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Seasonal and spatial fluctuations of estuarine rotifers in a Baltic inlet

With 9 Figures and 2 Tables

Abstract

The general patterns in seasonal and spatial distributions of planktic rotifers were investigated in the estuarine shallow waters south of the Darss-Zingst Peninsulæ (south coast of the Arkona Sea, Baltic). *Keratella cochlearis*, *Filinia longiseta*, and *Brachionus quadridentatus* form the major part of the summer rotifer biomass peak. Rotifer abundances vary considerably over very small as well as over large distances. The diurnal vertical migration of rotifers is not strong but recognizable. It seems that the rotifers perform shore avoidance reactions. Some possible causes of our observations are discussed and conclusions for optimization of sampling have been drawn.

1. Introduction

Zooplankton abundances were measured regularly at routine stations in the course of complex ecological investigations in the shallow waters (boddens) south of the Darss-Zingst Peninsula (south coast of the Arkona Sea, Baltic) since 1970.

The zooplankton biomass produced by the monogonont rotifers in these waters is considerable, especially in summer. The rotifers not only achieve high abundances but, due to their smallness, also have a relatively high metabolic rate. They are therefore an important link in the material flux of this aquatic ecosystem (HEERKLOSS et al. 1981, this volume).

Detailed ecosystem analysis requires representative biomass values for the region concerned. The number of animal counts, however, must generally be reduced to a minimum for reasons of economy. Knowledge of variations in abundance and in seasonal and spatial distribution patterns of the rotifers is therefore essential in order to optimize zooplankton sampling activities.

2. Study area

As a major target for ecosystem analysis, the Barther Bodden (Fig. 1) was chosen for these investigations.

It has an area of 19.4 km² and a mean depth of 1.8 m (CORRENS 1976). Like a typical estuary it is characterized by major salinity fluctuations (1.5–9.0‰ S, average 5.5‰ S), high primary production, and high seston content (average 40 mg/l, HEERKLOSS et al. 1981, this volume).

SCHLUNGBAUM (1980) has given a detailed description of the area.

3. Material and methods

Rotifer abundance was determined from 1 l, 2 l and 5 l full samples. These were fixed with 4% formaldehyde and the animals were counted in a plankton chamber under the light microscope. The 2 l and 5 l samples were concentrated by means of plankton gauze (28 µm). Integrated samples were used in some cases (Fig. 6, 7).

4. Results and discussion

4.1. Seasonal fluctuations of dominant species

Fig. 1 shows the seasonal fluctuations in the abundance of planktic rotifers in the Barther Bodden. *Synchaeta* species which were not separated to species are not included in this figure (for further information see SCHWARZ 1963). The monthly abundance means from 1970–1979 indicate that *Keratella cochlearis* (GOSSE), *Filinia longiseta* (EHRENBERG) and *Brachionus quadridentatus* (HERMANN) form the major part of the summer rotifer biomass peak. During this period these species produce up to 60% of the zooplankton biomass.

