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Number 55                      November 6, 1961                      New Haven, Conn.

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## NOTES ON *SAGITTA FRIDERICI* RITTER-ZÁHONY COLLECTED OFF PERU\*

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In a paper on the chaetognath fauna off Peru, Bieri (1957) remarks, "In the 1941 Peru material a complete set of intergrades exists between *S. friderici* to the south and *S. tenuis* to the north. The same situation has been observed by the author in samples taken off Lower California except that there the *tenuis*-like form is to the south and the *friderici*-like form to the north" (pp. 261-262, fig. 13). He showed that *Sagitta bipunctata* described by Michael (1911) was identical with the *friderici*-like form and that *S. tenuis* and *S. friderici* were ecotypic variants of a single interbreeding population or species (p. 261). The smaller *tenuis*-form was considered a warm water form at that time.

In Bieri's 1952 material, however, only the larger *friderici*-form was found at stations as far north as the Gulf of Guayaquil. He then changed his opinion, admitting the validity of *S. friderici* and characterizing it as neritic or nearshore. He noted that the "distribution of *Sagitta friderici* off California,

\* Contributions from the Seto Marine Biological Laboratory, No. 359.

Peru and Chile, and North and South Africa, is correlated with upwelling and suggested that temperature and salinity are related to the distribution pattern of this species" (Bieri, 1959, pp. 14-18, fig. 17). He re-examined the specimens of Michael's *S. bipunctata* collected off California and found that they were in fact *S. friderici* (p. 14, footnote). The northernmost record of *S. friderici* in the eastern Pacific is evidently Monterey Bay where Bigelow and Leslie (1930) found Michael's *S. bipunctata* to be common (pp. 552-553). While there is no published record of *S. friderici* in Chilean waters, Bieri believes that the distribution of this species extends to the waters off Chile.

Sund (1959a) considers *S. friderici* as a synonym of *S. tenuis* and showed during the Eastropic Expedition (1959b) that *S. tenuis* occurred in only a limited area of the Gulf of Panama.

I have examined *S. tenuis* from Scammon's Lagoon and Manuela Lagoon, Baja California, and *S. friderici* collected in the blue-green water along the southern California coast near San Diego (1959). I have also found many specimens referable to *S. friderici* in collections of the Transpac and Shellback expeditions. Most of them were identified without any hesitation as *S. friderici*, but some doubtful specimens from the offshore waters in the Shellback Area were placed in Groups A and B (pp. 360-364, table 7, fig. 5). As these specimens were mostly found in more or less imperfect states of preservation, I could not examine the exact structure of the seminal vesicle or the corona ciliata.

Fortunately, however, I have had a chance to examine some excellently preserved specimens referable to *S. friderici* from the collection of the 1953 Yale Peruvian Expedition which were submitted to me for examination by Dr. G. B. Deevey of the Bingham Oceanographic Laboratory, Yale University, to whom I want to express my hearty thanks for her kindness.

These specimens include ten individuals, 8.9 mm - 13.3 mm in length, collected on April 2 at Station 34, 4° 3' S. Lat., 81° 10' W. Long.; and 12 individuals, 10.0 mm - 13.5 mm in length, collected on April 14 at Station 81, 3° 36' S. Lat., 80° 47' W. Long. Measurements of the specimens from the two stations are given in tables 1 and 2 and resemble each other closely except

Nov. 6, 1961 *Sagitta friderici* Ritter-Záhony

for the TC value (ratio of anterior part of the posterior fin along the trunk to posterior part of the posterior fin along the caudal segment times 100). All the morphological characteristics mentioned below are common to the specimens from both stations.

TABLE 1

*Sagitta friderici*, armature formulae of individuals from Sta. 34.

