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POPULATION DYNAMICS AND PRODUCTION OF *ACARTIA TONSA* (COPEPODA: CALANOIDA) IN THE DARSS-ZINGST ESTUARY, SOUTHERN BALTIC

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ABSTRACT

The population dynamics and production of *Acartia tonsa* Dana were studied by means of regular field sampling at a routine station in the shallow Darss-Zingst estuary, southern Baltic (S: 3-7‰; T_w: 0-25 °C), in 1981 and 1982. The first individuals hatch from resting eggs in April/May when temperatures are above 10 °C. By December, about 8-9 generations have been produced. When temperatures are above 15 °C only subitaneous eggs are produced, and below 10 °C only resting eggs are to be found. Using development times from the literature, instantaneous rates of growth, recruitment, and mortality were calculated. Mean P/B values for the growing season were high (about $0.27 \cdot d^{-1}$). Annual biomass production was 1.6 and 0.9 g $fw \cdot m^{-3}$ for 1981 and 1982, respectively. Planktivores consumed 50-100 % of daily *Acartia* production during summer.

INTRODUCTION

Acartia tonsa is a widespread thermophilic copepod in both hemispheres, occurring in Indopacific as well as in Atlantic coastal waters. Though thoroughly investigated in North American estuaries (e.g., Conover 1956, Heinle 1966), few studies have been published on the ecology of European populations (e.g., Hirche 1974, Bakker *et al.* 1977) despite *A. tonsa*'s significant contribution to zooplankton production in many estuaries.

Owing to this discrepancy we carried out investigations in the Darss-Zingst estuary at a routine station in the Zingster Strom (T_w: −0.5-+25.0 °C; S: 3-7‰), where *A. tonsa* in addition to *Eurytemora affinis* is the most productive planktonic copepod.

MATERIAL AND METHODS

Copepods were sampled by means of five 5 l-HYDROBIOS plankton samplers at weekly intervals in 1981 and 1982. Filtered and formalin-fixed samples were counted for all developmental stages under a light microscope (160×). Parameters

