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SEASONAL DYNAMICS OF *TRIOPS CANCRIFORMIS* (BOSC, 1801) (CRUSTACEA, BRANCHIOPODA) IN THE BANAT PROVINCE IN YUGOSLAVIA

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Abstract. At the territory of Banat province, in the southern part of the Pannonian Plain, about 100 kilometers north of Belgrade, the appearance and seasonal dynamics of a bisexual population of *Triops cancriformis* over the period 1991-1995 was observed.
A population of *T. cancriformis* appears regularly, i. e. every year when ephemeral ponds are formed. Hatching takes place between the beginning of March and the beginning of April when average temperature varies between 7 and 10 °C. Sexual maturity is reached after one month. A life span of two months is registered.
During one year, several generations may appear at one month intervals, i. e. when sexual maturity of a previous one is reached. Up to three generations may be present simultaneously. Males are present during the whole season. They make 15-40 % of the population.

Key words: Crustacea, Branchiopoda, bisexual population of Triops cancriformis, ephemeral ponds

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Introduction

Marinček (1961) registered, for the first time in Yugoslavia, presence of *Triops cancriformis* (Bosc 1801) near the village Ečka close to Zrenjanin (Banat province). Later, this species was discovered in many other localities in the Pannonian Plain and in the easternmost part of the limnological area of the Dinaric West Balkan (according to Illies 1978). In the material collected only females were present (Marinček and Petrov 1994).

During our investigations of Branchiopod fauna in 1991, at the territory of Banat province, about 100 kilometers north of Belgrade, in the vicinity of the village Melenci, a rich fauna of these shrimps and among them a species *Triops cancriformis*, was discovered. Males of *Triops cancriformis* were found for the first time in Yugoslavia (Petrov and Cvetković 1995). Since it has been the only finding of a bisexual population in Yugoslavia up till now, the appearance and seasonal dynamics of this species during the period 1991 - 1995 was observed.

Material and methods

Material was collected from ephemeral ponds on a pasture ground. In late winter, ponds were formed by snow melting while later on they were drained or refilled by rain falls.

The area was observed at two week intervals from the beginning of February up to the beginning of August. Depending on the rain fall, the number and size of ponds varied considerably. The number of ponds was between 3 and 46, but after heavy rains almost all the area was covered with water and ponds were fused (sometimes completely). The volume of ponds varied between 88 and 0.03 m^3 (most frequently less than 5 m^3) and their depth did not exceed 50 cm, most frequently being 5 - 20 cm.

The presence of a species was established by intensive sampling. Samples were taken with a hand net mesh size 1 mm. Because of the small size of ponds and the restricted number of individuals in them, only a few specimens of different size were always taken from each pond and fixed in 70%

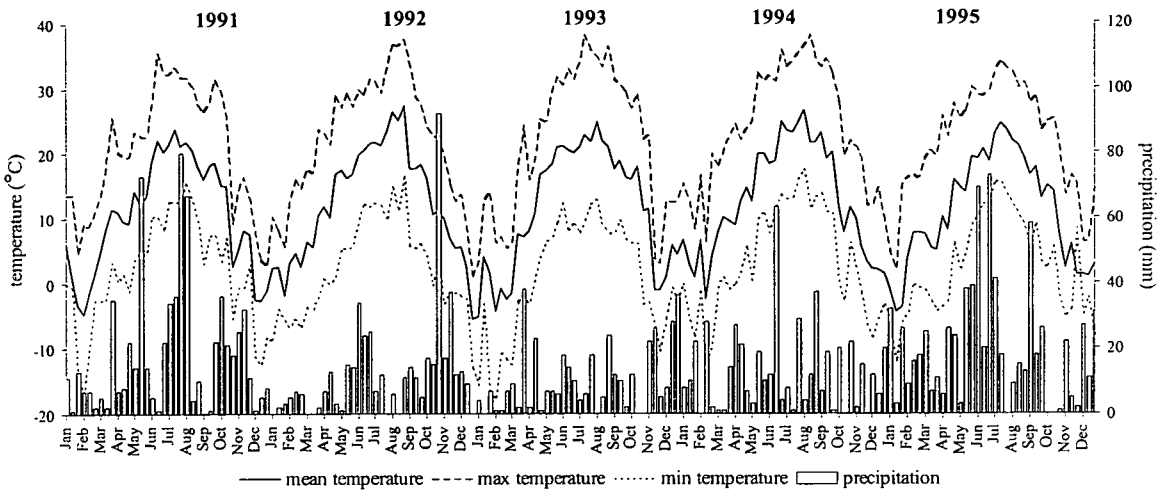

Fig. 1. Annual fluctuation of temperature and rain fall in 1991 - 1995 (mean, maximum and minimum temperatures, and precipitation amount for decades are shown)

ethyl-alcohol. Carapace length was measured in order to establish the size of an animal .