Body length	Caudal segment in per cent*	Hooks	Anterior teeth	Posterior teeth	TC-value
8.9 mm	27.0	8-9	6-6	15-16	81.6-84.7
11.7	26.4	7-7	9-9	20-21	80.4-88.9
11.9	25.6	7-7	9-9	22-22	73.3-80.0
11.9	26.4	7-7	8-9	20-20	87.4-87.5
12.0	26.4	7-7	9-9	18-21	86.9-88.7
12.3	25.2	7-8	8-9	20-20	76.9-82.7
12.5	25.8	7-7	8-8	21-22	78.6-83.2
12.7	25.3	7-7	9-10	20-20	84.7-85.9
13.0	27.4	7-7	9-10	21-23	69.5-75.8
13.3	25.7	7-7	8-8	20-21	80.5-84.8

\* Caudal fin included.

TABLE 2

*Sagitta friderici*, armature formulae of individuals from Sta. 81.

Body length	Caudal segment in per cent*	Hooks	Anterior teeth	Posterior teeth	TC-value
10.0 mm	25.5	9-?	8-8	18-19	67.3-76.8
10.6	26.6	8-8	8-8	18-19	67.5-71.4
11.1	26.6	7-8	8-8	19-19	77.8-83.3
11.3	27.4	8	8	18	78.6-80.7
11.6	26.2	7-7	9-10	20-22	83.8-87.0
11.7	27.4	7-8	10-10	23-23	87.3-91.4
11.9	26.7	7-7	10-10	22-23	83.1-85.2
12.0	26.5	8-8	8-9	21-21	64.2-76.5
12.3	26.9	7	11	23	85.7-91.1
12.4	25.4	8-8	8-8	21-22	70.9-79.5
12.6	27.1	7-8	9-9	21-22	79.5-80.0
13.5	26.7	7-8	9	22	66.4-71.0

\* Caudal fin included.

## DESCRIPTION

Length up to 13.5 mm; the tail segment occupies 25.2% to 27.4% of the whole body length including the caudal fin, with an average of 26.4% for 22 measurements. The body is moderately rigid or rather soft and so translucent that the whitish and opaque intestine can be seen. It is usually widest in the posterior part of the trunk in the region of the posterior fins; there is no constriction at the trunk-tail septum. The anterior fin usually begins at the level of the posterior end of the ventral ganglion, although in a few specimens there may be a short distance, less than half of the ganglion's length, between the posterior end of the ventral ganglion and the anterior end of the anterior fin. The posterior fin is very slightly shorter than the anterior one; the ratio for anterior fin to posterior fin times 100 is 86-113, with an average of 105 for 22 individuals. The value is slightly higher in individuals from Sta. 34 than in those from Sta. 81, namely 100-113 (with an average of 108 for ten individuals) compared with 86-113 (with an average of 102 for 12 individuals). The fin is widest behind the trunk-tail septum. Both anterior and posterior fins are fully rayed; the rays are set vertically to the base in a small anterior part of each fin. The TC value is 69.5-88.9, with an average of 82.1 for ten individuals from Sta. 34; while it is 66.4-91.4, with an average of 78.6 for 12 individuals from Sta. 81. The distance between the anterior and posterior fins is highly variable, with an average value of  $1/3.75$  of the length of the anterior fin for 22 individuals; the distance is slightly shorter in individuals from Sta. 81 than in those from Sta. 34, the denominator being 3.1-6.0 (an average of 4.18 for 12 individuals) as against 2.3-4.1 (3.23, average for ten individuals). The collarete is distinct around the neck and diminishes in thickness posteriorly, reaching one half to two thirds of the distance from the neck to the ventral ganglion. The eye pigment (figs. 5-6) is small to medium, roundish or oval in shape, and the eyes are situated rather widely apart. The distance between the eyes is 24.7%-36.8% (average, 32.7% for five specimens) of the width of the head at the level of the eyes. The corona ciliata (figs. 2-4)\* is \* Heydorn (1959) described the corona ciliata as starting just behind or in front of the eyes in South African specimens, but I have never seen any specimen with the corona beginning just behind the eyes.

elongate. It begins just behind the brain and extends posteriorly for two-thirds of the distance from the neck to the ventral ganglion, or for one and one-half to three times and most frequently two and a half times the head length (see fig. 1). The corona has a pair of very prominent sinuses behind the eyes, but posteriorly it is only slightly sinuous. Usually six pairs of tufts of large tactile setae are found along the corona, although they fluctuate in number from five to seven. Intestinal diverticula are absent. Hooks number seven or eight, rarely up to nine; anterior teeth number six to ten, rarely up to 11; and both rows meet each other at an acute angle. There are 15 to 23 posterior teeth.

