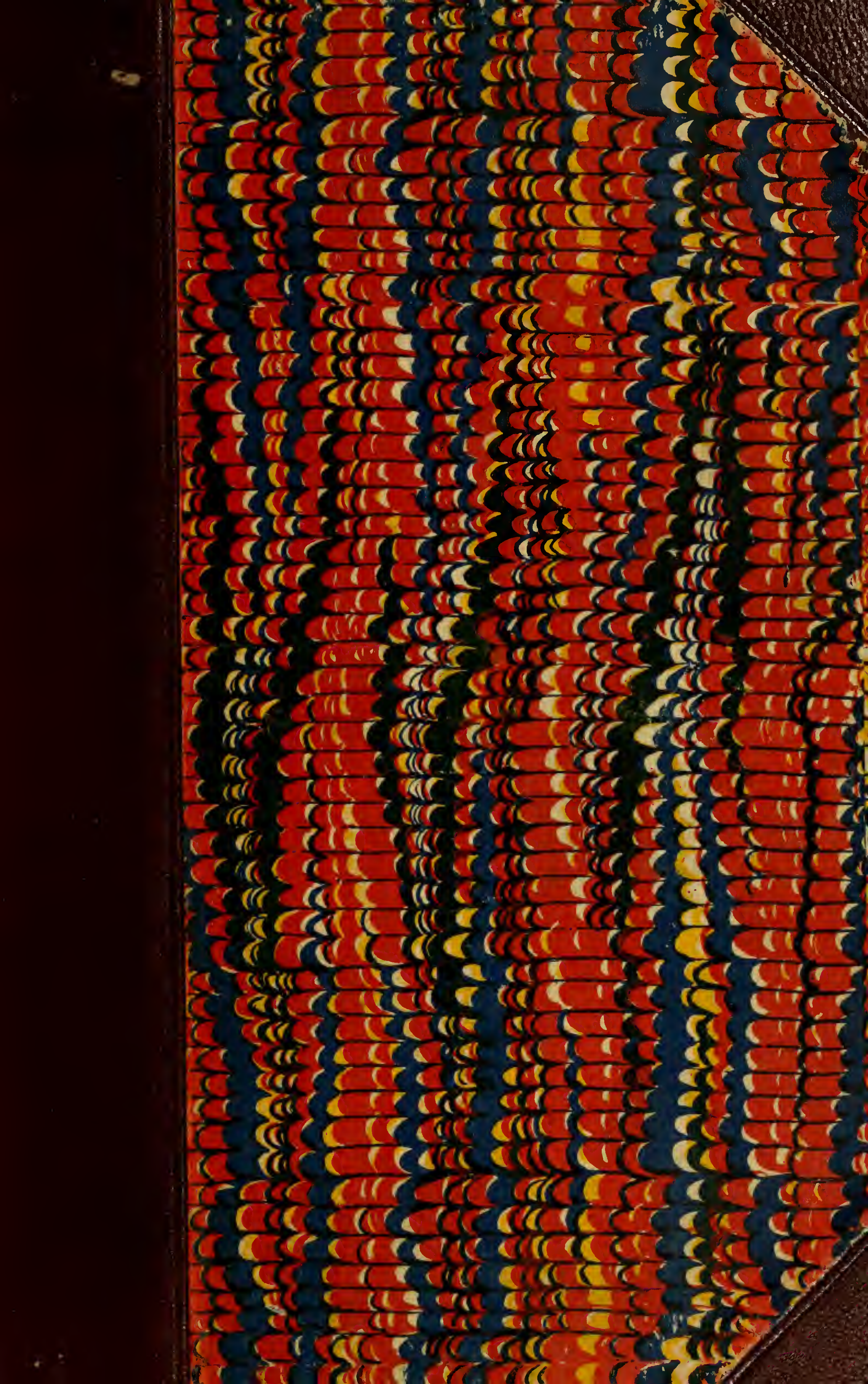

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ZOOLOGY

WILLIAM EMERSON RITTER
AND
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VOLUME 8

WITH 25 PLATES

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THE VERTICAL DISTRIBUTION OF *EUCALANUS ELONGATUS* IN THE SAN DIEGO REGION DURING 1909

BY

CALVIN O. ESTERLY

BERKELEY
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THE VERTICAL DISTRIBUTION OF *EUCALANUS ELONGATUS* IN THE SAN DIEGO REGION DURING 1909

BY

CALVIN O. ESTERLY

(Contribution from the Laboratory of the Marine Biological Association of San Diego)

This species is a very common one in the San Diego region, ranking next to *Calanus finmarchicus* in that respect. *Eucalanus* is characterized by the remarkable transparency of the body; the living animals are practically invisible in a dish of water. The body is also almost entirely colorless; the median eye may reveal a slight reddish tint and some individuals have one or two oil drops in the hinder part of the cephalothorax that are of a faint orange or reddish color. In some cases the bristles on some of the appendages are of a more or less evident orange. However, these copepods are the most difficult to see of any with which I am familiar.

Because of its transparency and lack of noticeable color, *Eucalanus* is highly adapted for its life as a plankton animal (Steuer, 1910, p. 275), and on this account, also, it has seemed to me that its vertical distribution during day and night would be interesting. It does not seem likely that if vertical migrations take place they could add much to the protection of the animals by leading to their removal from levels at which they would be easily visible during the day and so apt to be preyed upon. The animals would be practically invisible at any level.

The collections on which this paper is based were made with an ordinary 000 surface net and with the Kofoid closing net of 000 mesh. The diameter of aperture of the former was 97.5 cm., that of the latter was 18.5 cm. I have attempted to make up for this difference in area of aperture in the following way. The average number of animals taken by several hauls with the closing net at a certain depth and within certain time limits, was standardised to a haul one hour in duration; this number was multiplied by 28 since that represents the ratio between the areas of the apertures of the two sorts of nets. It may be said that the result gives numbers that seem far too large, and that the method of correlation employed is very rough at the most since it does not take into account such factors as the rate and distance of hauling, filtering capacity and variations in water pressure. The following tabular view of the more general data for the hauls that are concerned in this discussion may be useful.

TABLE 1

GENERAL DATA FOR THE COLLECTIONS STUDIED

	Approximate direction from La Jolla	Distance statute miles from shore	Number of hauls Surface	Deep	Depths at which hauls were made. In fathoms
1.	SW	15	0	5	50, 100, 200, 400, 550
2.	W × S	15.5	1	0	0
3.	W × S	2.2	1	0	0
4.	W × S	16	0	1	200
5.	W × S	14	12	26	0, 5, 10, 25, 50, 100, 110, 150, 160, 200, 220, 250, 300
6.	WNW	2.5	0	1	15
7.	WNW	2.3	0	1	50
8.	W × S	39.75	0	1	200
9.	NW × W	2.5	1	1	0, 15
10.	W × N	3.5	3	17	0, 5, 7.5, 10, 15, 25, 30, 35, 50, 100
11.	WNW	3.3	0	4	5, 7.5, 30
12.	W × S	37.4	0	1	125
13.	W × S	17.75	1	0	0
14.	W × S	15.75	0	1	250
15.	NW	3	1	4	0, 5, 10, 15, 25
16.	W × S	15.5	0	1	150
17.	W	13.6	0	1	200
18.	W × S	36	2	1	0, 50
19.	NW × W	3.7	0	4	15, 25, 50, 100
20.	W	13.25	0	1	100
21.	W	13.4	0	1	50
22.	W × S	35.1	0	1	25

Table 2, which follows, shows the hourly averages which have been reckoned in the way already mentioned and arranged according to depths and times of day. The fractions in each column represent the proportion of hauls in which the animals were found, and in all cases the denominator shows how many hauls were made at that depth and within the hours indicated. The first figure in any of the time divisions is the hour at which the earliest of all the hauls began; the second figure is the time at which the latest haul was finished. In other words, all the hauls began and ended within the time limits indicated at the head of each column.

The surface hauls were made between June 21 and July 10; the deep hauls between June 21 and November 5, with 22 hauls in June, 37 in July, 5 in September and 9 in November. There seem to be no significant differences between the summer and fall collections in the numbers of animals taken.

TABLE 2

THE VERTICAL DISTRIBUTION OF *Eucalanus elongatus* IN HOURLY AVERAGES AT THE DEPTHS AND WITHIN THE TIMES INDICATED; SURFACE AND CLOSING NETS

Time within which the hauls were made

	Surface	6:10 A.M.–6:20 P.M.		6 P.M.–8:50 P.M.				3:30 A.M.–6:35 A.M.	
	Deep	6:05 A M.–5:55 P.M.		6:13 P.M.–8 P.M.		11:30 P.M.-12:37 A.M.		4:25 A.M.–6:03 A.M.	
	Depths fathoms	Hourly averages							
		A		B		C		D	
1.	0	2/5	8	2/9	15			0/8	0
2.	5–10	0/5	0	0/2	0	0/2	0	0/4	0
3.	15–25	3/4	616	3/5	308	1/2	420	3/5	308
4.	30–50	6/7	756	3/5	84			2/3	280
5.	100	2/2	1792	4/4	812			2/3	280
6.	110–160	3/3	2520	3/4	236			2/2	1540
7.	200–250	5/6	2968	3/4	236				
8.	300–550	3/4	280						

The figures in this table show (line 1) that *Eucalanus* is never abundant at the surface, for it was taken there in only four out of 22 hauls; but when found it is most abundant from 6 to 9 p.m. These surface hauls do not help us to understand why such distribution should occur, but it may be said that light does not appear to have any influence.

It is worthy of remark that the surface haul that took the largest number of *Eucalanus* also took more *Calanus finmarchicus* than any other haul; there is thus an indication that the conditions which are particularly favorable for surface aggregations of one species are in some cases favorable for another species. This is not always true, because two other very large surface collections of *Calanus* did not contain any *Eucalanus*. I have been unable to find a clue, thus far, as to the conditions that favor accumulations of the latter species at the surface. When we consider that *Eucalanus* was uniformly absent from collections with the closing net at levels down to ten fathoms (Table 2, line 2), it seems strange that the species should have occurred at all at the surface. This may be connected with the difference between the areas of the two sorts of nets.

The plurimum for *Eucalanus* during daylight is at about 200 fathoms. Though in the table (column A, line 7) it would seem to be between 200 and 250 fathoms, five hauls at 200 fathoms took 3640 per hour during the day and one haul at 250 fathoms did not take any; it seems fair, therefore, to conclude that the depth at which the animals are most abundant during the day is 200 fathoms.

It is plain from Table 2 that *Eucalanus* does not exhibit any well-marked diurnal migration. There are no significant increases in daily averages at any level after 6 p.m., and if vertical migrations really occur we could reasonably expect that fact to be indicated somewhere in the amount of data available. If a change in the number of animals taken per hour may be regarded as showing that there is a movement of the species, Table 2 shows that fact most clearly, but the movement does not appear to be away from the lower levels at twilight or later in the night. If columns A and B of the table and lines 3 to 7 are compared, it will be seen that in every case the hourly averages are smaller in the early portion of the night than during the day. There is hardly any other conclusion to be drawn than that there is some movement of the species as a whole which leads to a decrease in the hourly averages at all levels [represented in our collections] from 6 to about 9 p.m. At one level (Table 2, column C, line 3), there seems to be an increase about midnight, but this does not bring up the hourly average to what it was during the day. The hourly averages in line 6 of columns A, B, and D indicate a return in the early morning to the daylight plurimum, but in the light of the other figures it is difficult to see what significance this can have.

To repeat, Table 2 shows that *Eucalanus,* as a whole, keeps well down during the day (column A), the plurimum being at 200 fathoms. During the early part of the night (column B, lines 3-7), the population at all depths is materially decreased. There is no corresponding increase, therefore, at any of the levels and accordingly there does not seem to be a vertical migration. The fact of the decreased hourly averages, however, deserves emphasis, because the decrease is in evidence at a time when the light is much reduced, and also at the time (6-9 p.m.) that collections with the surface nets show an increase (columns A and B, line 1).

It does not seem likely that the smaller opening of the closing net can be the reason for this apparent inconsistency, because in another species (*Calanus finmarchicus*) the collections with the same kinds of nets bore out each other. Likewise, it does not seem probable that collections at other levels would show where the animals are at night; there is no reason to think that the depths at which collections were made do not give a fair enough indication of the vertical distribution of the species. A third suggestion is that the distribution shown in Table 2 may be due to horizontal migration, such as described by Juday (1904, p. 558) for some of the fresh water Crustacea; however, the fact that the decrease in hourly averages takes place over the entire area does not bear out this idea. Lastly, the animals may spread over a wider horizontal area, as night comes on, than that which they occupy during the day, on account of active wandering or a ''nocturnal habit.'' Even if this were known to be the case it would not add much to our understanding of the movements of the plankton organisms.

A study of the movements or distribution of an organism so perfectly adapted on account of transparency and lack of color as is *Eucalanus*, leads to speculation as to the meaning of diurnal migrations. (Compare Morgan, 1903, pp. 391-394, 404-405). Here we find that a species which is entirely without need of the protection that is probably afforded by the dim light at 200 fathoms, remains, for the most part, at that depth during the day. In a species not very transparent, this behavior would at least suggest that protection from predaceous organisms is secured. It is well known that many fish, for example, feed largely upon copepods, but it is indeed difficult to conceive how a fish could detect a *Eucalanus* by sight. This is suggestive of the possibility that the degree to which an animal is adapted to a life in the plankton through transparency and lack of color has something to do with the vertical migrations. In other words, it might be possible to show that there is a relation between the coloration or opacity of an animal and its vertical movements in a body of water. If it should be found that vertical migrations are more characteristic of forms that would be easily visible, and less so of colorless and transparent forms, it would be an indication that the migrations are themselves in the nature of an adaptation. This would, of course, be more true of the movement to deeper levels for the day. It is suggestive, at any rate, that *Eucalanus* does not appear to have a behavior that would be in part protective while, at the same time, protection is secured in another way.

It would be worth while to know whether species that live below the depth to which light penetrates execute the vertical migrations. If so, it could not be urged that the movement is protective or adaptive. It is not to be expected that the behavior of one species will be characteristic of all others, yet it does not seem too much to hope that there are some far-reaching fundamental principles underlying the movements of plankton organisms. We could not expect an adaptive behavior in all cases, for diurnal migrations may be of no more use to some organisms than the migration of pigment in the eye of a crayfish, under the influence of heat. The latter is probably a manifestation of one of the general properties of protoplasm, and the same may be true in a general way of the movements of plankton organisms.

In conclusion, while the distribution of *Eucalanus* as presented here does not show that this species exhibits diurnal migrations, there is a very evident set of movements that are certainly as puzzling, and even harder to explain. This behavior is suggestive that diurnal migrations may be in a measure protective, since *Eucalanus* is adapted in other ways to the conditions of existence in the plankton. At any rate, this possibility deserves further investigation.

Occidental College, Los Angeles, California.
Transmitted February 1, 1911.

BIBLIOGRAPHY

Juday, C.

1904. The diurnal movement of plankton Crustacea. Trans. Wisc. Acad. Sci. Arts and Letters, **14**, 534-568.

Morgan, T. H.

1903. Evolution and Adaptation (New York and London, Macmillan), xiii + 470, 7 figs.

Steuer, A.

1910. Planktonkunde (Leipzig and Berlin, Teubner), xv + 723, 1 pl., 365 figs. in text.

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BY

EDWIN CHAPIN STARKS AND WILLIAM M. MANN

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NEW AND RARE FISHES FROM SOUTHERN CALIFORNIA

BY

EDWIN CHAPIN STARKS AND WILLIAM M. MANN

(Contribution from the Laboratory of the Marine Biological Association of San Diego)

The following report is of a collection of fishes made in the vicinity of La Jolla and San Diego, California, by the Marine Biological Association of San Diego at various times since 1907. The collection also includes a few specimens taken at Cerros Island, Lower California, in the summer of 1908. Only that part of the collection that is of interest on account of hitherto unrecorded characters or distribution is here included. When locality is not specified specimens are from the general vicinity of San Diego.

The accompanying drawings are by Chloe Lesley Starks.

Etrumeus micropus Schlegel

We may note here the receipt at Stanford University of two specimens of this species from San Diego. They were sent by Mr. A. V. Pearson, who states the species to be common. From the fact that it has not been seen by any collector since it was described twenty years ago by Rosa Smith Eigenmann under the name of *Perkinsia orthonops* (*American Naturalist*, 1891, p. 153), it is remarkable that it should be at any time common, especially in light of the many collections that have been made in the vicinity. It is probably a migratory species common at certain more or less infrequent intervals. It is a common species in Japan and in the Hawaiian Islands.

Polydactylus approximans (Lay and Bennett)

A specimen a foot in length, preserved by the San Diego Chamber of Commerce, is included in the collection. This is the first record of the occurrence of this species north of the Gulf of California. Starks and Morris in their "Marine Fishes of Southern California" (*Univ. Calif. Publ. Zool.*, vol. 3, no. 11, p. 188, 1907) recorded *Polydactylus opercularis* from an oil painting made by Mrs. Andrews, of San Diego, of a fish she had procured in the local market. The painting may have been of the species now at hand, or it is possible that both species occur on our coast.

Lepidopus xantusi Goode and Bean

The second adult specimen known is in the collection. It is of the same size as, and entirely agrees with the specimen described by Jordan and Starks (*Proc. U. S. Nat. Mus.*, 32, p. 70, 1907).

Abeona minima (Gibbons)

In a young specimen dark vertical bars are very distinct. An anterior one commences as a blotch at the first ray of the soft dorsal and extends vertically downward two-thirds of the height of the body. A posterior one extends only slightly past the black band along the axis of the body. In adult specimens in alcohol these dark cross bars are quite indistinct.

Halichoeres semicinctus (Ayres)

A single female specimen, 7 inches in length, from La Jolla, shows color markings not before described. Following the third longitudinal row of scales from the dorsal base is a row of round black spots, one on the base of each scale. These are frequently, but not regularly, duplicated below thus making an irregular double row. It is interrupted on the caudal peduncle for 2 or 3 scales, but at the base of the caudal it is represented by two pairs of spots. A less definite row follows the row of scales at the base of the dorsal, and above the pectoral are a few scattered spots.