Official records of temperature and rain fall for this period were used.

Results

In 1991, from the beginning of the year until the end of March the amount of rain fall was very small (Fig. 1). The last 10 days of March were characterized by considerable increase of precipitation. This caused a formation of numerous ephemeral ponds and a hatching of *Triops cancriformis* at the beginning of April. At this time the average temperature for the decade was 10.9 °C and the minimum temperature 0.1 °C. Only young individuals were collected on April 13th (Fig. 2), and from May 12th, sexually differentiated specimens were found. Up to the beginning of June a high amount of precipitation was maintained. A rapid decrease of rain fall in June, followed by increase of temperature (maximum temperature up to 35.5 °C) caused drying of ponds to the middle of June, and consequently a disappearance of *Triops*. Average temperature for the decade was 22.1 °C and the maximum was 32.4 °C. During its whole life span *Triops* grew rapidly; maximum length of carapace attained was 3.2 cm.

Since the climatic conditions were favourable the second generation appeared in May and the third one in June. In the second generation the growth was faster than in the first one. Individuals of the third generation did not reach sexual maturity because soon after their appearance ponds were dried up.

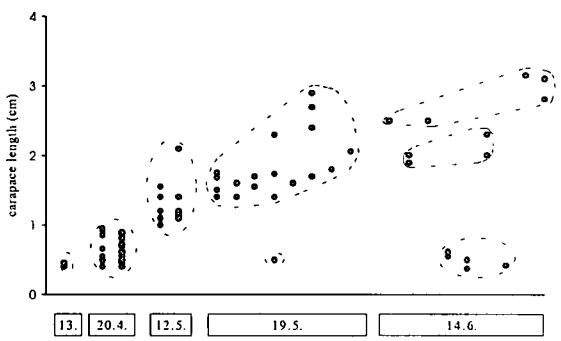

Fig. 2. Carapace length of *Triops cancriformis* of different age in 1991. (Specimens of individual generations grouped together. Individuals from different ponds are in separate columns)

In 1991, males appeared simultaneously with females. They were present during the whole season and their proportion was 16-40 % of the population.

From the end of June to the beginning of August the amount of precipitation was very high again, but the ponds were not formed because of high temperature (average above 21 °C, and the maximum up to 29.7 °C) and extremely desiccated soil.

The whole 1992 was very dry and warm so that the ephemeral ponds were not formed, and *T. cancriformis* could not develop.

The year 1993 was similar, but with somewhat more rain fall at the end of March and in the mid-April. During that period ephemeral ponds were formed. Their number and distribution was similar to those in 1991, but because of higher temperature and considerably lower precipitation from the end of April, these ponds lasted only for one month. *T. can-*

criformis appeared by the mid-April, but it could not reach a sexual maturity. At the time of hatching, average and minimum temperatures were similar to those in 1991 (10.7 °C and 0.6 °C respectively), while at the time of disappearance of *T. cancriformis* average temperature was only 17.2 °C and maximum was 24.7 °C.

The year 1994 was characterized by higher amount of rain fall and also with higher temperature in January and February compared to previous years. This caused an early formation of ponds but to much less extent than in previous years, and earlier appearance of *T. cancriformis*. Hatching took place in the second half of March when average temperature was about 10 °C and a minimum one 0.7 °C. The development was faster because of a higher temperature in the period after hatching; adult specimens were present as early as the middle of April. It is interesting that in the period of maturation the temperature dropped twice beneath zero (-1.2 and -0.4 °C). As the amount of precipitation was very low from the end of February, and the temperature increased rapidly, the ponds were dried out by the middle of May when the population of *Triops* disappeared. At this time average and maximum temperatures were 19.8 °C and 32.2 °C respectively.

In 1995 climatic conditions were especially favourable; extremely high amount of precipitation and its timing, together with favourable temperature, caused a formation of ponds and their drying for several times, what made the appearance of several generations of *T. cancriformis* possible.

High amount of precipitation in January caused an early formation of ponds (at the beginning of February) in a much higher number than in previous years, but hatching did not take place until the beginning of March. At the time of hatching average temperature was 7.5 °C and the minimum -1 °C. Young individuals were collected for the first time on March 17th (Fig. 3). As in the previous year, temperature dropped several times below zero (up to -2.9 °C) over the period from hatching to sexual maturity.

Because of a considerably low precipitation at the end of March and the beginning of April, and an increase of temperature most ponds were dried out. In a few that remained, sexually differentiated specimens were found at April 15th. During the period of sexual maturation a relatively slow growth was observed. Having attained sexual maturity, the growth became considerably faster so that in mid-May, when the last individual of this generation was found, carapace reached 3.2 cm in length.

