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Nannocalanus minor (Claus, 1863) (Crustacea: Calanoida: Calanidae) from the Sicilian Channel of the Mediterranean Sea

Nannocalanus minor (Claus, 1863) (Crustacea: Calanoida: Calanidae) из Тунисского пролива Средиземного моря

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КЛЮЧЕВЫЕ СЛОВА: *Nannocalanus minor,* Calanidae, Средиземное море, переописание.

ABSTRACT. A redescription of *Nannocalanus minor* from waters of the Sicilian Channel of the Mediterranean Sea is provided. This area is close to the northeast part of Sicily, near the locality where the *locus typicus* was described. Originally, this description contained only the text [Claus, 1863]; later Giesbrecht's [1892] brief description of a species was added by numerous figures. Unfortunately, several characters, that would allow to distinguish *N. minor* from representatives of *Nannocalanus* occurring in other areas of the World Ocean were not provided. In particular, it was the lack of a detailed description and figures of the female's genital somite and some details of the male's leg P5 that led to the false impression that *N. minor* might have a cosmopolitan distribution. Recent publications testify that *Nannocalanus* includes, at least, 2 species: *N. minor* (Claus) and *N. elegans* Andronov. The present studies shows that *N. elegans* from the southeast areas of the Pacific Ocean is morphologically very close to *N. minor* from the Mediterranean Sea.

РЕЗЮМЕ. Приводится полное иллюстрированное переописание *Nannocalanus minor* из вод Тунисского пролива Средиземного моря. Этот район достаточно близок к северо-восточной части Сицилии, месту первого описания вида. Первоначально это описание содержало только текст [Claus, 1863], позднее Giesbrecht [1892] краткое описание вида сопроводил многочисленными рисунками. К сожалению, эти и последующие исследователи не акцентировали внимание на ряде признаков, позволяющих различать *N. minor* и представителей рода *Nannocalanus* из других районов Мирового океана. В частности, отсутствие детального описания и рисунков генитального сегмента самки и некоторых деталей строения ноги P5 самцов привело к представлению о том, что *N. minor* имеет всесветное распространение. Однако публикации последних лет свидетельствуют о том, что род *Nannocalanus* включает, по меньшей мере, 2 вида: *N. minor* (Claus) и *N. elegans* Andronov. Настоящее исследование показывает, что *N. elegans* из юго-восточных районов Тихого океана морфологически очень близок к *N. minor* из Средиземного моря.

Introduction

The genus *Nannocalanus* was established by G.O. Sars [1925]. Copepod species belonging to this genus are widely distributed in tropical and subtropical waters of the World Ocean [Vervoort, 1949]. At the same time, single specimens of this species were also found in waters of moderate and high latitudes [Bradford, 1971].

The morphology of females and males of *Nannocalanus* from different regions of the World Ocean is very similar, although researchers found some distinctions in the shape of their body [Candeias, 1926 (cit. after Vervoort, 1946); Dakin and Colefax, 1940]. Sewell [1929, 1947] has described 2 forms of this species, *N. minor* f. *minor* and *N. minor* f. *major*, differing in size of the body and in some morphological features of the operculum belonging to the genital somite of the females, leg 2 of female and leg 5 of female and male. Recent population genetic analyses of *N. minor* from the Gulf Stream showed that this species can be divided into several genetically differentiated groups that are allocated to separate species [Bucklin, 1995, 1998; Bucklin et al., 1996].

Taxonomic problems within the genus are eminent; also the initial description of *N. minor* by Claus (as *Cetochilus minor*) from the Messina area (north-eastern Sicily) provides no illustrations [Claus, 1863]. Later, Giesbrecht [1892] presented a brief description with many detailed figures of this species from the

Neapolitan Bay. They included: shape of a female (from dorsal), its head, abdomen (schematically), gnathobase of mandible, leg 3 and leg 5, and also the lateral head of a male, its antennule and leg 5. Unfortunately, among these illustrations, there was no detailed figure of the female's genital segment, and internal edge of male's coxa of leg 5 is drawn with a lack of detail.

Being guided only by these illustrations and rather brief description of a species, not having an opportunity to compare specimens of *Nannocalanus* from different areas of the World Ocean, researchers did not doubt the correctness of their species identification, and diagnosed all representatives as *N. minor*. In later publications on Calanoida from different areas of the World Ocean the figures of body shape and leg 5 were provided only superficially [Mori, 1937; Rose, 1933; Dakin & Colefax; 1940; Brodsky, 1962, 1972; Bradford-Grieve, 1994]. Denticles at the internal edge of the female's coxa of leg 5 and features and the position of a line of denticles at the internal edge of the male's leg 5 were not provided usually. An exception is made, perhaps, only in the contribution of K.A. Brodsky [1972] in different parts of which the following figures are submitted: the head end of a female body, its distal part of the last thoracic segment in lateral view, leg 1, leg 5, inner edge of leg 5 coxa, coxa and endopod of leg 5, genital field in frontal and lateral view, and also male leg 5. Unfortunately, the place of capture of *N. minor* is specified only for females.

