 1997, combination of different fish species after elimination of extreme data sets.

y-axis: n m^{-2}



Herring

Plaice

Flounder

x-axis: n m^{-2}

Cod Herring Dab Plaice Flounder

In Figure 8 can be seen that only a few flounder larvae were sampled on stations with high cod abundances and on stations with high plaice larvae abundances too. On stations with high cod larvae abundances only low herring larvae abundances were found. But there was no indication of significant correlations ($\alpha=0.05$) because of many pairs of variables with low abundances closely 0. This indicates a possible non-linear relationship between the variables.

Table V shows the Pearson product moment correlations between each pair of variables of the survey in May/June 1997. Furthermore it is shown in parentheses the number of pairs of data values. The third number in each location of the table is the P-value. It is a sign for a significant correlation between both parameters, if $p < a$ (first kind of error) with a = 0 05.

Table V. Correlations between all fish species in 1997.

	Cod	Herring	Dab	Plaice
Herring	*-0 2527* (52) *0.0707*			Correlation *(Sample size)* *P-Value*

Dab	0.1698 (52) 0.2289	-0.0747 (52) 0.5986		
Plaice	0.1898 (52) 0.1777	-0.1691 (52) 0.2308	0.3881 (52) 0.0045	
Flounder	-0.2145 (52) 0.1268	0.6372 (52) 0.0000	-0.1130 (52) 0.4252	-0.1769 (52) 0.2096

Significant positive correlations are indicated by P-values less than **a** = 0.05, which resulted for the following pairs of variables: Herring and flounder, Common dab and plaice. That means: On stations with high herring larvae abundances simultaneously many flounder larvae could be sampled and in reverse manner too. On stations with high plaice larvae abundances many Common dab larvae were present in the Bongo-Net samples and in reverse manner too.

Figure 9 shows the x-y plots of the larvae abundances per station for the combination of different fish species in 1998.

Fiq. 9. X-Y plots of larvae abundances (n m^{-2}) of the survey in 1998. combination of different fish species after elimination of extreme data sets.

v-axis: n m^{-2}

Herring

Plaice

Flounder

x-axis: n m^{-2}

Cod Herring Dab Plaice Flounder

Figure 9 shows that during the ichthyoplankton survey in 1998 only a few Common dab larvae could be sampled on stations with high cod larvae abundances. Only low herring larvae abundances could be observed on stations with high cod abundances. There was no indication of significant correlations (α=0.05) because of many pairs of variables with low abundances closely 0. Like in 1997 this indicates a possible non-linear relationship between the vanables.

Table VI gives the correlations between the pairs of variables for 1998.

Table VI. Correlations between all fish species in 1998.

	Cod	Herring	Dab	Plaice
Herring	0.1532 (57) 0.255			Correlation (Sample size) P-Value
Dab	0.0159 (57) 0.9065	0.1662 (57) 0.2165		
Plaice	0.3521 (57) 0.0072	0.1181 (57) 0.3818	0.2958 (57) 0.0255	
Flounder	0.1543 (57) 0.2517	0.0607 (57) 0.6535	02042 (57) 0.1277	0.1611 (57) 0.2311

The following pairs of variables have P-values less than α=0.05: Cod and plaice, Common dab and plaice
On stations with many cod larvae simultaneously many plaice larvae could be caught and vice versa. The positive significant correlation between plaice and Common dab means that on stations with many plaice larvae also many Common dab larvae were to be observed and in reverse manner too.
In 1997 and 1998 the correlations were strongly influenced by single stations with the combination of extreme data (see Figure 8 and 9).
For the surveys considered the multiple variable analysis showed no general relations between the larvae abundances of the fish species. The results were different in the years investigated. Reasons could be the varying plankton survey time from year to year and the yearly different dynamic in the development of the early life stages of the fish species.

In 1993 no cod larvae and flounder larvae were sampled with the plankton gear Plaice larvae were observed only on two stations. Flounder larvae and plaice larvae we:-e not present in the Bongo-Net samples of 1994 and 1996. Therefore the multivariate statistical analysis was limited to the species combination cod - herring - Common dab in 1994 and 1996. There could be ascertained no significant correlations between the larvae abundances of the fish species investigated. All p-values were more than 0.4 at $\alpha=0.05$.

IV. **Discussion**

Two distinct stocks of cod exist in the Baltic Sea with a border immediately west of Bomholm (14" 30' E): the western Baltic cod stock *Gadus morhua morhua* and the eastern Baltic cod stock *Gadus morhua callarias*.

Three main spawning areas for the eastern Baltic cod stock (the Bornholm Basin the Gotland Basin and the Gdansk Deep) and a secondary spawning site in the Slupsk Furrow are identified (Bagge *et* a/. 1994).