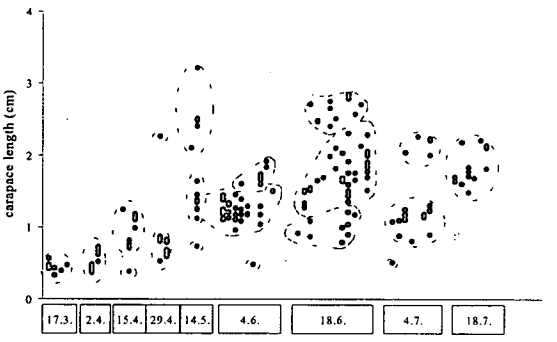

Fig. 3. Carapace length of *Triops cancriformis* of different age in 1995. (Specimens of individual generations grouped together. Individuals from different ponds are in separate columns)

In the middle of April the increase of rain fall caused a new formation of ponds, but to a much less amount than earlier. Most of newly formed ponds lasted for only a month when they went dry again.

At the time when ponds refilled, a second generation of *T. cancriformis* appeared. This generation reached sexual maturity by mid-May, and disappeared by mid-June. A growth of the specimens was, in contrast to the first generation, uniform during the whole life time, but a maximum size they reached was smaller (carapace length about 2.8 cm).

About in the middle of May a third generation appeared. This generation reached sexual maturity somewhat earlier (at the beginning of June) and disappeared by the beginning of July. The growth of this generation was uniform, like the previous one, and with a similar rate, but a maximum body size attained was smaller (carapace length about 2.3 cm).

From the end of May to the middle of July unusually high amount of precipitation caused a formation of numerous ponds for the third time during that year. The number of ponds and their distribution was at the beginning similar to that after second formation of ponds, but in mid-July almost all the area investigated was covered with water. The ponds lasted by the beginning of August.

At about the time when ponds refilled for third time, a new, forth generation of *T. cancriformis* appeared. This generation reached sexual maturity by the middle of June and was present in the ponds until they dried out at the end of July. The growth of this generation, like two previous ones, was uniform. Maximum carapace size attained was about 2.2 cm.

Finally, at the beginning of July a fifth generation appeared; it lasted until the drying of ponds. At the time when a population of *T. cancriformis* finally disappeared the average temperature was about 23.3 °C and a maximum temperature attained 32.7 °C.

In September the amount of precipitation was high again, but the ponds were not formed because of high temperature (average temperature was 16.4 °C, maximum one 27.5 °C) and extremely desiccated soil.

As in 1991, season males were present during the whole; they appeared in each generation and made 15-38 % of the population. By the beginning of June they were considerably less frequent than later on (Fig. 4).

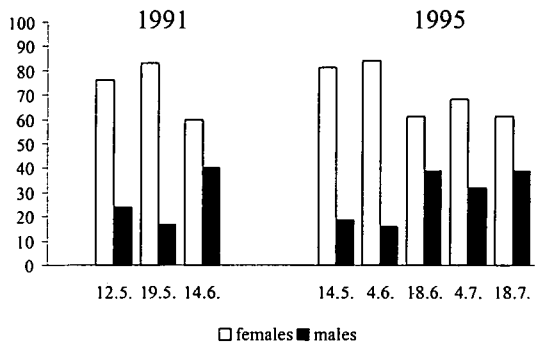

Fig. 4. Fluctuation of sex ratio in the population during the season

It is interesting to mention that *Triops cancriformis* was never present in all the ponds formed, although they were very close to each other, sometimes less than 1 m apart. *Triops cancriformis* was found in 8 - 39% of ponds (an example is given in Fig. 5). When ponds were fused it was restricted to certain areas.

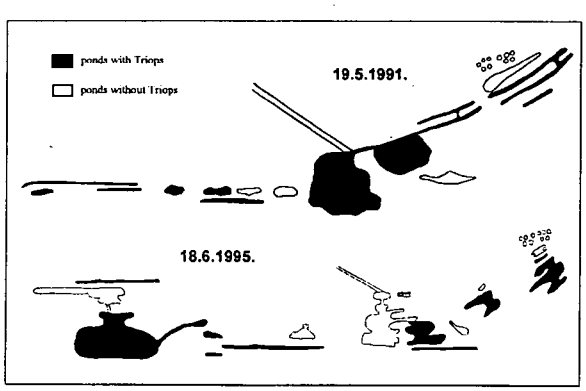

Fig. 5. Spatial distribution of *Triops cancriformis*

Discussion

Due to a periodical fusion of individual ponds in the area studied, and high possibility of transferring eggs from one pond to another, it may be assumed that the individuals of *Triops cancriformis* inhabiting different ephemeral ponds make a single population.

A population of *Triops cancriformis* appears with large individual numbers and regularly, i. e. every year when ephemeral ponds are formed. This is opposite to Hempel-Zawitkowska's (1967) observation in Poland where this species seldom occurs in small water bodies, and with a small abundance. Although regularly present, *T. cancriformis* is never found in all the ponds formed. At the beginning of the season (in early spring) its distribution is sporadic. Later on it is present in more and more ponds, but never in all of them.

