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On the Acartia species of the northern wadden sea of Sylt

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Abstract

From June 1975 to June 1976 the zooplankton and phytoplankton content of the Lister Ley (northern wadden sea of Sylt, German Bight) was measured. The dominant group of the zooplankton were the calanoid copepods with the main genus *Acartia*. Three species of *Acartia* were found during the period of investigation. *Acartia tonsa* could be found in large numbers only in spring 76. *Acartia clausi* and *Acartia discaudata* showed several peaks from June 75 to October 75. Three of these populations were produced by larval development in the research area; the time span of each generation was 5 to 5 1/2 weeks. In many cases there were correlations between the increase of *Acartia* nauplii and blooms of distinct phytoplankton species. A bloom of *Phaeocystis pouchetii* had a negative effect on the copepod populations. When drifting through the northern wadden sea of Sylt, *Acartia clausi* formed larger populations than in the north Frisian coastal water. In *Acartia tonsa* there was a marked decrease in population density within the wadden sea area.

Introduction

Along the whole German North Sea coast the transition zone between the mainland and the open sea is formed by the wadden sea areas. They stretch over 450 km between the Netherlands and Denmark. Because of their ecological characteristics they occupy a special position. Nowhere else in the world can comparable ecosystems of such dimensions be found. They are of great practical importance with regard to the protection of the coastal areas, the reclamation of land, fishery and tourism. The northern wadden sea of Sylt (German Bight) occupies a special position within the German wadden sea areas. It is isolated from the neighbouring wadden sea areas by the Römö Dam in the North and the Hindenburg Dam in the South. There is only a small inlet, about 3 km wide, between the islands of Römö and Sylt, through which the water exchange with the north Frisian coastal water can take place. As a result of the Coriolis-effect the inflowing tidal current is deviated in a southward direction. This leads to a counterclockwise current within this wadden sea area. The mean tidal range in this area is about 1.7 m. 52 % of the northern wadden sea of Sylt is tidal land (HICKEL in prep.).

This study is a contribution to the knowledge of the structure of this ecosystem dealing with the dominating calanoid copepod *Acartia* sp. (MARTENS 1980).

Material and methods

From June 1975 to June 1976 the zooplankton and phytoplankton content of the Lister Ley was measured on 83 days (Fig. 1). Samples were taken with water bottles at high and low tide. 35 liters were taken for zooplankton analysis and sieved using a mesh size of 75 μm. The preserved zooplankton (3 % formalehyde solution) was analysed

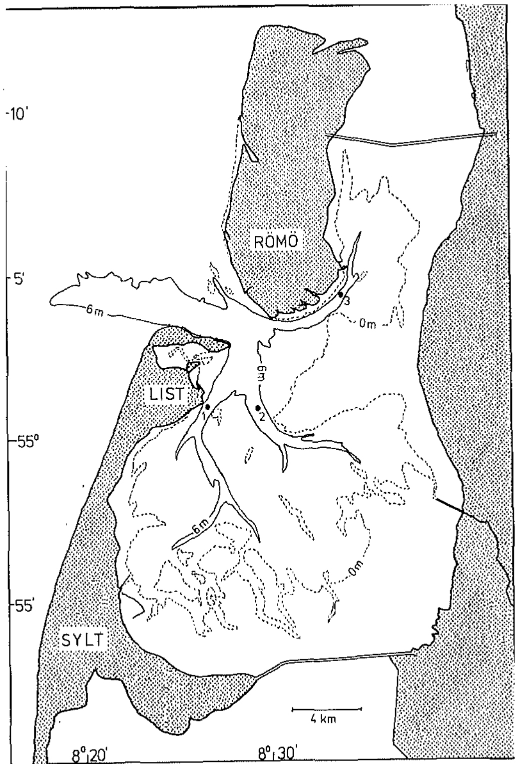

Figure 1

Map of the northern wadden sea of Sylt. Depths refer to mean spring low tide. Station 1: Lister Ley; Station 2: Höjer Dyb; Station 3: Römö Dyb

under the stereo microscope down to the species level. Phytoplankton, preserved and stained with Lugol solution, was counted by means of an inverted microscope.