Rather recently it has been shown from material collected in the southeast Pacific Ocean, that the genus *Nannocalanus* includes at least 2 groups of specimens that are morphologically distinctly different. One group is described as *N. elegans* Andronov, 2001[1] . The other most numerous group of individuals has been perceived as *N. minor* by the shape of the body in lateral view and by the quantity of denticles on the coxa of leg 5. That coincided very well with illustrations and descriptions of this species in the publications listed above.

Further research of original material on *Nannocalanus* from different areas of the Atlantic Ocean has shown that females can differ distinctly in features of the genital segment and some other characteristics. This holds particularly for differences in the form and length of the distal ends of the caudalmost thoracic sommites, in the distribution of denticles on the internal surface of the male's leg 5 coxa. Essential distinctions in the quantity of such denticles in the females are already reported in the literature [Brodsky, 1972].

It became obvious, that it is necessary to have a more detailed description of *N. minor* from its first place of description, that is, from the middle part of the Mediterranean Sea. This will allow a competent comparison of individuals of this genus from different areas of the ocean with the original *N. minor*. There are doubts that representatives of the more abundant Pacific group or *Nannocalanus* are represented by *N. minor*. Therefore, special attention was accentuated on a structure of the genital somite of females and on the arrangement of denticles on the internal edge of the male's coxa of leg 5 in the description of *N. minor*.

The following abbreviations are used in the descriptions given below: P1–P5 — swimming legs of 1–5; SmP1–SmP5 — somites bearing 1st–5th swimming legs; Re1–Re7 — 1st–7th segments of exopod; Ri1–Ri3 — 1st–3rd segments of endopod. A scale ruler is 0.1 mm.

Material and methods

Calanoid copepods of *N. minor* used for this study were selected from 13 samples of zooplankton, obtained by employees of the Institute of Biology of the Southern Seas (IBSS, Sevastopol) during a research cruise of R/V "Akademik A. Kovalevsky". Stations were located across the Sicilian Channel between points 36°40'5N, 12°35'5E and 38°57'0N, 09°50'7E. Samples were taken in the period from January 16 until February 9, 1970 by a open-closing JUDAY net with a 37 cm ring diameter and 112–120 μm mesh size. Integrated hauls (0–100m) were taken. Samples were preserved in 3–4% buffered solution of formaldehyde in sea water.

Material examined: 128 females and 30 males. Also, about 20 Pacific females of *Nannocalanus* of both species were analyzed more carefully from material obtained earlier [Andronov, 2001] to compare these with Mediterranean individuals of *N. minor*.

Binocular optic microscopes (MBS–1 and MBD–1) were used for microscopic investigations. Figures are drawn by means of a drawing device RA–4.

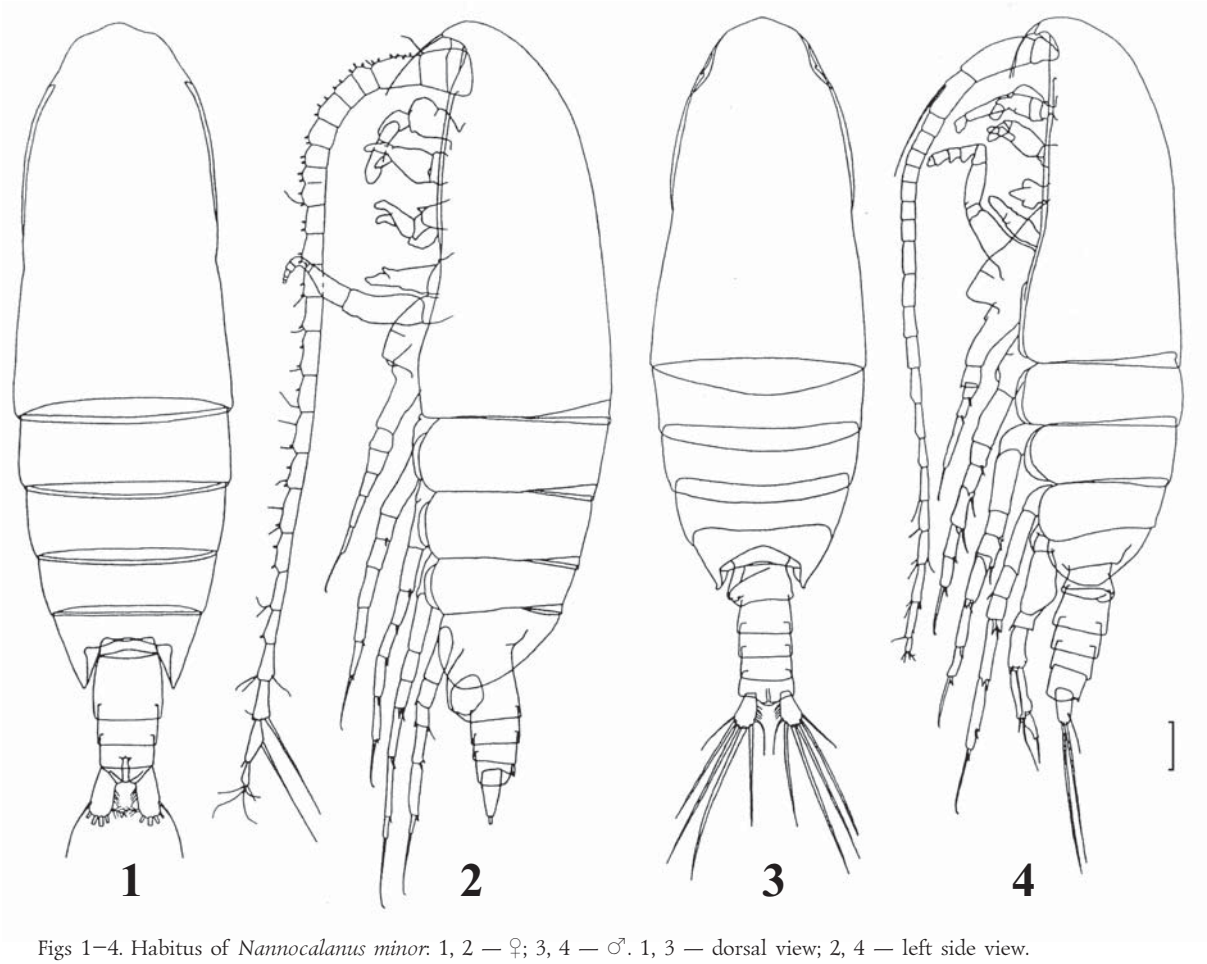
Description of *Nannocalanus minor* from the Sicilian Channel