Temperature and food conditions are generally

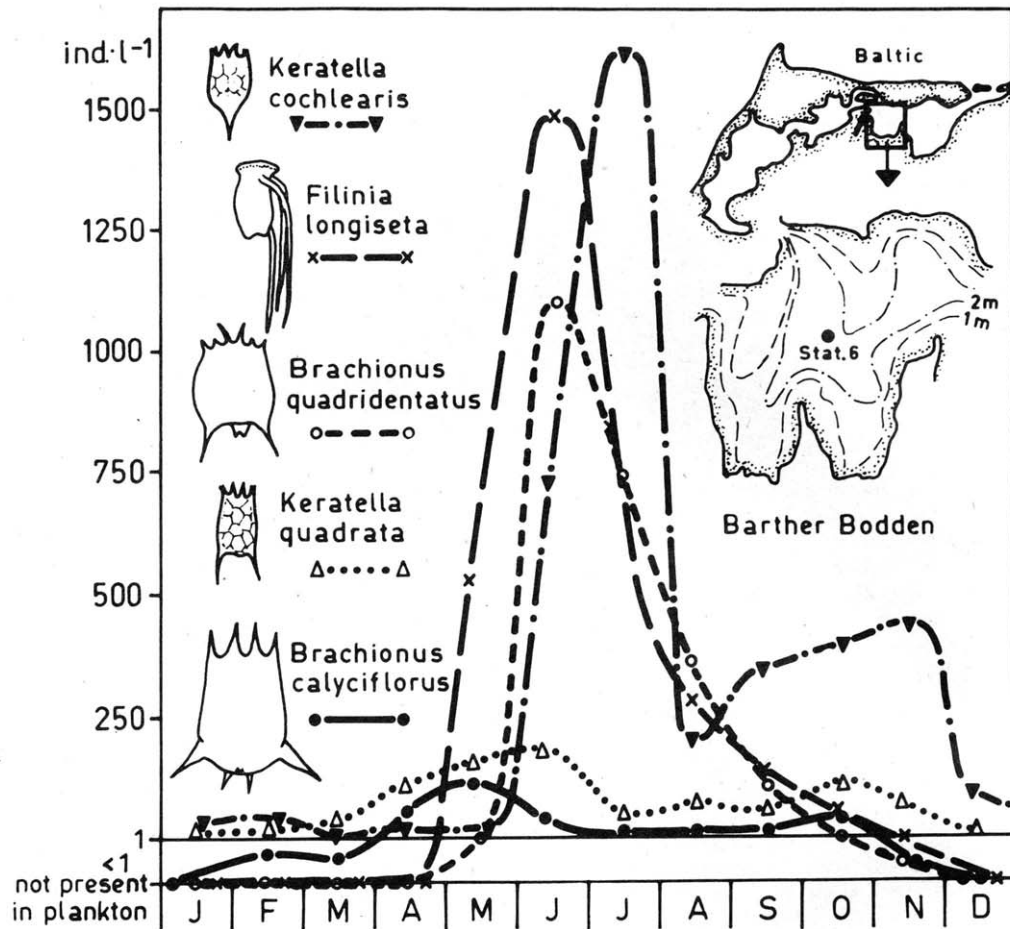


Fig. 1. Monthly mean abundances (1970–1979) at a depth of 0.5 m for the dominant rotifers at stat. 6.

the factors governing rotifer production. The resting eggs hatch when the water temperature rises rapidly in May, and the rotifer populations grow exponentially in June. The feeding biology of these three dominant species is adapted to detritus as the main food source (SPITTLER 1969, POURRIOT 1977, RUTTNER-KOLISKO 1980, STARKWEATHER & BOGDAN 1980). Deterioration in food quality and quantity due to the increasing numbers of blue-greens appears to be the cause for the rapid decline of the rotifer population in August (VIETINGHOFF et al., 1984).

4.2. Spatial distribution

4.2.1. Distribution patterns

a) Microdistribution: Results obtained by thorough investigation at station 6 in the middle of the bodden indicate that rotifer abundances vary considerably over very small distances in both the horizontal and vertical direction (Fig. 2). Rotifer abundances at single sampling points differed by factors up to 10. Vertical distribution patterns are shown in Fig. 3 for a few stations and reveal a slight

preference for the upper layers (0–1.5 m) during the daytime.

b) Horizontal distribution: Considerable fluctuations in rotifer abundance like those found in only small areas have also been found over large horizontal distances. Fig. 6 (for detail see 4.2.1.c) indicates that the horizontal distribution of *Keratella quadrata* was patchy over distances of 50–500 m in Kirrbucht (northern Barther Bodden). Fluctuations in

the abundances of different species along a horizontal transect (3.2 km) in Barther Bodden are shown in Fig. 4. The differences between stations were in all cases greater than the differences between samples taken at any one station. Simple analysis of variance using log-transformed data revealed significant horizontal differences ($p < 0.01$). In some cases numbers at adjacent stations differed by factors up to 10 and more.

