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Interrelation between invertebrate plankton and larval fish development in the Schlei fjord, Western Baltic

D. Schnack and R. Böttger

Institut für Hydrobiologie und
Fischereiwissenschaft der
Universität Hamburg, Hamburg, Germany

Abstract

Results obtained from plankton sampling in the Schlei during spring over a couple of years are discussed with regard to the significance of predator-prey relations for the development of invertebrate plankton and larval fish populations. In spite of a large number of fish larvae growing up in this area in spring, a characteristic minimum in total biomass of the invertebrate plankton in June does not appear to be caused by predation. However, in years of high abundance of herring larvae, the size selective feeding at the estimated rates may be supposed to accelerate the decline of the copepod population, and thus to expand and intensify food limitation for the larvae in June.

Introduction

The Schlei fjord, a shallow, long and narrow inlet of the western Baltic Sea (Fig. 1), is an area of high plankton production. It is intensively utilized as a nursery area by larval fish populations in spring and early summer and by the young fish later on.

Compared to neighbouring coastal inlets in this region, the Schlei is a fairly closed area. The exchange of water masses with the Baltic Sea is largely restricted (NELLEN and RHEINHEIMER 1970), but varying in and outflow conditions may still change the distribution of the plankton in the outer parts of this fjord within short time intervals. In general, passive transport of organisms out of or into the Schlei is considered to be of minor importance for the total standing stock in the area, and conditions appear favourable for studies on the development of plankton populations and interactions within the plankton community.

Corresponding to a pronounced decrease in salinity within the area, the characteristic mass development of scyphomedusae in spring and summer in western Baltic waters (MÖLLER 1979) does not spread very far into the Schlei. Thus, in the absence of any significant predator and competitor population, larval fish seem to find optimal conditions for their development in this fjord. The high abundance of fish larvae observed in spring and a pronounced decline of the copepod population during the time of larval development lead to the questions of whether predation by fish larvae might have any significant effect on the copepod population and, on the other hand, how fluctuations in the plankton composition and abundance may influence the development of the fish larvae.

Plankton sampling in the Schlei during spring over a couple of years provided results that allow some discussion of these problems.

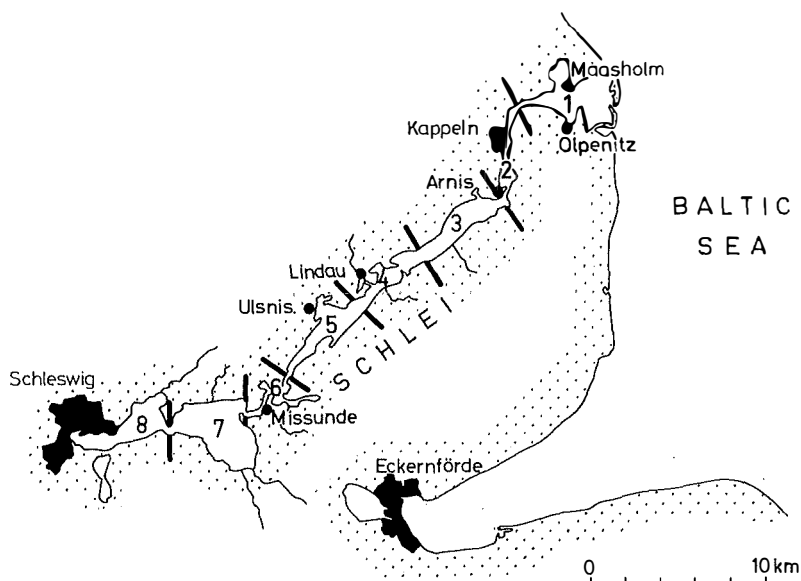


Figure 1

The Schlei divided into sub-areas within which at least one sample was taken during each survey

Material and methods

Sampling was carried out during the period of April to June in the years 1972 to 1975. Stations were situated in the fairway of the Schlei within 8 successive sub-areas, indicated in Figure 1.

Fish larvae were sampled by Miller nets (MILLER 1961), towed simultaneously at 3–4 different depths within a range of 3 m; in addition, surface samples were taken by a modified David Neuston sampler (HEMPEL and WEIKERT 1972). Both types of nets had a 0.3 mm mesh size.