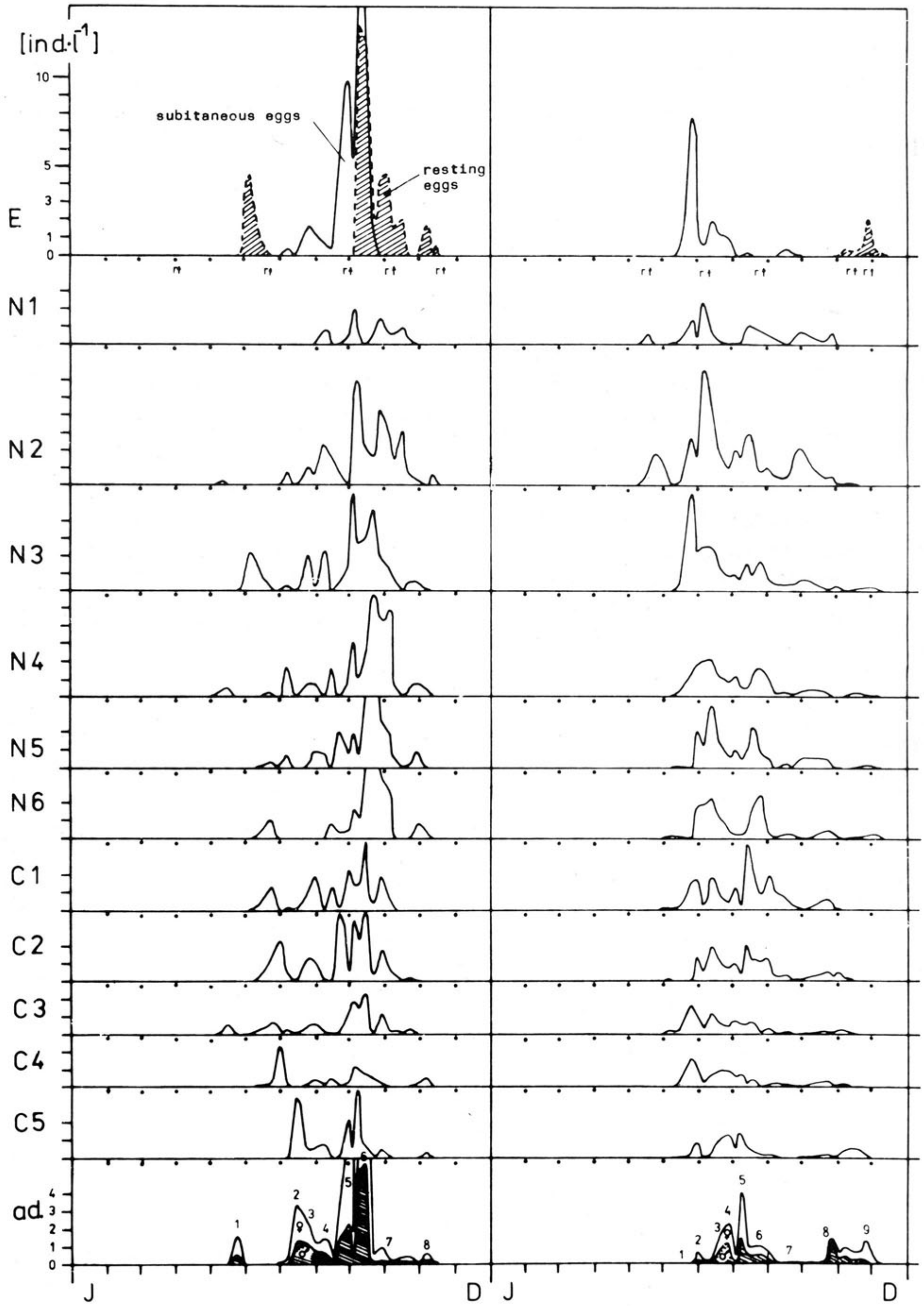

Fig. 1. Seasonal changes in abundances of developmental stages of *Acartia tonsa* in 1981 and 1982.

of population dynamics and production were calculated according to methods described by Uye (1982) using values of other authors for development times of eggs, nauplii and copepodids (average values from Heinle 1966, Uye & Fleminger 1976, Gentile & Sosnowski 1978, Johnson 1981) and length-weight relationships (Heerkloss unpubl.).

RESULTS AND DISCUSSION

Reproduction

The first individuals arise from resting eggs in April/May when water temperatures are above 10 °C. There are other, quantitatively unimportant pulses of hatched resting eggs in the plankton (r↑ in Fig. 1) corresponding to short term increases in water temperature. By December, about 8-9 generations have been produced (see numerals in Fig. 1, lower graph), abundances being highest during summer. When temperatures rise above 15 °C only subitaneous eggs are produced, and below 10 °C only resting eggs are to be found. Due to low temperatures the first generation in 1981 produced only resting eggs. The relationship between egg types and temperature is in accordance with laboratory experiments by Zillioux & Gonzalez