Short term fluctuations of *Filinia* abundances at one sampling station (Fig. 5) indicate that the horizontal distribution patterns vary considerably. Therefore any recorded distribution pattern reflects only a momentary situation and cannot be interpreted as a function of distance from shore.

c) Optimization of sampling: In view of the heterogeneity of plankton distribution we tried to solve the problem of obtaining representative abundance values by taking vertically and horizontally mixed samples from different regions of the study area and by removing aliquotic amounts of water for observation (cf. VIETINGHOFF et al. 1984). The results of such sampling activities in Kirrbucht are shown in Fig. 6. Integrated sampling (3×21 per stat. 1–10, 5 subsamples) gives a relatively good estimation of the mean abundance (stat. 1–10, $n = 10 \times 5$) by means of only five counts. It is evident that samples at only a single station permit no conclusion to be drawn regarding the mean abundance for the area concerned.

The natural variability of abundances is reduced by integrated sampling, but the mean abundance obtained will be more accurate, and

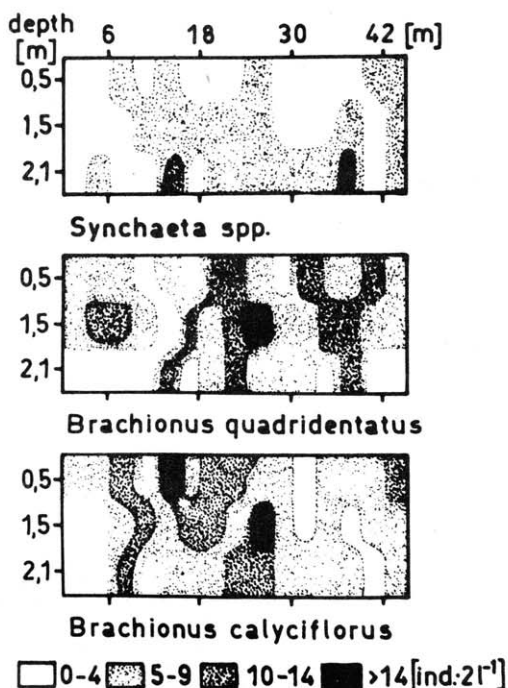


Fig. 2. Microdistribution of rotifers at stat. 6 (12. 10. 79, 21 – samples, $\varnothing T_w = 10^\circ\text{C}$, $3.8\text{--}5.3\text{‰}$ S)

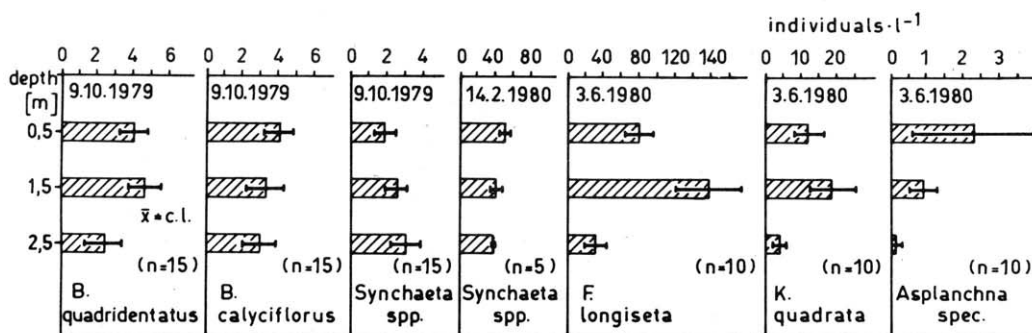


Fig. 3. Vertical distribution patterns of rotifers in Barther Bodden (95% confidence limits)

