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Taxonomic review of three species of Sipuncula (Golfingiidae, Phascolosomatidae, Themistidae) from the Eastern Pacific Ocean

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Abstract Based on our examination of type material plus additional specimens, it is concluded that *Thysanocardia melanium* Popkov is a junior synonym of the northern Pacific *T. nigra* Ikeda, with a tentacular crown pigmented in many but not all members of the population, and the shape of its nuchal organ may resemble a bicycle seat, a heart, or a thick-sided V. *Apionsoma* (*Phadeonis*) *claviformes* Popkov is shown to be a junior synonym of *A. murinae bilobatae* Cutler, this subgenus therefore becomes a nomen nudum. *Themiste* (*Themiste*) *maculosum* Popkov is a valid new species from the Sea of Japan.

Key words: Sipuncula, Pacific, taxonomic revision, *Apionsoma*, *Themiste*, *Thysanocardia*

Introduction

In 1993, three taxonomic papers on three species of three genera of Sipuncula in the Eastern Pacific by Popkov (1993a-c) appeared in the Russian Zoological Journal (*Zoologicheskii Zhurnal*). In each of them Popkov described a new species, and for one species he created a new subgenus, *Apionsoma* (*Phadeonis*). Between May 1991 and January 1992 one of us (EC) had an exchange of a few letters with Mr. Popkov. This involved a sharing of information and ideas, including several items that were being developed for a monograph in preparation at that time (Cutler, 1994). However, he chose to ignore much of the feedback he received. According to G. Murina, Sevastopol (pers. comm.) Popkov has left science. We here review his works and propose a different interpretation. The articles will be considered in the order they were published.

In his first paper Popkov (1993a) considers the nuchal organ to be dorsal, as have all earlier sipunculan biologists. However, in the next two (1993b, c) he states that the nuchal organ and nuchal tentacles are ventral without explaining this change. Additionally, the introvert was not fully extended in his two *Apionsoma* specimens and he acknowledged on page 21 that "the relative position of the tentacles to the mouth could not be determined". Examination of his *Themiste* specimens show the nuchal organs to be dorsal, i.e. on the same side as the anus and opposite the ventral nerve cord.

It should be noted here that his 1991 article in which he proposed a new genus, *Cutlerensis* for one species was reviewed in Cutler (1994). The name was retained but treated as a subgenus of *Nephasoma*.

Thysanocardia melanium Popkov, 1993a

Material examined

Three paratypes. Zoological Museum Moscow State Univ. (ZMUM) #Jc2-54. Also reexamined specimens of *T. nigra* from Japan collected by Ikeda in 1898 National Museum of Natural History, Washington (NMNH #59986) and by Cutler in 1979 from northern Japan

(called *T. zenibakense*, NMNH #59987), from Washington (named *T. pugettensis* collected by M. Rice and M. Pettibone (NMNH #21215, 22715, 36562-63, 49853), and from California (type of *T. macginitiei* of W. K. Fisher NMNH #21223). We also reexamined three of Cutler's *T. catharinae* from the northwestern Atlantic Ocean.

This taxon was the most troublesome of the three requiring a reappraisal of other *Thysanocardia* populations with particular attention paid to tentacles and nuchal organs. Popkov's description was based on 93 specimens, 49 being newly collected by him and 44 being museum material collected during the 1960's. The bulk of these worms came from northeast Russia in the Gulf of Posiet, Sea of Japan, from depths less than 10 m. A single worm was collected by a Russian ship from 280 m off northwestern Mexico (Baja California, not California as Popkov stated). Most of his specimens were 10-20 mm long with the longest having a 35 mm trunk. Japanese representatives of this genus commonly reach 40 mm, while in the eastern Pacific 100 mm worms are known.