Invertebrate plankton was sampled by a small version of an unencased Gulf III model, so-called Babyhai (SCHNACK 1972), fitted with a net of 0.05 mm mesh size.

Average densities of larvae at each station were calculated by linear interpolation between results from sampled depth layers.

Selected Babyhai samples were analysed for the composition and abundance of invertebrate plankton. Biomass estimates were made based on length-weight relationships established for the main copepod species *Eurytemora affinis* from unpreserved material, and on published data for other zooplankters. Additionally, settling volumes were determined as a rough measure of biomass from a larger number of samples.

Ichthyoplankton

During the three months considered here, a large number of fish larvae grew up in the Schlei. The species diversity is low and – as may be expected – the composition changes when proceeding from the western Baltic water of the outer region to the inner oligohaline parts of this fjord. Only two groups of larvae, herring and gobiids,

populate the whole area of the Schleie, and quantitatively, these two groups account almost exclusively for the high ichthyoplankton abundance in this area.

Herring larvae form the predominant group, being on average about twice as abundant as all other fish larvae. Quantitative data are therefore given for herring and other fish larvae separately.

The distribution and abundance of fish larvae except herring are presented in Fig. 2. Results from different years are combined for each month in one graph in order to show the range of variation between years at comparable time periods. (Note the logarithmic scale.)

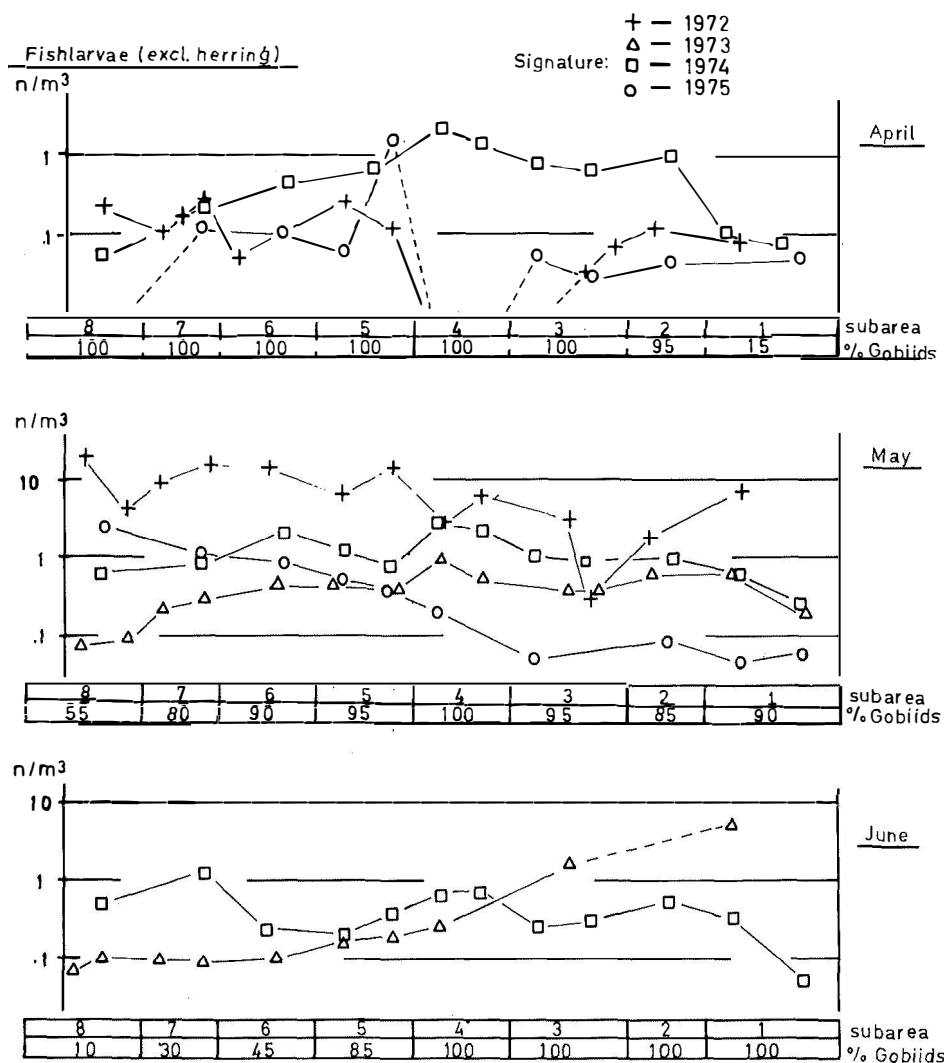


Figure 2

Variation in time of the abundance and distribution of fish larvae in the Schleie, except herring. Percent gobiids refers to total catch in the respective sub-area