Margonski ef al. (1996) estimated an average of 3.8 larvae/m^2 for August 1994 and for September 1994 an average of 1.3 larvae/m^2 for the eastern stock in the Bornholm Basin. Other authors (Anon. 1998) found maximum concentrations between 0.26 individuals/m* (July and August 1996) and 1.26 individuals/m^2 (May 1995). According to the definition of Margonski et al. (1996) and Grauman (1973) these abundances **are closely** the values characteristically for a low spawnlng efficiency. In the eastern Baltic Sea the decrease of cod larvae abundance after mid 1980's is determined by a strong decrease of the spawning stock size and also with changes in spawning time towards the late summer in 1990's (Anon. 1998). Furthermore the reproduction of cod in the Bomholm Sea is greatly influenced by environmental conditions. An important factor for the successful cod egg survival and development is the reproductive volume, i.e. the thickness of the reproduction layer with salinity values more than 11 PSU and oxygen contents more than 2 ml/l (Margonski *et* al. 1996, Tomkiewicz and Köster 1999).

The time series derived from the Bongo-Net samples in the western Baltic Sea shows a very slight increase in larval abundances of the cod stock *Gadus morhua morhua*. But in the period investigated the level of the mean values (O-O.13 cod larvae and juveniles/m*) was below the mean abundances of cod larvae in the Bornholm Basin (according **to** Margonski ef al. 1996 and Anon. 1998: 0.26-3.8 larvae/m^2).

The major spawning ground of the western Baltic cod stock can be subdivided into four typical subareas (Hinrichsen et al. 1999 and Bagge et al. 1994):

Great Belt

Little Belt, Kiel Bay, Langeland Belt and Fehmam Belt

Mecklenburg Bay

Œresund

52 % of cod sampled during the ichthyoplankton survey in May 1998 were newly hatched larvae. These small cod larvae were concentrated on stations in one of the subareas of the major spawning ground: in the southern Little Belt,

For 1994 Oeberst and Bleil (1996) showed that despite a decreased size of this cod stock an essentially larger amount of spawned eggs was produced. This may due to the changed age composition of the stock in 1994 compared with 1993. A good egg production but low larvae numbers were confirmed by Anon. (1994) too. In accordance with these results only a low number of cod larvae as a part of altogether 3,194 fish larvae were sampled during the ichthyoplankton survey in June 1994.

The recruitment success of the western Baltic cod stock is influenced by factors different from those, which are important for the eastern stock (Oeberst and Bleil 1999, 2000). The influence of the hydrographic situation at the spawning time and the influence of the predator sprat can be neglected in the ICES Subdivisions 22 and 24. The condition of female cod in March (Fulton's condition factor) has no statistically significant influence on the year-class strength. According to the authors the year-classes in the western Baltic Sea are mainly determined by the strong variations of the portions of female cods, which participated in the spawning activities in this region. The individuals within the length range from 35 cm to 45 cm have a special importance at this time, caused by the actual age structure of the cod stock (Oeberst and Bleil 2000). The hypothesis that inflow events in autumn/winter of the previous year influence the year-class strength is supported by the fact that between 1983 and 1990 mostly poor year-classes and no effective inflow events could be observed in the western Baltic Sea (Oeberst and Bleil 1999). The authors conclude that for the development of a cod year-class in the western Baltic Sea factors are important, which have effects before the egg output. This differs from the results in other marine areas. There factors after the spawning mainly determine the year-class strength. ICES (1998), Ernst (1997), and Frieß (1997) estimated strong cod year-classes 1994, 1996, and 1997 on the basis of youngfish surveys. This is in contrast to the low numbers of cod larvae sampled during the ichthyoplankton surveys of those years.

According to Bleil and Oeberst (1997) in ICES Subdivision 22 the spawning process of cod began in February. In March the cod spawning intensity was high. At the same time the spawning process began in the Arkona Sea (ICES SD 24) and in the Bornholm Basin (ICES SD 25) (Bleil and Oeberst 1997). Thompson and Riley (1981) presented regression curves for the temperature and the duration of the egg development for North Sea cod using artificially fertilised eggs in the laboratory. Wieland (1994) confirmed these incubation times for artificially fertilised cod eggs from the central Bomholm Basin. Kuhn (1998) investigated the egg development and hatching success of the western Baltic cod (*Gadus morhua L.*) under defined conditions in a marine aquaculture hatchery. The author described the larvae hatching at mean water temperatures of 10° C after 12-14 days of the embryonic development. Successful cod egg survival with high survival rates could be observed during investigations of Baltic cod broodstocks under natural conditions in the Kiel Bay (Oeberst and Böttcher 1996). According to the authors the duration of egg development before hatching was about 14 days at water temperatures of 6" C to 7" C. From hydrographic observations of the Institute for Baltic Sea Research Wamemunde it is known that the bottom temperature in the western Baltic Sea in February, when the cod spawning process is starting in ICES SD 22, vanes between 2" C and 4" C. From these results Oeberst and Böttcher (1998) used a mean value of 20 days for the time interval between the spawning and the hatching of cod larvae in this area. Following the results of the authors above mentioned ship time for sampling cod larvae after the peak spawning in the western Baltic Sea must be at the end of April. Cod larvae sampled during a survey that started at the 20th April will also represent the hatching cohorts of the end of March, when the cod spawning intensity in ICES SD 22 is high. The ichthyoplankton surveys in ICES SD 22 and 24 as part of the cruises in May or June were too late in time for sampling cod larvae after the peak spawning. A temporal shift of these surveys was impossible due to the vessel's schedule. In 1998 the survey has been performed in the same area of investigation during the period 15 May-29 May. Newly hatched cod larvae could be sampled for instance in the Lübeck Bay and in the southern Little Belt. That was for the first time in our time series.

