On variability of *Acanthocyclops robustus* Sars from waterbodies of southeastern Kazakhstan (Crustacea: Cyclopidae)[1]

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Variability of *Acanthocyclops robustus* Sars is studied with use of five indices applied in the *Acanthocyclops* taxonomy. Differences in 3-5 indices are found between populations characterized by presence of spine or seta on the outer side of endopod 3 of leg 4.

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Introduction

Two species of the genus *Acanthocyclops*, *A. vernalis* Fischer and *A. robustus* Sars, are known from waterbodies of southeastern Kazakhstan (Sharapova, 1975; Malinovskaya & Ten, 1983). The taxonomy of the *vernalis-robustus* group gave rise to numerous arguments among copepod specialists during over one hundred years. Gurney (1933) distinguished only one species, *A. vernalis*, as a widely variable one. Rylov (1948) considered *A. robustus* to be a form of *A. vernalis*. Recently, it has been proved that *A. vernalis* and *A. robustus* are separate species. These species differ in the chromosome numbers and in a set of morphological characters (Einsle, 1993). *A. americanus* Marsh is similar to cyclops of the discussed group. In the revision of the *vernalis-robustus* group, Kiefer (1976) has distinguished only two mentioned species and placed *A. americanus* in synonymy with *A. robustus*[2].

Material and methods

The material was collected in the Almaty vicinity (SE Kazakhstan) from May to September at the water temperature of 17-28 °C in the following waterbodies: a pond in the city park ("waterbody 1" in the text below), the pond Sayran (waterbody 2), the Kok-Uzek Reservoir (waterbody 3), final storage of the Almaty sewage (waterbody 4), a fishpond of the Chilik Fishfarm (waterbody 5), and an unnamed pond (waterbody 6). The first two waterbodies are within the Almaty territory, others, at a distance of 10-70 km from Almaty.

The zooplankton samples were fixed with 4% formaldehyde. A total of 30-55 females from each population were measured. The measurements of each specimen were as follows: (1) body length, including furcal rami; (2) length and width of furcal rami; (3) length of the innermost and the outermost setae of furca; (4) length and width of endopod 3 of leg 4; (5) length of inner and outer apical spines of endopod 3 of leg 4. The values obtained have allowed calculation of several indices (in percents) used in the taxonomy of the genus *Acanthocyclops* (Table): (1) ratio of lengths of innermost seta of furca and outermost one – Set1/Set4 (%) (for numeration of setae, see Fig. 4); (2) ratio of length of innermost seta of furca to furcal length – Set1/Lf (%); (3) ratio of endopod 3 of leg 4 length to its width – Lart/Wart (%); (4) ratio of length of inner apical spine of endopod 3 of leg 4 to this segment length – In.sp./Lart (%); (5) ratio of lengths of inner and outer apical spines of this segment – In.sp./Ex.sp. (%). Attention was also paid to the following characters: shape of the sides of genital somite; armament of outer side of endopod 3 of leg 4; hair cover of inner setae of endopod 3 and exopod 3 of

[1] Paper read at the symposium "New methods in copepod taxonomy", St.Petersburg, 6-8 May 1998.

[2] Recently, *A. americanus* has been again separated from *A. robustus* based on the shape of the abdominal double-somite (Alekseev et al., 2002). The paper by E.G. Krupa is dealing with *A. americanus* (comment by V.R. Alekseev).

leg 4; dimensions of the spines on legs 5; modifications of leg 6 structure in males.

The Student's *t*-test was used to estimate the significance of differences in the mean values (Beili, 1962; Lakin, 1990). Abbreviations used in the text below: Enp – endopod; Exp – exopod, P – leg.

Results

The study of *A. robustus* populations revealed a heterogeneity in their structure. They can be tentatively divided into three groups: (1) populations consisting of individuals having a spine on the outer side of Enp3 of P4 (waterbodies 1 and 2); (2) populations consisting of individuals having a seta on the outer side of Enp3 of P4 (waterbodies 4-6); (3) mixed populations, with some individuals having a spine and some having a seta (waterbody 3).