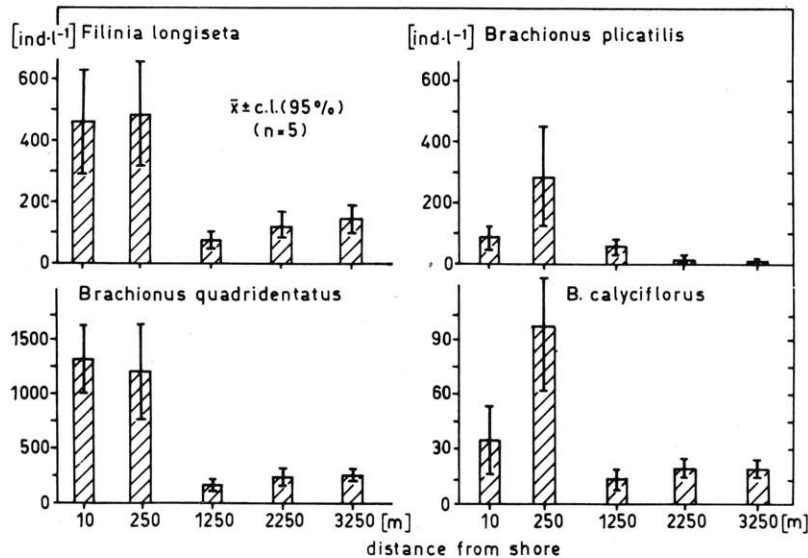


Fig. 4. Horizontal distribution patterns of rotifers (Barther Bodden, 30. 8. 79. 0,5 m depth $\varnothing T_w = 14^\circ\text{C}$, $\varnothing 5.0\text{‰}$ S)

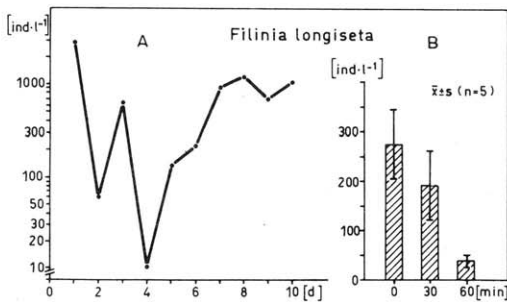


Fig. 5. Short term fluctuations of *Filinia longiseta* abundances (A: Stat. 6, 22. 6.—1. 7. 79, 4.00 p.m.; B: Zingster Strom, 3. 6. 80, 4.00—5.00 p.m.)

this is required for ecosystem analysis. Furthermore, the nearly normal distribution of the abundances in the subsamples simplify the statistical analysis of the results of counts (WARD et al. 1979, VIETINGHOFF, pers. comm.).

4.2.2. Active migrations

a) Diurnal vertical migration: Table 1 shows the results of a synoptic investigation at six stations in the central parts of the boddens

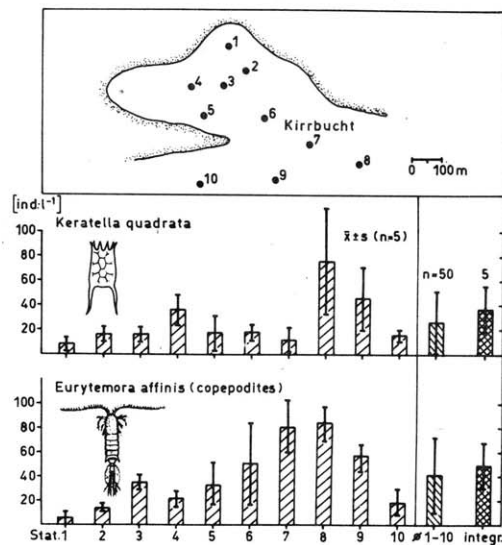


Fig. 6. Discrete and integrated sampling in Kirrbucht (3. 6. 80, 0.25 m depth, $\varnothing T_w = 13.3^\circ\text{C}$, $\varnothing 4.2\text{‰}$ S)

south of the Darss-Zingst Peninsula. Full surface samples (1 l) were taken simultaneously at all stations every day at 00.00, 08.00 and 16.00 h from 22 June—1 July 1979. The proportion of rotifers in the total biomass of rotifers for that day at 00.00 h was lower than