The three surveys in April were each carried out near the end of the month. This is about the start of the hatching period of the gobiids (NELLEN 1968), which contribute almost exclusively to the ichthyoplankton at that time besides herring. Youngest stages of gobiids are present only, and differences between years in the abundance and distribution of the larvae largely depend on the varying state of progress in spawning and hatching governed by the seasonal increase in temperature.

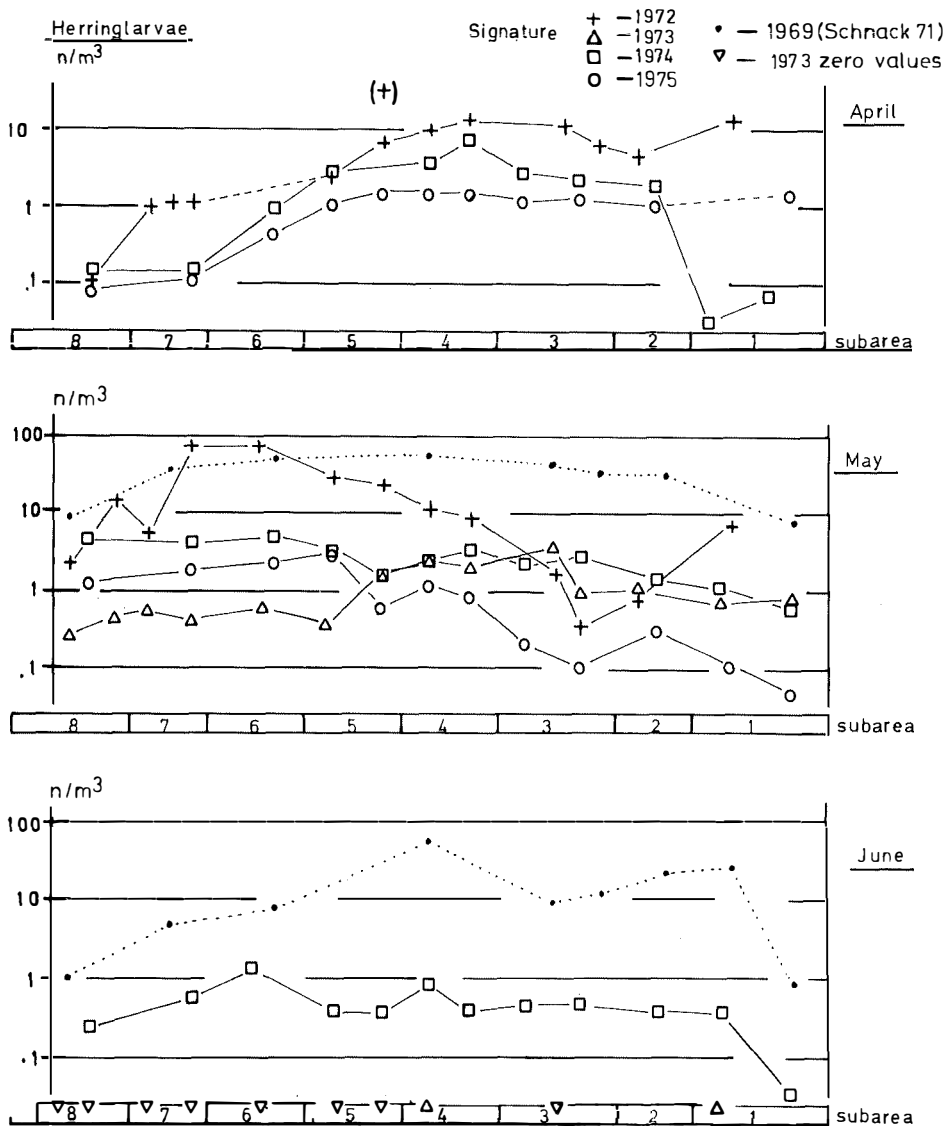


Figure 3

Variation in time of the abundance and distribution of herring larvae in the Schlei

In May and June, fish larvae are more completely distributed over the whole area. Spawning and hatching of gobiids are not terminated during the three months period of observation. Thus youngest stages are present in June as well as before. Since older stages settle to the bottom, most of the gobiids in the plankton are not larger than 10 – 20 mm in length.