In addition measurements were made on temperature (bucket temperature), salinity (Autolab-salinometer), particulate organic carbon and nitrogen (CHN-Analyzer HP 185 B), seston dry weight (v. BRÖCKEL 1973) and micro-nutrients (auto-analyzer) (HICKEL, in prep.). Strong turbulent water movements prevented vertical stratification (HICKEL 1975), so one water depth was taken as representative for the whole water column (current speed up to 3 knots). In addition to the measurements at station 1 (Fig. 1), the same measurements were made from January to June 1976 at stations 2 and 3 at low tide for 20 days altogether. As a result of the counterclockwise current, the plankton populations found at stations 2 and 3 have been exposed to wadden sea effects for a longer time than those found at station 1. So possible effects will best be demonstrated in a comparison of the populations at station 1 to those at stations 2 and 3 (MARTENS 1980). Differences in the zooplankton standing stock at the three stations were tested with the U-Test after Mann and Whitney (SACHS 1974). A value '$\hat{z}$' with a probability of 0.05 at the most was regarded as significant.

The significance of correlations between the parameters measured was tested by Spearman's rank correlation (SACHS 1974). Normal linear correlation gave the same results in all cases. A calculation of the relation between nauplii and adults of *Acartia* was done in the following way: An observed increase of nauplii over a certain time period up to a maximum was correlated with an observed increase of adults of a certain *Acartia* species. This increase of adults happened some weeks later than the increase of nauplii (time lag correlation). The difference in time between the increase of nauplii and adults (the time lag) is assumed to be the generation time, the time of larval development from egg to the adult female. A correlation between nauplii and adults is regarded as significant when the probability of its occurring by chance reaches or falls below the 5 % level. A comparable method was used by KRAUSE and RADACH (1980).

Results

Three *Acartia* species were found during the year. *Acartia tonsa* was found in higher numbers only in spring 1976 (Fig. 2). Increase and decrease of the standing stock was correlated significantly with changes in salinity (Table 2). A larval development from nauplii to adults in the research area could not be determined. With the beginning of the bloom of *Phaeocystis pouchetii* the standing stock decreased to zero values.

In early summer 1975, after the *Phaeocystis* bloom had come to an end, *Acartia clausi* (Fig. 3) and *Acartia discaudata* (Fig. 4) reached higher numbers. Up to October 1975 several distinct maxima of occurrence could be found in both species. In three cases there was a significant correlation between nauplii and the adults of these two species. An increase of nauplii in August 1975 was correlated with an increase of *Acartia clausi* ($n = 11$; $r_s = +0.555$) and *Acartia discaudata* ($n = 11$; $r_s = +0.564$) in September (Fig. 5 and 6). An increase of nauplii in September was correlated with adults of *Acartia clausi* in October ($n = 11$; $r_s = +0.727$) (Fig. 7). Therefore two generations of *Acartia clausi* and one of *Acartia discaudata* developed in the research area during

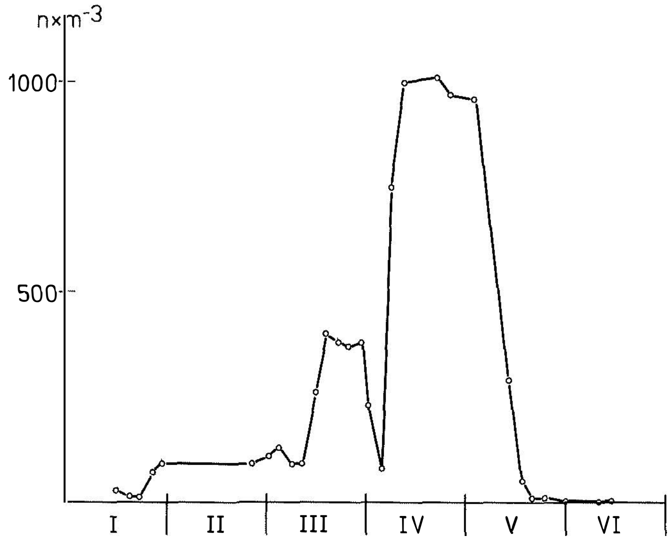

Figure 2

Occurrence of *Acartia tonsa* in the Lister Ley (Station 1) at high tide from January to June 1976; the curve was smoothed using a 5-times overlapping mean