Sebastolobus altivelis Gilbert

A specimen taken in the trawl at a depth of 413 fathoms. In this specimen no scales can be detected on the branchiostegal rays or membrane.

Sebastodes diploproa (Gilbert)

One specimen taken off La Jolla in a depth of 160 fathoms. It has been directly compared with one of the cotypes with which it agrees in all of its characters.

Orthonopias, new genus

Top of head between eyes covered with fine ctenoid scales; a row of slender cirri back from each eye; the entire course of lateral line with a series of enlarged ctenoid scales; sides of back with a broad band of fine scales, leaving a narrow naked strip above lateral line and another below base of dorsal; villiform teeth on jaws, vomer, and palatines; four preopercular spines; the upper one trifid; dorsals separate; gill membranes united, free from isthmus; no slit behind last gill; ventrals 1, 3.

This genus is most closely related to *Axyrias* and *Astrolytes*. It differs from *Axyrias* in the trifid preopercular spine; from *Astrolytes* in the very much wider band of scales between the lateral line and the base of the dorsal, and in the armed lateral line.

Orthonopias triacis Starks and Mann, new species

Head 3¾ in length of body to base of caudal; depth 4. Eye 3¼ in length of head; maxillary 2¾. Dorsal IX-17; anal 12.

Profile very steep from tip of snout to tip of nasal spines. Lower jaw included; maxillary reaching to vertical from middle of eye. Villiform teeth on jaws, vomer, and palatines. Eye set high in head, standing a little above profile; its diameter almost as great as length of snout. Interorbital space a little less than half as wide as diameter of eye. A narrow depression running midway between the eyes from a point opposite the posterior border of the eye to a depression behind the nasal spines. Upper preopercular spine slightly over half as long as diameter of eye; trifid; its upper two forks strong, its lower fork shorter, close to middle fork, and little separated from it; upper fork directed upwards and backwards; lower forks nearly straight backwards.

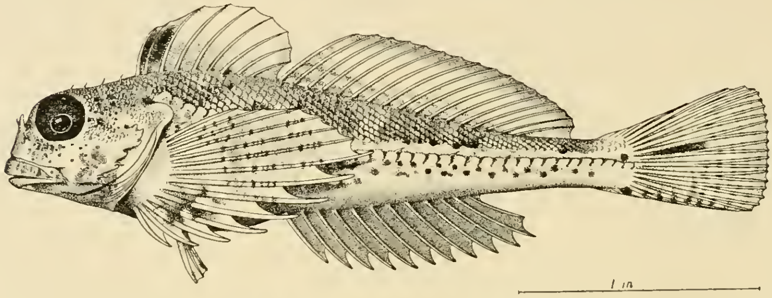

Fig. 1. *Orthonopias triacis* Starks and Mann.

Second and third preopercular spines subequal, and not half so long as first; fourth spine short, at lower angle of preoperculum. Nasal spines prominent; sharp; nearly as long as diameter of pupil; reaching to a level with upper edge of pupil. Top of head with cirri among the scales, one at each nostril; a line of four extending backwards from each eye; one back of each eye opposite the second of this line; two at tip of maxillary; two at lower angle of preopercle; one at angle of opercle.

Fine etenoid scales on interorbital space which become larger and more separated on the occiput. Snout and the space below preopercular stay naked. Preopercle above level of upper spine, and opercle with small ctenoid scales. Lateral line with a series of 38 plate-like scales; their upper posterior edges free and dentate. A naked area just above lateral line about as wide as lateral line scales, and a similar narrow naked area at base of dorsal; between these two a band of rough scales 5 or 6 scales wide below origin of soft dorsal counting vertically; counting the series running down and back it is from 10 to 12 scales wide; the band is composed of 36 oblique series counting longitudinally. Scales of posterior part of band growing smaller and irregularly arranged; the band connecting with its fellow of the opposite side on caudal peduncle. Body below lateral line naked.

Dorsal spines slender; weak; those from the 4th to the 7th longest. Dorsals not connected; first ray of soft dorsal over twice the height of last spine; anterior rays about equal; posterior growing only slightly shorter; the highest ray twice the diameter of eye. Pectoral large; contained 2⅞ times in body; reaching to opposite base of 6th or 7th dorsal ray. Ventrals reaching slightly past vent; first ray of anal beneath 3rd dorsal ray; last ray beneath 14th dorsal ray; anal rays nearly equal in length throughout length of fin; caudal broadly rounded behind.

Color in alcohol light brown; a dark blotch below the anterior part of spinous dorsal; a small blotch below posterior part; three blotches below soft dorsal; and one on caudal peduncle. Sides below lateral line with irregular dark blotches on anterior half of body, and with smaller spots on posterior half. A black blotch on front of spinous dorsal; soft dorsal narrowly margined with brown, and with some narrow dark oblique bars on its base; membrane of anal uniformly brown; the rays somewhat lighter; caudal with a longitudinal streak through its middle; pectorals brown with a darker blotch at base; ventrals colorless.

The type and only specimen of this species is a trifle over three inches in length, and was taken at Cortez Banks in a trawl at a depth of from 11 to 16 fathoms.

Rusulus, new genus

Head naked and with numerous large pores and several small cirri; no enlarged external plates along lateral line; anterior pores of lateral line with cirri; sides of body covered sparsely with one, two, and three-pointed scales or spinules which extend below lateral line above anal region; teeth on jaws, vomer, and palatines; upper preopercular spine bifid; lower spines but little developed; dorsals separate, or contiguous at extreme base only; gill membranes united, and free from isthmus; no slit behind last gill arch; ventrals with one spine and three rays.

This genus is most closely related to *Clinocottus* from which it differs in the larger spinules on the body, the absence of cirri on the back and at the base of the dorsals, and in having fewer and smaller cirri on the top of the head.

Rusulus saburrae Starks and Mann, new species

Head $3\frac{1}{8}$ in length of body to base of caudal; depth 4. Eye 4 in head; maxillary 3; highest dorsal spine $2\frac{3}{4}$; length of ventral $1\frac{4}{5}$; pectoral $1\frac{1}{5}$; caudal $1\frac{1}{5}$. Dorsal IX, 17; anal 14; pores in lateral line 38.

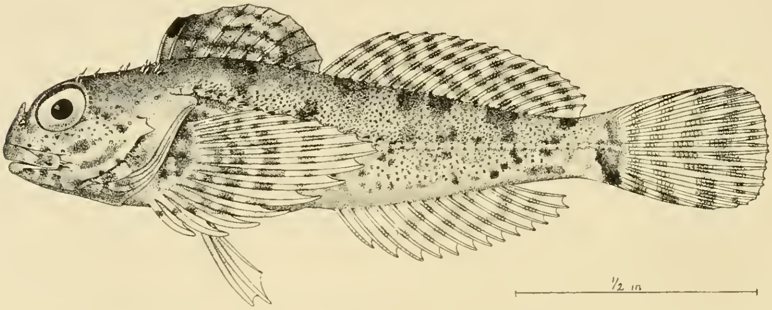

Fig. 2. *Rusulus saburrae*, type.

Body short, moderately thick, heaviest at shoulders. Profile of head precipitous anteriorly; slightly concave at occiput; lower profile gently curved from chin to ventrals. Lower jaw included; maxillary reaching to below center of eye; fine villiform teeth on jaws, vomer, and palatines. Interorbital space shallowly concave; equal to half diameter of eye. Eye on level with upper margin of head; its diameter a little less than length of snout. Nasal spines blunt; distance from their tip to mouth a little greater than length of eye. Upper preopercular spine bifid; its superior spine the shorter, directed upward and backward; the inferior directed backward and slightly upward; two slight angles on lower edge of preopercle represent the usual lower spines. Head entirely naked and with many large pores behind and below eye. Three or four cirri on the margin of the preoperculum, and a row behind each eye on top of head.

Lateral line curving downward to tip of pectoral where it is slightly angulated, and thence runs straight to caudal; the part anterior to angle with cirri at each pore. Small scattered one. two, and three-pointed scales on side of body, becoming more numerous posteriorly and opposite soft dorsal extending below the lateral line.

Dorsal fins separate, or only in contact at extreme base. Third and fourth dorsal spines the longest; first dorsal ray 2½ times the length of the last dorsal spine; pectoral reaching to base of fifth dorsal ray; ventrals reaching a fourth of their length past vent; first ray of anal beneath third ray of dorsal.

Color in alcohol brown, belly lighter; back, sides, and head everywhere with small dark dots arranged in patches; a narrow band across occiput; back with 5 interrupted bands, the last at tip of last ray; a row of irregular blotches below lateral line; dorsals, pectoral, and anal with dark, oblique, dusky bands; ventrals without color.

The type and only specimen of this species is 1 5/8 inches in length and was taken in a dredge opposite Ballast Point, at the mouth of San Diego Bay, in a depth of 10 fathoms.

Icelinus quadriseriatus (Lockington)

Many specimens were taken near Cerros Island. Lower California, in 40 fathoms of water. Some of them have the branchiostegal membrane black, the ventrals dusky, and the anal very dark, appearing black when the fin is closed. Others have these parts entirely colorless. All gradations between these extremes are represented. Specimens with the lower parts dark may have the pectoral variously colored from very dark to almost entirely colorless, but the pectoral is always light when the other parts are.

Tarandichthys cavifrons (Gilbert)

Several specimens of this species were taken at a depth of from 46 to 50 fathoms about San Diego.

Xeneretmus triacanthus (Gilbert)

Two specimens were taken in water from 50 to 100 fathoms deep off La Jolla. It has not before been taken in southern California.

This species may be readily known from *X. latifrons,* its nearest relative, by the possession of 2 or 3 buckler-like plates below the suborbital ridge (where it is naked in the latter species), by its having 6 rather than 7 or 8 anal rays, and by its having a free fold posteriorly on the branchiostegal membrane. But it is most readily known by the absence of a black margin to the spinous dorsal posteriorly. In *X. latifrons* a black margin is always present and conspicuous.

Rhinogobius nicholsii (Bean)

A specimen taken in 50 fathoms of water.

Porichthys notatus Girard

The collection contains specimens taken at various depths from very shallow water to 40 fathoms.

Cryptotrema corallinum Gilbert

A single specimen, 2¼ inches in length, taken at a depth of 50 fathoms. While the scales of the front part of the lateral line are very prominent and slightly larger than those at each side of them they are not nearly so much larger in proportion as in larger specimens.

Chilara taylori (Girard)

A specimen 7 inches in length taken off Cerros Island in 40 fathoms of water. It does not show the usual spots, being uniformly light dusky above, shading to lighter on sides.

Maynea californica Gilbert. (MS.)

Three specimens of this species without data, other than locality, are in the collection from off La Jolla. The species is known only from the type (from off San Nicholas Island) and unpublished description by Dr. Gilbert.

Two species from the north temperate Pacific have been referred to this genus, but are now considered under the genus *Bothrocara*, (*B. pusilla* [Bean], and *B. mollis* Bean). The present species, however, differs from the type of the genus

Maynea (*M. patagonica* Cunningham, from the Straits of Magellen) only in specific characters, and it is the only one of the genus known from northern waters. *Maynea* differs from *Bothrocara* in having the flesh firm, the skin thick, the head not cavernous, the eyes small, and the body tapering to a blunt point with the dorsal and ventral outlines of the body approaching each other in convex curves. *Bothrocara* has the body loosely organized and covered with thin, lax skin, the head soft and cavernous, the eyes very large, and the body tapering to a fine point with the ventral and dorsal outlines approaching each other in straight lines.

Maynea californica resembles the picture of *M. patagonica* that was published by Dr. Gunther (*Proc. Zool. Soc. Lond.* 1881, pl. II), but differs in having the front of the dorsal placed much more posteriorly, and in the absence of cross bars in the young.

The largest of the specimens at hand is a little over five inches in length, or nearly as large as the type; the others are considerably smaller. They differ from the type in having the maxillary a little shorter, the interorbital space a little narrower, though the width of the interorbital bone is similar, and in being darker in color.

The following description is of the largest specimen. The smaller ones agree with it in all essential respects.

Length of head 7¼ in length of body to base of caudal; depth 12¼. Eye 6 in head; maxillary 3½; snout 4.

Snout blunt and rounded, very slightly overhanging mouth in large specimen, even with mouth in small ones. Rather coarse teeth in bands on jaws, vomer, and palatines. Anterior nostril in a short tube extending forward a little beyond the snout; posterior nostril a large pore scarcely larger than various other pores on head. A line of pores around lower and posterior part of eye; a line of four pores running straight back from eye and connected with its fellow of the opposite side by a transverse line of three pores at nape. The line from eye continued on side of body by a few very fine pores which do not reach as far back as the tip of the pectoral fin. A line of pores present around edge of preopercle and continued on mandible anteriorly to its point.

Interorbital space flat and without a longitudinal channel; its width a little less than eye. Maxillary reaching a very little past front of eye. Gill slit reaching slightly below base of pectoral; its length equal to distance from tip of snout to middle of eye.

Pectoral rather broad and rounded; its width at its base contained 5 times in head; its length nearly 2. Origin of dorsal a distance behind nape equal to the distance from nape to middle of eye; its distance behind base of pectoral equal to length of snout. Origin of dorsal from tip of snout a distance contained in entire lenth to base of caudal 5½ times. Origin of anal from tip of snout 2⅗ times in length. Dorsal and anal low, and continuous around tail without a notch. The length of the anterior dorsal rays barely exceed the length of the eye; the posterior rays a little longer, at beginning of posterior fourth of fin 1⅗ times longer than eye. Ventrals entirely absent. Body covered with scattered imbedded scales extending onto bases of dorsal and anal fins.

Color in alcohol dark bluish-brown, darker on back and top of head, changing to light dusky below. The sides of body everywhere with small light spots formed by the scales. Pectoral colorless; dorsal and anal with an inconspicuous lighter border.

Citharichthys fragilis Gilbert

A number of small specimens of this species were taken off Cerros Island at a depth of 40 fathoms in company with *Citharichthys xanthostigmus.* They have been compared directly with the type specimens and found to agree in all essential characters. The scales in the lateral line vary from 44 to 49 in number, and the rays in the dorsal from 80 to 86. The species has been known heretofore only from the Gulf of California.

Citharichthys stigmaeus Jordan and Gilbert

This species is represented in the collection by a large number of specimens, and though reported rare is evidently common off southern California.

The following key includes all of the west coast species of *Citharichthys* known outside of the tropics.

- A. 9 to 11 gill rakers on anterior limb of arch.
  - B. Ventrals longer than head. *xanthostigmus.*
  - BB. Ventrals shorter than head. *stigmaeus.*
- AA. 16 to 18 gill rakers on anterior limb of arch.
  - C. Scales from 65 to 70; dorsal 95. *sordidus.*
  - CC. Scales from 46 to 51; dorsal 80 to 87. *fragilis.*

Symphurus atricauda (Jordan and Gilbert)

This rather common southern California species is represented in the collection by a single specimen. A specimen taken some years ago in the San Francisco market by Dr. Gilbert, and another recently at Santa Cruz increases the northern range of this species. It has hitherto not been recorded north of Point Conception.

From *Symphurus leei,* with which this species intermingles in tropical waters, *Symphurus atricauda* may be distinguished by its finer scales, having from 105 to 108 transverse series rather than from 75 to 90, and in having a smaller head, which is contained 4⅘ to 5⅓ times in the length of the body rather than 4¼ times.

The following color-description was taken from a fresh specimen. The eyed side is greyish-brown with a series of 7 or 8 dark brown cross bars at the bases of the dorsal and anal fins, but fading out at the middle of the body. These become gradually darker posteriorly, and are brownish-black on the tail. The fin membranes are broadly edged with pale orange. The blind side is colorless except the fins of the caudal region, which grow gradually black posteriorly, and the visceral region, which is a deep pink.

Transmitted April 7, 1911.

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INCLUDING REDESCRIPTIONS OF SOME DOUBTFUL SPECIES OF THE GROUP

BY
ELLIS L. MICHAEL

BERKELEY
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INTRODUCTION

This paper is based upon material collected by the San Diego Marine Biological Station from 1904 to 1909. During this period the station has explored a region lying, in the main, between the parallels of 32° 20′ and 33° 30′ N, and extending from the coast to 119° W. In this material we recognize seven out of eighteen valid species of *Sagitta*, two of the three species of *Eukrohnia* (= *Krohnia* Langerhans), and one of the two species of *Spadella*. The seven species of *Sagitta* are *S. enflata*, *S. hexaptera*, *S. lyra*, *S. serratodentata*, *S. bipunctata*, *S. planktonis*, and *S. neglecta*. *Eukrohnia* is represented by *E. hamata* and *E. subtilis*. The one species of *Spadella* is *S. draco*. Though I have spent much time in detailed and critical examination of this material, I have failed to discover any indication of new species.

The species of *Eukrohnia* and *Spadella* are readily recognized, but those of *Sagitta* are more difficult to identify. The latter naturally fall into two groups, those with and those without collarettes. Although, in the species of each group, the diagnostic characters are annoyingly alike, each species has a definite and distinctive appearance.

It is my aim to give (pls. 1, 2) some idea of this distinctive appearance, in addition to the usual taxonomic characters.

Primarily this depends upon degree of transparency of the species. Doncaster (1902b) has represented this appearance, but his drawings lack accuracy of measurement, which renders them useless for purposes of identification. Most authors, however, have published merely outline drawings and, while accurate in measurements, they do not suggest the distinctive appearance of the species. To make this paper more serviceable to those unacquainted with the group I have endeavored to combine the merits of Doncaster's (1902b) drawings with accuracy of measurement.

Krumbach (1903) has discovered characters of much taxonomic value in the minute anatomy of the seizing jaws, and I have endeavored to extend his descriptions to the San Diego species. This author's contribution merits more attention than it has received, for these hard structures offer the only means of identification applicable to poorly preserved material. It is well to note, however, that to recognize these distinctive characters requires the most delicate microscopic manipulation.

In measuring the curvature of the seizing jaws the following method has been employed. A camera drawing (text fig. 1) was first made. A perpendicular, *ab,* was then erected upon the edge of the jaw at the junction of the shaft, *sh,* with the ventral column, *vent. col.* A second line, *cd,* was then drawn tangential to the point, *pt.* The proportion *ab*/*cd* indicates the extent of the curvature.