This putative species is described as having pigmented tentacles and to be, in all ways except one, identical to the northern Pacific *T. nigra*. The following quote is from p. 32 where there is a small but confusing typographical error - a comma instead of a full stop to close the preceding sentence (italics ours). "Both *T. nigra* and *T. melanium* have pigmented tentacles, differing only in the form of the nuchal organ which practically is impossible to notice in specimens with retracted introverts." The dorsal nuchal organ is described as heart-shaped, two lobes joined at the bottom (Fig. 1b). Popkov asserts that greater taxonomic weight should be given to the nuchal organ shape than to pigmentation. We will address these two separately.

Tentacular Pigmentation: While none of the Atlantic Ocean representatives of this genus have been seen to have pigmented tentacles the Pacific populations are said to bear pigmented spots or stripes. We now know this to be only true for some, and its absence in some is not an artifact of bleaching due to long-term preservation in ethanol. The following were without pigment: 1 of Popkov's 3 paratypes; 1 of 3 from Japan; 3 of 5 from the U.S. West Coast making a total of 5/11. Also included in the older museum material Popkov examined were 30 worms previously identified by unnamed persons as *T. catharinae*, 2 identified as *T. procera* (both unpigmented species), plus 10 as *T. nigra*, and 1 *T. pavlenkovi* (both pigmented taxa).

This means, assuming the original identifier used tentacle pigmentation as a 'key'

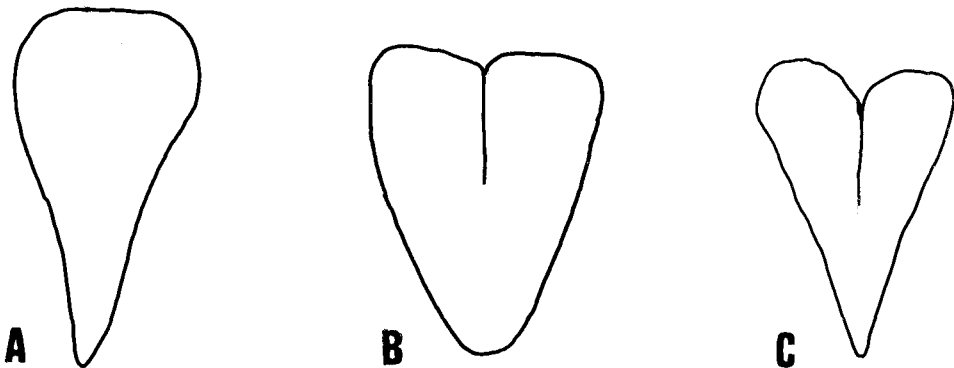


Fig. 1. Variations of the nuchal organ in *Thysanocardia nigra*: A. Bicycle seat shape; B. Heart shape; C. Thick V shape. (lengths 0.5-1.0 mm)

character, that 32/43 of these northwestern Pacific worms had unpigmented tentacles. Popkov did not state in which samples he found pigment lacking, but did assert that absence of pigment was due to bleaching (instead of an inherited variation?). Popkov's assertion that some worms lacked pigment because of the effects of alcohol is not supported by our observations, i.e. the absence in 1/3 of his own freshly collected and homogeneously processed paratypes, and the presence of pigment in two of Ikeda's worms collected 98 years ago. Pigment on the tentacles now appears to be a character state present in 50–65% of the northern Pacific population, but absent in the remaining 35–50%, pointing to differing gene frequencies in different demes.

Nuchal Organ: The significance Popkov gives to this one attribute, which is impossible to determine in the vast majority of specimens whose introverts are less than 100% extended, is a serious problem. Popkov neither tells us how many of his specimens had their nuchal organs visible, nor what variation existed in the shape of this organ. Additionally, we do not know how the external shape of this soft organ might change as a worm increases in size.