The 8.9 mm specimen from Station 34 is devoid of ovaries and seminal vesicles, but all others are provided with these structures in various stages of development. The anterior end of the ovary is situated most frequently near the anterior end of the posterior fin, but it may occur a considerable distance from this level; in five individuals the ovaries extend far beyond the anterior end of the posterior fin and attain the level of the middle of the anterior fin. Immature ova are only 83  $\mu$  in long diameter for an average of 11 measurements, whereas mature ones are 210-240  $\mu$  in long diameter. The seminal vesicle (figs. 7-14) is situated just at the base of the caudal fin; the posterior fin also ends very close to the vesicle. In earlier stages of development, the anterior glandular portion, which is somewhat rounded and walled with a tall epithelium that secretes the mucus for agglomerating sperm, is very prominent as compared with the low and inconspicuous saccular portion. However, the saccular portion becomes very prominent in advanced stages when it swells outwards more than the anterior glandular portion. The rupture seems to occur along the lateral side of the glandular portion at maturity.

#### REMARKS

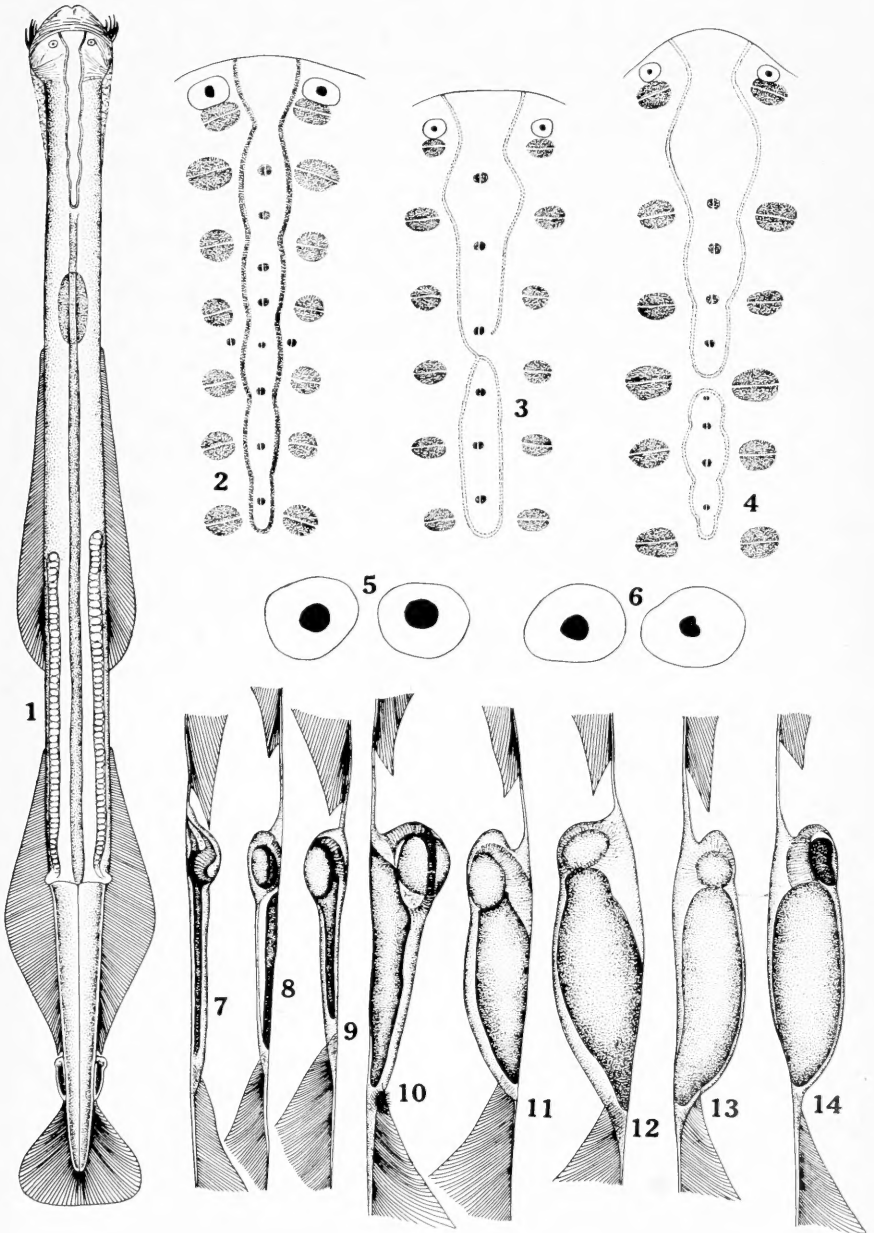
The difference in TC value between the specimens from Station 34 and Station 81 is 3.5 when average values are compared. However, the value varies considerably since it is much