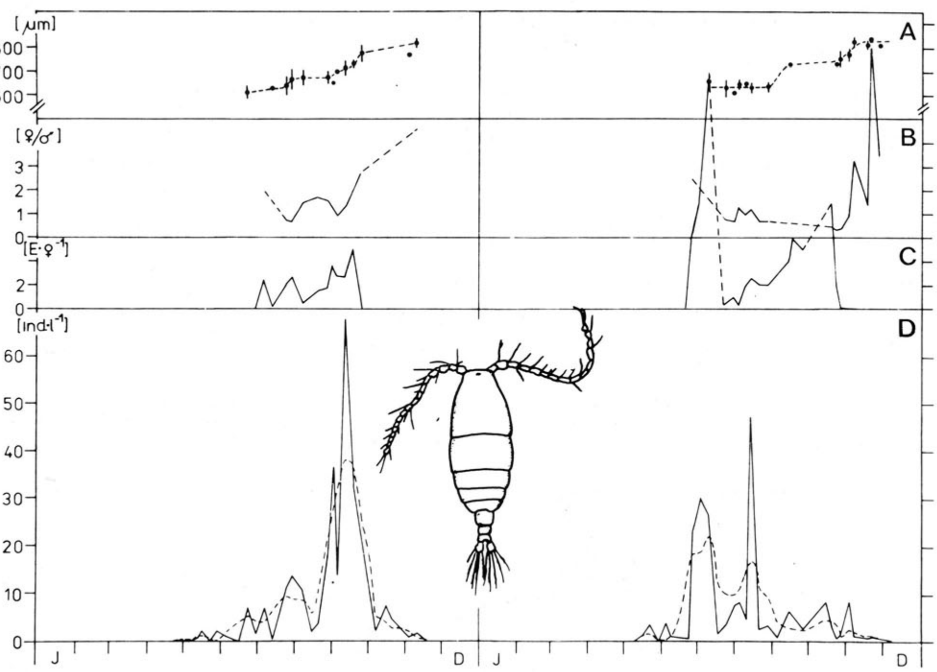

Fig. 2. A, seasonal changes in cephalothorax length of females ($\bar{x} \pm 95\,\%$ c.l.); B, sex ratio (adult females to males); C, egg ratio (subitaneous eggs per female) and D, abundance of *A. tonsa*.

(1972). Despite intensive mixing processes in the shallow estuary (mean depth 1.7 m) plankton egg numbers and ratios are underestimated due to sinking out of eggs. Tendencies of higher egg ratios were observed in early summer and early autumn (Fig. 2). There were considerable seasonal changes in sex ratios (♀/♂), which are negatively correlated ($p<0.01$, Spearman rank test) with population densities of *A. tonsa*. According to Heinle (1981) this could optimize the reproductive potential. The cephalothorax length of females increased with decreasing temperatures in the course of the year, a fact which is well known from many calanoid populations (cf. Deevey 1960, Hart & McLaren 1978).

Growth

Instantaneous growth rates (r, see Fig. 3) were estimated using gliding averages of abundances (broken line in Fig. 2D, calculated by means of fitted third-order equations) to avoid unrealistic low or high values due to patchiness (e.g. Arndt *et al.* 1984). Positive growth rates were recorded only at temperatures above 15 °C.