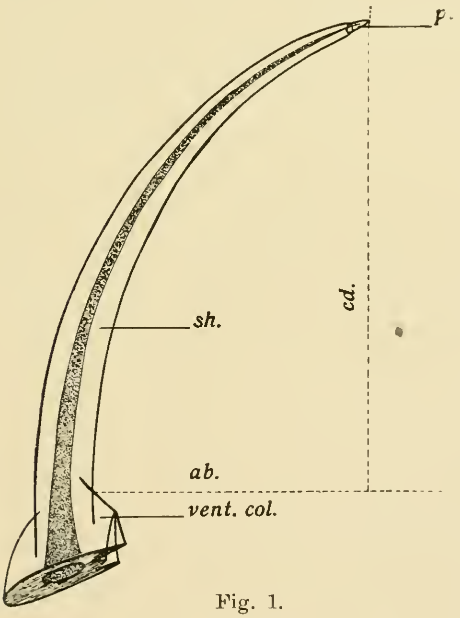

Fig. 1.

In preparing the tables of diagnostic measurements for each species only the most perfectly preserved material has been used. In specimens not well preserved some characters are always distorted, so that measurements based upon such material can not be relied upon. I have endeavored to include enough measurements in these tables to permit a fairly accurate reconstruction of the outline of each individual considered. All measurements, unless otherwise stated, have been made in proportion to total length of specimen as measured from tip of tail-fin to anterior extremity of head.

In my "Notes on the Identification of the Chatognatha" (1908) I stated that length and shape of ovaries, together with size of ova, could not be depended upon for identification because these organs were the last to develop. While this is partly true, it is their distinctive appearance, together with degree of transparency of the species, that catches the eye and affords the first basis of separation. These differences are brought out in plates 1, 2, 5 and 6. On pages 55 to 64, measurements of the ovaries are tabulated and discussed. However, owing to immaturity of the individuals of some species, it has been impossible to make these tabulations complete.

To facilitate identification, all known species of Chaetognatha are here described. Those obtained from the San Diego region are considered at some length, and the remaining species are briefly described at the close of the systematic part of this paper. In addition a few doubtful species of the group, including *Sagitta hispida*, *S. elegans*, *S. arctica*, and *S. tenuis* are redescribed.

While most expeditions have scattered their observations over a large territory, the Marine Biological Station of San Diego has confined its collecting to *one locality*. Until the present we have depended upon surface nets of various sizes and meshes, open vertical nets, the Kofoid closing net (see Kofoid, 1911), and the Kofoid water bucket (see Kofoid, 1905), for the collection of plankton, and on non-registering centigrade thermometers and the Kofoid water bucket for our hydrographic work. While all temperature and salinity determinations made in connection with our hydrographic work are as accurate as the best apparatus permits when in the hands of an expert physicist (see McEwen, 1910), our data could not be made complete without more apparatus. However, our explorations have taught us much regarding methods of collection and apparatus necessary for an adequate quantitative study of plankton distribution. We are convinced that direction and velocity of currents, temperature and salinity of water, wind, clouds, fog, rain, light, and darkness all affect the distribution of plankton *even within a very small area.* The influence of all these conditions must be known to solve any problem concerning the quantitative distribution of plankton. To increase our facilities in meeting this requirement we have recently installed the Ekman (1905a) reversing water bottles, the Nansen vertical closing net (see Herdman, Scott, and Dakin, 1910, p. 275), Richter self-registering deep sea thermometers (see Ekman, 1905a), and the Ekman (1905b) current-meter that records the velocity and direction of currents encountered in deep water. With this apparatus we hope to discover relations in the horizontal and vertical movements of plankton which will be valuable not only to students of planktology, but to the commercial fisheries as well. By strict attention to one locality we have obtained data containing significant facts not present in the results of most expeditions. Following the systematic part of this paper I have discussed these data in so far as they concern the Chaetognatha.

I desire to express my obligation to Professor William E. Ritter, Director of this station, and to Professor C. A. Kofoid of the University of California for suggestions and advice concerning the preparation of this paper. I am further indebted to Dr. G. Herbert Fowler, Secretary of the Challenger Society, to Dr. Hjalmar Broch of the Zoological Institute of the University of Christiana, to Dr. Rudolph von Ritter-Záhony of the Royal Zoological Museum, Berlin, and to the Smithsonian Institution for specimens of a number of rare and doubtful species.

PART I. SYSTEMATIC

KEY TO THE GENERA OF CHAETOGNATHA

1. Two pairs of lateral fins. Two pairs of rows of teeth. Only slight epidermal thickening on body............................**Sagitta.**

2. One pair of lateral fins, partly on body and tail. One pair of rows of teeth. No epidermal thickening behind head.. **Eukrohnia.**

3. One pair of lateral fins, entirely upon tail-segment. Two pairs of rows of teeth. Prominent thickening of epidermis, extending from behind head to tail....................................**Spadella.**

KEY TO THE SPECIES OF SAGITTA

1. Species without collarette 2
1. Species with collarette 9
2. Shaft of seizing jaw serrated ....**Sagitta serratodentata.**
2. Shaft of seizing jaw not serrated.. 3
3. At least 50 per cent of posterior fin in front of tail-septum.......... 4
3. Less than 50 per cent of posterior fin in front of tail-septum........ .... **Sagitta bedoti.**
4. Tail 28 to 40 per cent of total length............**Sagitta macrocephala.**
4. Tail 10 to 25 per cent of total length.. 5
5. Vestibular ridge composed entirely of papillae.............................. 6
5. Vestibular ridge provided with usual skeletal parts........................ 8
6. Tail 10 to 14 per cent of total length, mature ovary short, not over 7 per cent of total length............................**Sagitta gazelle.**
6. Tail at least 15 per cent of total length, mature ovary long, over 20 per cent of total length.. 7
7. Anterior fin shorter than posterior fin, with large interval between them ....**Sagitta hexaptera.**
7. Anterior fin longer than posterior fin; in the mature specimens the fins are confluent ....**Sagitta lyra.**
8. Body transparent. Top of shaft and base of point in seizing jaws converge toward edge of jaw........................**Sagitta enflata.**
8. Body opaque. Top of shaft and base of point parallel................. .... **Sagitta elegans.**
9. At least 50 per cent of posterior fin in front of tail-septum.......... 10
9. Less than 50 per cent of posterior fin in front of tail-septum........ 14
10. Collarette extending to ventral ganglion..........**Sagitta planktonis.**
10. Collarette never extending more than half way to ganglion.......... 11
11. Anterior fin extending to ventral ganglion.................................... 12
11. Anterior fin never extends to ventral ganglion.............................. 13

12. Body transparent. First third of anterior fin without the usual rays .... **Sagitta pulchra.**

12. Body opaque. Anterior fin with rays throughout .... **Sagitta sibogae.**

13. Tail 28 to 40 per cent of total length. No constriction at tail-septum .... **Sagitta decipiens.**

13. Tail not over 25 per cent of total length. Constriction at tail-septum evident .... **Sagitta bipunctata.**

14. Collarette extends to anterior fins 15

14. Collarette never extends much over half way to anterior fins 16

15. Anterior fin longer than posterior fin .... **Sagitta ferox.**

15. Anterior fin shorter than posterior fin .... **Sagitta regularis.**

16. Anterior fin extends to ventral ganglion 17

16. Anterior fin never extends to ventral ganglion .... **Sagitta hispida.**

17. Collarette exceedingly small. Sexually mature at a length from 5 to 6 mm. .... **Sagitta tenuis.**

17. Collarette well developed, extending nearly half way to ventral ganglion. Never sexually mature under 10 mm .... **Sagitta neglecta.**

KEY TO THE SPECIES OF EUKROHNIA

1. Lateral fin extends from the region of the ventral ganglion to somewhat behind the tail-septum; never reaches to seminal vesicles; more than 60 per cent in front of the tail-septum .... **Eukrohnia hamata.**

1. Cephalic limit of lateral fin never more than half the distance from the tail-septum to the ventral ganglion; extends caudally to the seminal vesicles; more than 40 per cent of fin behind septum 2

2. Body width about 4 per cent of total length. Tail 30 to 40 per cent of total length. Seizing jaws evenly curved, 6 to 9 in number. Teeth 9 to 13 .... **Eukrohnia subtilis.**

2. Body width about 5 per cent of total length. Tail 25 to 41 per cent of total length (usually not over 33 per cent). Teeth 11 to 15. Seizing jaws 6 to 9, with the convex edge made up of two curves, the junction of which makes an obtuse angle at a point about one-fourth the length of the jaw proximad of the tip .... **Eukrohnia pacifica.**

KEY TO THE SPECIES OF SPADELLA.

1. Average width of collarette nearly half that of body, widest slightly anterior to the tail-septum. Length of fin always less than 5 times its width. Anterior teeth 7 to 10. Posterior teeth 11 to 16 .... **Spadella draco.**

1. Average width of collarette much less than half that of body; widest slightly posterior to head. Length of fin always more than 5 times its width. Anterior teeth 3 to 5. Posterior teeth 3 to 4 .... **Spadella cephaloptera.**

Genus **Sagitta**

Sagitta enflata Grassi

Pl. 1, fig. 1; pl. 3, fig. 14; pl. 4, fig. 26; pl. 5, fig. 39; pl. 7, fig. 45; pl. 8, fig. 47.

Sagitta enflata Grassi (1883), p. 16; Strodtmann (1892), p. 18; Béraneck (1895), p. 254; Aida (1897), p. 15; Doncaster (1902a), p. 20; Krumbach (1903), p. 632; Fowler (1906), p. 8.
Sagitta flaccida Conant (1896), p. 85.
Sagitta gardineri Doncaster (1902b), p. 212.
Sagitta brachycephala Moltschanoff (1907), p. 208.
Sagitta inflata, Ritter-Záhony (1908), p. 13; (1909b), p. 5.
Sagitta furcata, Michael (1908), p. 68.

General Appearance

This species is the most transparent of all the Chaetognatha. When immersed in formalin and placed on a white background the body is very indistinctly seen, appearing like a very thin piece of slightly ground glass. The head and ovaries assume a yellowish-cream color considerably more opaque than the rest of the body. The tail is likewise more opaque, especially at the tip, shading gradually into the transparency of the body. On a black background (pl. 1, fig. 1) the head, intestine, ventral ganglion, ovaries, seminal vesicles, and tip of tail assume a whitish appearance contrasting markedly with the body which, though nearly transparent, presents a slight tinge of grayish-slate. From tip of tail the white gradually shades into the black of the body. The outlines of the fins are barely visible.

Characters

Body tumid, retaining its form well. A distinct neck separates head from body. Body much the widest at a point from 40 to 50 per cent of total length from head. Lateral fields large. Muscles weak and thin, being barely perceptible under a hand lens. Pronounced constriction at tail-septum. Collarette absent.

Anterior fin never extends to ventral ganglion. Distance from fin to ganglion usually about 20 per cent, but varies from 17 to 26 per cent. Position of greatest width always behind center of fin, varying from 63 to 73 per cent of its own length. Triangular in form with apex directed anteriorly.

Posterior fin longer and broader than anterior fin. Never extends caudally much more than half the distance from tail-septum to seminal vesicles. Never less than 50 per cent of fin in front of tail-septum, varying from 57 to 70 per cent. Position of greatest width almost uniformly opposite tail-septum. Interval from anterior to posterior fin usually about 10 per cent, but varies from 9 to 15 per cent. Interval always less than length of posterior fin.

Vestibular ridge (pl. 3, fig. 14) provided with low rounded papillae having the appearance of a number of irregular semicircles. Number of papillae usually the same as number of posterior teeth. Two teeth (sometimes one) project beyond wing of ridge, the third (or second) barely reaching the wing. Notch covers the first three or four teeth. External process from one-half to one-third the length of ridge. It is blunt and narrow, its length being about ten times its width.

Anterior teeth, 5 to 8. *Posterior teeth*, 8 to 12, somewhat higher and broader than corresponding anterior teeth.

Seizing jaws (pl. 4, fig. 26), 8 to 9 in number. Curvature of jaw about 55 per cent. Point with an oval base and imbedded from 24 to 27 per cent of its height into shaft. Near its base the edge of point is notched. Base of point and top of shaft converge in approaching edge of jaw. Pulp-canal displaced slightly toward back of jaw. Pulp evenly distributed throughout canal.

Corona ciliata (pl. 7, fig. 45), short and almost entirely on head. It was characteristically absent in most of the San Diego material. According to Fowler (1906) it varies from a "simple sinuous outline to a complex hour glass shape." The same variation has also been noted by Ritter-Záhony (1909b).

TABLE 1

Measurements of *Sagitta enflata*[1]

					Anterior fin				Posterior fin					
Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	Length	Width	To ventral ganglion	To posterior fin	Length	Width	Tail-septum[2]	Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
1	15	12	18	74	8.9	1.9	17	10	15	3.9	62.5	7–6	10–9	9–9
2	16.5	12	17	67	13.8	2.4	19	15	17	1.7	57	7–8	10–8	9–8
3	16	8	17	68	12.5	1.5	18	11	16	3.8	63	6–6	11–11	9–9
4	18	9	17	69	8.2	1.3	23	10	16	3.9	61	7–7	10–11	9–9
5	15	6	18	70	12.0	1.4	19	10	17	4.1	63	6–?	9–9	9–9
6	17	8	18	66	11.1	2.7	17	14	16	4.0	61	6–6	11–11	9–9
7	17	9	18	66	9.3	1.5	18	9	17	4.5	60	6–6	11–10	9–9
8	19	11	21	76	13.6	2.3	21	11	15	5.3	59	7–7	11–11	8–9
9	17	11	18	72	9.4	1.4	19	10	18	4.0	66	7–7	11–11	9–9
10	16	10	16	68	13.8	1.6	20	13	16	3.9	70	7–7	11–11	9–9
11	12	8	16	68	12.8	1.6	20	11	17	3.7	59	6–6	9–9	8–9
12	17	11	22	66	13.4	2.2	26	11	21	5.7	62	6–7	11–12	8–9
13	8	8	19	73	9.0	1.5	21	8	18	4.5	59	?–?	?–?	8–6
14	10	9	20	63	12.9	2.4	17	10	17	4.9	59	?–?	?–?	?–8
15	21	9	17	70	8.6	1.2	25	11	15	3.0	63	7–?	12–10	9–8
16	20	10	15	70	7.4	1.0	26	14	15	4.1	65	6–5	11–11	9–9
17	20	10	18	71	15.9	2.8	16	8	17	5.3	69	?–?	10–10	9–8
18	10	7	24	67	10.6	2.0	20	16	12	2.6	61	4–4	8–7	9–9
19	20	11	17	70	12.3	1.0	20	11	17	4.4	61	?–?	?–?	?–?
20	18	8	18	71	10.7	1.4	29	11	18	4.4	60	6–5	10–9	9–9

---

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

The table above shows more accurately the measurable taxonomic features of this species. In nos. 1 and 2 the width appears as 12 per cent, but is probably incorrect owing to pressure of the cover glass. Also in no. 2 the posterior fin was so torn that the width appears too small. Again no. 5 was wrinkled so as to make the width appear too small.

In comparing this table with that of Fowler (1906) we notice several interesting differences. The number of anterior teeth averages less than he has obtained, the variation he found being from 6 to 10, while the San Diego material varies only from 4 to 8. The usual number he found to be 8, while we have found but one instance of 8, the usual number being 7. We never found an individual with more than 8, while Fowler (1906) records some twenty per cent having 10. Again, in the number of posterior teeth, Fowler (1906) finds a variation often to 17, while the San Diego specimens vary only from 6 to 12, the usual number being 10 or 11. Rarely the number drops as low as 5.

Sagitta enflata, at first sight, very strikingly resembles *S. pulchra*, *S. hexaptera*, and *S. lyra*. This is especially true if the specimens are not well preserved. It is, however, readily separable from *S. hexaptera* by the tooth-formula, and especially the structure of the vestibular ridge. It differs from *S. lyra* by not having confluent anterior and posterior fins, and from *S. pulchra* by absence of the collarette.

Sagitta hexaptera d'Orbigny

Pl. 1, fig. 2; pl. 3, fig. 15; pl. 4, figs. 27, 28; pl. 6, fig. 44.

Sagitta hexaptera d'Orbigny (1843), p. 140; Darwin (1844), p. 2; Hertwig (1880), p. 196; Grassi (1883), p. 10; Krumbach (1903), pp. 633, 634; Fowler (1906), p. 11; Ritter-Záhony (1908), p. 9, (1909b), p. 8.

Sagitta bipunctata, Krohn (1884), p. 108; Gegenbaur (1856), p. 14; Langerhans (1880), p. 135.

Sagitta tricuspidata Kent (1870), p. 268.

Sagitta magna Langerhans (1880), p. 135; Grassi (1883), p. 11.

Sagitta darwini Grassi (1883), p. 19.

General Appearance

This species may be recognized as one of the largest of the Chaetognatha, sometimes reaching a length of 70 mm. When placed upon a black background *S. hexaptera* presents a very translucent, nearly transparent appearance. The general color of the body is grayish-white while the tip of the tail, ovaries, intestine, ventral ganglion, and head are much more opaque (pl. 1, fig. 2). When well-developed the seminal vesicles also offer a decided contrast to the body proper. The fins are readily seen, appearing as very transparent areas.

Characters

Body tumid, but not always retaining its form. Neck fairly evident though not so pronounced as in *S. enflata*. Body widest at a point from 35 to 45 per cent of the total length behind the head. Lateral fields large. Muscles weak and thin, but stronger than in *S. enflata*. They are barely perceptible to the naked eye. Slight constriction at tail-septum. Collarette absent.

Anterior fin shorter and narrower than posterior fin. Never extends to ventral ganglion, the distance from the ganglion being at least equal to the length of the fin. Position of greatest width approximately central. Form of fin half-elliptical.

Posterior fin always extends more than half the distance from tail-septum to seminal vesicles, but never reaches them. More than 50 (usually about 60) per cent of fin in front of tail-septum. Position of greatest width almost uniformly opposite tail-septum. Broadly triangular in form. Interval from anterior to posterior fin usually less than the length of anterior fin.