## EXPLANATION OF PLATE

*Sagitta friderici* Ritter-Záhony from Peruvian waters.

1. Dorsal side of specimen 12.3 mm in length from Sta. 81.
2. Corona ciliata of the same individual.
3. Aberrant corona ciliata of specimen 10.6 mm in length from Sta. 81.
4. Aberrant corona ciliata of specimen 11.3 mm in length from Sta. 81.
5. Eyes of specimen 11.9 mm in length from Sta. 81. 300x.
6. Eyes of specimen 12.0 mm in length from Sta. 81. 300x.
- 7-14. Seminal vesicles arranged in order of developmental stages. 100x.
  7. Specimen 12.0 mm in length from Sta. 34.
  8. Specimen 11.7 mm in length from Sta. 34.
  9. Specimen 12.3 mm in length from Sta. 34.
  10. Specimen 13.0 mm in length from Sta. 34.
  11. Specimen 12.5 mm in length from Sta. 34.
  12. Specimen 10.0 mm in length from Sta. 81.
  13. Right vesicle of specimen 11.9 mm in length from Sta. 34; dorsal view.
  14. Left vesicle of same individual; ventral view.





affected by contraction or bending of the body. Even for the same individual, the value can be different between the right and left sides. For the 22 specimens examined here, the difference in value found between the two sides of the same individual fluctuates from 0.1 to 12.3, most frequently in the range from 1 to 7; and the average difference is 4.7. This is clearly greater than the difference noted between the samples from the two stations and suggests that the difference in TC value found for these specimens is insignificant. Thus, individuals from Station 34 may be considered to be identical with those from Station 81, and all these are identical with those of my Group A (Tokioka, 1959, p. 361). The latter vary up to 13.8 mm in body length, are armed with seven to nine hooks, have up to 11 anterior teeth and up to 25 posterior teeth, and show a TC value fluctuating from 80 to 91.1 (average, 86.3). The differences between Group A and Group B mentioned in the same paper are too great for these groups to be merged.

The appearance and structure of the specimens from the Bingham Oceanographic Collection resemble closely those of *Sagitta friderici* as described repeatedly in many previous papers, except for the armature formulae. The maximal numbers of anterior teeth (11) and posterior teeth (23) exceed those known previously for *Sagitta friderici*. Thus it is necessary to review the previous descriptions of *S. friderici* in order to establish the range of variation. There follows a list of dimensions for *S. friderici* published by previous authors. As the species was established by Ritter-Záhony (1911) and examined and described most exactly by Faure (1952) and Furnestin (1957), I shall begin with the data of these authors.

Ritter-Záhony (1911)

*Loc.*: The surface layer off South-West Africa and Cape Verde.