Figs 1–36.

FEMALE (Figs 1, 2). Body total length 1.72–2.20 mm (n=128), average 1.84 mm. Prosome length 1.12–1.60 mm, average 1.40 mm. Body elongated dorsally, more thickset, than in *N. elegans*, and more extended, than in *N. minor* from the southern Pacific [Bradford-Grieve, 1994; Andronov, 2001]. Forehead broadly rounded in dorsal view, narrowly rounded in lateral view. Rostrum with two long filaments. Head merged with SmP1, SmP4 and SmP5 separated. Distal corners of SmP5 produced distally in symmetrically rounded lobes and reach the middle of the genital complex. Urosome consisting of four somites is short. Ratio of length of prosome to length of urosome 3.2:1. Genital somite emarginates ventrally.

Genital double-somite is the largest, practically symmetric, with slightly convex sides (Figs 5–8, 11, 12). Its length approximately one third of the length of the 4-segmented urosome. Genital field located a little closer to the dorsal edge of a somite and occupies up to 95% of its width. Morphological and anatomic details of the genital complex

[1] Caption signatures to figures 2–9 are mixed in the article of Andronov [2001]. It is necessary to read: Figs 2–9. Habitus of *Nannocalanus elegans* sp. n (2, 3, 6, 7) and *N. minor* (Claus) (4, 5, 8, 9). 2, 3, female, holotype; 6, 7, male, paratype; 4, 5, female; 8–9, male. 2, 5, 6, 9, dorsal view; 3, 4, 7, 8, left side view.



Figs 1–4. Habitus of *Nannocalanus minor*: 1, 2 — ♀; 3, 4 — ♂. 1, 3 — dorsal view; 2, 4 — left side view.
Рис. 1–4. *Nannocalanus minor*, внешний вид: 1, 2 — ♀, 3, 4 — ♂. 1, 3 — вид со спины; 2, 4 — вид слева.

differ with the physiological and reproductive state. Inseminated females in stage of spawning with lowered or raised operculum occur more often (Figs 7–10). Separate eggs and dark brown non-uniform granular contents of internal genital structures are distinct in atrial cavities (Figs 7–12, sm, at). Unfertilized (virgin) individuals were found much less. Their genital complex is rather transparent owing to the absence of sexual products (Figs 5, 6).