Hatching takes place between the beginning of March and the beginning of April when the average air temperature varies from 7 to 10 °C, and a minimum one is usually between 4 and 6 °C, but sometimes also about zero. Since the investigated ponds are very shallow, there is a little difference in temperature between the water and the air. This means that temperatures at which hatching takes place in our population are much below the level of temperature (12-25 °C) established by Gaschott (1928) and Hempel-Zawitkowska (1967) at which eggs of *T. cancriformis* may hatch. Furthermore, after hatching, larvae and young individuals can endure even lower temperatures (up to -2.9 °C). This is in accordance with Gaschott (1928) who states that *T. cancriformis* can tolerate temperatures between 0 and 41 °C.

Eggs of the population investigated may hatch with or without previous drying. In the later case hatching usually follows after heavy rain fall. This causes a change of osmotic pressure what is probably a stimulus for hatching. The time of the appearance of *T. cancriformis* and its distribution in individual ponds during the season confirms the existence of all three types of eggs that Hempel-Zawitkowska (1967) has established in the parthenogenetic population of this species, i. e. eggs which may hatch in the same year without drying, eggs which will hatch next year after drying and eggs which hatch only after several times of repeated drying and irrigation.

Sexual maturity is reached after one month. The first sexually differentiated individuals may be found between the middle of April and the beginning of May. Individuals of our population need much more time to attain sexual maturity than those from a parthenogenetic population from Poland (about 12 days; Hempel-Zawitkowska 1967) or France (10 days; Nourisson and Aguesse 1962).

An individual life span of about 2 months and a 5 months life span of a population is established during our investigations. From the literature it may be concluded that the life span of a population of *T. cancriformis* varies considerably, e. g. it is 12-29 days (Hempel-Zawitkowska 1967) or about 3.5

months (Grasser 1933) or 4 months (Čuvachin 1929). Ramult (1938) found that the population always died shortly after attaining maximal development, and Hempel-Zawitkowska (1967) stated that most of the populations observed died suddenly before the drainage of the pond. During our investigations we have not noticed such cases; on the contrary, our population was present in the pond up to their desiccation.

Hempel-Zawitkowska (1967) investigated the effects of temperature and drying on the hatching of larvae of *T. cancriformis* and found that eggs may hatch without previous drying, but she did not found the second generation in the same season. She supposed that some unknown factors exist which cause an inhibition of egg development, or that metanauplii are eaten by adult individuals. We have found that several generations (up to 5) may appear during one year. New generations appear at one month intervals; this is a time when sexual maturity of previous generation is reached. Since up to three generations may be present in the same pond at a time, it is obvious that the parental generation does not affect the new one.

The growth rate of succeeding generations is faster and more uniform than that of the first one, and sexual maturity is reached earlier (after 25 and 20 days) probably because of more favourable conditions (higher temperatures in the first place). A time necessary for reaching sexual maturity in the youngest generation is closer to that in the parthenogenetic populations from Poland and France. A maximum size of individuals attained is smaller in every succeeding generation, and a life span is somewhat shorter.

The investigated area was inhabited with bisexual population of *T. cancriformis*. The presence of males was established whenever ponds were maintained long enough to reach sexual maturity. Males appeared simultaneously with females; they were present in the population during the whole period and in all generations. Males made 15-40 % of the population. At the beginning of the season (up to the end of May) they were less frequent, while later on they were twice as abundant. An increase of temperature could be the reason of this, since it is known that within the species of *T. cancriformis* bisexuality is normal in the southern part of its range, while in more northerly regions males become less frequent and they are totally absent in the extreme north of the range (Longhurst 1955, Hempel-Zawitkowska 1967). The frequency of males varied considerably in individual ponds at the same time probably due to local conditions. On July 6th in one pond, as many as 77 % of males were present.

Conclusions

On the basis of our five years investigations it may be concluded that a bisexual population of *Triops cancriformis* appears regularly with large individual numbers in the vicinity of the village Melence, in the Banat province. This species is never present in all the ponds formed.

Hatching takes place when the average temperature reaches 7-10 °C, and the minumum one 4-6°C. Larvae and young individuals can endure even lower temperatures. Eggs may hatch with or without previous drying. Three types of eggs are produced.

Sexual maturity is reached after one month. Individual life span is about 2 months, and life span of a population is 5 months.

If the climatic conditions are favourable during one year, several generations may appear. Up to three generations may be present at a time. The growth rate of succeeding generations is faster, but a maximum size of individuals and a life span is shorter in every succeeding generation.

Males appear regularly and in all generations. The frequency of males increases during the season.

Acknowledgements

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