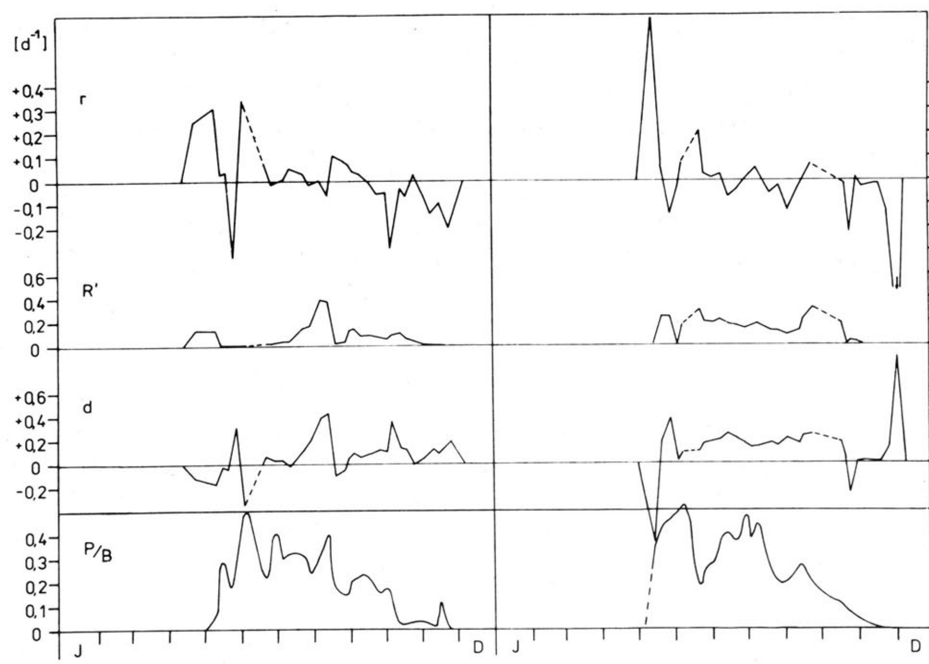

Fig. 3. Seasonal changes of instantaneous rates of growth (r), recruitment (R′), and mortality (d), and seasonal changes of daily production and biomass (P/B) ratios for *A. tonsa* in 1981 and 1982.

Recruitment and mortality

Temperature should be the most important factor governing changes in instantaneous rates of recruitment (R′) of this thermophilic copepod in a temperate estuary ($p<0.001$). Furthermore, salinity is positively correlated to rates of recruitment ($p<0.01$; 3‰S was the lower limit of reproduction of *A. tonsa*). Positive correlations ($p<0.05$) could also be found with abundances of the centric diatom *Stephanodiscus hantzschii*. High abundances of *Acartia* correspond to high mortality rates of *Eurytemora* nauplii (Arndt 1985). But due to the broad spectrum of food particles ingestable by *A. tonsa* (e.g., Kinne 1977, Tackx & Polk 1982) food supply should not be quantitatively limiting in the eutrophic estuary. Perhaps there are some important qualitative limitations (cf. Heerkloss *et al.* 1984a, b). Changes in instantaneous death rates were closely related to changes in recruitment rates. This implies a short life time of individuals. Negative death rates could mostly be attributed to the recruitment from resting eggs. Within the life cycle highest mortality rates occurred up to the third nauplius stage. Of the individuals in the nauplius stage III an average of about 60% survived to N6, about 40% to C3, and about 30% to C5. Adults survived on average 7 days in 1981 and 2.6 days in 1982. This is far below the life expectancy determined by Sosnowski & Gentile (1978). Looking for the reason for the high mortality we estimated predation rates of dominant planktivores (*Neomysis integer*, smelt, stickleback, juvenile herring and perch) by analysis of predator abundances, stomach contents, and assumed food ratios (Arndt *et al.*, in prep.). Predators consume 50-100% of daily *Acartia* production. Thus a large part of the mortality could be explained by predation, other possible factors are low salinities and high pH values (>9).

Production

The estimated annual production (cumulative growth method) of *A. tonsa* in 1981 and 1982 was 1.6 and 0.9 g fresh weight $\cdot m^{-3}$, respectively. The mean P/B value for the growing seasons was $0.27 \cdot d^{-1}$, which is lower than values reported by Heinle (1981), but high compared to values for other copepods (cf. Greze 1978). Above 20 °C P/B ratios are significantly higher than those of the only competing species *Eurytemora affinis* (Arndt 1985). This and the relatively lower consumption by predators explain the dominance of *A. tonsa* during summer.

The ability to produce resting eggs and the very high productivity of the thermophile *Acartia tonsa* should be considered as important reasons for the high abundance of this species in the middle and outer parts of many shallow (and therefore warmer) European estuaries. Our results once more point to the fact that predation is an important component of zooplankton mortality in coastal waters.

REFERENCES

Arndt, H., 1985. Untersuchungen zur Populationsökologie der Zooplankter eines inneren Küstengewässers der Ostsee. – Doctoral thesis, Wilhelm-Pieck-University Rostock.

Arndt, H., R. Heerkloss & W. Schnese, 1984. Seasonal and spatial fluctuations of estuarine rotifers in a Baltic inlet. – Limnologica (Berl.) **15**: 377-385.