During the period 1987 to 1992 the Institute for Marine Research Kiel sampled in the Kiel Bay cod larvae only in single numbers (O-l larva per 10 000 m 3) (Schnack 1993). This may reflect a presently extremely low cod stock size. However in the catches of special youngfish surveys a larger amount of juvenile cod was ascertained. According to Schnack the slight numbers of larvae could suppose that the juveniles are not primarily from local spawning grounds in the Kiel Bay, but immigrated from the adjacent area.

The low numbers of cod larvae sampled after the peak spawning during the surveys in May or June could be caused by the eastward orientated drift of early cod life stages too. Hinrichsen et *al.* (1999) pointed out that the pelagic early life stages of the western Cod stock can be transported from the Kiel Bay and the Mecklenburg Bay towards the east by wind-induced drift. Results are based on the numerical simulations of the circulation of the Baltic Sea during the major spawning season of cod for two years with considerably different wind forcing conditions (1 986 and 1993) by application of the three-dimensional eddy-resolving baroclinic model of the Baltic Sea (Lehmann 1995). Extent and range of the drift of the eggs, larvae and juveniles of Baltic cod are dependent on the wind forcing conditions. Transport from the Œresund as well as from the Great Belt could be assumed to be possible only during periods of strong wind forcing of mainly western direction. According to Hinrichsen *et* al. (1999) significant eastward orientated drift of early cod life stages from the Kiel and Mecklenburg Bay also was evident during periods of minor westerly wind influence.

Oeberst (1999) used the results of bottom trawl surveys to estimate the portion of cod in different year-classes of the eastern Baltic Sea stock, which was spawned in the Kiel or Mecklenburg Bay. The analyses showed that in every year between 1993 and 1998 juvenile cods, which were spawned in ICES Sub-division 22, were transported into the Bornholm Sea.

At present the herring, which is spawning during the spring onshore in shallow estuaries, bights and haffs (Rechlin and Bagge 1996), prevails in the western Baltic Sea. In these shallow areas the early developmental stages grow up after hatching. Kändler (1952, 1961) pointed out that the Kiel Fjord plays an important role as spawning ground and nursery area for the recruitment of the spring spawning herring of the Kiel Bay. Numerous spawning grounds of the herring population of the western Baltic Sea are distributed onshore from the north of the River Schlei to the Pommeranian Bay. During the ichthyoplankton surveys in all the years investigated (1996-1998) newly hatched herring larvae could be sampled on small regional spawning grounds along the German coast, especially on stations in the Kiel Fjord, in the Eckernförde Bight and in front of the River Schlei mouth. These results are in accordance with the statements of Kändler (1952, 1961) and Rechlin and Bagge (1996).

Rechlin and Bagge (1996) described a continuously increasing sprat stock in the Baltic Sea with a prolonged spawning period since 1988. Sprat biomass is currently on its highest level on record (Anon. 1998). International time series of sprat recruitment and spawning stock biomass of the central Baltic Sea (Anon. 1998) demonstrate large variabilrty. But there is no evidence of relationship between these variables.

For the period 1977-1980 Krenkel (1981) reported mean densities of O-O.1 sprat larvae/m^2 in the Belt Sea (ICES Subdivision 22). The author discussed that in May and June in this area either the peak spawning time had not been reached or the ICES area SD 22 was unimportant for sprat spawning. It must be noticed that in 'I978 only four and in 1980 only nine ichthyoplankton stations were sampled by Krenkel with the UNESCO WP 2 Closing Net In the Arkona Sea (ICES Subdivision 24) the total number of the sprat larvae caught by Krenkel (1981) was low (O-l.3 larvae/m*). According to different authors (Kändler 1949 in Krenkel 1981, Lindblom 1973, Anon. 1998) the ICES area SD 24 is not an important sprat spawning area. That is supported by the results of our time series: In ICES Subdivisions 22 and 24 only two juvenile sprat in 1997 and 1998 and no early life stages of sprat in the other years were sampled. The most important area for the reproduction of sprat is east of the Island Bomholm (ICES Subdivision 25) (Grauman and Krenkel 1986).

Rechlin and Bagge (1996) reported that in the western Baltic Sea the size of the European plaice stock decreased to 7 % of the previous level during the nineties. This is in accordance with our results: During the ichthyoplankton surveys larvae of this commercially important species were sampled only in 1993 and 1997. And they were caught only in low numbers.

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