Vestibuar ridge (pl. 3, fig. 15) without the usual skeletal structures and composed entirely of a few irregular conical papillae. They apparently alternate in position with the few teeth that may be present. They are broader and much shorter than the teeth. Sometimes there is a double row of papillae present, presumably in the older individuals.

Anterior teeth usually 3 in number, varying from 2 to 4. They are long, slender, and diverging distally. The appearance of the anterior teeth, together with the skeletal areas upon which they rest, as two pronounced triangular spaces, offers an almost certain criterion for the identification of this species with the unaided eye.

Posterior teeth 2 to 4, rarely 5 in number. I have never found a specimen with more than 5, and but one with that number. Similar to anterior teeth in form but usually longer.

Seizing jaws (pl. 4, figs. 27, 28) 6 to 9 in number. Curvature about 75 per cent. Points with oval base, and imbedded from 25 to 30 per cent of their height into shaft. Tip of point blunt. Shaft below point, in most instances, provided with a short, massive crest which extends proximally for a short distance on a line with the edge of the point, and then makes an abrupt turn inward toward the shaft. Pulp-canal displaced slightly toward the back of shaft. Pulp evenly distributed and extending into the point from 55 to 66 per cent of its height.

TABLE 2

Measurements of *Sagitta hexaptera*[1]

					Anterior fin				Posterior fin					
Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	Length	Width	To ventral ganglion	To posterior fin	Length	Width	Tail-septum[2]	Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
1	27	11.0	26.8	68.8	9.8	3.6	9.2	8.2	22.2	7.0	62.5	3–3	4–4	9–9
2	24	10.0	24.1	65.0	8.6	1.7	12.2	7.9	19.9	4.1	59.7	3–3	2–2	9–9
3	55	7.3	19.0	71.5	11.8	2.7	18.5	9.3	20.0	5.2	66.2	?–?	3–2	6–5
4	40	8.3	23.0	69.0	10.7	2.5	11.5	8.6	23.0	4.9	64.1	3–3	4–3	8–8
5	22	9.0	22.2	71.0	9.0	2.4	12.0	9.0	21.0	4.5	57.0	3–2	4–4	8–9
6	52	7.6	22.0	69.5	9.9	2.5	14.8	10.8	19.5	5.3	59.0	?–?	3–2	7–6
7	52	8.0	21.0	72.0	11.5	2.8	17.0	9.0	21.0	5.6	65.3	?–3	?–2	6–5
8	41	9.7	21.3	69.0	10.1	2.1	15.0	9.5	22.0	6.0	61.2	3–3	4–4	6–?

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

Sagitta hexaptera in general resembles *S. enflata,* and more especially *S. lyra.* It differs, however, from the former by its greater size, tooth-formula, and various proportional measurements. From the latter it differs radically in the absence of confluence of anterior and posterior fins, and in nearly all proportional measurements. Practically the only similarity between the two species consists of size, degree of transparency, and tooth-formula, the latter being often identical.

Sagitta lyra Krohn

Pl. 1, fig. 3; pl. 3, fig. 16; pl. 4, fig. 29; pl. 6, fig. 43.

Sagitta lyra Krohn (1853), p. 272; Hertwig (1880), p. 61; Grassi (1883), p. 11; Ritter-Záhony (1908), p. 10.

Sagitta hexaptera Strodtmann (1892), p. 10; Moltschanoff (1907), p. 209.

Sagitta furcata Steinhaus (1896), p. 26; Krumbach (1903), p. 630; Fowler (1905), p. 63.

Sagitta whartoni Fowler (1896), p. 992; Günther (1903), p. 336.

Spadella maxima Conant (1896), p. 212.

Sagitta gigantea Broch (1906), p. 146.

Sagitta maxima, Ritter-Záhony (1910), p. 264.

General Appearance

When well-preserved *S. lyra* appears translucent, nearly transparent upon a black background (pl. 1, fig. 3). The general color of the body is grayish-slate, the ovaries and intestines appearing more opaque. Tip of tail and especially the head and ventral ganglion are much more opaque, presenting a distinct contrast to the body proper. Tail fin and lateral fins are readily seen with the naked eye.

Characters

Body tumid, but does not always retain its form well. It is of much the same consistency as *S. hexaptera.* Neck fairly well marked but not so pronounced as in *S. hexaptera.* Body widest at a point from 50 to 60 per cent behind the head, usually corresponding in position with the widest portion of the anterior fin. Lateral fields large. Muscles rather weak and thin, as in *S. hexaptera.* Slight constriction at tail-septum. Collarette absent.

Anterior fin longer and narrower than posterior fin. Always extends anteriorly nearly to the ventral ganglion, sometimes reaching beyond the middle of that structure. Form subject to considerable variation, but usually, in the San Diego specimens, an elongated acute triangle. It is confluent with the posterior fin.

Posterior fin extends caudally to seminal vesicles, when the latter are tumid. Never less than 50 per cent of fin in front of tail-septum. Position of greatest width is exceedingly variable, but is usually at or in front of tail-septum. Semi-elliptical in form. Interval from anterior to posterior fin is marked by the presence of a fin-bridge that renders the two fins confluent. Width at narrowest part of bridge about 1 per cent.

Vestibular ridge (pl. 3, fig. 16) consists entirely of papillae of the same style as in *S. hexaptera.* They are high, rounded, and roughly semicircular in form being, in many cases, provided with a tooth-like projection (barb) at the apex. They are more numerous than the posterior teeth, extending from beyond the external tooth to the near vicinity of the mouth. The nature of the ridge is better shown in the accompanying table.

TABLE 3

Measurements of Vestibular Ridge of *Sagitta lyra.*

Number of specimen	Length of specimen in mm.	Number of teeth	Number of papillae			Extent of ridge in Microns			Extent of tooth-row in Microns	Remarks
			Total	External to teeth	Internal to teeth	Total	From internal tooth	From external tooth		(See pl. 3, fig. 16)
1	40	4	12	3	5	909	585	169	154	Right ridge, papilla 3 and 6 with barbs
1	40	4	12	3	5	846	523	154	169	Left ridge, papilla 1 and 2 with barbs
2	33	4	14	3	5	831	477	169	184	Right ridge, papillae acutely tipped, no barbs
3	37	3	12	3	6	800	538	154	108	Right ridge, papillae acutely tipped, no barbs
4	37	4	11	2	5	800	462	154	184	Right ridge, papillae acutely tipped, no barbs
4	37	4	11	2	5	724	432	108	184	Left ridge, papillae acutely tipped, no barbs

Anterior teeth 3 to 7, closely set, conical, and converging distally. *Posterior teeth* 3 to 8, seldom closely set, and usually shorter than anterior teeth. There is considerable evidence that tends to show that the older specimens very frequently lose their teeth.

Seizing jaws (pl. 4, fig. 29) 4 to 8. Curvature about 57 per cent. Points very blunt, with oval base, and imbedded about 25 per cent of their height into shaft. Back of point has greater curvature than back of shaft, but edge of point and edge of shaft have the same curvature, so that apex of point lies nearer edge of jaw. Near its base the point makes an acute angle with both back and edge of shaft. Base of point and top of shaft converge in approaching back of jaw. Pulp-canal slightly displaced toward back of shaft. Pulp evenly distributed throughout canal, extending into the point from 52 to 64 per cent of its height.

TABLE 4

Measurements of *Sagitta lyra*[1]

					Anterior fin			Posterior fin					
Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	Length[2]	Width	Width of fin-bridge[2]	Length[2]	Width	Tail-septum[3]	Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
1	48	7.6	22.9	67.4	39.5	2.9	1.5	14.7	4.7	55.4	4–4	4–4	4–4
2	40	6.3	15.9	73.0	36.1	2.5	0.6	19.0	4.3	83.4	7–7	?–10	8–7
3	30	7.5	24.5	70.8	34.4	2.8	1.4	18.9	4.7	57.5	5–5	5–5	6–6
4	40	6.7	15.6	70.4	31.4	2.6	0.4	20.4	4.1	81.9	6–6	8–8	9–9
5	30	7.3	22.8	69.5	37.0	3.7	1.4	19.2	5.2	54.8	7–7	?–6	5–6
6	18	10.1	17.8	71.3	34.9	3.1	0.8	20.2	3.9	76.9	4–?	?–10	8–8
7	20	8.4	17.6	73.2	34.5	2.8	0.7	25.4	4.9	77.8	4–4	6–8	9–8
8	30	8.7	23.4	69.0	36.6	3.8	0.9	15.1	4.7	69.5	4–4	4–4	7–5
9	35	8.5	16.2	76.6	34.3	2.8	0.4	25.0	4.8	80.6	5–6	8–6	8–8
10	24	8.1	18.8	69.4	32.5	2.5	0.6	22.4	3.8	80.6	5–5	7–7	8–8
11	44	8.6	27.6	61.0	44.5	3.1	1.0	16.6	5.2	53.1	?–?	3–3	4–4
12	33	8.4	16.0	73.5	38.0	2.8	0.8	25.2	4.4	81.0	?–?	7–9	?–?
13	30	10.4	22.2	73.3	37.8	3.6	0.4	20.9	4.9	53.2	?–?	4–4	6–6
14	30	10.5	23.8	66.5	34.2	3.8	1.4	21.4	6.2	51.1	?–?	3–4	4–4
15	20	7.1	17.7	71.4	32.2	2.1	0.7	25.0	3.6	71.4	?–?	?–?	?–?
16	33	9.0	16.6	77.5	32.6	3.7	0.6	29.0	4.9	83.1	6–6	7–?	?–?
17	36	10.3	26.1	73.6	36.8	3.9	1.1	19.9	6.2	59.3	4–4	?–?	?–4
18	24	10.0	22.2	73.0	36.1	2.8	1.1	19.5	5.6	53.2	?–3	3–4	5–5
19	40	10.3	24.8	76.0	42.2	2.7	0.7	21.6	5.1	54.6	4–4	4–4	4–4

[1] All measurements made in per cent of total length of animal.

[2] The length of the anterior fin is measured from its most anterior extremity to the narrowest point of the fin-bridge. The posterior fin is measured from the same point, and the width of the bridge is taken at its narrowest point. The distance from anterior fin to ventral ganglion in every case has been zero.

[3] Per cent of posterior fin in front of tail-septum.

In comparing *S. lyra* from San Diego with Fowler's (1905) description and figures of *S. furcata*, one can not fail to see a great resemblance, brought out especially in his plate 4, figures 9 and 10. Furthermore the structure of the seizing jaws described by Krumbach (1903) for *S. furcata*, tallies except in two points, with the jaws in *S. lyra* from this region. The two exceptions consist, first in the absence in *S. lyra* of the cucumber-shaped area near the base of the shaft in which the pulp is absent from the canal, and, second, in the fact that the point, near its base, makes an angle with edge and back of shaft.

Twice Fowler has been on the point of asserting identity between the two species. In his report on Biscayan Plankton (1905, p. 64) he says of *S. lyra*: "*Krohn very likely had furcata before him.*" Later, in the Siboga Report (1906, p. 33) he says: "A few specimens with this label [*S. lyra* Krohn] were received from the Zoological Station in Naples. *I still think that this species is probably furcata Steinhaus. . . . But on spirit material it is impossible to feel positive on this point.*" [Italics mine.]

Finally, through the excellent work of Ritter-Záhony (1908) there is practically no doubt left as to the identity of these two species. He finds that *S. furcata* is really a younger stage in the development of *S. lyra*.

In comparing *S. lyra* from San Diego with the description of *S. whartoni*, the similarity of the two species is very striking. Below are given measurements of *S. whartoni* taken from Fowler's (1896) original description and drawings.

TABLE 5

Measurements of *S. whartoni*

(All measurements made in per cent of total length of animal.)

Length in mm.	Width	Length of tail	Anterior fin		Posterior fin		Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
			Length	Width	Length	Width			
30–45	6.6–10.5	20–26	44–66	2.8	19–33	5.7	3–5	5–7	8–10

In comparing these measurements with those just given for *S. lyra*, the only differences consist in the greater length of anterior and posterior fins. San Diego material has yielded no specimens with a length of more than 44.5 per cent for the anterior, nor more than 29 per cent for the posterior fin.

Fowler (1896, p. 992) recognized this similarity to *S. lyra* but defined differences on the ground of number of teeth and seizing jaws, and of the absence of a constriction at the tail-septum in *S. whartoni*. In the San Diego *S. lyra* the constriction at the tail-septum varies, and in many instances is practically absent, and the number of teeth and seizing jaws are essentially the same as in Fowler's *S. whartoni*, as shown by comparison of tables 4 and 5. It is to be regretted that Fowler (1896) did not describe the vestibular ridge. However, from the data at hand, it seems only reasonable to regard *S. whartoni* as a synonym of *S. lyra*.

Through the courtesy of Dr. Broch of the University of Christiania, I have been enabled to work over three of his specimens of *S. gigantea*, the measurements of which are as follows:

TABLE 6

Measurements of *S. gigantea*[1]

					Anterior fin				Posterior fin					
Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	To ventral ganglion	Length	Width	Width of fin-bridge	Length	Width	Tail-septum[2]	Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
1	78	6.4	22	70.6	0	42.3	2.6	1.3	16.7	3.8	61.5	?–?	4–?	4–4
2	56	7.1	23.2	69.6	0	42.0	3.6	1.8	14.3	4.4	62.5	5–4	6–4	7–6
3	69	5.8	23.2	72.0	0	39.8	2.9	1.4	16.7	4.3	61.0	6–5	5–5	6–6

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

In no. 1 the posterior fin is widest at tail-septum, and does not quite reach the seminal vesicles. In nos. 2 and 3 the fin is widest behind tail-septum and the seminal vesicles are not developed.

Comparison of this material with *S. lyra* from San Diego presents only a very few differences. Broch's specimens are larger, the smallest measuring some 4 mm. more than the largest S. lyra from this region. In one instance the width of *S. gigantea* is only 5.8 per cent, while none of our specimens measure less than 6.3 per cent. With these two exceptions all the measurements of *S. gigantea* agree with those of *S. lyra*.

Furthermore, the nature of the vestibular ridge (pl. 3, figs. 16, 17), while totally different from nearly all other species, is precisely the same in the two forms.

Broch (1906) says that *S. gigantea* seems to resemble *S. whartoni* but differs in size, smaller number of seizing jaws, and larger number of teeth. Fowler (1896) records 3 to 5 as the variation in number of anterior teeth of *S. whartoni.* In two of the three specimens of *S. gigantea* considered in table 6, the teeth are 5-4 and 6-5, a difference of only one tooth from the number reported by Fowler (1896). Broch (1906) finds from 7 to 8 posterior teeth but, in the above specimens, I have been unable to discover more than 6. Even if 8 were frequently present there would be only one more tooth than is recorded by Fowler (1896) for *S. whartoni.* Again, some of the San Diego specimens of *S. lyra* bear 9 seizing jaws on each side of the head which otherwise agree perfectly with *S. gigantea*, except in their smaller size. With such similarity the identity of *S. gigantea* with *S. lyra* seems quite evident.

Through the courtesy of the United States National Museum I have had the privilege of examining three specimens of *Spadella maxima* Conant. That they are identical with the San Diego material there is not the slightest doubt. In fact the agreement is so close that I am unable to detect any differences except that in *S. maxima* the vestibular papillae are more uniformly provided with barbs than is true of the *S. lyra* from San Diego.

Through a letter received from Dr. Rudolph von Ritter-Záhony I find that he agrees with me in regarding *S. whartoni*, *S. gigantea*, and *S. maxima* as synonyms (see also Ritter-Záhony, 1910, p. 264), but fails to understand how I can identify them with *S. lyra.* He says: "Ich begreife nicht wie Sie die Species [*S. lyra*] mit *S. whartoni*, und *S. gigantea* vereinigen können, da aus dem Beschreibungen Fowler's und Broch's sich ja schon bedeutende Unterschiede ergeben." The only differences mentioned in these two papers by Fowler (1896) and Broch (1906) have already been considered sufficiently to indicate that the differences are not so significant as might at first appear. Furthermore, I have sent three of the San Diego specimens of *S. lyra* to Ritter-Záhony for corroborative identification and I take the liberty to quote his reply. He says: "Sie haben sie ganz richtig als *S. lyra* bestimmt, es kann darüber gar kein Zweifel sein." I am therefore quite positive that my specimens are referable to *S. lyra* and if so I can detect no appreciable difference between them and *S. gigantea* or *S. maxima*. It is possible that I may have obtained both *S. lyra* and *S. maxima* and confused them, but such an error is improbable.

S. lyra also bears a striking resemblance to *S. gazelle*. In regard to the latter species Ritter-Záhony (1909c, p. 788) says: "Durch die Gestalt der Vestibularorgane und *die ausserordentliche relative Kürze des Schwanzabschnittes* [italics mine] ist diese Art so gut gekennzeichnet dass die Identifizierung späterhin mit Sicherheit möglich sein wird." Nevertheless this species bears a striking resemblance to our specimens of *S. lyra*. While in *S. gazelle* Ritter-Záhony (1909c) records the tail per cent as 10 to 14, with one possible instance of 19, the San Diego *S. lyra* shows a variation as low as 15.6 per cent, a difference of only 1.6 per cent from his measurements of *S. gazelle*. From his tabulation for *S. lyra* (1908, p. 12) in specimens of 27 mm. in length he records 4 mm. as the tail length, which amounts to 14.8 per cent, but he describes the tail as 17 to 23 per cent. From his tabulations it frequently falls below 16 per cent, which means that there is an error somewhere in his data. Surely the difference between *S. lyra* and *S. gazelle* in this matter of the length of tail is not great. The vestibular ridge, again, is amazingly similar to that of *S. lyra*, and the nature of the posterior teeth in *S. gazelle* that Ritter-Záhony (1909c, p. 788) describes as "aneinanderschliessend (d.h. nicht durch Zwischenräume getrennt wie bei manchen Arten)" is essentially the same in San Diego specimens of *S. lyra* possessing 7 to 10 teeth. On the other hand, the mature ovary in *S. lyra* (see p. 59, tab. 18, and pl. 6, fig. 43) extends nearly, if not quite to the ventral ganglion, whereas in *S. gazelle* Ritter-Záhony (1909c, p. 788) says: "Die Ovarien machten trotz ihrer Kürze bei einigen Individuen schon den Eindruck der Reife." Inasmuch as a figure of *S. gazelle* has not been published and as the fins were too damaged for description, it seems best to have it remain a valid species until redescription is possible.