*Body length*: up to 13 mm.

*Hooks*: 8 - 9.

*Anterior teeth*: up to 9.

*Posterior teeth*: up to 22.

Faure (1952)

*Loc.*: The neritic waters off Morocco.

*Body length*: up to 15 mm.

*Hooks*: 5 - 9, most frequently 7 - 8.

*Anterior teeth*: up to 8, most frequently 6.

*Posterior teeth*: up to 21, most frequently 12 - 13.

Furnestin (1953)

*Loc.*: Israel.

*Body length*: up to 10.2 mm.

*Hooks*: 6 - 8.

*Anterior teeth*: 4 - 8.

*Posterior teeth*: 8 - 14.

Furnestin (1956)

*Loc.*: Tangier Bay and the west entrance to the Gibraltar Straits.

*Body length*: up to 12.5 mm.

Furnestin (1957)

*Loc.*: The neritic waters off Morocco.

*Body length*: up to 15.1 mm.

*Hooks*: 5 - 9, most frequently 7 - 8.

*Anterior teeth*: up to 8.

*Posterior teeth*: up to 17.

Michael (1911), as *Sagitta bipunctata*

*Loc.*: San Diego region.

*Body length*: up to 17 mm.

*Hooks*: 7 - 8.

*Anterior teeth*: 5 - 7.

*Posterior teeth*: 12 - 14.

Scaccini and Ghirardelli (1941)

*Loc.*: Rio de Oro.

*Body length*: 7 mm - 10 mm.

*Hooks*: 7 - 8.

*Anterior teeth*: 6 - 8.

*Posterior teeth*: 14 - 20.

## Vannucci and Hosoé (1952)

*Loc.*: Near Trinidad in the South Atlantic.

*Body length*: 8.2 mm - 8.5 mm.

*Hooks*: 8.

*Anterior teeth*: 7.

*Posterior teeth*: 12.

## Colman (1959)

*Loc.*: Eastern Central Atlantic.

*Body length*: 6.8 mm and 12.7 mm.

*Hooks*: 7 - 8.

*Anterior teeth*: 6 - 8.

*Posterior teeth*: 12 - 18.

## Heydorn (1959)

*Loc.*: The neritic waters off South West Africa.

*Body length*: up to 18 mm.

*Hooks*: up to 9.

*Anterior teeth*: up to 8.

*Posterior teeth*: up to 20.

## Tokioka (1955)

*Loc.*: The neritic waters off Morocco.

*Body length*: up to 11.6 mm.

*Hooks*: 7 - 9.

*Anterior teeth*: 5 - 7.

*Posterior teeth*: 11 - 17.

*TC value*: 71.1 - 91.0; av. 82.0.

## Tokioka (1959)

*Loc.*: Blue-green water off lower California.

*Body length*: up to 19 mm.

*Hooks*: 7 - 9.

*Anterior teeth*: up to 6.

*Posterior teeth*: up to 12.

*TC value*: 83.3 - 134.0; av. 107.1.

## Tokioka (1959), Group B

*Loc.*: The waters off central and northwestern South America.

*Body length*: up to 9.4 mm.

*Hooks*: 5 - 6.

*Anterior teeth*: 6 - 9.

*Posterior teeth*: 13 - 19.

*TC value*: 88.4 - 114.3; av. 96.6.

The present specimens and Tokioka's Group A are characterized by the following data:

*Loc.*: The waters off central and northwestern South America.

*Body length*: up to 13.8 mm.

*Hooks*: 7 to 9.

*Anterior teeth*: up to 11.

*Posterior teeth*: up to 25.

*TC value*: 78.6 to 86.3.

As nine anterior and 22 posterior teeth are already recorded for *Sagitta friderici*, the existence of 11 anterior and 25 posterior teeth is not unreasonable; these may be accepted as the upper limits in the species. Group B is characterized by fewer hooks than usual, but this low number of hooks is shared by some specimens from neritic waters off Morocco and Israel. Thus Group B may most probably be included in *S. friderici* as an unusual group. The maximum body length is 19 mm, found in the collection from the blue-green water along Southern California (Tokioka, 1959, table 27 on p. 390).