Our re-examination of other populations met with mixed success since only a few had fully extended introverts. Nevertheless, we now have a better sense of what this very small (often less than 1 mm) soft organ looks like. In general the drawings presented as Fig. 2 in Popkov (1993a) are too simplistic. His heart-shape image (Fig. 1b) is accurate for some, but a more general model is that of a bicycle seat made from clay (Fig. 1a). If, from this point one imagines pressing in along the back of the seat to create a cleft (heart-shape), or continued to press and divide the broad end of the seat (thick V-shape like Fig. 1c), one has a better sense of what is actually present.

Thysanocardia Conclusions:

1. Pigmented tentacles are present in many, but not all members of this population.
2. Nuchal organ shape varies around a heart-shaped, bicycle seat center with variations, but since it can only rarely be observed, it should not be utilized as a species specific character.
3. Popkov has contributed to a better understanding of the morphological variation in small *T. nigra*.
4. We consider *T. melanium* to be a junior synonym of the northern amph-Pacific *T. nigra*.

***Apionsoma* species**

***Apionsoma (Phadeonis) claviformes* Popkov, 1993b**

Material examined

Holotype. ZMUM # Jc2-51 plus several *A. murinae bilobatae* collected by Cutler (NMNH #119267, 119276, 143922-24).

Popkov's second paper in this series described a new subgenus and new species. The basic problem with this work rests in drawing broad conclusions based on detailed examination of a single specimen (he had a second worm with a 3 mm trunk, but evidently did not dissect it). When that specimen is large (11 mm in this case), old, or damaged, mistaken conclusions can be reached. In this case the crucial systems were the nature of the hooks (lacking basal spinelets) and the spindle muscle (bifurcated and not extending to the posterior trunk). We focus on these two first then return to the remainder of the paper.

Spindle Muscle: On p. 24 Popkov said that, had it not been for the clear difference

in the structure of the spindle muscle he would have been wary of creating a new species and subgenus. His focusing on this purported difference is unfortunate. Examination of his holotype shows that the spindle muscle has been broken at the end of the gut coil - the posterior portion of the muscle remains as a very short stump at the posterior tip of the trunk. The thin side branch is not unlike the fixing muscles found in many genera.

A re-examination of material from off the U.S. east coast (Cutler, 1969) revealed that there may be 0-4 thin fixing muscles connecting the digestive tube to the body wall. The spindle muscle does exhibit the standard form of a continuous strand originating from the body wall near the anus, going along the rectum, through the gut coil (attaching to the coil at points), out to the posterior trunk wall. This muscle is very thin and fragile and occasionally this is either incomplete or broken and may be very hard to see in places. Structural anomalies do occur and damage during handling is known to occur.

Hooks: Popkov's specimen appears to have hooks that lack the distinct basal spinelets typical of other *Apionsoma*. The 11 mm trunk of the *A. claviformis* holotype is large for this genus. Most examples of *A. murinae bilobatae* are less than 7 mm long and *A. murinae* trunks only rarely reach 10 mm. Popkov did not examine hooks on the smaller of the two specimens which is unfortunate since this specimen might have exhibited well-formed spinelets. Since Popkov had removed the entire distal tip of the introvert, no hooks were left for us to examine.

Popkov's Fig. 1 is an SEM photograph showing hooks, but the tissue seems to have been inadequately cleaned during preparation. Thus, the extraneous material may be hiding the most basal part of the hooks where spinelets occur. Apparently he did not examine hooks using a standard light microscope which would have been a better way to clearly see what is present towards the base of these very small hooks.

This article contains mistakes of differing degrees of significance (error in parentheses):

1. p. 18. Says that the species *papillifera* was based on a single (species) - should be 'specimen'.
2. p. 19: "...added by Cutler (and) *Apionsoma* - should be 'to'.
3. p. 20: In the synonymy of *A. misakiana* he lists Cutler et al, 1984 but incorrectly says that they used *Golfingia misakiana*, rather than the first *Apionsoma misakiana* combination.
4. p. 22: Fig. 1 legend: Hooks of the (spine)... This is probably a mistake since the Russian word for introvert is similar to the word for spine, and 'introvert' would make sense here.
5. p. 24: Under *Ap. (Fisherana)* sp. material, he has (north) latitude where he means 'south', and for longitude 'east' he has (south).
6. p. 25: Fig. 3 legend - Scale line in (mm), A = 20 - May be 20 microns, but cannot be mm, and B=5 - There is no scale line on this figure.