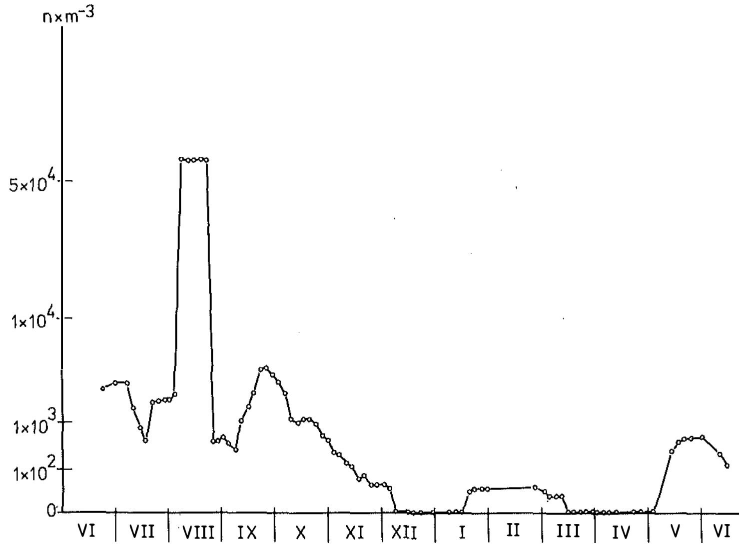

Figure 3

Occurrence of *Acartia clausi* in the Lister Ley (Station 1) at high tide from June 1975 to June 1976. The curve was smoothed using a 5-times overlapping mean. The y-coordinate was distorted by using the cubic root

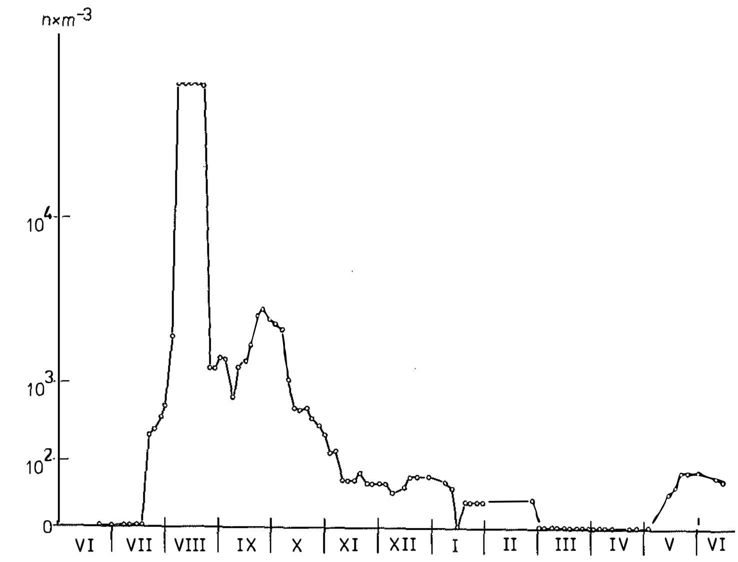

Figure 4

Occurrence of *Acartia discaudata* in the Lister Ley (Station 1) at high tide from June 1975 to June 1976. The curve was smoothed using a 5-times overlapping mean. The y-coordinate was distorted by using the cubic root