The genital somite is rounded in specimens with a seta (Figs 1, 2) and has angular outlines in specimens with a spine (Figs 9, 10). The following characters are shared by both: the shape and structure of receptaculum seminis as in Figs 1 and 2; Enp3 of P4 elongate; inner apical spine longer than or rarely as long as outer spine; innermost seta of furcal rami shorter than, rarely as long as or longer than furcal rami; basipodite of antenna with a typical pattern of spinelets (Figs 3, 11).

The body length of females is rather variable. The largest specimens (body length 1500-1700 μm) were found in spring at water temperature 17-20°C, the smallest (950-1100 μm), in summer at water temperature 25-28°C. The correlation of the body size with temperature was described in literature (Coker, 1934; Lescher-Moutoue, 1996).

Group 1 populations (specimens with spine, waterbodies 1 and 2)

Female. Body length 975-1700 μm. Furcal rami on the average 4.44-4.6 times as long as wide. Third apical seta of furca with short hairs in distal part (Fig. 12). Setae on inner side of Enp3 and Exp3 of P4 with very short hairs in distal part and long hairs in upper part (Figs 13, 14). Spine on distal segment of P5 highly variable in size. Along with specimens with very reduced spine, as reported by Monchenko (1961) for *A. americanus* (= *robustus*) from the Ukraine, some specimens from waterbody 1 had strongly elongated spine of P5; distal segment of P5 elongate (Figs 15, 16).

Male. Outermost seta of furca spiniform (Fig. 19). Third apical seta of furca with short hairs in distal part. Spine of P6 as in Figs 17, 18.

Group 2 populations (specimens with seta, waterbodies 4-6)

Female. Body length 950-1400 μm. Furcal rami on the average 4.14-4.44 times as long as wide. Setae on inner side of Enp3 and Exp3 of P4 and third apical seta of furca with equal hairs along the entire length (Figs 4-6). Spine of P5 of usual shape and size (Fig. 7).

Male. Outer side of Enp3 of P4 with seta. Outermost seta of furca usual. Third apical seta of furca with short hairs along the entire length. P6 as in Fig. 8.

Group 3 populations (mixed population, waterbody 3)

Cyclopidae with different types of armament on Enp3 of P4 were found in the same samples in subequal number. Specimens with setae and with spines were measured separately.

Female. Body length on the average 1226 μm in specimens with spine and 1154 μm in those with seta. Both groups of specimens have similar values of indices (Table). Significant difference was found only in the ratio of the innermost to the outermost setae of furca (Set1/Set4), but specimens with a spine are characterized by the slightly more elongate Enp3 of P4, lesser ratio of apical spines of this segment, and more elongate furcal rami. Inner setae of Enp3 and Exp3 of P4 in specimens with spines covered with short hairs in the distal part only. The number of such setae is 1 to 3. Most specimens with seta bearing short hairs along its entire length, but 15% with seta bearing hairs in distal part only. Third apical seta of furca with hairs of equal length in cyclopids of both groups.