Table 1. Diurnal fluctuations of rotifer biomass in boddens south of the Darss-Zingst Peninsula, 22. 6.—1. 7. 1979, at 0.5 m depth

absolute biomass (abs.) in mg wet weight m^{-3} ; relative biomass (rel.) at one sampling time as a percentage of the total biomass of all three sampling times of the day

study area	routine station	\varnothing ‰ S	0.00 a.m.		8.00 a.m.		4.00 p.m.	
			abs.	rel.	abs.	rel.	abs.	rel.
Aue	1	6.4	0,833	26.60	1,119	35.74	1,179	37.66
Grabow	2	5.5	2,982	29.22	3,825	37.48	3,398	32.58
Barther Bodden	6	4.1	1,072	27.87	1,212	31.51	1,563	40.63
Bodstedter Bodden	10	2.8	2,205	30.89	2,538	35.55	2,396	33.56
Saaler Bodden	16	1.7	1,758	32.44	1,942	35.84	1,719	31.72
Ribnitzer See	19	1.3	1,931	32.86	2,078	35.36	1,868	31.78
\bar{x}				29.98		35.25		34.65
\pm				± 2.52		± 1.98		± 3.66

at 08.00 h ($p < 0.01$) and 16.00 h ($p < 0.05$). The higher proportion of rotifers among the biomass at the surface during the daytime confirms the observations published by DUMONT (1972) and ADENIJI (1978). DUMONT interpreted this diurnal migration as a mean for the rotifers to avoid the more active crustacean population at the surface during the night. In addition PREISSLER (1980) showed experimentally that the migrational habits of rotifers differ in the presence and absence of copepods. During our investigations also the diurnal

copepod migration (HEERKLOSS et al. 1980) was distinctly in the opposite direction to that of the rotifers.

b) Horizontal migration: The results of several investigations revealed that planktic rotifers were considerably less abundant in the immediate vicinity of the shore than in the open water except for littoral forms such as *Euchlanis dilatata* (EHRENBERG) which are found almost exclusively immediately beside the shore. Fig. 7 shows as an example that the abundances of *Brachionus calyciflorus* (PALLAS), *Filinia*

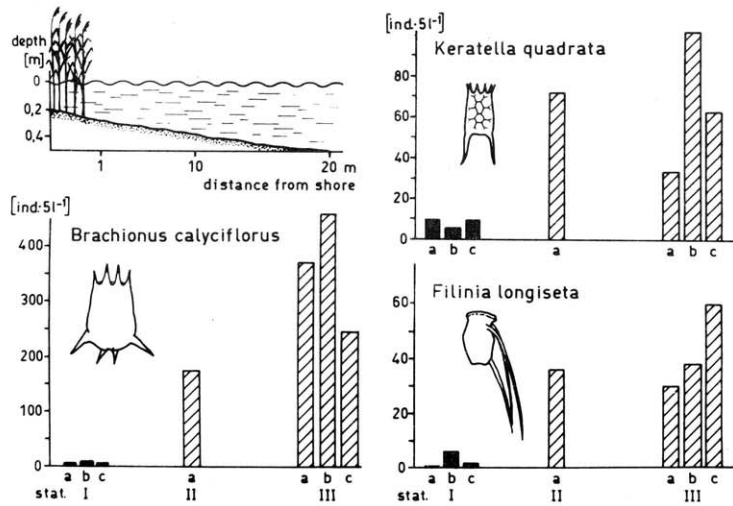


Fig. 7. Horizontal distribution of rotifers close to the shore (Kirrbucht, 29. 4. 81, 2.00 p.m., mixed 5 l-samples, $\varnothing T_w = 12^\circ C$, $\varnothing 2.6^\circ S$)