Detailed comparisons have been made between *Sagitta friderici* and *S. bipunctata* by Faure (1952) and Furnestin (1957), between *S. friderici* and *S. setosa* by Furnestin (1957, 1958) and between *S. friderici* and *S. hispida* by Furnestin (1957). However, the most serious problem concerns the separation of *S. friderici* from *S. tenuis*. Pierce (1951) considers these two species as ecological forms of *S. tenuis*, and Sund (1959a) seems to agree without giving any clear reasons. On the other hand, Fraser (1952), Furnestin (1957), Bieri

(1959), Colman (1959), and the present writer (Tokioka, 1955, 1959) admit the validity of *S. friderici*. *S. tenuis* can be separated from *S. friderici* by the smaller size of mature individuals (less than 10.7 mm), the slightly larger number of anterior and posterior teeth (up to eight anterior and up to 19 posterior teeth for individuals less than 8 mm), and the comparatively smaller TC value (55.3 - 84.5, with an average of 64.7, given by Tokioka, 1955; 29.9 - 72.4, usually 40.8 - 61.3 as reported by Colman, 1959). Furthermore, Fraser (1952) mentions the difference in general appearance between *S. tenuis* and *S. friderici*.

However, according to Furnestin's (1959) descriptions of the variability of *S. friderici*, the specimens from the waters along the Senegal coast sometimes look more massive and have longer ovaries than those from the Gulf of Guinea which seem to be weaker in body appearance and attain maturity more rapidly than those of Morocco waters. Colman (1959) records that individuals of *S. tenuis* from Cedar Keys, Florida, differ from those of British Guiana in having a somewhat shorter caudal segment (26%-29% v. 27%-34%), slightly fewer hooks (7-8 v. 7-9), and a higher TC value (53.8%-92.3% v. 29.9%-72.4%). Also, the anterior fin begins more posteriorly and is consequently slightly shorter. The massive body appearance of *S. friderici* from the waters along the Senegal coast somewhat resembles that of *S. tenuis*, and the contrarily higher TC value (53.8%-92.3%) of *S. tenuis* from Cedar Keys, Florida, lies within the range of variation of TC values for *S. friderici*. These two points are noteworthy, although they do not provide sufficient evidence to combine *S. friderici* with *S. tenuis* completely. Usually *S. tenuis* is found in embayments or in areas more or less protected from the open sea (Suárez, 1955; Pierce, 1958; Colman, 1959; and Tokioka, 1959), although its distribution extends more than five miles offshore in the coastal waters of western Florida. On the other hand, the distribution of *S. friderici* is confined to the neritic water mass according to Scaccini and Ghirardelli (1941), Faure (1952), Furnestin (1956, 1957, 1959, 1960), Bieri (1957, 1959), Sund (1959b), Heydorn (1959), and Tokioka (1959). The reported occurrences of *S. friderici* near Trinidad Island in the South Atlantic

(Vannucci and Hosóé, 1952) and in the eastern Central Atlantic (Colman, 1959) indicate that this species is not confined to neritic waters as suggested by Faure. It is probable, however, that the specimens found by these authors are drift forms carried far offshore from neritic waters.

Finally, it may be noted that the individuals of *S. friderici* occurring in the northern part of the range of the species in the Eastern Pacific and those occurring in the southern part differ considerably from each other in tooth number.

#### SUMMARY

A collection of chaetognaths from the waters off Peru is described; all are referred to *Sagitta friderici* Ritter-Záhony. The range of variation within this species and the distinctness of *S. tenuis* Conant from it are discussed. *S. friderici* is found in neritic water masses, while *S. tenuis* occurs in embayments and areas more or less protected from the open sea.

#### POSTSCRIPT

After I had sent the manuscript of this paper to the editor, five more papers including descriptions or notes on *Sagitta friderici*, *S. tenuis* or on some forms allied to them were published.