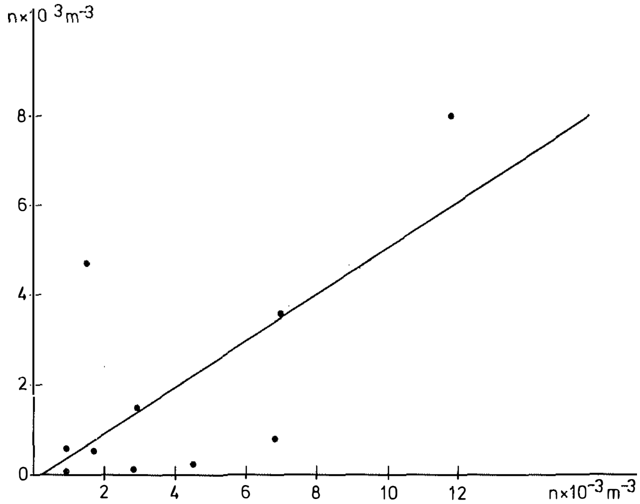

Figure 5

Linear correlation between adult *Acartia clausi* and *Acartia* nauplii in August-September 1975 (Station 1; high tide)
Acartia clausi = –0.117 + 0.517 x nauplii
number of data-pairs: 10
linear correlation coefficient r = + 0.6896
Spearman's rank correlation coefficient r_s = + 0.555

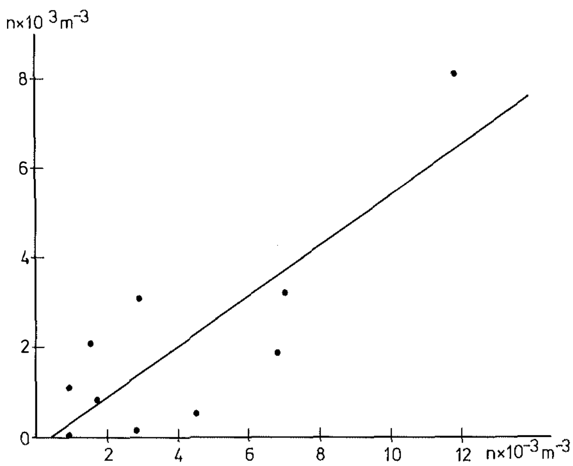

Figure 6

Linear correlation between adult *Acartia discaudata* and *Acartia* nauplii in August-September 1975 (Station 1: high tide)
Acartia discaudata = –0.2109 + 0.5635 x nauplii
number of data pairs: 10
linear correlation coefficient r = + 0.8241
Spearman's rank correlation coefficient r_s = + 0.564

September–October. The space of time between the maxima of occurrence of nauplii and adults, the generation span, was 5 to 5 1/2 weeks.

The relation of females to males, the so-called sex ratio, can be an indication of the age of a copepod population. As the females live longer than the males (MARSHALL 1949, ERIKSSON 1973), the ratio of females to males rises during aging of the population. The sex ratio of the three populations which developed from nauplii in the research area was markedly lower than 1 (Table 1), which indicates a low age of the population.

Table 1

The sex ratio of different *Acartia* populations in 1975 in the northern wadden sea of Sylt

$\bar{X}$ = mean value
n = number of values to compute $\bar{X}$

Copepod species	time of research	sex ratio ($\bar{X}$)	n
Acartia clausi	September 1975	0.81	9
Acartia clausi	October 1975	0.75	10
Acartia discaudata	September 1975	0.64	10
Acartia clausi	June–August 1975	2.10	10
Acartia discaudata	June–August 1975	2.10	6

The populations found in July-August could not be explained by larval development in the wadden sea area. There was no correlation between nauplii and adults. However, there was a significant correlation between the increase of adult *Acartia* sp. and changes in salinity (Table 2), indicating an influx of new water bodies. The sex-ratio of these populations was markedly higher than 1 (Table 1) with a maximum of 6.2. This indicates an old age for these populations which drifted into the wadden sea area by hydrographical processes.