longiseta (EHRENBERG) and *Keratella quadrata* (MÜLLER) in samples made up of five one-litre samples increase considerably as the distance to the shore increases from one to 10 metres. Recent studies by PREISLER (1980) indicate that the shore avoidance behaviour often observed in pelagic crustaceans according to SIEBECK (1964) is also common among pelagic rotifers. PREISLER showed that, like in crustaceans, this avoidance reaction is a result of optical orientation by means of the spatial light distribution near the shore. The slight elevation of the horizon in this area possibly explains the shore avoidance distance of only 10 m. In addition to the species mentioned by PREISLER 1977a, b; 1980) also *F. longiseta* and *B. calyciflorus* seem to show a shore avoidance behaviour. The horizontal orientation on spatial light distribution seems to be the reason why several authors (e. g. BLOMQUIST & PEJLER 1980) could find no clear positive phototaxis of rotifers for vertical light source. In our simple experiments with laboratory cultures (5‰ S) of *Keratella cochlearis* (GOSSE) *Brachionus calyciflorus* and *B. angularis* (GOSSE) we found definite phototaxis in petri dishes with horizontally arranged lamps.

4.2.3. General discussion

Rotifer distribution patterns in this estuary indicate obviously that distribution is very

patchy over distances ranging from 1 m through the mesoscale (up to hundreds of metres) to several kilometres. Patchiness on this scale is well-known to both limnic planktologists (e. g. ELSTER 1958, DE NIE et al. 1980) and marine planktologists (e. g. ANRAKU 1975, ANGEL 1977).

One of the most important factors influencing plankton distribution in the Barther Bodden is obviously the complex current system. Winds from several directions have a strong effect on water movements in the shallow bodden (BRINKMANN et al. 1981). GEORGE & EDWARDS (1976) reported considerable effects of such currents on plankton distribution patterns. Furthermore, the concentration effect of outflow situations and the dilution effect of inflow situation on rotifer abundances must also be taken into account. Short term fluctuations in *Filinia longiseta* abundance at a single sampling station give an impression of the action of water currents (Fig. 5). The variances and confidence limits of three distribution studies (Table 2) indicate the particularly great patchiness of rotifer distribution of this area. The average confidence limit (12% of the transformed mean) exceeds the values recorded by the I.B.P. (BOTRELL et al. 1976, average 10%) and the average variance (1.01, transformed data) is much larger than the values reported by DE NIE et al. (1980) from Lake Tjeukemeer (0.32). Lake Tjeukemeer has a

Table 2. Mean density (\bar{x}), variance (s^2) and confidence limits (c.l.) of plankton rotifers during 3 investigations in Barther Bodden

95% confidence limits as a percentage of the mean; all numbers (ind./l) transformed to natural logarithms

study area	date	species	n	\bar{x}	s^2	c.l.
Barther Bodden surface (0.5 m) horizontal transect	26-6-79	<i>B. quadridentatus</i>	25	2.772	2.244	22.31
		<i>B. calyciflorus</i>	25	1.890	0.604	16.97
		Σ rotifers	25	3.184	1.402	15.35
Barther Bodden surface (0.5 m) horizontal transect	30-8-79	<i>B. quadridentatus</i>	25	5.936	0.903	6.61
		<i>B. calyciflorus</i>	25	3.126	0.794	11.77
		<i>B. plicatilis</i>	25	3.649	1.960	15.84
		<i>B. angularis</i>	25	2.156	1.270	21.58
		<i>K. cochlearis</i>	22	4.796	0.841	8.48
		<i>K. quadrata</i>	22	3.057	0.312	8.11
		<i>F. longiseta</i>	25	5.146	0.830	7.31
Σ rotifers	22	6.642	0.566	5.02		
Barther Bodden microdistribution at stat. 6	12-10-79	Σ rotifers	45	2.856	0.362	6.35

morphometry similar to the Barther Bodden. So the complex inflow and outflow situations seem to be one of the major causes of this patchiness. This agrees with the results of LEE & MCALICE (1979) who found that tides are the most dominant factor governing sampling variability in an estuary. The fact that there are no significant differences (F-test) between the variances of abundances for all rotifers and for copepod species supports the discussion of one dominant distributing mechanism (ARNDT et al. 1981).