Bainbridge, V. (1960: The plankton of inshore waters off Freetown, Sierra Leone. Colonial Off. Fish. Publ. No. 13,) mentions that *S. friderici* and *S. hispida* were the most important chaetognaths in that area, while the occurrence of *S. tenuis* was sporadic.

Suárez-Caabro, J. A. and Madruga, J. E. (1960: The Chaetognatha of the northeastern coast of Honduras, Central America. Bull. mar. Sci. Gulf Carib., 10: 421-429.) found a small number of *S. tenuis* near the entrance to Caratasca Lagoon on the northeastern coast of Honduras. These specimens were 4 mm-8 mm in length with the tail segment 26.7%-28.5% as long as the body length, were armed with 6-8 hooks, and had 4-7 anterior and 6-8 (4 mm-5 mm long individuals) to 10-13 (7 mm-8 mm long individuals) posterior teeth. The TC-value

measured on Fig. 3A is 86.4. This is unusually large for *S. tenuis* if the figure is made quite accurately.

Fraser, J. H. (1961: Nigerian Chaetognatha-*Sagitta friderici* R. Z. Ann. Mag. nat. Hist. (13) 3: 289-290.) examined *S. friderici* found in four tubes of plankton taken during half-hour hauls made in August - October 1957 in the estuary of the Bonny River, off Port Harcourt, Nigeria. Only the present species of chaetognath was found in the collections. The maximum length was 9 mm in the August sample, 13 mm in September, and 11.5 mm in October. The annual temperature and salinity ranges are 26 - 30°C and 12 - 23 ‰, but the salinity dropped to 11.5 ‰ in September 1957.

Alvarino A. (1961: Two new chaetognaths from the Pacific. Pacif. Sci. 15: 67-77.) established a new species, *Sagitta euneritica*, which occurs close to shore from Cape Mendocino to Punta Eugenia in Baja California. She considers this new species as identical with the form which Bieri (1957 and 1959) recorded as *S. friderici* (?) in the same area along the coast of North America and extending south to the waters of Peru and Chile. And very probably many of the *S. friderici* collected and examined by me in the blue-green water along southern California (1959) are to be included in the new species according to her opinion. She compared *S. euneritica* with *S. friderici* and *S. setosa*, but the last species differs distinctly from *S. friderici* and *S. euneritica* in the fully matured state as the seminal vesicle is far from the tail fin. Thus, the most important point is the distinction between *S. euneritica* and *S. friderici*. As far as I am aware, two of the characteristics given by Alvarino for *S. euneritica* seem to be significant. One is the position of the posterior fin which lies more on the trunk than on the tail; the other is the structure of the seminal vesicle. However, the TC-value varied from 76 to 141.7 in 33 specimens of *S. friderici* collected in the blue-green water and vicinity and therefore the former character cannot be a definite one. The latter character may be the only one differentiating *S. euneritica* from *S. friderici*. The author of *S. euneritica* mentions that the seminal vesicle of her species is like that of *S. neglecta* and her Fig. 9 shows that it is devoid of any glandular portion at the anterior end of the vesicle. But I observed seminal vesicles



just like those of typical *S. friderici* in some individuals collected in the blue-green water. Moreover, it is noteworthy that the outline of the vesicle shown by Alvariño in Fig. 9 resembles closely some of those shown in Figs. 7-14 of this paper. It is not impossible that *S. euneritica* is nothing but an intraspecific variant of *S. friderici*.

Sund, P. N. (1961: Two new species of Chaetognatha from the waters off Peru. *Pacif. Sci.* 15: 105-111.) established two new species, *Sagitta peruviana*, distributed rather widely in the coastal waters of Peru, and *Sagitta popovicii*, found only near the entrance to the Port of Talara, Peru. Evidently *S. peruviana* is identical with the individuals of *S. friderici* treated in this paper, and *S. popovicii* seems to be identical with *S. tenuis*.

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