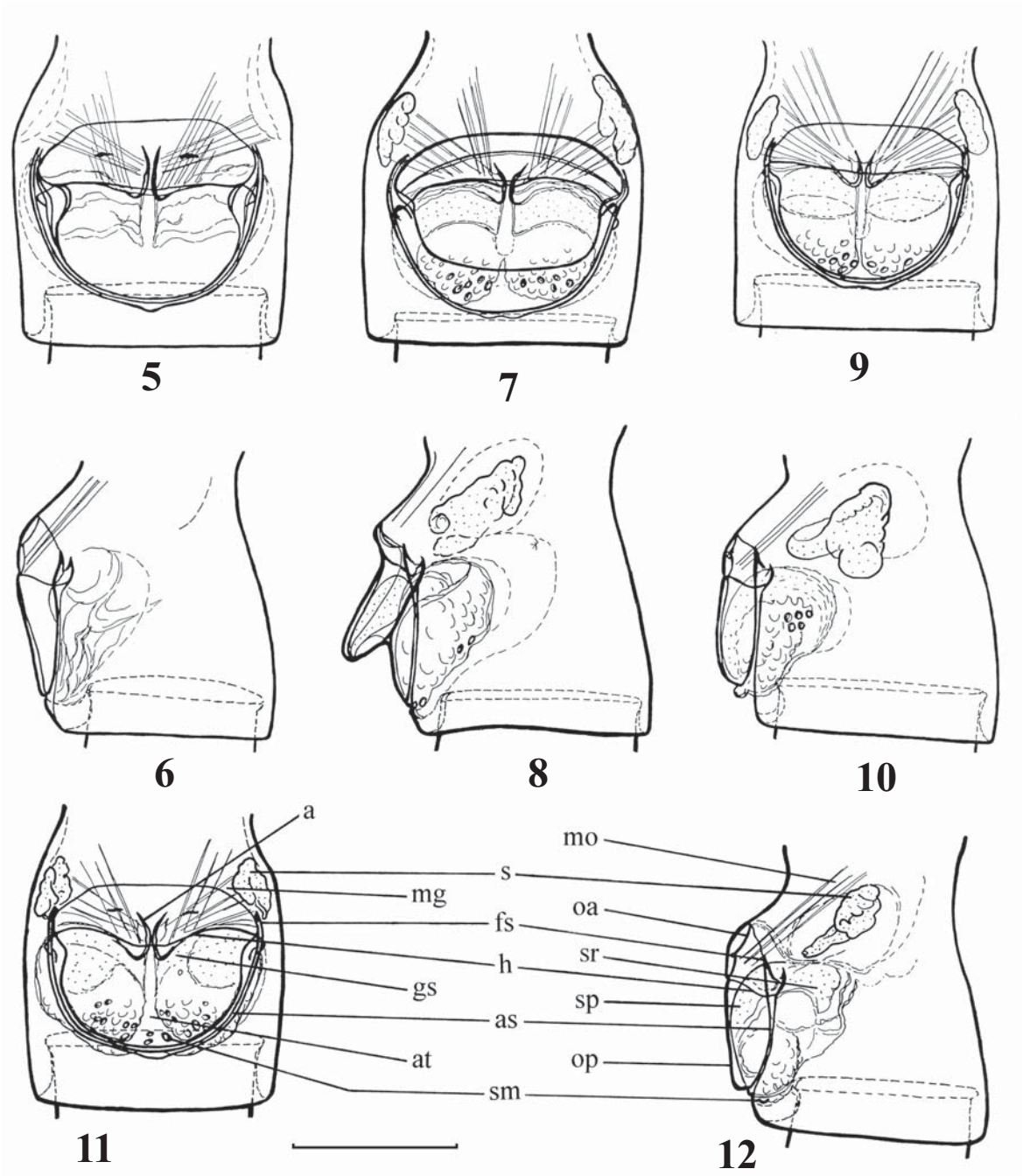
Gonopores covered by operculum (=genital flap). The operculum represents an unpaired median, mobile structure with a hinge along all its width. Two sites are perceptibly distinguished: anterior, narrower, and posterior, opening access in atrium. The anterior part of operculum has the form of an oval strongly extended in width with the cut-off basis, whereas its posterior part is of semicircular form.

It appears that gonoporal slits (terminal site of gonopore, a place of an output of eggs from oviducts into the atrial cavity) are located across a somite behind the hinged operculum. Their length is close to half of the operculum width (Figs 5, 11, gs). Eggs (Figs 11, 12, sm), leaving the atrium through an atrial slit (Figs 11, 12, gs), well differentiated among masses of sexual products at inseminated females.

In ventral view the segment provides two groups of muscles, such as the gonoporal and opercular muscle. Muscles of the operculum connect its central part with the ventral wall of the somite (Fig. 12, mo). One end of each muscle bundle is attached to rigid crescent-shaped structures (Fig. 11 a), the other end it is attached to an emarginating part of the lateral walls (Fig. 11, mg). These rigid structures (apodemes — according to Barthélémy, 1999, Fig. 2) are parts of the gonoducts, serving for an exclusion of the eggs from oviducts in the atrial cavity. Small cuticular depressions are clearly visible outside on lateral walls of a somite, in places of an attachment of the gonoporal muscles. Here, grape-formed structures of pinky-golden color are usually appreciable irrespective of a foreshortening at inseminated females (Figs 11, 12, s). These formations have no determined form and are absent in virgin females. Probably, these structures are involved in the process of insemination.