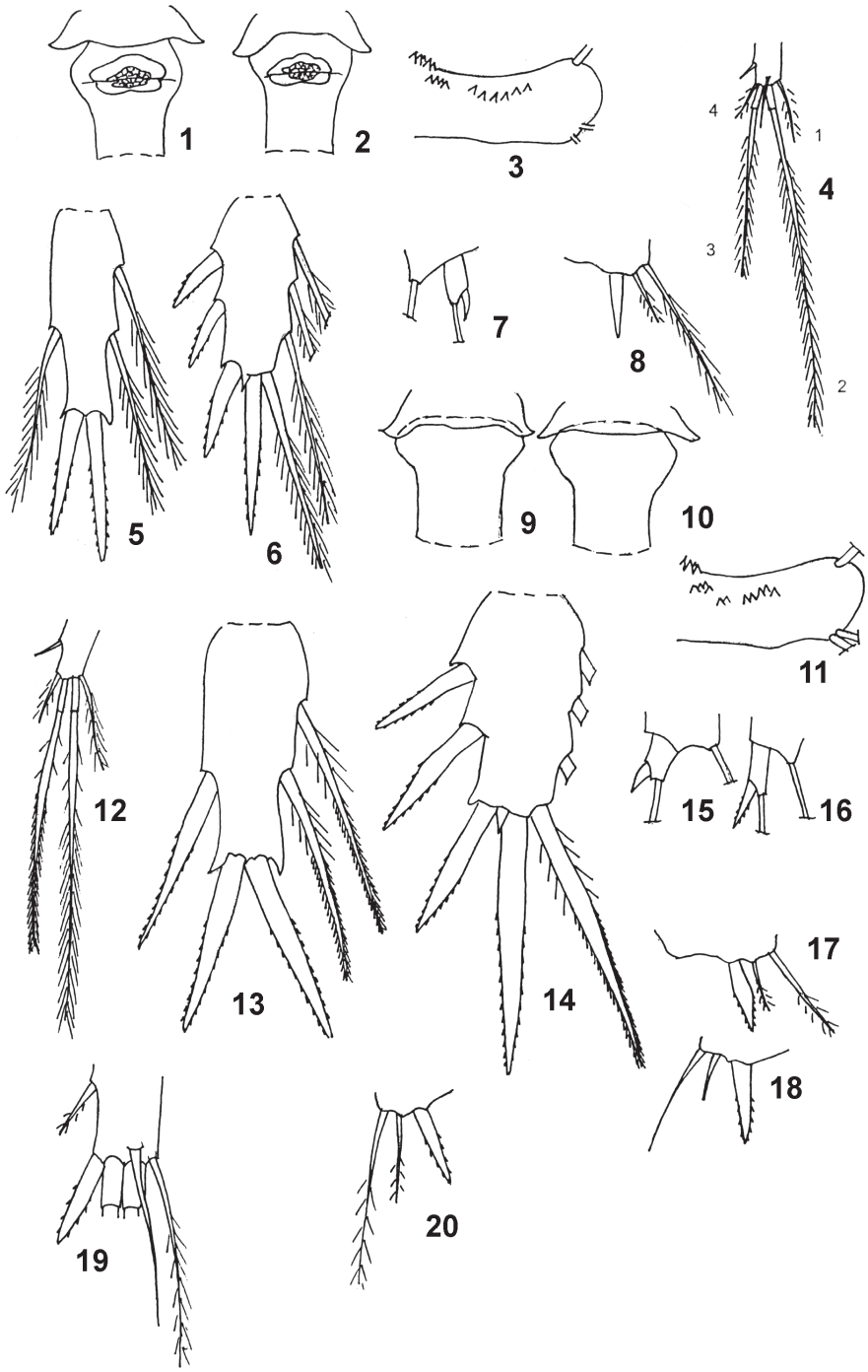
Male. Only males with spine on outer side of Enp3 of P4 were found in our samples. Outermost seta of furca spiniform (Fig. 19). Third apical seta of furca with short hairs along the entire length. Spine of P6 as in Fig. 20.

Discussion

The populations of group 1 (with spine) differ significantly from those of group 2 (with seta) in 3-5 indices (Figs 21, 22) and in some morphological characters. The most typical distinctions are as follows.

1. Sides of the genital somite are curved in specimens of group 2 (with seta) and angular in those of group 1. In all specimens of *A. americanus* (= *robustus*) from the Ukraine, the sides of the genital somite are rounded (Monchenko, 1961).

2. The ratio of the innermost and the outermost apical setae of furca (in percentage) is 180-



Figs 1-20. *Acanthocyclops robustus* Sars. **1-8**, specimens with seta on Enp3 of P4 (1-7, female; 8, male): **1**, **2**, genital somite; **3**, basipodite of antenna; **4**, furcal rami with furcal setae; **5**, Enp3 of P4; **6**, Exp3 of P4; **7**, P5; **8**, P6; **9-20**, specimens with spine on Enp3 of P4 (9-16, female; 17-20, male): **9**, **10**, genital somite; **11**, basipodite of antenna; **12**, furcal rami with furcal setae; **13**, Enp3 of P4; **14**, Exp3 of P4; **15**, **16**, P5; **17, 18**, **20**, P6; **19**, furcal rami.