Bakker, C., W.J. Phaff, M. v. Ewijk-Rosier & N. De Pauw, 1977. Copepod biomass in an estuarine and a stagnant brackish environment. – Hydrobiologia **52**: 3-13.

Conover, R.J., 1956. Oceanography of Long Island Sound, 1952-1954. VI. Biology of *Acartia clausi* and *A. tonsa*. – Bull. Bingham oceanogr. Coll. **15**: 156-233.

Deevey, G.B., 1960. Relative effects of temperature and food on seasonal variations in length of marine copepods in some American and western European waters. – Bull. Bingham oceanogr. Coll. **17**: 54-86.

Gentile, J.H. & S.L. Sosnowski, 1978. Methods for the culture and short term bioassay for the calanoid copepod (*Acartia tonsa*). – EPA report 600/9-78-010: 28-45.

Greze, V.N., 1978. Production in animal populations. – *In* O. Kinne (ed.): Marine Ecology. Vol. 4, pp. 89-114. John Wiley and Sons, New York.

Hart, R.C. & I.A. McLaren, 1978. Temperature acclimation and other influences on embryonic duration in the copepod *Pseudocalanus* sp. – Mar. Biol. **45**: 23-30.

Heerkloss, R., H. Arndt, J. Hellwig, U. Vietinghoff, F. Georgi, B. Wessel & W. Schnese, 1984a. Consumption and assimilation by zooplankton related to primary production in the Baltic inlet Barther Bodden. – Limnologica (Berl.) **15**: 387-394.

Heerkloss, R., R. Börner, B. Krummhaar, H. Arndt & W. Schnese, 1984b. Growth inhibition in estuarine zooplankters due to blue-green algae. – Ophelia, Suppl. **3**: 45-49.

Heinle, D.R., 1966. Production of a calanoid copepod, *Acartia tonsa*, in the Patuxent River estuary. – Chesapeake Sci. **7**: 59-74.

Heinle, D.R., 1981. Zooplankton. – *In* F.J. Vernberg & W.B. Vernberg (eds): Functional Adaptations of Marine Organisms, pp. 85-145. Academic Press, New York.

Hirche, H.-J., 1974. Die Copepoden *Eurytemora affinis* (Poppe) und *Acartia tonsa* Dana und ihre Besiedlung durch *Myoschiston centropagidarum* Precht (Peritricha) in der Schlei. – Kieler Meeresforsch. **30**: 43-64.

Johnson, J.K., 1981. Population dynamics and cohort persistence of *Acartia californiensis* (Copepoda: Calanoida) in Yaquina Bay, Oregon. – Ph. D. Thesis, Oregon State University Corvallis.

Kinne, O., 1977. Marine Ecology. Vol. III. Cultivation, Part 2. John Wiley and Sons, New York.

Sosnowski, S.L. & J.H. Gentile, 1978. Toxicological comparison of natural and cultured populations of *Acartia tonsa* to cadmium, copper, and mercury. – J. Fish. Res. Bd Can. **35**: 1366-1369.

Tackx, M. & P. Polk, 1982. Feeding of *Acartia tonsa* Dana (Copepoda, Calanoida): predation of nauplii of *Canuella perplexa* T. et A. Scott (Copepoda, Harpacticoida) in the sluice-dock at Ostend. – Hydrobiologia **94**: 131-133.

Uye, S.-I., 1982. Population dynamics and production of *Acartia clausi* Giesbrecht (Copepoda, Calanoida) in inlet waters. – J. exp. mar. Biol. Ecol. **57**: 55-83.

Uye, S.-I. & A. Fleminger, 1976. Effects of various environmental factors on egg development of several species of *Acartia* in southern California. – Mar. Biol. **38**: 253-262.

Zillioux, E.J. & J.G. Gonzalez, 1972. Egg dormancy in a neritic calanoid copepod and its implications to overwintering in boreal waters. – *In* B. Battaglia (ed.): 5th Eur. Mar. Biol. Symp., pp. 217-230. Piccin Editore, Padua & London.