Other Points: On p. 17 Popkov said that there is a small number of species in this genus, only 6 or 8 valid ones. While this is true it may leave the false impression that this is exceptionally small. In this phylum, 8 of the 17 genera have fewer than 5 species, so by comparison to other sipunculan genera the genus *Apionsoma* is solidly in the middle of the species richness range.

In his diagnosis of the genus *Apionsoma* Popkov states that the tentacles are gathered ventrally. Since from other places he understands the nerve cord to be ventral it is hard to understand why he reversed the historical understanding of the dorsal position of the nuchal organ and tentacles. In his *Themiste* paper he repeats this assertion so it is not a one-time mistake here. However, this is a change, for as noted above, he described the

nuchal organ as a dorsal structure in *Thysanocardia*. Since Popkov removed the distal tip of the holotype's introvert we cannot comment further.

For the type species of his subgenus *A. (Fisherana)*, he used the species *Phascolosoma papillifera* Stephen, 1964. However, Stephen was not the author of the name *papillifera* Keferstein, 1865 was.

On p. 24 Popkov made reference to something said in a personal letter from Cutler that was not intended for publication. Also, this very speculative idea about the reduction of spinelets, was represented in his text as a fact - an unfortunate distortion. One item from this correspondence Popkov did not mention is that in January, 1992 Cutler told him of his plans to resurrect the genus name *Fisherana* as a subgenus (of *Phascolosoma*) in the monograph that was then in preparation (Cutler, 1994). Popkov's manuscript, in which he used *Fisherana* as a subgenus (of *Apionsoma*), was submitted for publication one year later.

At the close of his discussion on p. 24, Popkov differentiates his new species from *A. murinae* on the basis of what he asserts to be the smaller size of the posterior papillae in *A. claviformis*. To the best of our knowledge Popkov has never looked at, or closely considered the subspecies *A. murinae bilobatae*. This population has papillae, but they are smaller than in the nominate form. Papillae size varies greatly within populations, but even on one worm size varies from small in the middle to larger at both ends of the trunk.

Apionsoma (Fisherana) sp.

Popkov's description (p. 24) of this worm's body wall and papillae would fit many *A. capitata* we have examined and described (e.g. Cutler, 1979; 1994 fig. 48). The small bump on the concave side of the hook of his single specimen is insufficiently distinctive and should not be used to separate this species. The somewhat longer nephridia are also not meaningful as this varies considerably within many species. Popkov again asserts that the nuchal tentacles in this species are ventral to the mouth, not dorsal.

His mention of Leroy's 1936 unconfirmed report of *Phascolosoma capitata* off the coast of California merits a comment. When examining other material in the Paris museum several years ago we did look at this animal. First, the location is not the coast of California, but the Gulf of California which is Mexican water. Second, the animal is clearly a *Phascolosoma* s.s. with longitudinal muscle bands, and probably *P. nigrescens* based on papillae and hook morphology. Therefore, Popkov is right to disregard this record.

Popkov's hesitancy to name this single worm is admirable. However, to consider it a member of a far-flung *Phascolosoma (Fisherana) capitata* population seems most appropriate.

As presented in Cutler (1994), *Apionsoma* does contain a second subgenus, *A. (Edmondsius)* (Gibbs & Cutler, 1987) containing, *A. (E.) pectinatum*. Given this understanding of the genus, containing the species *misakiana*, *murinae*, *pectinatum*, and *trichocephala*, point #4 in Popkov's 'Zooogeographical Notes' p. 27 ("Species of *Apionsoma* live mostly at bathyal depths of the world ocean.") would need to be re-written: Three of the four *Apionsoma* species live in warm shallow water, the fourth lives in cold bathyal water.