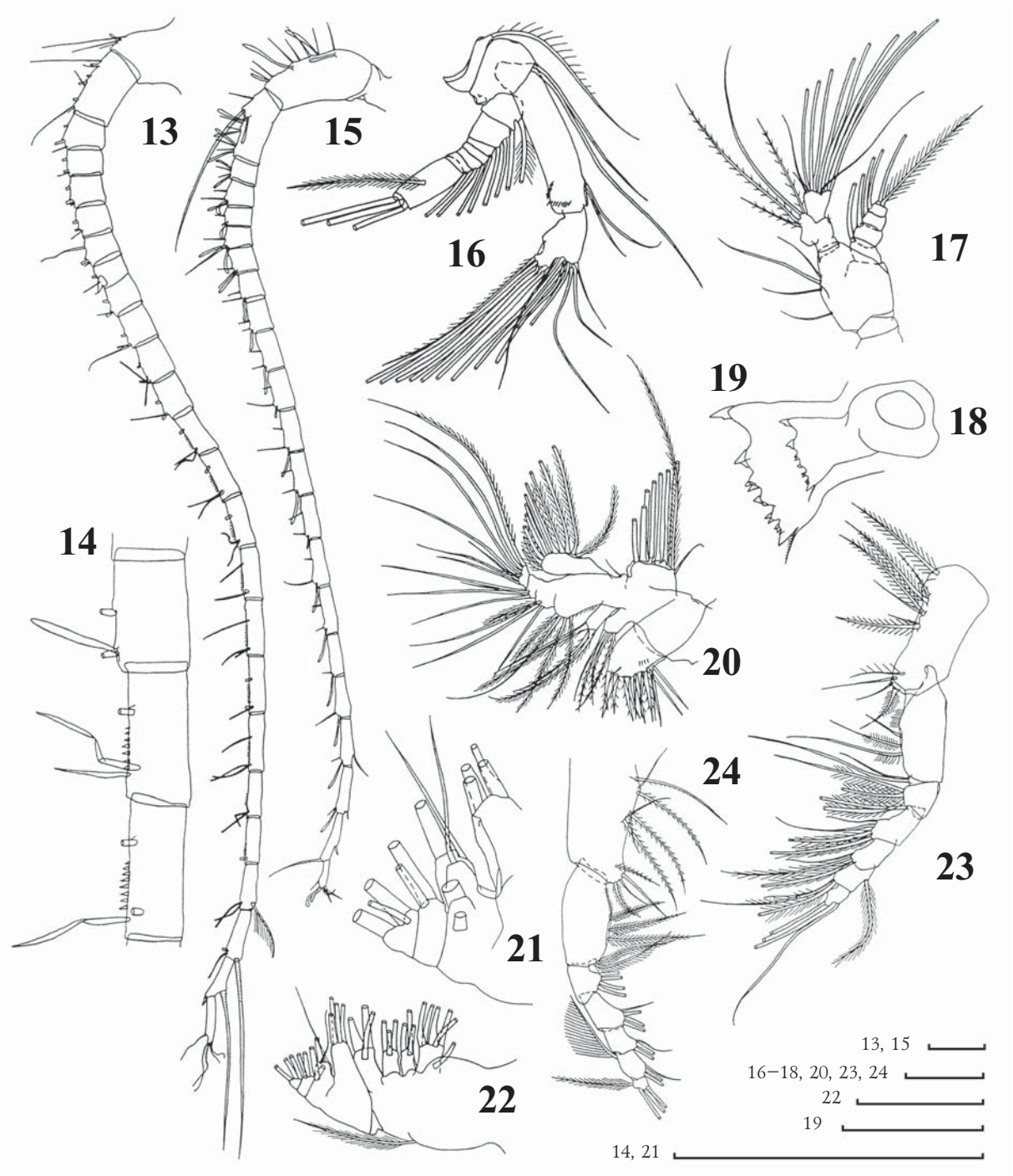
The fine-grained dark mass located directly under the operculum from the inside is best visible in lateral view. Most likely, it can correspond to active spermatozoa. This mass smoothly passes from the back part to the structure surrounding an internal central part of higher optical density. The last one corresponds to zones of gonopores and products of their functioning (Fig. 11, gs). Thus, zones of lower optical density can represent cavities of the presumed seminal receptacles (Fig. 12, sr). They surround an anterior part of internal structures of a genital complex and reach for a hinge of operculum from the dorsal side.

Mouthparts and P1–P5 (Figs 13–32) as in *N. elegans* [Andronov, 2001].