The abundance and distribution of herring larvae are summarized in Fig. 3. Hatching starts somewhat earlier as compared to the gobiids, and at the end of April already significant numbers of herring larvae have been encountered over an extended central part of the Schlei. Youngest stages predominate.

In May, herring larvae show very much the same general pattern of distribution as gobiids, and also a very similar variation in the distribution between single survey dates. This similarity supports the assumption that the actual distribution over the length of the Schlei of these two main groups of larvae is governed to some significant degree on passive transport by water masses related to the varying in and outflow conditions.

Irrespective, however, of the specific distribution at the date of sampling in May, the observed abundance values in the central part of the Schlei (sub-areas 4 and 5) represent roughly average values for the whole area. The variation in the abundance between years is in the range of about two orders of magnitude.

On average, density levels tend to be in the range of 1 – 10 larvae/m³.

During May, hatching of herring larvae still continues with decreasing intensity, and a shift of the hatching areas to the outer region is noticed. In late May, however, the main part of the larval herring population consists of older larvae. Modes in the length distribution of the dominant size groups are frequently around 15 mm and approach 20 mm in the inner part of the Schlei. In June, mean lengths are mostly well above 20 mm or even above 30 mm at the end of the month.

The restricted spawning period of the herring is reflected by the decrease in abundance of larvae from May to June. Taking into account the different time spans between the monthly surveys in 1969 and 1974, the rate of decrease is in the order of 5 % per day in both years. In 1973 the population was almost depleted in June.

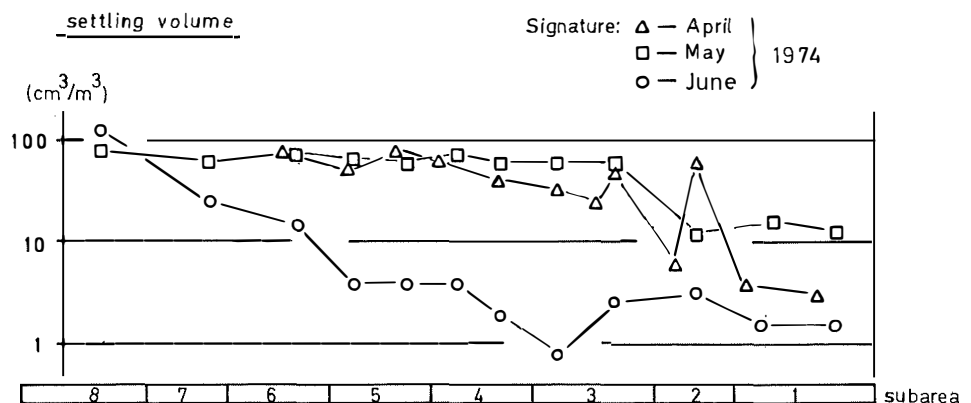


Figure 4

Distribution of invertebrate plankton biomass (settling volume) in the Schlei at three survey dates

Invertebrate plankton

The most comprehensive faunistic description of the plankton in the Schlei fjord, including the annual succession cycle, is given by BUCHHOLZ (1952). Quantitative results have been discussed under different aspects by LENZ (1970), SCHNACK (1972), HIRCHE (1974). The copepod *Eurytemora affinis* Poppe, a widely distributed and important estuarine species (e.g. JEFFRIES 1962) largely predominates in the Schlei plankton in spring and is replaced for the most part by *Acartia tonsa* Dana in summer. The present study is restricted to a period prior to the development of the *Acartia* population.

A general picture of the plankton density in the Schlei and of its variation in space and time may be derived from the data of settling volume. Only results from 1974 are presented, since for this year the most complete series of samples is available (Fig. 4).