Table. Values of indices (%) in populations of *Acanthocyclops robustus* from SE Kazakhstan

Waterbody, number of specimens, armament on outer side of Enp3 of P4	Set1/Set4	Set1/Lfur	Lart/Wart	Int.sp./Lart	Int.sp./Ex.sp.
Waterbody 1; n = 55; spine	186.0 ± 4.0 136-233 29.4 ± 2.8 15.8 ± 1.5	87.1 ± 1.3 69-111 9.7 ± 0.9 11.1 ± 1.1	239.0 ± 4.3 192-300 29.0 ± 3.0 12.0 ± 1.3	88.0 ± 1.1 74-108 7.5 ± 0.8 8.5 ± 0.9	115.1 ± 1.7 100-167 12.4 ± 1.2 10.5 ± 1.1
Waterbody 2; n = 31; spine	188.0 ± 2.8 157-236 15.7 ± 2.0 8.4 ± 1.1	97.2 ± 1.3 82-113 7.2 ± 0.9 7.4 ± 0.9	267.8 ± 3.4 238-300 18.2 ± 2.4 6.8 ± 0.9	86.1 ± 1.0 74-95 5.3 ± 0.7 6.2 ± 0.8	117.7 ± 1.1 109-129 6.0 ± 0.8 5.1 ± 0.7
Waterbody 3; n = 30; spine	180.7 ± 2.6 156-205 13.1 ± 1.8 7.2 ± 1.0	91.5 ± 1.2 82-106 6.3 ± 0.9 6.9 ± 1.0	243.3 ± 3.1 209-264 16.3 ± 2.2 6.7 ± 0.9	92.1 ± 0.9 84-100 4.5 ± 0.6 4.9 ± 0.7	112.9 ± 0.8 102-119 3.9 ± 0.5 3.5 ± 0.5
Waterbody 3; n = 32; seta	173.3 ± 2.1 158-204 12.2 ± 1.5 7.0 ± 0.9	91.1 ± 1.3 74-104 7.2 ± 0.9 7.9 ± 1.0	236.9 ± 3.6 200-280 20.6 ± 2.6 8.7 ± 1.1	92.6 ± 1.0 79-108 5.7 ± 0.7 6.1 ± 0.8	114.6 ± 0.9 102-124 5.0 ± 0.6 4.4 ± 0.5
Waterbody 4; n = 32; seta	168.2 ± 1.9 143-188 10.6 ± 1.3 6.3 ± 0.8	95.0 ± 1.1 84-110 6.1 ± 0.8 6.4 ± 0.8	280.6 ± 4.2 230-320 23.8 ± 3.0 8.5 ± 1.1	81.2 ± 1.3 69-96 7.1 ± 0.9 8.7 ± 1.1	124.0 ± 1.1 112-139 6.2 ± 0.8 5.0 ± 0.6
Waterbody 5; n = 31; seta	166.3 ± 2.0 146-189 11.3 ± 1.4 6.8 ± 0.9	92.3 ± 1.5 75-107 8.5 ± 1.1 9.2 ± 1.2	264.2±4.6 210-310 25.8±3.3 9.8±1.2	82.3 ± 0.9 69-100 5.3 ± 0.7 6.4 ± 0.8	121.1 ± 1.5 105-137 8.4 ± 1.1 6.2 ± 0.9
Waterbody 6; n = 31; seta	165.5 ± 2.4 132-195 13.5 ± 1.7 8.2 ± 1.0	94.2 ± 1.6 74-115 8.9 ± 1.1 9.4 ± 1.2	249.6±4.0 210-300 21.6 ± 2.8 8.7 ± 1.1	87.6 ± 1.0 81-100 5.4 ± 0.7 6.2 ± 0.8	122.2 ± 1.3 108-141 7.3 ± 0.9 6.0 ± 0.8

190 in group 1 populations and 165-168 in group 2 populations. Cyclopids from the Ukraine have similar ratios: 197 and 173, respectively. In *A. robustus* with spine from the Oslo Museum, this ratio is 123-143 (Kiefer, 1979).

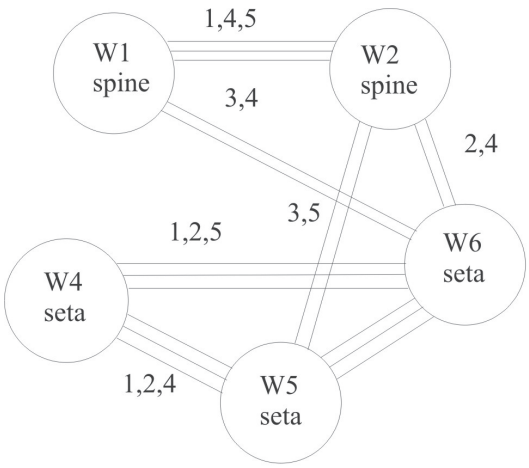
3. The ratio of apical spines on Enp3 of P4 is 115-118 in group 1 populations and 120-124 in group 2 populations. Cyclopids from the Ukraine have similar values of these indices: 113 and 118, respectively. In specimens with spine from the Oslo Museum, this index is 105 (Kiefer, 1979).