Sagitta serratodentata Krohn

Pl. 1, fig. 4; pl. 3, fig. 20; pl. 4, fig. 30; pl. 5, fig. 41.

Sagitta serratodentata Krohn (1853), fig. 2; Hertwig (1880), p. 64; Strodtmann (1892), p. 17; Krumbach (1903), p. 636; Fowler (1905), p. 58; Ritter-Záhony (1908), p. 15 (1909b), p. 8.
Sagitta sp. innom., Gegenbaur (1856), p. 15.
Sagitta gegenbauri Fol (1879), p. 123.

General Appearance

This slender, pin-shaped species, when placed upon a black background, appears very opaque (pl. 1, fig. 4). The head, ventral ganglion, intestine, and seminal vesicles are readily distinguished as slightly more opaque than the body proper. The seminal vesicles, when fully ripe, stand out clearly as extremely opaque areas. The tail is slightly more transparent than the body. The tail-fin and both pairs of lateral fins, in perfectly preserved material, are barely visible to the naked eye, appearing as nearly transparent areas. The ovaries, owing to the opacity of the body, are very indistinctly seen. It is to be noted that, when sexually mature (pl. 5, fig. 41) *S. serratodentata* presents a much greater opacity, owing probably to the greater length and opacity of the ovaries. When not mature this species is slightly less opaque than *S. planktonis*, but when fully developed it is more opaque.

Characters

Body firm and rigid, retaining its form well. Neck very prominent. Body widest at about middle of length, varying from 50 to 55 per cent, and tapering very gradually toward head and tail. Lateral fields small. Muscles broad and strong. No constriction at tail-septum. Collarette absent.

Anterior fin shorter and somewhat narrower than posterior fin. Extends to ventral ganglion. Position of greatest width well toward posterior end. Form approximately triangular.

Posterior fin extends caudally to seminal vesicles when they are tumid. In exception to all the other San Diego species, the proportion of posterior fin in front of tail-septum is exceedingly variable, there being sometimes more and sometimes less than 50 per cent. Position of greatest width well behind septum, usually at a point about half the distance to seminal vesicles. Interval from anterior to posterior fin small.

Vestibular ridge (pl. 3, fig. 20) well developed, as long as posterior row of teeth and provided with low, rounded papillae, each one approximately representing the quadrant of a circle. They are fewer in number than posterior teeth. Three or four teeth project beyond wing of ridge, the notch extending to the sixth or seventh tooth. External process one-fourth to one-fifth the length of entire ridge. It is from two to three times broader at end than at wing.

Anterior teeth, 6 to 9 in number. They are conical, closely set, and slightly diverging distally. *Posterior teeth,* 13 to 19 in number. Similar in form to anterior teeth, but apparently shorter and broader. They are very closely set.

Seizing jaws (pl. 4, fig. 30), according to Fowler (1905), vary from 6 to 8 in number. In the San Diego specimens the number varies from 5 to 7. Curvature about 54 per cent. Shaft usually conspicuously serrated, the serrations, gradually and somewhat irregularly, increasing in size proximally, and disappearing entirely somewhat above middle of jaw. Point curved toward edge of jaw presenting the variation that Krumbach (1903) demonstrated. Point imbedded about 25 per cent of its height into shaft. Top of shaft and base of point parallel. Pulp evenly distributed throughout canal, the latter being slightly displaced toward back of jaw.

TABLE 7

Measurements of *Sagitta serratodentata*[1]

Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	Anterior fin To ventral ganglion	Anterior fin Length	Anterior fin To posterior fin	Posterior fin Length	Posterior fin Tail-septum[2]	Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
1	14.0	6.5	28.0	66.0	0	22.0	4.4	27.5	41.0	8–9	18–19	6–6
2	13.0	5.7	26.0	67.0	0	20.0	9.1	27.0	44.0	8–7	17–17	6–6
3	16.0	5.6	22.0	58.6	0	12.5	11.5	18.3	44.5	7–8	16–16	6–6
4	13.0	5.3	26.1	80.0	0	27.8	7.7	30.0	62.6	9–8	16–17	6–6
5	11.4	4.8	25.2	73.0	0	27.1	2.4	29.0	57.5	7–7	14–14	6–6
6	14.0	6.2	28.0	68.5	0	25.0	3.8	27.0	46.0	8–7	14–13	5–5
7	14.3	4.5	22.8	63.2	0	18.2	4.2	29.0	62.4	7–6	13–13	7–6
8	10.0	5.4	27.2	56.0	0	16.3	5.4	25.0	56.5	6–7	14–14	6–6
9	15.3	4.6	22.7	69.0	0	19.8	5.3	22.0	51.5	8–8	16–17	6–?
10	14.5	3.4	26.1	69.0	0	20.4	10.0	22.4	50.0	6–6	14–15	5–5
11	15.4	3.9	23.0	70.5	0	23.0	12.4	24.8	57.1	7–7	16–15	7–7
12	12.7	4.3	23.5	72.5	0	23.5	11.9	25.6	50.0	8–7	16–17	6–6
13	12.7	3.8	26.0	70.0	0	21.3	7.2	22.6	58.5	?–?	?–?	?–?
14	14.4	4.5	21.8	61.4	0	23.3	4.9	24.5	61.5	7–?	16–?	6–?
15	17.1	5.1	22.1	63.0	0	20.6	6.3	25.3	62.5	6–6	15–15	6–6

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

The action of formalin causes the lateral fields to shrink inward, with the result that the fins are nearly hidden from view. As a consequence, width-measurements of the fins could not be made with any accuracy except in the first two specimens, which were measured directly after preservation. In no. 1 width of anterior fin was 3.5 per cent, posterior fin 6.2 per cent. In no. 2 the widths were 3.0 and 6.0 per cent.

In comparing the San Diego specimens with those which Fowler (1905) obtained, we notice a great difference in number of anterior and posterior teeth. He records from 3 to 7 anterior and 3 to 13 posterior teeth in individuals ranging from 5 to 15 mm. in length. For a length of 13-14 mm. he finds 5 to 7 anterior and 8 to 12 posterior teeth. The specimens from San Diego, therefore, present a greater number of teeth for the same length of individual.

Sagitta bipunctata Quoy et Gaimard

Pl. 1, fig. 5; pl. 3, figs. 18, 19; pl. 4, figs. 31, 32; pl. 5, fig. 40.

Sagitta bipunctata Quoy et Gaimard (1827), p. 232; Busk (1856), p. 16; Hertwig (1880), p. 258; Strodtmann (1892), p. 344; Fowler (1905), p. 69, (1906), p. 31; Ritter-Záhony (1908), p. 15.
Sagitta sp. innom., Oersted (1849), p. 26.
Sagitta multidentata Krohn (1853), p. 271.
Sagitta germanica Leuckart und Pagenstecher (1858), p. 593; Uljanin (1871), p. 77.
Sagitta setosa Keferstein (1862), p. 135.
Spadella bipunctata, Grassi (1883), p. 13.
Spadella mariona Gourret (1884), p. 103.
Spadella hamata, Aurivillius (1898), p. 117.
Sagitta decipiens, Michael (1908), p. 68.
Sagitta pulchra, Michael (1908), p. 68.
Sagitta bipunctata forma typica Ritter-Záhony (1910), p. 255.

General Appearance

This species is only slightly more opaque than *S. enflata*, but appears to the naked eye somewhat narrower, more rigid, and of more uniform width from head to tail. When on a black background (pl. 1, fig. 5) the head, intestine, ventral ganglion, ovaries, seminal vesicles, and tail present a distinct, though rather less, contrast to the body proper than is the case with *S. enflata*.

Characters

Body rigid, retaining its form well. Neck nearly, if not quite absent. Body widest usually behind middle, but varies from 40 to 60 per cent. It tapers very gradually forward and backward from this point. Lateral fields large. Muscles thin and weak but stronger than those of *S. enflata*, the strands being barely visible under a dissecting lens. Constriction at tail-septum evident. Collarette present but very short.

Anterior fin never extends forward to ventral ganglion. Interval between fin and ganglion usually about 7 per cent, but varies from 4 to 10 per cent. Fin rather triangular in form.

Posterior fin longer and broader than anterior fin, extending to seminal vesicles when latter are tumid. Always more than 50 per cent of fin in front of tail-septum. Interval from anterior to posterior fin varies from 4 to 11 per cent, but is usually 6 or 7 per cent, and is never over half the length of posterior fin.

Vestibular ridge (pl. 3, fig. 18) provided with low, blunt papillae considerably irregular in form. Usually one papilla for every posterior tooth. Ridge covers all except the last one or two teeth. External process acute, narrow, and long, being about half as long as the rest of the ridge. Certain individuals present the appearance (pl. 3, fig. 19) of a double ridge similar to that noted by Fowler (1905) in *S. decipiens*, both parts possessing acute external processes which fork apart at the point where the wing of the ridge descends.

Anterior teeth, 5 to 8 in number. They are closely set and conical in form. *Posterior teeth* 9 to 14, and similar, in form, to anterior teeth. They are, however, larger excepting the first and last, which may be slightly shorter.

TABLE 8

Measurements of *Sagitta bipunctata*[1]

Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	Anterior fin				Posterior fin			Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
					To ventral ganglion	Length	Width	To posterior fin	Length	Width	Tail-septum[2]			
1	12	6	23	71	7	21.6	2.4	7	22.4	4.5	64	5–5	14–13	8–8
2	17	5	22	71	10	17.4	2.3	10	21.3	3.1	56	5–5	?–13	?–?
3	16	6	21	70	9	15.9	2.0	8	23.2	3.6	57	?–?	?–?	?–?
4	17	6	22	70	7	21.5	2.0	4	23.1	3.7	65	?–?	?–?	?–?
5	9	5	22	69	5	22.5	2.4	4	24.5	3.8	63	?–?	13–?	8–?
6	16	6	21	70	5	22.5	2.3	8	24.9	3.8	62	6–7	13–14	8–8
7	16	6	24	70	8	20.6	2.0	7	24.2	3.3	58	?–?	13–13	?–?
8	17	6	24	70	6	20.0	2.5	6	23.4	3.9	50	6–6	13–13	7–8
9	17	7	25	73	6	20.4	1.6	7	26.5	4.1	60	5–5	12–?	?–?
10	14	6	22	70	8	20.2	1.4	9	21.6	3.8	53	6–5	12–?	8–?
11	15	6	24	71	7	22.4	1.8	6	23.5	4.1	62	?–6	?–12	?–?
12	16	6	23	69	7	18.6	1.7	8	22.1	3.8	56	?–?	12–?	8–8
13	17	5	24	69	5	20.0	2.1	6	25.3	4.3	58	?–6	?–13	8–8
14	16	6	23	71	8	19.9	1.7	6	23.3	3.6	58	?–?	?–?	8–8
15	15	6	23	71	5	20.8	2.2	4	24.9	3.9	60	5–5	13–?	8–8
16	17	6	23	71	8	18.9	2.0	7	26.2	4.0	57	?–?	?–?	?–?
17	15	5	23	70	5	20.4	2.2	7	24.8	3.9	60	5–5	13–13	7–8
18	16	6	23	70	5	20.5	2.1	7	25.1	4.2	58	5–5	13–12	8–8
19	15	6	24	72	5	23.7	2.3	6	26.4	4.1	60	5–5	13–?	?–8
20	14	6	22	70	5	20.9	2.3	5	23.2	4.2	60	?–?	?–?	?–?

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

Though obtained by the thousand, the head in nearly every case was extremely contracted, thereby making a correct count of the teeth almost impossible.

Seizing jaws (pl. 4, figs. 31, 32), 7 to 8 in number. Curvature about 33 per cent. Points of same general form as those described by Krumbach (1903) for *S. furcata*, the curvature along the back being greater than along the edge so that apex of point lies toward edge of jaw. Point inserted about 27 per cent of its height into shaft. Base of point and top of shaft converge on approaching edge of jaw. Pulp evenly distributed throughout canal, the latter being displaced toward back of shaft. Pulp-canal extends into the point from 66 to 75 per cent of the height of the point. Apex of canal lies very near back of point. Older jaws sometimes present a swollen place in the pulp slightly below point. The convergence of top of shaft and base of point is more marked in the older jaws.

During the summer of 1907 I had the opportunity of examining a large number of individuals of this species alive, and the characters presented forcibly remind one of Conant's (1895) description and figure of *Sagitta hispida*. Covering the body at intervals, arranged symmetrically on the two sides forming twelve longitudinal rows, are numerous tactile hairs which present a remarkably *hispid* appearance. This appearance ceases entirely when the animal is killed and preserved. The *corona ciliata* was also found to agree very closely with that figured by Conant (1895) for *S. hispida*. It is rather broad, somewhat sinuous, and roughly resembles a ten-pin in outline. It extends from in front of the eyes to a point about half way from the head to the ventral ganglion, being more on body than head.

At first I was inclined to think that *S. hispida* was a synonym for *S. bipunctata*, but careful comparison has convinced me that they are not the same species. The tail of *S. bipunctata* is proportionally too short, the posterior fins present more than 50 per cent in front of tail-septum, and the general appearance of the body is much different.

S. bipunctata bears a strong resemblance to *S. decipiens*. In fact the similarity is so great that I made (1908) the mistake of identifying my material as *S. decipiens*. The nature of the mature ovaries is much the same, and nearly all the proportional measurements overlap to a surprising extent. There are, however, a few points of difference. The tail in *S. decipiens* varies from 28 to 40 per cent, the seizing jaws are 5 to 6, the number of anterior and posterior teeth is somewhat greater, and there is no constriction at the tail-septum. Whether or not the two species are in reality distinct I am not sure, but until I am enabled to study *S. decipiens* with care I can not feel positive concerning their relationship.

Sagitta planktonis Steinhaus

Pl. 1, fig. 6; pl. 3, fig. 21; pl. 4, fig. 33; pl. 5, fig. 42; pl. 7, fig. 46; pl. 8, fig. 48.

Sagitta planktonis Steinhaus (1896), p. 39; Ritter-Záhony (1909c), p. 790.

Sagitta zetesios Fowler (1905), p. 67, (1906), p. 22.

General Appearance

On a white background *S. planktonis* appears very opaque. The body proper assumes a light cream color, while the seizing jaws and tail present a light brown tint. The ovaries when immature are so slender and the muscles so thick that it is impossible to see the ovaries with the naked eye. Even with a microscope they are usually difficult to discern. On a black background (pl. 1, fig. 6) the animal appears nearly white, the body proper assuming a very pale bluish tint, while the head and ventral ganglion appear somewhat whiter. The tail fin and both pairs of lateral fins are readily seen with the naked eye, appearing as transparent areas in decided contrast to the general opacity of the body.

Characters

Body stout and rigid, retaining its form almost perfectly. Neck evident. Body widest behind center, at a point from 50 to 63 per cent of its length, gradually tapering toward head and tail. Lateral fields small. Muscles strong and thick. No constriction at tail-septum. Collarette present (pl. 7, fig. 46; pl. 8, fig. 48), extending posteriorly to anterior fins.

Anterior fin longer and narrower than posterior fin. It usually extends to ventral ganglion, but rarely falls short by not more than 0.1 per cent of the total length of the animal. Widest point of fin about 80 per cent of its length from anterior end. Triangular in form, with the acute apex continuous with the collarette.

Posterior fin never extends to seminal vesicles. From 55 to 72 per cent of fin in front of tail-septum. Point of greatest width in front of tail-septum. Triangular in form, the obtuse angle being on the line of greatest width. Interval from anterior to posterior fin varies from 7 to 12 per cent.

Vestibular ridge (pl. 3, fig. 21) well developed, the papillae being small and very irregular in form and position. They are not present over the posterior half of the ridge. Wing of ridge covers all but the first tooth. In some rare instances two teeth are left exposed, and in others all the teeth are covered. External process short and thick, about one-third the length of ridge, and from two to three times longer than broad. Notch extends inward beyond the fourth and nearly to the fifth tooth.

Anterior teeth 4 to 7 in number. Closely set and increasing in size as they approach internal angle. They are narrow in proportion to their height. *Posterior teeth* 11 to 15 in number. Similar in form to anterior teeth but higher and relatively narrower.

Seizing jaws (pl. 4, fig. 33) 8 to 9, rarely 10 in number. Curvature about 12.7 per cent. Points with oval base. Tip of point rather blunt. Curvature of back greater than curvature of edge of point so that apex lies nearer edge. Point imbedded from 20 to 25 per cent of its height into shaft. Base of point and top of shaft converge in approaching back of jaw. Pulp-canal approximately central with the pulp evenly distributed.

TABLE 9

Measurements of *Sagitta planktonis*[1]

					Anterior fin				Posterior fin					
Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	Length	Width	To ventral ganglion	To posterior fin	Length	Width	Tail-septum[2]	Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
1	24	7	25	70	23.5	2.5	0	9	17.9	3.9	60	5–5	12–13	8–8
2	25	9	25	59	22.3	2.4	0	9	17.4	3.3	60	?–4	12–13	8–8
3	26	7	26	70	23.1	2.6	0	9	20.5	4.1	56	5–6	12–?	9–8
4	24	7	24	69	19.9	2.5	0	11	19.2	3.1	63	?–?	?–?	?–?
5	26	7	26	70	22.8	2.2	0	8	16.9	3.8	60	5–6	?–15	8–8
6	15	10	38	63	27.0	3.6	0	9	23.6	5.4	62	5–7	13–13	8–8
7	17	9	37	69	22.5	2.8	0	10	16.3	3.6	59	6–6	?–?	8–9
8	22	8	27	50	18.8	1.8	0	11	15.8	3.6	58	7–?	?–?	8–9
9	26	8	25	68	22.8	2.5	0	9	16.5	4.3	62	7–7	12–11	8–8
10	24	7	27	69	21.2	2.3	0	8	17.9	4.4	62	6–7	?–?	8–9
11	23	8	27	69	22.3	2.3	0	7	17.2	4.3	70	?–?	?–?	?–?
12	17	9	25	66	21.2	2.4	0	10	18.3	3.3	71	?–?	?–?	8–8
13	20	8	28	70	21.6	3.0	0	10	17.6	3.7	59	7–6	?–?	9–8

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

In my material none of the individuals was sexually mature. The ovaries were slender and the eggs small, notwithstanding the fact that the ovaries extended to the cephalic end of anterior fin. Most of the specimens show apparent transverse septa across the intestine, as described by Doncaster (1902a) for *S. minima,* and his explanation of this fact as due to the drawing apart of the walls of the intestine is evidently true in *S. planktonis.* One specimen still retained the *corona ciliata* (pl. 7, fig. 46). It is skein-shaped with more than three-fourths on head, and extending from one-third to one-half its length anterior to the eyes.