A comparison of settling volumes of samples from different years with corresponding data on dry weight, calculated from the number and weight of the organisms (BÖTTGER 1979), resulted in fairly constant relations between both measures for the central part of the Schlei. The ratio of cm³ settling volume to mg dry weight was in the range of 1/30 to 1/40, which corresponds well to a respective value of 1/37 given by LENZ (1970).

Thus, in 1974, the actual biomass in the central part of the Schlei was above 1.5–2 g dry weight per m³ in April and May and less than 0.1–0.2 g/m³ in June.

Proceeding from the center to both ends of the Schlei, the actual biomass is increasingly overestimated by the settling volume due to an increasing amount of

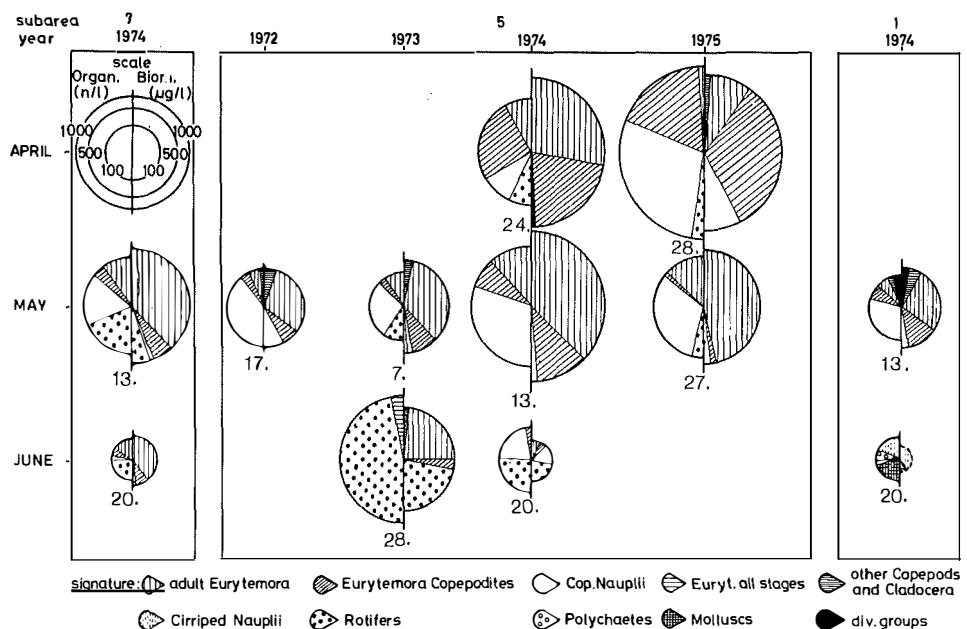


Figure 5

Variation in time of the abundance and composition of invertebrate plankton in three sub-areas of the Schlei. The radius of each half sphere is proportional to the cube root of the actual density level; the number at each sphere indicates the day of sampling

detritus in the samples. In June, the settling volume is additionally affected by high amounts of Cyanophyceae, so that the actual difference between May and June in the zooplankton biomass is even more pronounced than indicated in Figure 4.

Figure 5 summarizes results of the composition and abundance in number and dry weight of the invertebrate plankton for three sub-areas, representing the inner, the central, and the outer part of the Schlei. The comparison between years is restricted to the central sub-area 5, since this area is out of the range of major variations related to in and outflow conditions, and also it provides the most reasonable value of larval fish density for comparison.

In April and May the invertebrate plankton – retained by 0.05 mm mesh size – consists almost exclusively of the copepod species *Eurytemora affinis*. It may be pointed out that in May nauplii are regularly abundant in relative and absolute numbers and copepodites are present in rather low proportion only, being less abundant than adults. A drastic change is apparent from May to June: rotifers are now dominant in the central part of the Schlei, and in 1974, the adult and copepodite population of *Eurytemora* has largely decreased, despite of the high number of nauplii in May. In June 1973, at a rather late sampling date, the adult *Eurytemora* population was not very different in size from the population in early May.

For 1972, HIRCHE (1974) reported extremely low values (< 10 adults and copepodites/l) in early June and higher values (130/l) in late June for the sub-area considered.

Also, in 1969 SCHNACK (1972) found a very low abundance of *Eurytemora* in mid-June (27/l) and LENZ (1970) reported low levels at the end of June as compared to May values; in the latter case, absolute values (about 180/l, interpolated between stations) were not as low as those of the earlier sampling dates in June of the years 1969, 1972 and 1974.