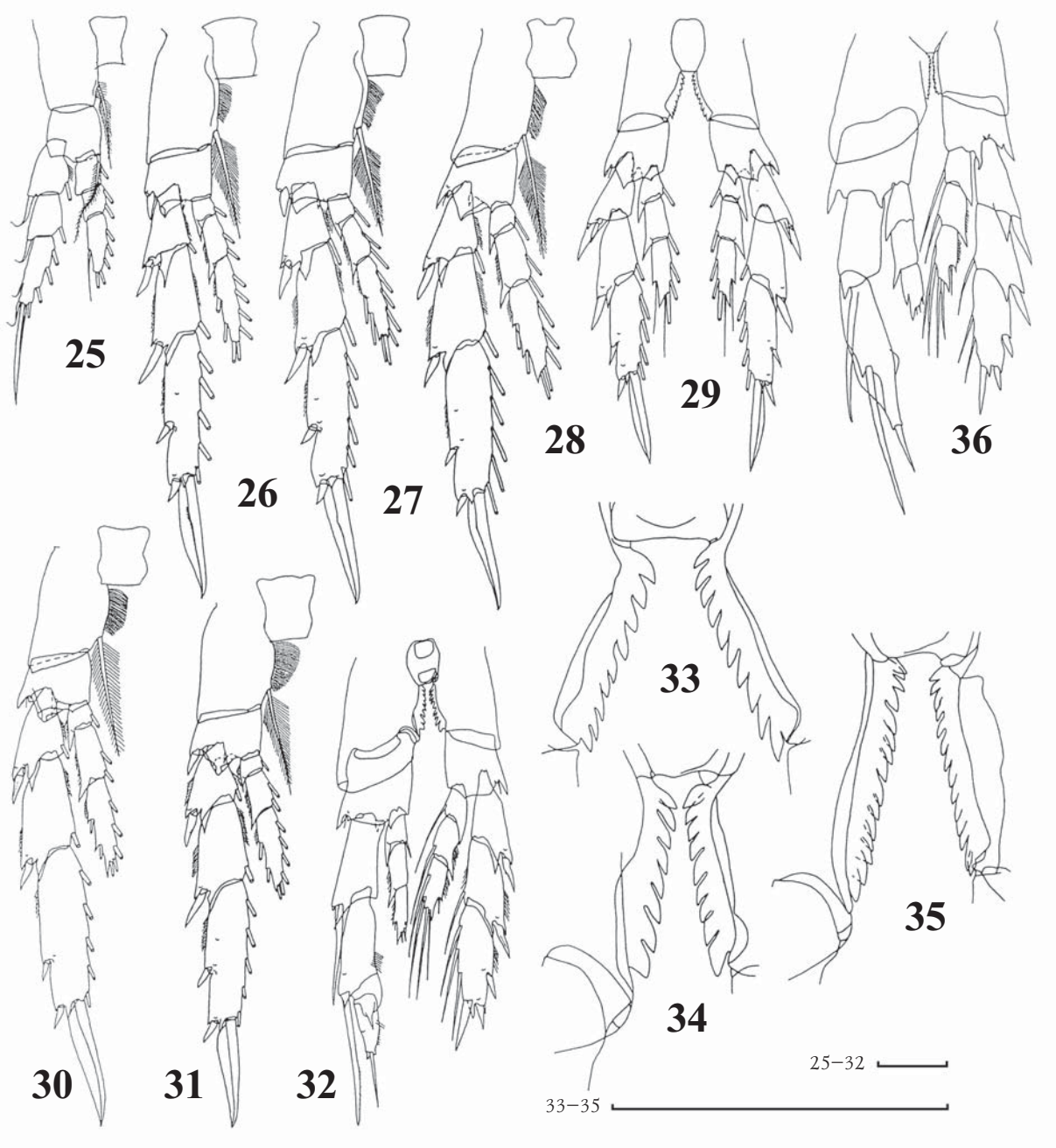
Figs 5–12. *Nannocalanus minor,* genital double somite of ♀♀: 5, 7, 9, 11 — ventral view; 6, 8, 10, 12 — left side view; total length of ♀♀: 5–10 — 1.9 mm; 11, 12 — 1.8 mm; 5–8, 11, 12 — Sicilian channel, Mediterranean Sea; 9, 10 — South-Western Pacific. a — apodemes, chitinous structures of attachment places of muscle bundles; as — atrial slit; at — genital atrium (atrial cavity, in which eggs are fertilized); fs — structure of border of lateral edge of atrial cavity; gs — localization place of gonoporal slit; h — hinge of operculum between his anterior and posterior parts; mg — bundle of gonoporal muscles (by consideration in lateral view it is not distinct); mo — bundle of opercular muscles; oa — anterior part of genital operculum; op — posterior part of genital operculum; s — grape-form structures; sm — mass of the eggs leaving atrial cavity; sp — mass of spermatozoa under opercular internal surface; sr — dorso-lateral edge of seminal receptacle.