Ritter-Záhony (1909c, p. 790) says: "Zweifellos ist *S. zetesios* mit ihr [*S. planktonis*] identisch," and I think we must fully agree with him. The similarity extends to nearly every point. Fowler (1905, p. 71) records three specimens which he doubtfully identifies as *S. planktonis*, but states that "they bear a close general resemblance to *zetesios*." He then points out the following differences: In *S. zetesius* the anterior and posterior fins are closer together, and the former extends farther forward. The widest portion of the posterior fin is level with or behind the tail-septum, the posterior fin is more on the trunk than tail, and the posterior teeth number less for the same length. In all these points the specimens from San Diego are quite variable, except that the posterior fin is more on the trunk than on the tail, which condition is the same as described by Fowler (1905) for *S. zetesios*.

S. planktonis at first sight bears a certain resemblance to *S. bedoti*, and *S. ferox*. It is however readily separable from the former by the presence of such a conspicuous collarette, and by the fact that the anterior fin is longer than the posterior one. From the latter it differs in having a greater number of seizing jaws, more than 50 per cent of the posterior fin in front of tail-septum, narrower collarette, and in many of the proportional measurements. It bears some resemblance to *S. robusta*, but the body of the latter is proportionally narrower, the collarette is less extensive, and the anterior fin is shorter than the posterior fin.

Sagitta neglecta Aida.

Pl. 2, fig. 7; pl. 3, fig. 22; pl. 4, fig. 34

Sagitta neglecta Aida (1897), p. 16; Fowler (1906), p. 15.
Sagitta bipunctata, Béraneck (1895), p. 153.

General Appearance

In degree of opacity this species bears a strong resemblance to *S. serratodentata*. It is, however, more slender and pin-shaped. Upon a black background (pl. 2, fig. 7) the head, ventral ganglion, and seminal vesicles appear more opaque than the body. The intestine and ovaries are only slightly different in opacity from the body. The entire tail segment is slightly less opaque than the body, and the seminal vesicles do not present such decided contrast as in *S. serratodentata.* The form, with the comparatively large head and the body gradually tapering from the head to a point at the tail, reminds one very forcibly of a pin. The fins are barely visible as nearly transparent areas.

Characters

Body firm and rigid, retaining its form well. Neck very pronounced but made less conspicuous by the *collarette* which extends well toward, but never reaches the ventral ganglion. Body nearly of uniform width, but slightly wider from a point at a level with posterior end of anterior fins to a point at a level with anterior end of posterior fins. This point of greatest width varies from 52 to 60 per cent. Lateral fields small. Muscles rather broad and strong. No constriction at tail-septum.

Anterior fin shorter and narrower than posterior fin. Extends to posterior end of ventral ganglion. In form it is narrowly and acutely triangular.

Posterior fin extends nearly, if not quite to seminal vesicles when the latter are tumid. Never more than 50 per cent of fin in front of tail-septum. Widest slightly behind tail-septum. Half elliptical in form. Interval from anterior fin to posterior fin considerably less than the length of anterior fin. It varies from 8 to 16 per cent.

Vestibular ridge (pl. 3, fig. 22) with very low and regular papillae. Usually one papilla over each tooth. Wing of ridge covers all but one tooth. Rarely two teeth are exposed. External process very short, barely including the first tooth. It is three or four times longer than broad and about one-fourth the length of entire ridge.

Anterior teeth 3 to 5, closely set, and not diverging much distally. *Posterior teeth* 8 to 11, somewhat longer and proportionally narrower than anterior teeth. Like anterior teeth, they do not diverge much distally.

Seizing jaws (pl. 4, fig. 34) 7 to 9. Curvature about 53 per cent. Point resembles, in form, that described by Krumbach (1903) for *S. bipunctata.* It is, however, broader for its height and is inserted about one-fifth instead of one-fourth of its height into the shaft. Top of shaft and base of point parallel. Edge of point at intersection with top of shaft, makes an acute angle with edge of shaft. Edge of point and edge of shaft diverge proximad of this intersection. Back of point and back of shaft parallel. Pulp-canal central, with the pulp evenly distributed.

TABLE 10

Measurements of *Sagitta neglecta*[1]

					Anterior fin				Posterior fin					
Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	To ventral ganglion	To posterior fin	Length	Width	Length	Width	Tail-septum[2]	Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
1	12	5.1	26	71	0	8.7	23	2.5	26	5.0	49	3–3	10–11	8–9
2	12	5.4	26	69	0	15.6	18	1.8	20	3.0	43	4–4	9–10	8–8
3	7.9	4.3	27	68	0	11.0	20	1.4	22	2.5	40	?–?	8–8	8–8
4	11	4.2	27	69	0	11.0	21	1.6	23	3.2	47	4–5	9–9	9–8
5	12	5.3	26	69	0	13.2	19	1.6	22	2.9	45	4–4	11–10	8–7
6	10	5.0	28	73	0	10.8	19	1.6	22	2.8	49	4–4	9–8	8–7
7	8	4.2	28	69	0	10.5	19	1.4	25	3.5	48	4–4	9–8	8–8
8	11	6.0	28	70	0	9.5	20	2.2	26	3.9	48	4–4	8–8	8–8
9	13	5.4	26	68	0	11.6	20	1.5	24	3.6	45	3–3	10–10	8–8
10	12	6.3	27	69	0	11.0	20	2.1	21	3.1	44	4–4	8–8	?–?
11	10	4.9	30	70	0	11.7	19	1.8	23	3.1	40	4–3	8–8	?–?
12	13	6.4	26	68	0	11.3	21	2.2	22	3.2	44	?–?	9–9	8–8

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

In comparison with Fowler (1906) a number of differences in some of the measurements are evident. He finds the tail to vary from 26 to 37 per cent in individuals ranging from 7.5 to 10 mm. in length. In the San Diego specimens the variation is only 26 to 30 per cent. The seizing jaws we found to vary from 7 to 9, instead of from 5 to 8 in number as recorded in the "Siboga" material. Fowler (1906) records the anterior teeth as 3 to 7, the usual number, perhaps, being 6, while San Diego specimens present 5 as the greatest number. Similarly *S. neglecta* from this region are provided with fewer posterior teeth, 8 to 11 as against 9 to 15 recorded by Fowler (1906).

From Aida (1897), however, we find the variation as follows: seizing jaws 8, anterior teeth 4 to 5, posterior teeth 10 to 12. Aida (1897) describes the tail as 24.3 per cent, but draws it 35 per cent, and one is at a loss to know which expresses the truth. Nevertheless there is striking agreement between Aida's description and specimens from San Diego.

I know of no two species more perplexing to identify than *S. neglecta* and *S. regularis*, both first described by Aida (1897). He defines the following differences. Anterior fin in *S. regu-*

laris nearly half as long as posterior fin, while the fin in *S. neglecta* is very little shorter than posterior fin. The posterior fin in the latter species extends further in front of tail-septum than in *S. regularis.* Measurements taken from Aida's (1897) drawings of the two species show the following relations.

TABLE 11

Measurements taken from Aida's Drawings[1]

Species	Width	Length of tail	Anterior fin			Posterior fin			Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
			Length	Width	To posterior fin	Length	Width	Tail-septum[2]			
S. neglecta	5	35	17.5	2.5	7.5	25	3.8	40	4–5	10–12	8
S. regularis	7	37	16.3	4.5	7.0	28	5.6	33	2–4	5–7	7

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

In the matter of relative lengths of anterior and posterior fins of the two species the drawings do not show much difference. The relative per cent of posterior fin in front of tail-septum has more significance, although a large number of measurements of both species are necessary in order to definitely establish any specific difference in this regard.

Fowler (1906) has defined certain other characteristics, some of which seem invalid. He claims (1906, p. 16) that in *S. neglecta* "the tail is slightly shorter" than in *S. regularis*, which he regards as one of the "*main points of difference.*" [Italics mine.] However, when his data are brought together as in the accompanying table, it is seen that for the lengths of

TABLE 12

Comparative Lengths of Tail

Length of specimen in mm.	*S. neglecta* per cent	*S. regularis* per cent
4.5		33
5.0	30–40	40
5.5	30–36	36
6.0	33	33
6.5	30	
7.0	26–35	28
7.5	26–33	
8.0	30–37	
9.5	31	
10.0	30	

5, 5.5, and 6 mm. there is perfect correspondence in the length of the tail in the two species, and in specimens 7 mm. in length *S. neglecta* actually oversteps *S. regularis.* Even if taken in their entirety, the total variation Fowler (1906) finds is 26 to 40 per cent in *S. neglecta* and 28 to 40 per cent in *S. regularis.* Certainly there is no significant difference in the tail measurements of the two species.

Fowler (1906) also finds a difference in the number of anterior and posterior teeth, as indicated in table 13.

TABLE 13

Number of Teeth according to Fowler (1906)

Common length in mm.	*Sagitta neglecta* Anterior teeth	*Sagitta neglecta* Posterior teeth	*Sagitta regularis* Anterior teeth	*Sagitta regularis* Posterior teeth
4.5			2	2
5.0	3–4	7–10	2–3	5–6
5.5	4	10–11	2	4
6.0	3–5	9–11	2–3	6
6.5	4–5	9–10		
7.0	4–6	9–12	4	6

From this table we see that the anterior teeth present a difference of only two. The difference in the posterior teeth is greater but, on account of a much larger variation in some species, notably *S. enflata* and *S. bipunctata*, it is impossible to feel sure that this difference signifies anything beyond individual variation.

Fowler (1906) regards the *corona ciliata* as longer in *S. neglecta* and extending for some little distance onto the head. In *S. regularis* he finds it is entirely confined to the body. In certain instances, however, he finds the *corona of S. neglecta* confined to the body, and in his drawing (1906, pl. 1, figs. 43, 44) he represents two lengths of the structure. One would desire to know the variation in length and exact position of this structure before placing much confidence in this criterion for separating two such closely allied forms.

Finally, it was pointed out that the collarette is much wider and longer in *S. regularis*, extending to the anterior fins as in *S. planktonis.* In no instance was this true of the San Diego specimens of *S. neglecta.*

Apparently, we have but two fairly sure characters for distinguishing between *S. neglecta* and *S. regularis.* One consists in the per cent of posterior fin in front of tail-septum, which is 33 in *S. regularis* and never less than 38 in *S. neglecta.* The other point of difference consists in the width, and especially the length of collarette as defined above. Perhaps we have here the explanation of the more uniform width of body in *S. regularis.*

S. neglecta also bears considerable resemblance to *S. bipunctata.* The following differences, however, exist. In the latter species the anterior fins never reach the ventral ganglion, there is more instead of less than 50 per cent of posterior fin in front of tail-septum, and the general appearance is much more transparent.

Genus **Eukrohnia** Ritter-Záhony

Syn. *Krohnia* Langerhans

Eukrohnia hamata (Möbius)

Pl. 2, fig. 8; pl. 4, fig. 35.

Eukrohnia hamata, Ritter-Záhony (1909c), p. 792, (1910), p. 268.
Sagitta hamata Möbius (1875), p. 158.
Spadella hamata, Hertwig (1880), p. 73.
Krohnia hamata, Langerhans (1880), p. 136; Krumbach (1903), p. 639; Strodtmann (1892), p. 20; Fowler (1905), p. 74, (1906), p. 23.
Krohnia foliacea Aida (1897), p. 19.

Characters

Body firm and opaque (pl. 2, fig. 8) as in *S. serratodentata.* Neck well marked. Body thickest throughout middle third, tapering gradually toward head and tail. Muscles heavy and thick. Slight constriction at tail-septum.

Lateral fins long, extending from ventral ganglion to some distance behind tail-septum. They never extend more than half way from tail-septum to seminal vesicles. Widest near plane of tail-septum, sometimes slightly in front and sometimes slightly behind. As described by Fowler (1905), the absence of fin rays seems to be characteristic.

Vestibular ridge apparently absent. According to Fowler (1906, p. 23) there ''exists a very slight ridge with sense bulbs in the position of the vestibular ridge in *Sagitta.*'' In the San Diego specimens I have been unable to determine this with certainty.

Teeth 10 to 13 in the San Diego specimens. This agrees more nearly with Fowler's (1905) variety of *E. hamata* than with the usual species, which bears from 16 to 22.

Seizing jaws (pl. 4, fig. 35) 8 to 11, similar in form and structure to Krumbach's (1903) description. Jaws with oval cross-section, the pulp very scantily filling center of canal. In some instances the pulp is swollen near the base of the point. Base of point and top of shaft converge upon approaching edge of jaw. Points sickle-shaped, the amount of curvature varying among the individuals and also among the different jaws of the same specimen. Pulp-canal approximately central. Unlike Krumbach (1903), I have been unable to detect any evidence of sagination.

TABLE 14

Measurements of *Eukrohnia hamata*[1]

Number	Length in mm.	Width	Length of tail	Lateral fin			Length of ovary	Tail-septum[2]	Number of teeth	Number of seizing jaws
				To ventral ganglion	Length	Width				
1	13	5.2	28.2	0	52	1.7		80	?–?	8–8
2	14	6.0	32.0	0	77	2.4	25.0	85	10–10	11–10
3	14.5	5.0	29.0	0	58	2.3		86	10–11	9–9
4	14.5	5.0	28.0	0	59	2.7	34.0	84	11–?	10–9
5	15	5.2	29.6	0	44	1.5		77	?–?	9–8
6	15	4.0	29.0	0	63	2.2		82	12–11	9–8
7	15.5	5.6	28.0	0	76	3.9	46.0	88	13–?	10–?
8	17.5	4.3	29.0	0	62	3.3	13.5	80	10–10	10–9

[1] All measurements made in per cent of total length of animal.

[2] Per cent of lateral fin in front of tail-septum.

In most of the specimens the ovaries were well developed and the eggs well toward maturity, but for some unknown reason the upper third of the ovaries had burst and the eggs were scattered throughout the body-cavity. This made it impossible to determine the length of the ovary except in a very few instances.

Eukrohnia hamata is very readily distinguished from both the other species of the genus. To the naked eye it bears considerable resemblance to *Sagitta serratodentata.* In fact the resemblance is so striking that it is difficult to distinguish the two with the naked eye. The microscope, however, readily reveals the difference.

Eukrohnia subtilis (Grassi)

Pl. 2, fig. 9; pl. 3, fig. 25; pl. 4, fig. 36.

Spadella subtilis Grassi (1883), p. 23.

Krohnia subtilis, Strodtmann (1892), p. 22; Fowler (1905), p. 78, (1906), p. 25.

Characters

Body, unlike *E. hamata*, nearly transparent (pl. 2, fig. 9). Extremely long and slender, the width being about 4 per cent. Body slightly widest between ventral ganglion and origin of lateral fins, tapering very gradually forward and backward from this point. Neck evident. Constriction at tail-septum nearly absent.

Lateral fin extends to seminal vesicles. More than 50 per cent of fin behind tail-septum. The interval between anterior limit of fin and ventral ganglion varies from 17 to 21 per cent.

Vestibular ridge is apparently absent. *Teeth* 10 to 14 in the San Diego specimens. Fowler (1905) records 7 to 13. Unlike *E. pacifica*, the teeth (pl. 3, fig. 25) are not conspicuously bayonet-shaped. *Seizing jaws* (pl. 4, fig. 36), 7 to 9, very flat, broad, thin, and evenly curved. The points are extremely fine and delicate.

TABLE 15

Measurements of *Eukrohnia subtilis*[1]

					Lateral fin					
Number	Length in mm.	Width	Length of tail	Length of ovary	To ventral ganglion	Length	Width	Tail-septum[2]	Number of teeth	Number of seizing jaws
1	13.0	4.0	32	4.9	18	38	4.6	40	12–12	8–9
2	14.5	3.4	34	3.4	17	36	4.4	42	11–12	8–9
3	15.0	4.0	33	6.5	20	35	5.8	36	12–11	7–8
4	14	3.9	31	4.8	20	34	3.9	37	?–?	7–7
5	16	3.7	32	5.9	23	34	3.9	40	12–?	8–8
6	15.5	4.1	31	5.6	18	32	4.6	41	12–12	9–8
7	15.5	3.8	33	6.6	21	33	6.0	44	14–13	8–8
8	14	3.8	33	5.9		34	4.9	35	10–?	8–7
9	12	4.2	30	3.2	20	34	5.1	37	10–?	7–7

[1] All measurements made in per cent of total length of animal.

[2] Per cent of lateral fin in front of tail-septum.

This species is readily distinguished from all other Chaetognatha except *E. pacifica*, to which it bears a remarkably strong resemblance. The few points of difference are as follows. Teeth of *E. subtilis* not so conspicuously bayonet-shaped. Body thinner for its length, and slightly more uniform in width. Seizing jaws thinner and more uniformly curved. Whether these differences are sufficient to distinguish two otherwise almost identical species is doubtful but, owing to the scarcity of material, it is impossible to make a positive statement regarding either their identity or validity.

Genus **Spadella** Langerhans

Spadella draco Krohn

Pl. 2, fig. 10; pl. 3, fig. 23; pl. 4, fig. 37.

Spadella draco Krohn (1853), p. 273; Hertwig (1880), p. 71; Langerhans (1880), p. 136; Grassi (1883), p. 23; Krumbach (1903), p. 628; Fowler (1906), p. 25.
Pterosagitta mediterranea Costa (1869), p. 55.
Spadella vougai Béraneck (1895), p. 155.

Characters

Body firm and opaque (pl. 2, fig. 10), retaining its form well. Neck absent. Collarette very pronounced, measuring in width approximately 0.5 per cent on either side of the body. It extends from head to tail-septum and, in the San Diego specimen, it spreads out over the anterior part of the lateral fin. Muscles heavy and strong. Body, including collarette, nearly of uniform width from head to tail-septum. Ventral ganglion located about midway between tail-septum and head. *Corona ciliata* two-thirds on head, long and elliptical in shape. Lateral fin semicircular in form.