4. The setae on inner side of Enp3 and Exp3 of P4 and the third apical seta of furca are covered with short hairs in distal part in specimens of group 1 and along the entire length in specimens of group 2 (with seta).

5. The spine of P6 is stronger in males of group 1 (with spine) than in those of group 2.

A mixed population was found in one of the waterbodies. In this population, specimens with a spine differed significantly from those with a seta in a single index: the ratio of the innermost and the outermost setae of furca (Fig. 22). Though the difference is not significant, the ratio of apical spines on Enp3 of P4 in specimens with a spine is less than in those with a seta, like in populations of the corresponding group from other waterbodies. The specimens with spine from this waterbody differ significantly from specimens with a similar armament in 2-4 indices and from populations with seta, in 3-5 indices. The specimens with seta from this waterbody differ significantly from those collected from all other waterbodies in 3-5 indices (Figs 22-23).

There is published information on extraordinary variability of *A. robustus*. According to Dodson (1994) and Lescher-Moutoue (1996), the armament of Enp3 of P4 and appearance of inner setae on Enp3 and Exp3 of P4 as well as of the third apical seta of furca have seasonal vari-



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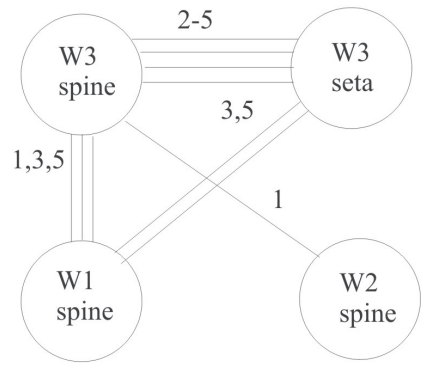

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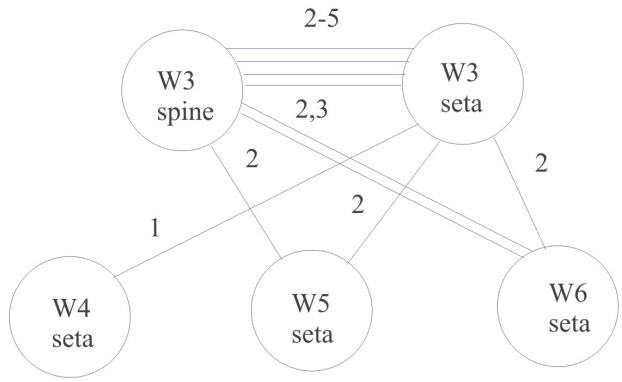

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Figs 21-23. *Acanthocyclops robustus* Sars. Morphological similarity between the examined populations from SE Kazakhstan. W1-W6: waterbodies 1-6. Lines connecting circles denote the absence of significant difference (*t*-test, $P \leq 0.05$) according to the specified indices (numbers at lines). **21**, comparison of group 1 (specimens with spine: W1, W2) and group 2 (specimens with seta: W4-W6) populations; **22**, comparison of group 3 (mixed population: W3) and group 1 (specimens with spine: W1, W2) populations; **23**, comparison of group 3 (mixed population: W3) and group 2 (specimens with seta: W4-W6) populations.

ation. At the water temperature above 10 °C, specimens with seta (plumose form) are developed, and such specimens form 90-100% of the population in summer. In autumn, at the water temperature below 15 °C, specimens with spine (spinose form) are developed. However, specimens with spine and with seta were found in our samples collected at the temperature 17-28 °C.

According to Kochina (1987), populations of three chromosome forms of *A. americanus* (= *robustus*), with 2n = 6, 8, 10, are revealed in the Ukraine. These forms are reproductively isolated, which testifies to the species status of the respective populations. Our data on the morphological heterogeneity of *A. robustus* populations from the watebodies of SE Kazakhstan agree with Kochina's

results. However, additional investigations and, possibly, an application of cytotaxonomic methods are needed for clarifying the taxonomic status of *A. robustus* populations from our samples.

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