Рис. 5–12. *Nannocalanus minor,* генитальный сегмент ♀♀: 5, 7, 9, 11 — с брюшной стороны, 6, 8, 10, 12 — слева; общий размер ♀♀: 5–10 — 1,9 мм, 11, 12 — 1,8 мм; 5–8, 11, 12 — Тунисский пролив Средиземного моря; 9, 10 — юго-восточная часть Тихого океана. a — аподемы, хитинизированные образования — места прикрепления пучков мышц; as — атриальная щель; at — генитальный атриум (полость, в которой происходит оплодотворение); fs — структура границы бокового края атриума; gs — место положения гонопоральной щели; h — место перегиба оперкулума между передней и задней частями; mg — пучок гонопоральных мышц (сбоку не виден); mo — пучок оперкулярных мышц; oa — передняя часть генитального оперкулума; op — задняя часть генитального оперкулума; s — гроздевидные структуры; sm — скопление готовых к вымету икринок; sp — скопление сперматозоидов под внутренней поверхностью оперкулума; sr — дорзо-латеральный край семяприемника.



Figs 13–24. *Nannocalanus minor*, Sicilian channel: 13, 14, 16–23 — ♀; 15, 24 — ♂; 13, 15 — antennule; 14 — ancestral segments of antennule XIV–XVI; 16 — antenna; 17 — mandibular palp; 18, 19 — mandibular blade; 20 — maxillule; 21 — distal end of maxilla; 22 — maxilla; 23, 24 — maxilliped.

Рис. 13–24. *Nannocalanus minor*, Тунисский пролив: 13, 14, 16–23 — ♀, 15, 24 — ♂, 13, 15 — антеннула; 14 — анцестральные членики антеннулы XIV–XVI; 16 — антенна; 17 — щупик мандибулы; 18, 19 — мандибулярная пластинка; 20 — максиллула; 21 — дистальная часть максиллы; 22 — максилла; 23, 24 — максиллипеда.



Figs 25–36. *Nannocalanus minor*. Mediterranean Sea: 25–29, 33 — ♀; 30–32, 34–36 — ♂; 25–29 — P1–P5, posterior; 30–32 — P3–P5, posterior; 33 — inner edge of ♀ coxa of P5; 34, 35 — inner edge of ♂ coxa of P5, different individuals, posterior; 36 — P5 of ♂, posterior (from Giesbrecht, 1892, with changes).

Рис. 25–36. *Nannocalanus minor*. Средиземное море: 25–29, 33 — ♀; 30–32, 34–36 — ♂; 25–29 — P1–P5, задняя поверхность; 30–32 — P3–P5, задняя поверхность; 33 — внутренний край коксоподита P5 ♀; 34, 35 — внутренний край коксоподита P5 ♂, разные экземпляры; 36 — P5 ♂(по Giesbrecht, 1892, с изменениями).

Antennule (Fig. 13) with 24 free segments extends to the end of the caudal rami. Ancestral segments X and XI are merged partially. External distal edge of ancestral segment X has specific short and stout setules as a characteristic for the representatives of Calanidae [Bowman, 1978; Fleminger, 1985; Andronov, 2001]. Segments XV–XXIII with a row of fine denticles, up to 18 in number. Their size decreases towards the distal end of the segment (Fig. 14). Presence of these denticles at *Nannocalanus* is marked for the first time though they were found in females of some other genera of the family Calanidae as well (e.g., *Calanus pacificus californicus*, *Calanoides philippinensis*) [Fleminger, 1985].

Antenna (Fig.16). Coxa with 1 inner seta. Basis with 2 unequal setae at inner distal corner. Distal end of Ri1 with 2

inner setae, and its external part with a row of minute setules. Distal end of Ri2 with 7+9 setae. Re1–7 with 2, 2, 1, 1, 1, 1 and 1+3 setae accordingly.

Mandible (Figs 17, 18). Gnathobase with cutting edge of one large ventral, four multitubercular central, three small dorsal teeth and one plumose seta dorsally. Internal edge of basis with 1 proximal and 3 distal setae. Internal part of distal end of Ri1 with a swell bearing 4 setae. Ri2 with 11 setae. Re1–Ri5 with 1, 1, 1, 1 and 2 internal setae, correspondingly.

Maxillule (Fig. 20). Medial arthrite of praecoxa with 13 teeth and setae of various forms. Epipodite with 9 and coxal endite with 4 setae. Proximal and distal endites of basis with 4 setae each, its outer lobe, exite, with 1 small seta. Exopod is armed with 11 marginal setae. Endopod 3-segmented bearing 4, 4 and 7 setae accordingly.

Maxilla (Fig. 21). Endites 1–4 and basis with 6, 3, 3, 3 and 4 setae accordingly. Distal part of endopod with 10 setae (Fig. 22). Coxa with 1 outer seta.

Maxilliped (Fig. 23). The inner edge of proximal part of basis with a number of flexible hairs. Middle part of basis with 4 setae. Ri1–6 with 2, 4, 4, 3, 3+1 and 4 setae accordingly.