Vestibular ridge (pl. 3, fig. 23) provided with a very few irregular papillae. Notch extends to middle of second tooth. Even the tip of first tooth is covered by the wing so that none are left entirely exposed. External process terminates abruptly just beyond the first tooth. It comprises about 26 per cent of the length of the entire ridge.

The *seizing jaws* (pl. 4, fig. 37) of the single specimen from San Diego bear out Krumbach's (1903) description. The points have an oval base, and are inserted about one-fourth or one-fifth their height into shaft. They are strongly needle-shaped. Pulp-canal central. Upper third of shaft strongly bent. Flat broad-edged crest along edge of shaft.

But one individual of this species was taken. It offers the following measurements:

Length	7 mm.
Width	12.1 per cent
Width without collarette	10.9 per cent
Tail	43.6 per cent
Tail to ventral ganglion	66 per cent
Lateral fin	21.2 × 5.4 per cent
Seizing jaws	8–?
Anterior teeth	4–4
Posterior teeth	9–8

The number of teeth and seizing jaws scarcely agrees with that reported by Krohn (1853) or Hertwig (1880). They record the seizing jaws as 10, anterior teeth 8, posterior teeth 18, while our specimen agrees more nearly with Béraneck's (1895) description of *S. vougae,* the formula of which is 9, 4-5, 6-7. However, the San Diego specimen is very immature, having not the slightest trace of ovary or seminal vesicle.

TABULATION AND DISCUSSION OF THE LENGTH OF OVARIES IN SOME OF THE SAN DIEGO SPECIES OF CHAETOGNATHA

In the following tabulations I have attempted to arrange the specimens of each species in several groups according to maturity of the ovaries. Such a separation is almost entirely a matter of judgment depending upon a combination of characters which baffles exact definition. Length and width of ovary, size and appearance of eggs, tumidity of seminal receptacles, and size of animal are some of the factors that influence judgment concerning maturity, but it is as impossible to define the value of each with respect to the others as it is to define exactly the value of each feature, expression, or mannerism that makes you sure of your acquaintance with a friend. I have, then, separated the stages of maturity, fully realizing the impossibility of stating the exact reason for placing this individual as mature and that one as only approaching maturity. But, crude as it may be, only by such a separation is it possible to consider variations of the mature ovary within a single species.

I have noticed that, in some species, the seminal vesicles and ovaries mature at the same time, while in other species their development is not parallel. In order to prevent the possibility of prejudice in associating the mature ovary with the mature seminal vesicle, the method of making tabulations has been as follows: The first entry concerned the maturity of the ovary; after this was settled, measurements of the ovary were made with an ocular micrometer and recorded. The specimens were then numbered, isolated, and laid aside for at least a week. Having by that time entirely forgotten what the measurements were, I entered on another sheet of paper, against the number of my specimen, my judgment concerning the maturity of the seminal vesicles. The results were then brought together, the measurements reduced to millimeters, and the data arranged as in the following tables.

TABLE 16

Measurements concerning the Ovary in *Sagitta enflata*

Number	Length	Length of ovary		Width of ovary		Distance to posterior fin[3]	Nature of seminal vesicles
		in mm.	in per cent[1]	in mm.	in per cent[2]		
Ovary sexually mature							
1	12.5	1.3	10.1	0.22	17	2.8	mature
2	15.5	1.0	6.7	0.29	29	7.0	mature
3	16	0.7	4.4	0.22	31	7.0	mature
4	16	1.1	6.7	0.34	31	4.3	mature
5	16.5	0.9	5.7	0.40	44	3.8	mature
6	16.5	1.2	7.2	0.35	29	2.7	mature
7	17	1.2	6.7	0.34	31	3.7	mature
8	17.5	1.1	6.1	0.33	30	3.9	mature
9	17.5	1.3	7.7	0.33	25	3.9	mature
10	18	1.0	5.4	0.29	29	6.3	mature
11	18	1.1	6.3	0.33	30	3.1	mature
12	18.5	1.0	5.3	0.33	33	3.8	mature
13	18.5	1.4	7.4	0.33	24	3.4	mature
14	19.5	1.2	6.2	0.28	23	4.7	mature
Ovary approaching maturity							
15	15	0.57	3.8	0.14	25	5.7	nearly mature
16	15	0.53	3.5	0.15	28	5.0	nearly mature
17	15.5	0.57	3.7	0.15	26	7.5	nearly mature
18	16	0.47	2.9	0.16	34	9.3	nearly mature
19	16	0.53	3.3	0.26	47	5.5	nearly mature
20	16	0.63	3.9	0.20	32	4.4	nearly mature
21	16.5	0.69	4.2	0.23	33	5.6	nearly mature
22	17.5	0.58	3.3	0.12	21	9.8	nearly mature
Ovary remote from maturity							
23	8	0.00	0.0	0.00	0		invisible
24	9	0.28	3.1	0.05	18	?	invisible
25	10.5	0.31	3.0	0.05	16	9.6	barely visible
26	11	0.22	2.0	0.06	27	?	invisible
27	12	0.34	2.8	0.08	24	6.5	barely visible
28	12.5	0.38	3.0	0.06	16	9.9	barely visible
29	12.5	0.35	2.8	0.09	26	9.5	barely visible
30	13	0.35	2.7	0.09	26	9.0	invisible
31	13.5	0.34	2.5	0.11	32	7.2	barely visible
32	14	0.39	2.8	0.11	28	6.8	barely visible
33	15.5	0.70	4.5	0.17	24	8.2	barely visible

[1] Measured in per cent of total length of animal.

[2] Measured in per cent of total length of ovary.

[3] Distance from anterior end of ovary to anterior end of posterior fin measured in per cent of total length of animal.

From these data we may arrive at the following tentative conclusions:

1. The ovary commences development first but, as a rule, it reaches maturity at the same time as the seminal vesicle.
2. The mature ovary (pl. 5, fig. 39) varies in length from 5 to 10 per cent of the total length of the animal, or from 0.7 to 1.4 mm.
3. In width the mature ovary varies from slightly under one-sixth to slightly over one-third its length.
4. In extent the mature ovary never reaches the anterior limit of the posterior fin.

So far as I am acquainted with the literature, Ritter-Záhony (1908) has been the only investigator who has attempted to make a systematic tabulation of the length of ovary. From his records for *S. enflata* I have extracted the following data:

Length of specimen in mm.	Length of ovary in mm.
9	0.25
10	0.25
11	0.25–1.0
12	0.60
13	1.00–1.8
14	0.80
15	0.50–1.2
16	0.50–1.1
17	0.70–2.2
18	1.00–1.8
19	1.00–1.5
20	0.90–1.6
21–23.3	1.50–2.0

A comparison of these data with the above table shows an agreement much closer than anyone would have expected. Taken as a whole, the ovary in his specimens attains a greater length (2.2 mm.) that those from San Diego (1.4 mm.).

TABLE 17

Measurement concerning the Ovary in *Sagitta bipunctata*

Number	Length in mm.	Length of ovary		Width of ovary		Distance to posterior fin[3]	Nature of seminal vesicles
		in mm.	in per cent[1]	in mm.	in per cent[2]		
				Ovary sexually mature			
1	10	1.7	17.3	0.34	20.0	+4.0	mature
2	10	1.4	13.6	0.23	16.7	—1.7	mature
3	10.5	1.3	12.5	0.23	17.4	0.0	mature
4	11.5	1.7	14.8	0.23	13.3	0.0	nearly mature
5	12	1.8	15.0	0.30	16.6	0.0	mature
6	12	1.3	11.1	0.23	17.9	+2.8	mature
7	12.5	1.9	15.2	0.29	15.2	+1.4	mature
8	12.5	2.1	16.6	0.23	16.8	0.0	nearly mature
9	13	1.6	12.1	0.30	18.5	—0.9	mature
10	13	1.8	13.9	0.29	16.1	—1.3	mature
11	13	1.5	11.8	0.23	15.4	—3.2	mature
12	13	1.5	11.6	0.26	17.2	—1.3	mature
13	13	1.9	14.4	0.30	15.6	0.0	mature
14	14	1.6	11.2	0.24	14.8	0.0	mature
15	14	2.0	14.5	0.29	14.3	0.0	mature
16	14	2.7	19.4	0.29	10.6	+2.5	mature
				Ovary approaching maturity			
17	11.5	1.1	9.5	0.17	15.8	—5.0	immature
18	11.5	1.0	9.1	0.14	13.9	—5.1	immature
19	11.5	0.98	8.6	0.14	14.7	—5.6	immature
20	12	1.0	8.7	0.11	11.1	—7.3	immature
21	12	0.94	7.8	0.12	12.5	—6.8	immature
22	12.5	1.3	10.5	0.27	20.8	—3.7	nearly mature
23	12.5	1.4	11.0	0.23	16.6	—5.5	nearly mature
24	13	1.3	10.0	0.21	15.9	—4.5	nearly mature
25	13	1.6	12.3	0.17	10.7	—4.0	nearly mature
				Ovary remote from maturity			
26	8.5	0.51	6.0	0.11	22.2	—10.6	barely visible
27	9	0.44	4.9	0.06	12.5	—8.0	barely visible
28	9.5	0.49	5.1	0.09	17.6	—6.6	barely visible
29	10	0.63	6.3	0.12	18.2	—9.7	barely visible
30	10	0.52	5.2	0.12	22.2	—5.7	barely visible
31	10.5	0.44	4.2	0.09	20.0	—11.7	barely visible
32	11	0.57	5.2	0.09	15.0	—10.5	barely visible

[1] Measured in per cent of total length of animal.

[2] Measured in per cent of total length of ovary.

[3] Distance from anterior end of ovary to anterior end of posterior fin measured in per cent of total length of animal. The + sign signifies that the ovary is anterior, and the — sign that it is posterior to this point.

The table presents the following generalizations:

1. As in *S. enflata*, the ovary and seminal vesicles reach maturity at aproximately the same time.
2. The mature ovary (pl. 5, fig. 40) varies in length from 1.3 to 2.7 mm. or from 11 to 20 per cent of total length of specimen.
3. In width the mature ovary varies from 0.22 to 0.35 mm. or from 10.5 to 20 per cent of its own length.
4. The mature ovary reaches the anterior limit of the posterior fin, the variation on either side of this point being about 4 per cent.

Ritter-Záhony (1910, p. 256) gives the length of mature ovary in individuals ranging from 9 to 12 mm. as from 1.2 to 1.8 mm., or from 13 to 15 per cent of the total length of the individual.

TABLE 18

Measurements concerning the Ovary in *Sagitta lyra.*

Ovary remote from maturity

Number	Length in mm.	Length of ovary		Width of ovary		Ovary to ventral ganglion[1]	Nature of seminal vesicles
		in mm.	in per cent[1]	in mm.	in per cent[2]		
1	20	0.00	0.0	0.00	0.0		not visible
2	20	0.38	1.9	0.06	16.7	—60.5	barely visible
3	24	0.70	2.9	0.06	9.1	—54.6	barely visible
4	24	1.92	8.0	0.06	3.3	—40.0	barely visible
5	25	0.00	0.0	0.00	0.0		not visible
6	28	0.00	0.0	0.00	0.0		not visible
7	28	2.20	8.0	0.06	2.9	—58.0	barely visible
8	29	2.20	7.7	0.06	4.3	—38.6	barely visible
9	31	3.07	9.9	0.19	6.25	—57.2	barely visible
10	32	1.28	7.5	0.09	7.5	—55.9	barely visible
11	32	2.90	9.0	0.13	4.5	—62.0	barely visible
12	33	2.00	6.2	0.13	6.3	—57.5	not visible
13	33	5.70	17.3	0.19	3.3	—44.3	barely visible
14	34	3.80	11.3	0.19	5.0	—32.9	barely visible
15	35	2.70	7.6	0.13	4.8	—38.8	not visible
16	36	4.70	13.0	0.19	4.1	—35.4	barely visible
17	37	6.10	16.4	0.19	3.2	—35.4	not visible
18	40	5.80	14.5	0.06	1.1	—29.4	not visible

[1] Measured in per cent of total length of animal.

[2] Measured in per cent of total length of ovary.

TABLE 18—*Continued*

Ovary immature

Number	Length in mm.	Length of ovary in mm.	Length of ovary in per cent	Width of ovary in mm.	Width of ovary in per cent	Ovary to ventral ganglion[1]	Nature of seminal vesicles
19	45	7.80	17.3	0.19	2.5	—42.5	barely visible
20	45	7.75	17.2	0.26	3.3	—42.5	well developed
21	49	5.70	11.7	0.22	3.9	—50.4	barely visible
				Ovary approaching maturity			
22	36	15.30	41.8	0.25	1.6	—4.1	well developed
23	44	9.90	22.5	0.26	2.6	—25.4	well developed
24	52	12.00	23.3	0.32	2.6	—27.0	well developed
		Three specimens sent by Broch from the North Sea.					
25	55	4.00	7.3	0.25	6.3	—38.2	not visible
26	71	6.00	8.5	0.50	8.3	—36.6	barely visible
27	75	11.00	14.7	1.50	7.3	—29.4	nearly mature

In the entire twenty-seven specimens there is none that appears to me to be fully mature. No. 22 (pl. 6, fig. 43) evidently has most nearly attained this condition, and I suspect that an examination of a larger series of individuals than the San Diego catches afford would show that the ventral ganglion is the object about which the maximum length of ovary fluctuates. Apparently the seminal vesicles may mature before the ovaries. Concerning this Ritter-Záhony (1908, p. 12) says: "Zur Zeit der männlichen Reife sind die Ovarien noch verhältnissmässig kurz; ihre völlige Reife fällt." This seems to indicate that the ovaries attain their complete maturity very rapidly during the last period of life. On his specimens of *S. lyra* Ritter-Záhony (1908) makes the following measurements:

Length of specimen in mm.	Length of ovary in mm.
16	0.8
18	1.0–1.5
19	1.6
21	2.8
22	0.75
25	0.35–1.8
26	0.25–0.75
27	0.5
28	1.0
29	0.5–2.2
30	2.2

For the lengths of individual paralleled in the San Diego material, the length of ovary corresponds as closely as one would expect, but as most of our specimens are very much larger an exact comparison is impossible. (Compare also the measurements recorded by Ritter-Záhony, 1910, pp. 265-6 for *S. maxima*.)

TABLE 19

Measurements concerning the Ovary in *Sagitta planktonis*.

Number	Length in mm.	Length of ovary		Width of ovary		Distance to posterior fin[1]	Distance to ventral ganglion[1]	Nature of seminal vesicles
		in mm.	in per cent[1]	in mm.	in per cent[2]			
				Ovary approaching maturity				
1	25	9.9	39.6	0.250	2.5	+32.0	0.0	well developed
2	24	11.4	47.5	0.136	1.2	+36.5	—6.8	nearly mature
3	24	11.0	46.0	0.217	2.0	+25.0	0.0	well developed
4	21	7.7	36.5	0.164	2.1	+23.5	—7.8	well developed
5	18.5	4.7	25.4	0.193	4.1	+13.4	—1.5	well developed
6	14.5	4.4	30.0	0.190	4.4	+20.6	—2.1	nearly mature
				Ovary well developed				
7	24.5	5.0	20.5	0.192	3.8	+ 9.0	—20.3	nearly mature
8	24	5.3	22.0	0.165	3.1	+10.4	—17.3	well developed
				Ovary remote from maturity				
9	19	1.6	8.6	0.027	1.6	—2.9	—33.0	invisible
10	17.6	1.4	8.1	0.027	1.9	—6.3	—47.0	invisible
11	17	1.7	10.0	0.085	5.0	+5.6	—34.6	barely visible
12	16.5	1.7	10.0	0.116	6.7	+5.5	—28.9	barely visible
13	13	0.7	5.1	0.027	4.2	—4.2	—38.0	invisible
14	11.5	0.0		0.000				invisible

[1] Measured in per cent of total length of animal.

[2] Measured in per cent of total length of ovary.

As in the case of *S. lyra*, none of the specimens examined appeared to be fully mature. Nos. 2 and 3 (pl. 5, fig. 42) approximate most nearly to complete maturity, which fact would indicate that the mature ovary extends nearly to the ventral ganglion.

TABLE 20

Measurements concerning the Ovary in *Sagitta serratodentata.*

Ovary approaching maturity

Number	Length in mm.	Length of ovary		Width of ovary		Distance to posterior fin[1]	Distance to ventral ganglion[1]	Nature of seminal vesicles
		in mm.	in per cent[1]	in mm.	in per cent[2]			
1	14	6.2	44.0	0.31	5.0	+26.4	0.0	mature
2	15	4.5	30.4	0.33	7.4	+14.8	—1.8	nearly mature
3	16	4.5	28.2	0.34	7.5	+15.5	—7.0	nearly mature
4	17	5.3	31.3	0.32	6.0	+14.5	—19.8	invisible
5	17	4.9	29.2	0.49	10.0	+18.7	—20.8	barely visible
				Ovary well developed				
6	13	3.0	23.0	0.28	9.3	+8.1		well developed
7	14	2.2	21.2	0.33	14.8	+8.1	—27.8	barely visible
8	16	3.5	22.2	0.28	8.0	+10.0	—25.6	barely visible
9	18	3.5	19.3	0.36	10.2	+7.9	—28.6	approaching maturity
				Ovary remote from maturity				
10	12.5	2.1	16.9	0.28	13.2			well developed
11	13	2.7	20.6	0.16	6.0			well developed
12	13	0.8	5.9	0.11	14.3	—5.5		barely visible
13	14	0.9	6.7	0.12	11.7	—3.5		barely visible
14	14	2.4	16.9	0.22	9.8	+5.9		well developed
15	14.5	1.9	13.4	0.31	16.4	+7.3	—30.8	barely visible
16	15	1.8	11.9	0.25	14.0	0.0		well developed
17	15.5	1.8	11.4	0.11	6.0	0.0	—32.0	barely visible
18	15.5	1.2	8.0	0.10	8.6	—2.7	—29.6	well developed
19	16	2.5	15.6	0.28	11.1	+3.5		well developed
20	17	2.3	13.5	0.22	9.8	+4.6		well developed
21	18.5	1.3	6.9	0.14	11.1	—4.8	—39.7	invisible

[1] Measured in per cent of total length of animal.