Table 2

Correlation between changes in salinity and increase of the population density of *Acartia* sp.

r_s = Spearman's rank correlation coefficient
n = number of data pairs
S = rate of change in salinity during the time of research

Copepod species	time of research	r_s	n	S
Acartia clausi	June–July 1975	+ 1.000	4	30.16–31.27 ‰
Acartia clausi	July–August 1975	+ 0.762	8	31.33–32.02 ‰
Acartia discaudata	July–August 1975	+ 0.714	8	31.33–32.02 ‰
Acartia tonsa	May 1976	− 0.555	10	30.17–29.80 ‰

A few days after the adult *Acartia* sp. showed a maximum, a maximum of nauplii could be found too (Fig. 8). From June to September 1975 the water temperature lay between 16 °C and 20 °C. At this temperature copepod eggs have a mean development time of 1–2 days (MARSHALL and ORR 1972). This means that first naupliar stages found in the research area were deposited as eggs within the wadden sea area. The massive increase of nauplii was often correlated with a bloom of certain phytoplankton species (Table 3; Fig. 9). The contrary happened in May 1976. A bloom of *Phaeocystis pouchetii* was correlated with a marked decrease of *Acartia* nauplii (Table 3) and adult *Acartia clausi* (n = 5; r_s = –0.900) (Fig. 10).

Comparing the standing stock of *Acartia clausi* at the stations Lister Ley, Höjer Dyb and Römö Dyb (Fig. 1), a clear increase can be seen at the stations of the inner wadden sea

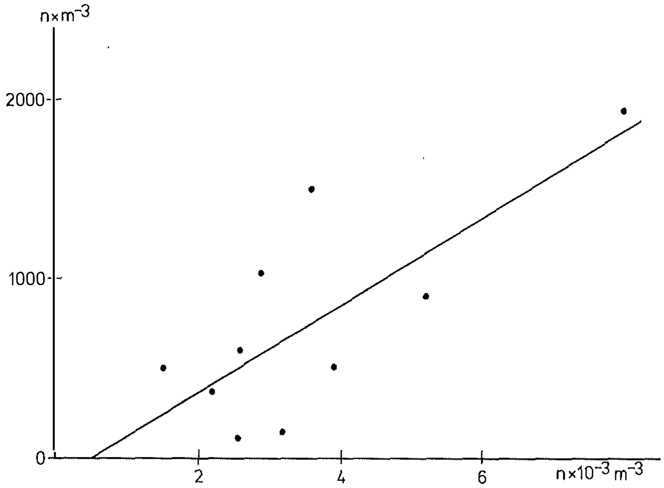

Figure 7

Linear correlation between adult *Acartia clausi* and *Acartia* nauplii in September-October 1975 (Station 1; high tide)
Acartia clausi = –0.1219 + 0.2433 x nauplii
number of data pairs: 11
linear correlation coefficient r = + 0.7780
Spearman's rank correlation coefficient r_s = + 0.727

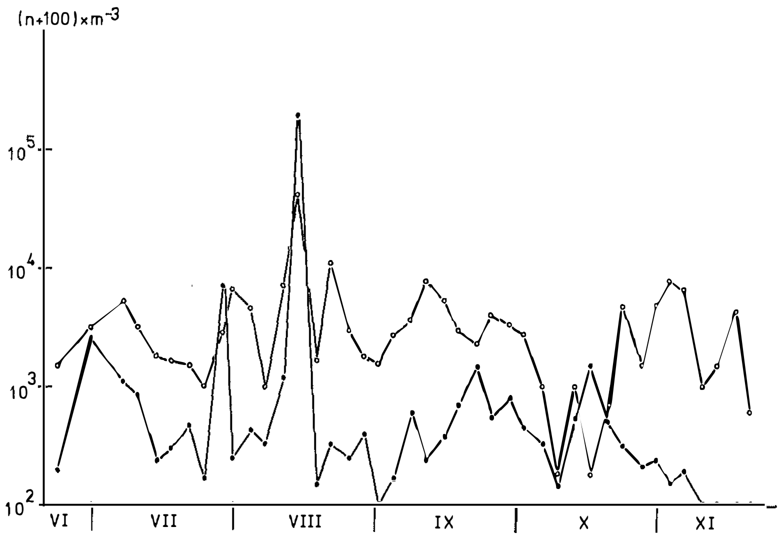

Figure 8

Occurence of *Acartia clausi* females and *Acartia* nauplii at Station 1 (Lister Ley) at high tide from June to November 1975. The y-coordinate was distorted by using log (n + 100)
●———● = *Acartia clausi* females
o———o = *Acartia* nauplii