P1–P5 with 3-segmented exopods and endopods. Inner edge of coxa of P1–P4 with haired inner border, with a long and plumose seta on its distal end. Distal part of basis of P2 and P3 with large outer tooth, separated from the somite bearing it. Distal part of basis of P3 and P4 with a large outer appendix completely fused with this segment. Thin and small seta deviates from a junction of this appendix and a segment bearing it. Coxa of P5 with a toothed inner border with a relatively small number of teeth (8–18, average 13, n=40) and without a distal inner seta (Figs 29, 33).

MALE (Figs 3, 4). Total length 1.62–1.80 mm (n=30), average — 1.70 mm. Prosome 1.24–1.34 mm, average — 1.30 mm. Body elongate and smoothly rounded as in the female. Dorsal cephalic hump characteristic for males of the genus *Calanus* is absent. Head is merged with 1st pedigerous somites, SmP1, SmP4 and SmP5 pedigerous somites 4 and 5 separated. Prosome 2.7 times as long as urosome. Antennule of 22 free segments, does not reach the distal end of urosome. Its ancestral segments I–IV and V–VII merged. Mouthparts and P1–P4, except maxilliped, almost of the same structure as in female. External feathered setae on Re5 and Re6 of maxilliped directed to the proximal end of the maxilliped (Fig. 24), as in others males of the family Calanidae (e.g., Sars [1903, Pl. III], Vyshkvartzeva [1976, Figs 16, 25]).

P5 asymmetric (Fig. 32). Inner border of left coxa of P5 is longer then the right one (Figs 34, 35). Inner edges of both coxae with a number of rather wide denticles. The number of denticles varies from 9 up to 17, average 13 (12 on left P5 and 14 on right P5, n=20). Coxa and basis of left P5 is larger and longer than the right one (Fig. 31). Sculptural chitinous formations between these segments of the left leg form the original "joint" allowing the leg to be bent to the left.

Right P5 of male differs from P5 of female only slightly. Inner edge of right Re3 P5 can be with 2–4 setae. Left Re3 P5 without inner seta. Their outer spine is thinner and longer in comparison with that on right P5. Usually these spines are longer than the somites bearing them. Setae on left Ri P5 is very short and thin. They are absent more often at the inner edge of the 1st and 2nd segments, distal segment with 2 or 3 setae.

Discussion

A comparison of *N. minor* from the Sicilian Channel with Giesbrecht's [1892] description of this species revealed only slight differences. They concern mainly the structure of the male's P5. In particular, in Giesbrecht's male [1892, Taf. 8, fig. 30] the length of an external spine of left Re1 P5 exceeds in distance from its basis up to the basis of the external thorn Re2 P5 approximately by 1.5 times (see our Fig. 36). In several males investigated by us this spine just reaches the basis of a spine on Re2 P5. However, in some individuals this spine is 20% longer. A comparison of the descriptions and the original material on *N. minor* and *N. elegans* let us conclude that these species are very closely related to each other. A structure of the genital somite of females of both species (Figs 7–12), mouthparts and P1–P5 of both females and males are practically identical.

Small divergences between published description of *N. elegans* and the Mediterranean *N. minor* are actually caused by rather subjective reasons. A reinvestigation of females of *N. elegans* has shown, that their antennules, as well as those of the females of *N. minor* also show fine denticles on corresponding segments, Ri1 of antenna with 2 setae; gnathobase of praecoxa of maxilla with 13 strong setae, 3 setae are present on the 6th lobe of the maxilla of *N. elegans* (though, on data Vyshkvartzeva [1976, Table 13] they can be 1–3), syncoxa of maxilliped with 1, 2, 4, 4 setae accordingly, and Re1 P1 with only 1 inner seta.

Some differences are also revealed in the head shape of females, in the relative length of the distal rounded lobes of SmP5 from dorsal and lateral view, and also in the shape of the genital somite in ventral view. In contrast to *N. minor,* the forehead of *N. elegans'* females is more sharply narrowed to its top. Distal lobes of SmP5 are relatively shorter in individuals from the Pacific, in comparison with Mediterranean individuals and differ by the shape in dorsal and lateral view slightly. Female genital somite of *N. elegans* with almost parallel lateral edges ventrally (Fig. 9), whereas at *N. minor* lateral edges are slightly produced laterally (Figs 5, 7, 11).

It has been shown in the article mentioned above [Andronov, 2001], that at least 2 distinct species of *Nannocalanus* live in the southeastern Pacific Ocean. One of them is designated as *N. minor*. A comparison of those representatives with individuals of *N. minor* from the Mediterranean Sea clearly shows that this is a different species. However, it will be necessary to reinvestigate individuals of this species from northern areas of the Indian Ocean before a distinct new taxon name can be allocated. At first, it will allow us to find out, whether these forms are independent species. Secondly, it will become clear, whether one of these forms represent the original *Nannocalanus minor*.

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