Based on this comparison, it is assumed that a pronounced decline of the *Eurytemora* population may generally be observed from May to June and that a period of extremely low abundance of copepodites and adults may occur in the first two to three weeks of June.

Discussion

The possible interrelations between the invertebrate plankton and larval fish populations will be discussed on the basis of the above given information, and of published data on the feeding of herring and gobiid larvae (SCHNACK 1972) WOSNITZA 1975), and the ecology of *Eurytemora affinis* (KATONA 1970, HIRCHE 1974). Referring to the succession of generations of *Eurytemora* in the Schlei, reported by HIRCHE (1974), the start of the hatching period of gobiids and the main hatching time of herring seem to coincide roughly with the start of the third generation of *Eurytemora* at the end of April/beginning of May. The generally high abundance of early developmental stages of copepods provides a very favourable food supply for the young fish larvae.

The continuously large portion of youngest larval stages in the pelagic gobiid population seems to correspond to favourable feeding conditions throughout the time of observation, according to the dominance of adequately small food organisms.

Most of the herring larvae in May preferably prey on copepodite stages and they also select adult copepods with increasing intensity in the course of May and June. The question thus arises whether, by the pronounced selective feeding on the larger

developmental stages of *Eurytemora* in May and June, the observed numbers of herring larvae significantly affect the copepod population.

A first estimate of the possible effect of predation refers to the conditions encountered in sub-area 5 in May 1974, a year of average abundance of larvae but comparably high plankton density:

The daily ration consumed is estimated on the basis of a feeding time of 18 hours per day (BLAXTER 1966), an average gut content of 5 and 10 food organisms with a mean size of 0.3 and 0.6 mm, as reported for two main length groups of herring larvae (14 and 19 mm) in the Schlei in May, and a rate of food passage through the gut of 1 and 2 mm/h respectively (SCHNACK 1972).

A total of about 200 organisms is thus estimated to be consumed per day by the average number of 3 larvae per m³. About half this amount is obtained by using a constant rate of food passage of 0.5 mm/h according to results from ROSENTHAL and HEMPEL 1970. This consumption appears negligible in view of the observed abundance of about 230 000 copepodites/m³ as the preferred prey.

Much higher numbers of larvae and lower levels of plankton density have been observed in 1972 and also in 1969 (SCHNACK 1972). In these years a value of about 30 000 copepodites per m³ has to be compared with the feeding potential of about 50 herring larvae per m³ in sub-area 5. The fact that the herring larvae do not exclusively feed on copepodite stages is assumed to be roughly counterbalanced by the additional feeding of all other fish larvae. The daily predation rate is estimated to be in the order of 1500 – 3500 organisms per day and m³, which is about 5 % – 10 % of the standing stock of copepodites per day.

The relative importance of this predation for the *Eurytemora* population as a whole may be assessed only by comparison with the total mortality and the rate of recruitment of those stages preferred as prey. The regularly high proportion of nauplii in May implies that the decline of the population of older stages from May to June is not primarily caused by predation and low reproduction, but rather by a high mortality of early developmental stages due to other reasons. An increased mortality at this time could be related, for instance, to the pronounced change during May in the dominating phytoplankton groups, as described by SCHIEMANN (1974) for the year 1972. On the other hand, in case of especially high mortality of nauplii and therefore largely restricted replacement of copepodites, the above estimated predation rates indicate that a dense larval herring population, by selectively feeding on the late stages of *Eurytemora*, may significantly accelerate the decline of the copepod population, and thus expand and intensify its own food limitation in June.

A more definite assessment of the indicated relationships needs further information on the main factors governing the reproduction of *Eurytemora* in the Schlei and the mortality especially of early developmental stages. With respect to the possible effects of food limitation on the larval fish population, more frequent observations are necessary for a better definition of the time sequence of changes in the food supply and the effect on the feeding rate. According to the results from BLAXTER and EHRLICH (1974) on the survival time of starving herring larvae, the indicated time span of possible food shortage in June does not give evidence that this period might be in fact critical for the development of the larval herring population in the Schlei. However, some density effect on growth and survival of herring larvae appears possible at the upper end of the observed range of variation in larval abundance.

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