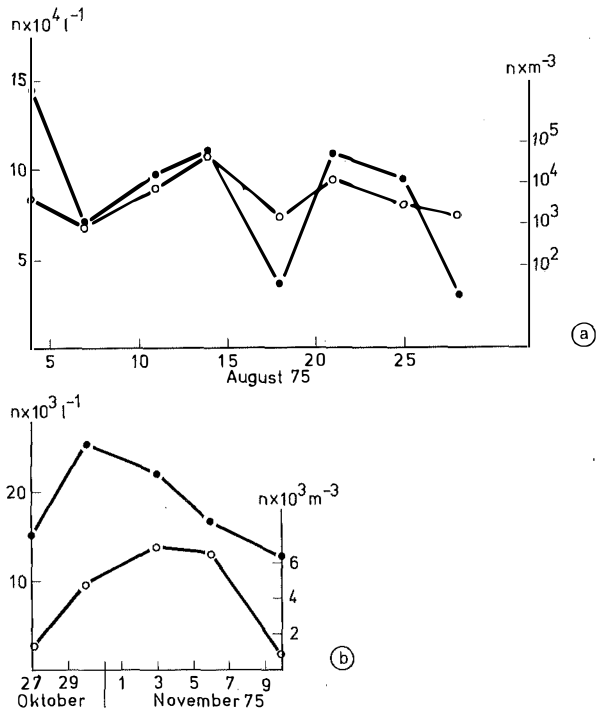

Figure 9

Occurrence of different phytoplankton species and *Acartia* nauplii at Station 1 (Lister Ley) at high tide

a. 4.8.1975 to 28.8.1975

The nauplii curve was distorted by using ln (n)

●———● = *Rhizosolenia delicatula*

o———o = *Acartia* nauplii

b. 27.10.1975 to 10.11.1975

The curves were smoothed by using a three times overlapping mean

●———● = *Thalassionema nitzschioides*

o———o = *Acartia* nauplii

Table 3

Correlation between the increase of copepod nauplii (*Acartia* sp.) and different phytoplankton species

r_s = Spearman's rank correlation coefficient

n = number of data pairs

phytoplankton species	time of research	r_s	n
Thalassiosira levanderi	June–July 1975	+ 0.576	10
Rhizosolenia delicatula	August 1975	+ 0.833	8
Thalassiosira decipiens	August 1975	+ 0.800	4
Thalassionema nitzschioides	October–November 1975	+ 0.607	8
Phaeocystis pouchetii	May 1976	− 0.795	7

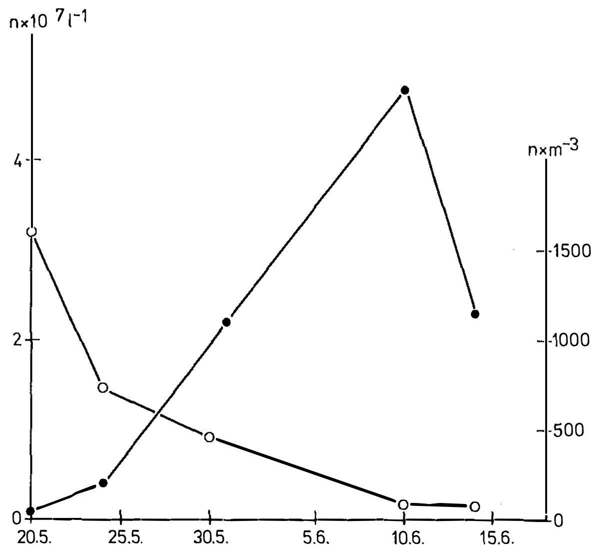

Figure 10

Occurrence of adult *Acartia clausi* and *Phaeocystis pouchetii* (cell numbers) in the Lister Ley (Station 1) at high tide during the *Phaeocystis* bloom in May-June 1976

o———o = adult *Acartia clausi*

●———● *Phaeocystis pouchetii*

area. The standing stocks at stations 2 and 3 are significantly higher (U-test after Mann and Whitney; SACHS 1974) than at station 1 ($\hat{z}$ = 2.96 α = 0.005). The sex ratio of the populations at station 2 and 3 lies between 0.22 and 0.38 (x = 0.30; n = 4).