On the other hand according to the literature and our own results actions of water currents combine with many other physical, physiological and ecological factors. Some of them should be mentioned here.

Density gradients often occur in this estuary due to very localized salinity differences (up to 1–1.5‰ S differences between points 3 m apart, see Fig. 8) and differences in water temperatures in shallow regions (about 20% of the area of the Barther Bodden) are 3–7 degrees Kelvin higher than in the central part. Density gradients could probably influence rotifer distribution by passive aggregation of food particles (cf. ANRAKU 1975) and specific behaviour (EPP & WINSTON 1978). Perhaps this explains the microdistribution (Fig. 2).

Rotifer reproductive rates are very sensitive to changes in living conditions. Therefore, the effect of the horizontal temperature differences mentioned above seems to be important. Fig. 9 shows the calculated development of *Brachionus calyciflorus* based on experimental data published by HALBACH (1970) starting with an assumed population (N_0) of 50 animals per litre. After five days at 20 °C the population would already be twice as large as after the same period at 15 °C. Other rotifer species inhabiting these waters are known to behave similarly. According to HALBACH (1973)

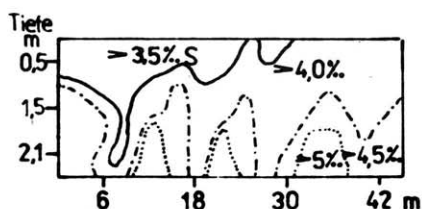


Fig. 8. Salinity patchiness at stat. 6 (12. 10. 1979)

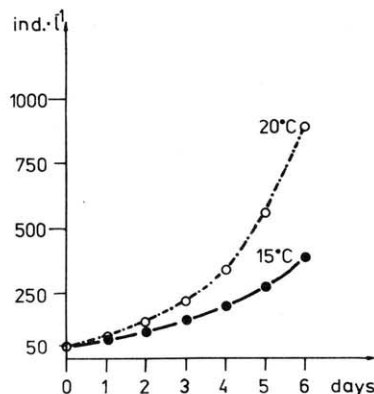


Fig. 9. Theoretical development of a population of *Brachionus calyciflorus* ($N_t = N_0 \cdot e^{r \cdot t}$, $r_{15^\circ\text{C}} = 0.34$, $r_{20^\circ\text{C}} = 0.48$ after HALBACH 1970)

temperature fluctuations could cause lower generation times. Thus the reproductive rate of rotifers in the shallower regions could be further enhanced by greater amplitudes in the diurnal temperature variations. In addition the patchy food environment (cf. NASEV 1980, GEORGI et al. 1980 and pers. comm.) could have some effect on patchy reproduction patterns. The extent of vertical migration of the rotifer population is not very considerable, but horizontal shore avoidance seems to play an important role in the distribution of rotifers near the shore of this estuary.

The distribution of plankton could also be effected by mortality due to intense predation (DODSON 1974). Recent comparative studies (July 1981) showed that mortality of rotifers is caused by, among other things, predation by juvenile cyprinids and sticklebacks as well as cyclopoid copepods and mysids close to the shore (cf. ARNDT et al. 1983) and schools of smelt in the central parts of the bodden.

5. Conclusions

Knowledge of seasonal and spatial zooplankton distribution patterns is essential to reduce errors during routine plankton sampling. According to our results on rotifer distribution patterns the following factors should be taken into consideration when planning sampling actions in coastal waters:

- a) short intervals between sampling during mass development (≤ 1 week),

- b) vertical distribution patterns,
- c) horizontal extent of patches,
- d) shore avoidance reactions.

Since SANDSTRÖM (1979) reported large scale patchiness in the Bothnian Sea and SCHULZ & BREUEL (1981 this volume) observed short-term variations at a single station in the Arkona Sea, it seems advisable that plankton samples should also be integrated horizontally and not only vertically as proposed in the First BMB Recommendations (DYBERN et al. 1976).

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