Apionsoma Conclusions:

1. Popkov's putative new species (*Apionsoma (Phadeonis) claviformes*) is considered to be two representatives of *A. murinae bilobatae* from New Zealand.

2. This is a major range extension of what had been a northern Atlantic and Mediterranean taxon. Note: Cutler (1994) mistakenly stated that this subspecies had been collected from the Indian Ocean. That reference should instead have been to the nominate subspecies (as in Cutler, 1977). However, in recently processed material from 350-625 m

near the Comoran Islands, 68 specimens of *A. murinae bilobatae* have been recorded (Cutler and Cutler, 1996).

3. Since the species is considered to be a junior synonym, it follows that the putative subgenus *Apionsoma* (*Phadeonis*) erected to contain this one species, also be considered to have no validity as a genus-group name (*nomen nudum*).

4. The specimen identified as *Apionsoma* (*Fisherana*) sp. should be considered as one *Phascolosoma* (*Fisherana*) *capitata*, thereby extending its known range to New Hebrides. Also, the definition and placement of the subgenus *Fisherana* as presented in Cutler (1994) within the genus *Phascolosoma* is reiterated.

***Themiste* (*Themiste*) *maculosum* Popkov, 1993c**

Material examined

Two paratypes. ZMUM #Jc2-58.

In this third article Popkov's new species description was based on several newly collected specimens taken from the Gulf of Posiet in the southwestern Sea of Japan, plus older museum specimens. Much of the new material was found among the byssal threads and 'drusa' of *Modiolus*, plus a few from sandy/rocky sediments at depths less than 10 m. Some of the older museum specimens came from mud down to 22 m. The trunk lengths of these worms ranged from 5-35 mm.

The following quote from the abstract highlights one of two confusing elements: "...the central nerve cord projecting above the surface of the ventral nerve chain". This attribute is nowhere defined. His SEM illustration of this complex (his Fig. 3a) is not informative. This dual concept (ventral nerve chain and central nerve cord) has not previously been used in sipunculan literature, and Popkov does not say why he chose to set aside the more familiar ventral nerve cord.

Examination of his specimens using a binocular dissecting light microscope, shows the ventral nerve cord to be somewhat loosely adhering, but well connected by connective tissue and the many lateral branches. There was no cord-like structures visible underneath the nerve cord.

The second confusing item has been mentioned above - Popkov's assertion that the nuchal organ is ventral. Given that this structure is on the same side as the anus and opposite the ventral nerve cord, it is dorsal.

In the revision of *Themiste* (Cutler and Cutler, 1988) an attempt was made to standardize and clarify the terms used when discussing these tentacular crowns. "The four structures arising from the oral disc are the stems; these stems divide into branches (primary, secondary, etc.); the final subdivisions or terminal units are tentacles. Finally, one tentacle is the entire array of subunits beginning with one stem." Unfortunately Popkov did not follow this suggestion (perhaps overlooking the 'u' in tentacule) so it is not always clear as to what part is being referred to since he uses only the term 'tentacle'.

Popkov places his new species in the *T. pyroides - blanda* group and differentiates his on the basis of the patchy (not solid) distribution of pigment on the collar and pigment spots on the tentacles (despite his assertion that bleaching may occur in ethanol). Additional features of the tentacles distinguish it from *T. blanda*, and the rounded shape of the posterior end of the trunk in *T. maculosum* separate it from *T. pyroides* which has bluntly pointed posterior ends. The peculiar nature of the ventral nerve cord is, for Popkov, very important and a distinctive feature of this new taxon.

Themiste Conclusions:

1. The status of *Themiste* (*Themiste*) *maculosum* as a new species is supported.
2. The nuchal organ is dorsal, not ventral.
3. The ventral nerve cord, while loosely connected to the body wall is not otherwise unique.

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