At the time of research at stations 2 and 3 the standing stock of *Acartia discaudata* was too low for statistical analysis. The standing stock of *Acartia tonsa* was significantly lower in the inner wadden sea area than at the station Lister Ley ($\hat{z}$ = 2.01; α = 0.05). No males of *Acartia tonsa* could be found at the stations Höjer Dyb and Römö Dyb.

Discussion

The increase of *Acartia* nauplii in the northern wadden sea of Sylt was often correlated with blooms of certain phytoplankton species. During the time of main occurrence of *Acartia* sp. the water temperature was about 16 °C to 20 °C. At this temperature eggs of *Acartia* sp. have a mean development time of 1 – 3 days (UYE and FLEMINGER 1976). The water of the northern wadden sea of Sylt is replaced at a rate of about 6 % to 7 % per tide (HICKEL, in prep.), and a population stays up to one week within the wadden sea area. This means that first naupliar stages found here hatched from eggs within the area. Therefore the correlation between nauplii and phytoplankton shows a relation between the rate of oviposition and the quality of food supply. This has been shown for *Calanus* sp. (MARSHALL and ORR 1972).

The size of the phytoplankton species correlating with the nauplii lies between 10 and 50 μm. This is a size range which can be used very efficiently as food by *Acartia* sp. because of the structure of the copepods mouthparts (SCHNACK 1975). In May 1976 a quite different influence of phytoplankton on zooplankton could be seen. A bloom of *Phaeocystis pouchetii* was correlated with a decrease in *Acartia* nauplii and adults.

This phenomenon could be found every year from 1975 to 1980 and is known from earlier years. An influence of *P. pouchetii* on the migration of herring has been recorded (SAVAGE 1930). Different explanations are possible, e.g. a mechanical influence such as a coagulation of mouthparts by the gelatinuous membrane or the release of dissolved organic substances. A third possibility would be that copepods do not find enough food during a *Phaeocystis* bloom. Colony sizes over 1 mm could be found after one week in culture experiments (KAYSER 1970). Single cells, which can still be found in the water, have a mean diameter of 5–7 μm. These sizes lie outside the size range which is optimal as food source for *Acartia* sp.

The copepod populations drift with the residual current in a counterclockwise direction through the northern wadden sea of Sylt. This current, caused by the Coriolis effect, means that the inflowing north Frisian coastal water is first found at station 1 (Lister Ley), then at station 2 and last of all at station 3 (Römö Dyb). Here it has been exposed for some days to the influence of the wadden sea. This influence could be seen in a decrease or increase of a copepod population on the way from the Lister Ley to the Römö Dyb. The standing stock of *Acartia clausi* at stations 2 and 3 was markedly higher than at station 1. Males could be found in higher numbers indicating a low age of the populations. *Acartia clausi*, which is a coastal species (MARSHALL 1949), seems to find favourable living conditions within the northern wadden sea of Sylt. This is not the case in *Acartia tonsa*. The standing stocks at stations 2 and 3 are lower than at station 1. First of all the males are affected. They could not be found in the Höjer Dyb or the Römö Dyb at all. As CONOVER (1956) has shown, young larval stages and males are more sensitive to changes in environmental conditions than females. The same has been shown for different copepod species in the wadden sea area of Sylt (MARTENS 1980). An explanation for this often massive decrease of copepod populations within the wadden sea area can not be given now. One harmful effect may be caused by the huge amount of detritus, often mineral substances, in the water. If copepods are not able to actively select between suitable food and other particles, they could merely die of starvation. This would mean that *Acartia clausi* is able to reject particles with low food value, for instance by chemo-sensory grazing as shown by POULET and MARSOT (1978) and FRIEDMAN and STRICKLER (1975).

Acknowledgement

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