[2] Measured in per cent of total length of ovary.

But one specimen (no. 1) appeared to be fully mature (pl. 5, fig. 41), although the first five seemed to be very nearly so. With some allowance I think we may draw the following conclusions:

1. The ovary approaches maturity when its length lies between 28 and 44 per cent of the total length of the specimen.
2. The mature ovary extends very nearly to the ventral ganglion.
3. The seminal vesicles may apparently be in any stage of development when the ovary is mature.

TABLE 21

Measurements concerning the Ovary in *Sagitta neglecta.*

Number	Length in mm.	Length of ovary		Width of ovary		Distance to posterior fin[1]	Nature of seminal vesicles
		in mm.	in per cent[1]	in mm.	in per cent[2]		
1	10	0.57	5.7	0.076	13.3	—9.1	barely visible
2	10	0.76	7.6	0.076	10.0	—3.8	barely visible
3	11	1.2	11.3	0.054	4.5	0.0	nearly mature
4	12	0.9	7.5	0.081	6.3	—2.2	barely visible
5	12	0.9	7.5	0.081	6.3	—2.5	well developed
6	12	1.2	9.7	0.058	4.8	—1.9	well developed
7	12.5	0.95	7.6	0.057	6.0	—2.1	well developed
8	13	1.9	15.1	0.146	7.7	0.0	nearly mature
9	14	1.1	8.1	0.074	6.7	—4.3	barely visible
10	14.5	0.8	5.7	0.054	6.8	—2.1	barely visible
11	14.5	1.7	11.5	0.097	5.7	+2.6	barely visible

[1] Measured in per cent of total length of animal.

[2] Measured in per cent of total length of ovary.

In the eleven specimens there is not a single instance of anything approaching maturity. Nos. 3, 8, and 11, according to my notes, are marked "well-developed but scarcely approaching maturity." All the others are clearly remote from maturity. The probabilites are that no. 8 represents nearly the maximum length of the ovary, but of this I can not be certain until I have more material with which to work.

The specimens of other species from this region in our collections are too few in number or too immature to allow any significant measurements of the ovary. We may however, in a general manner, divide the San Diego *Sagitta* into two groups.

1. Ovary long and slender, extending nearly to the ventral ganglion. This group includes *S. planktonis*, *S. hexaptera*, *S. lyra*, and *S. serratodentata*.
2. Ovary short and thick, never extending much beyond the anterior limit of the posterior fin. This group includes *S. enflata*, *S. bipunctata*, and probably *S. neglecta*.

These groups are very apparently different, even at first glance, least so among smaller individuals, but becoming more and more apparent as the length of specimen increases. I believe an extensive tabulation in this regard would present definite differences of much value in classification.

REDESCRIPTIONS OF SOME DOUBTFUL SPECIES OF CHAETOGNATHA

Sagitta hispida Conant

Sagitta hispida Conant (1895), p. 78, fig. 7; Aida (1897), p. 18.
Sagitta robusta Doncaster (1902b), p. 212; Fowler (1906), p. 19.

After some difficulty I have been fortunate enough to obtain one specimen of *S. hispida* which was identified by Conant himself. The specimen was obtained from Beaufort, North Carolina, and deposited in the United States National Museum. Through the courtesy of that institution I have been enabled to restudy the species.

The specimen is not in the best conditon for extensive study, so that there are many points which can not be determined. Like many Chaetognatha when preserved in alcohol, this specimen has not only shrunken, thereby making the width measurements appear too small, but it has also turned almost black, making it impossible to count the teeth or seizing jaws, or to locate the ventral ganglion. However, in connection with the literature, I believe the specimen presents enough facts to permit us with safety to identify it with *S. robusta* Doncaster.

Below is given a table of comparison for the two species, the information for which has been obtained from Doncaster (1902b), and Fowler (1906) for *S. robusta,* and from Conant (1895), and from the above-mentioned specimen for *S. hispida.*

TABLE 22

Comparison of *S. hispida* and *S. robusta*

Characters	*S. hispida*	*S. robusta*
Length in mm.	5.5–11	10–14
Width in per cent of length	4.2–4.3	5.7
Lateral fields	small	small
Muscles	strong	strong
Consistency	firm	firm

TABLE 22—*Continued*

Appearance	opaque	opaque
Collarette	present	present
Tail in per cent of length	28–33	25–33
Anterior fin, length and width	13–19 × 3.8 per cent	20 × 2.9 per cent
Anterior fin, to posterior fin	6.3–8.7 per cent	6.8 per cent
Posterior fin, length and width	23–28 × 4.9 per cent	26 × 3.7 per cent
Posterior fin, extends caudally	to seminal vesicles	to seminal vesicles
Posterior fin, greatest width	behind tail-septum	behind tail-septum
Posterior fin, per cent in front of tail-septum	36–40	35
Seizing jaws	8–9	5–7
Anterior teeth	4–5	5–10
Posterior teeth	8–15	11–14

In addition to the above characters, others not easily presented in tabular form are essentially the same in the two species. The form of the body, position of greatest width, and the gradual diminution on approaching either head or tail are very similar in the two forms. Again, the form of the fins is nearly the same. Finally, the extent of collarette and the position and form of *corona ciliata* are greatly alike.

A careful examination of the above table reveals but five points of difference. They consist of width, width of anterior fin, width of posterior fin, number of anterior teeth, and number of seizing jaws. Let us then look at these differences a little more closely.

1. *Width of Body.* Owing to inshrinking of the lateral fields, my measurement of 4.3 per cent is probably too small to represent the width in fresh or living material. Granting, however, that 4.3 per cent is the true width, an examination of width measurements of the San Diego species reveals greater variation than from 4.3 to 5.7 per cent. *S. enflata* varies from 6 to 12 per cent, *S. hexaptera* from 7 to 11 per cent, *S. lyra* from 6.3 to 10.5 per cent, and *S. serratodentata* from 3.4 to 6.5 per cent. Other species show as great variation. It seems, therefore, that this difference between *S. hispida* and *S. robusta* is of no specific importance.

2. *Width of Anterior Fin.* It was impossible to measure the width of anterior fin in the single specimen I had occasion to examine. Assuming, however, that Conant's (1895) measurement of 3.8 per cent is correct, we find that a variation from 2.9 to 3.8 per cent is no greater than the individual variations in this regard of some of the San Diego species. *S. enflata* varies from 1.0 to 2.8 per cent, *S. bipunctata* from 1.4 to 2.5 per cent, and many of the other species show as great variations. It is evident that this difference does not signify the existence of two species.

3. *Width of Posterior Fin.* The width of posterior fin of *S. robusta* is 3.7 per cent and that of *S. hispida* is 4.9 per cent. Nearly every San Diego species, however, presents a much greater variation. In *S. bipunctata* the fin varies from 3.1 to 4.5 per cent, in *S. planktonis* from 3.1 to 5.4 per cent, and in *S. enflata* from 2.6 to 5.7 per cent. It is probable, therefore, that this difference is only a measure of individual variation and not of specific difference.

4. *Number of Anterior Teeth.* Conant (1895) records the number of anterior teeth as 4 to 5, while in *S. robusta* there are 5 to 10. This looks like a more significant difference. Let us see how it bears comparison with other species. In individuals of *S. serratodentata* varying in length from 6 to 14 mm., Fowler (1905, p. 59) records the variation in anterior teeth as 3 to 6.

TABLE 23

Variation in Anterior Teeth in *S. serratodentata*

Length of specimen, in mm.	Biscayan report Fowler (1905)	"Siboga" report Fowler (1906)
14	5–6	9–10
12	4–7	9
11	6	8–9
10	4–6	8–9
6–9	3–4	5–9

In the "Siboga" Report (1906, p. 20), however, he finds a variation from 5 to 10 corresponding to individuals of similar lengths. Even a careful comparison of the number of anterior teeth recorded in the Biscayan and "Siboga" Reports, as given in table 23 does not show a single case of overlapping in the entire series.

Again, Fowler (1906, p. 9) finds the number of anterior teeth in *S. enflata* greater than we have found in San Diego specimens of the same lengths. Table 24 shows that, as in the case of *S. serratodentata*, there is not a single case of overlapping.

TABLE 24

Variation in Anterior Teeth in *S. enflata*

Length of specimen in mm.	"Siboga" area	San Diego region
20	8–9	5–6
17	8–9	6–7
16	8	6–7
15	8–9	6–7
12	9	6

Finally, in *S. sibogae* we discover a similar difference between those species obtained by Fowler (1906) and those taken by Ritter-Záhony (1909b). This difference is illustrated in table 25.

TABLE 25

Variation in Anterior Teeth of *S. sibogae*

Length of specimen in mm.	Fowler (1905)	Ritter-Záhony (1909)
11	7	10–12
10	7	9–11
9	8	7–13

Similar instances might be given, but enough has been said to prove that a wide variation in number of anterior teeth occurs in individuals of the same species. Furthermore, in the cases cited, the difference is greater than that found between *S. hispida* and *S. robusta*.

Considerable space has been utilized in this discussion of teeth relations because Fowler (1906) saw in this difference a reason for not identifying the two species in question. He remarked upon the similarity betwen the two forms and after identifying Aida's *S. hispida* with *S. robusta* concluded (p. 20): "At any rate it is apparent from the marked difference in number of anterior teeth that they [*S. hispida* Aida] were not *hispida* Conant." It seems, however, that variation in number of both anterior and posterior teeth in many species is not referable to specific differences, but probably to some distribution factor.

5. *Number of Seizing Jaws.* In number of seizing jaws we found that *S. robusta* varies from 5 to 7, while *S. hispida* has only 8 or 9. Shall we claim that this is of specific value? In looking over this paper we find the following variations in number of seizing jaws:

TABLE 26

Number of Seizing Jaws in the San Diego species.

Species	Number of jaws	Comparison with other reports	
S. enflata	8–9	6–10	Fowler (1906)
S. hexaptera	5–9	3–9	Fowler (1906)
S. lyra	4–9	7–9	Ritter-Záhony (1909)
S. serratodentata	5–7	6–8	Fowler (1905)
S. planktonis	8–9	8–10	Fowler (1905)
S. neglecta	7–9	5–8	Fowler (1906)
S. bipunctata	7–8	8–10	Fowler (1905)

A glance at this table shows that, in *S. enflata*, *S. hexaptera*, *S. lyra*, and *S. neglecta*, a variation of four or more seizing jaws occurs. We can be sure, therefore, that such a variation may be within the range of a single species. Finally, when we consider Aida's *S. hispida*, it becomes all the more probable that *S. hispida* Conant and *S. robusta* Doncaster are the same species, for the reason that Aida's specimens have 7 or 8 seizing jaws.

It is to be regretted that there was not more than one specimen of *S. hispida* at my disposal and that for this reason it has been impossible to dissect it and so draw and describe many of the features rendered obscure by its long preservation and discoloration. Nevertheless, I am convinced that the two species are identical. *S. hispida* Conant should, therefore, have prior claim and *S. robusta* Doncaster must take its place in synonymy.

Sagitta elegans Verrill

Pl. 2, figs. 12, 13; pl. 3, fig. 24; pl. 4, fig. 38.

Sagitta elegans Verrill (1873), p. 332; Conant (1896), p. 84.
Sagitta arctica Aurivillius (1896), p. 188.
Sagitta gracilis, Verrill (1883) [see Conant (1896), p. 84].
Sagitta bipunctata, Krumbach (1903), p. 628.
Sagitta bipunctata forma arctica, Ritter-Záhony (1910), p. 256.

Through the courtesy of the United States National Museum I have been enabled to study a few specimens of Verrill's *S. elegans.* The specimens were originally obtained from Vineyard Sound, Massachusetts. From Dr. Hjalmar Broch, of Christiania, Norway, I have also some specimens of *S. arctica,* obtained November 16, 1905, from the Skagerak. Fowler (1906) pointed out that these two forms were probably to be identified as a single species, and later Ritter-Záhony (1910) synonymized them with *S. bipunctata.* It is, therefore, advisable to redescribe them and inasmuch as they are so nearly alike (pl. 2, figs. 12, 13), I shall describe *S. elegans* and then briefly consider the main points in which it differs from *S. arctica.*

Characters

Body opaque (pl. 2, fig. 12), but rather flabby. Neck well marked, but scarcely so pronounced as in *S. enflata* or *S. hexaptera.* Body widest throughout posterior third, tapering gradually toward head and more rapidly toward tail. Lateral fields conspicuous but not large. Muscles strong and thick. Diminution at tail-septum rather abrupt. Collarette absent.

Anterior fin situated well forward, shorter and narrower than posterior fin. It does not extend to the ventral ganglion, the interval measuring about 6 per cent. Approximately triangular in form, the point of greatest width being located well toward its posterior end. Interval from anterior to posterior fin about 12 per cent.

Posterior fin extends nearly, if not quite, to seminal vesicles. Always more than 50 per cent of fin in front of tail-septum, and usually more than 60 per cent. Position of greatest width slightly behind tail-septum.

Vestibular ridge (pl. 3, fig. 24) provided with low, rounded papillae which are rather irregular in height and position. They are not so numerous as the posterior teeth. Four or five teeth usually project beyond wing of ridge. The external process could not be discerned.

Anterior teeth 6 to 11. *Posterior teeth* 13 to 17.

Seizing jaws (pl. 4 fig. 38) 9 to 12 in number, and of much the same form as described by Krumbach (1903) for *S. bipunctata.* Points needle-shaped but with the apex lying slightly nearer edge of jaw. Base of point and top of shaft parallel. Point inserted into shaft about one-fifth its own height. Pulp-canal slightly swollen just below point, and located somewhat nearer back of jaw. Pulp evenly distributed.

But two specimens were well enough preserved to permit accurate measurements. They are given below, following which the measurements of *S. arctica* are given.

TABLE 27

Measurements of *Sagitta elegans*[1]

					Anterior fin				Posterior fin		
Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	To ventral ganglion	Length	Width	To posterior fin	Length	Width	Tail-septum[2]
1	23	6.9	22	68	6.1	13.9	?	13.0	21.8	?	64
2	21	6.5	23	69	9.0	12.1	?	12.3	20.0	?	63
Measurements of *Sagitta arctica*[1]											
1	24	6.0	21	71.5	11.0	14.5	1.2	11.0	21.6	2.8	68
2	24	6.6	21	74.5	10.3	17.8	1.4	9.9	21.4	2.9	70
3	26	6.4	21	73.0	14.0	13.2	1.0	12.5	21.2	2.9	66
4	27	6.8	22	69.0	12.0	13.9	1.0	11.0	16.0	2.8	61
5	27	6.1	21	73.0	11.0	17.4	1.1	10.4	20.2	2.8	65
6	27	6.0	21	71.5	13.2	14.9	1.4	8.6	21.0	2.6	66
7	27	6.3	22	72.5	9.3	17.4	1.3	10.4	20.8	2.8	63
8	27	6.3	20	73.5	9.7	16.7	1.1	13.6	19.5	2.6	68
9	28	7.0	21	71.0	8.8	16.3	1.6	11.9	18.5	3.3	70
10	28	6.3	20	69.0	9.8	15.0	1.1	11.8	18.9	2.6	66
11	29	6.3	21	71.0	11.5	16.2	1.2	10.5	19.0	2.5	65
12	29	6.1	19	67.5	12.0	13.6	1.2	9.6	10.0	2.0	66

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

Anterior teeth in *S. arctica* 7-8, posterior teeth 13-14, seizing jaws 10-11.

This table presents a great similarity between the two species. The only noticeable difference is that, as a rule, the interval from anterior fin to ventral ganglion is larger in *S. arctica*. However, in nos. 7, 8, and 9 we see transition cases.

The other differences between *S. elegans* and *S. arctica* are as follows:

1. The body of the former is flabby, while that of *S. arctica* is firm.

2. *S. elegans* matures sexually at 23 mm., while in none of the specimens of *S. arctica* examined were the ovaries even well developed, nor the seminal vesicles evident.
3. The ovary is slightly broader and longer in *S. elegans*.

Outside of these points the two species are nearly identical. Inasmuch as the specimens of *S. elegans* were preserved in alcohol, and those of *S. arctica* in formalin, the fact that the former is more flabby loses most of its significance. The other two points are interdependent, for in individuals that are sexually mature we should expect the ovary to be slightly longer and broader. Finally, as to the size at which specimens mature, we have noticed considerable variation in such species as *S. enflata* and *S. hexaptera*. From this evidence we are compelled to place *S. elegans* and *S. arctica* in the same species, and as Fowler (1906) has pointed out, the former takes priority, and *S. arctica* becomes a synonym.

Having concluded that the two species are synonymous it remains to see whether *S. elegans* stands as a valid species or whether it must, in turn, be placed in the synonymy of another species.

Being without a collarette *S. elegans* naturally falls into the group with *S. enflata, S. hexaptera, S. lyra, S. bedoti, S. serratodentata*, and *S. macrocephala*. Being opaque and provided with strong muscles it is readily separable from the first three. From *S. bedoti* it is easily distinguished by the fact that *S. elegans* has more than 50 per cent of posterior fin in front of tail-septum, by the presence of a considerable interval between anterior fin and ventral ganglion, and by the fact that the posterior fin is longer than the anterior fin. From *S. serratodentata* it differs in the absence of serrations on the seizing jaws, in an interval between anterior fin and ventral ganglion, and in the presence of more than 50 per cent of posterior fin in front of tail-septum. Finally, it differs from *S. macrocephala* in having a much shorter tail, in the number of posterior teeth, and in the general form of the body.

Fowler (1906) suggested the possible synonymy of *S. elegans* and *S. zetesios* (which has been identified by Ritter-Záhony

(1909c) with *S. planktonis* Steinhaus). While the form of the body and degree of opacity is very similar, they differ radically from one another. In *S. zetesios* the heavy collarette serves to distinguish at once between the two. The anterior fins are also longer than the posterior fins, and originate at the ventral ganglion in the latter species.

According to Ritter-Záhony (1910), *S. elegans* is identified as a variety of *S. bipunctata*. He recognizes two varieties of the latter species, one of which he calls forma *typica*, and the other forma *arctica*. While there is great similarity between them there seems to be as much difference as that between some other species. In the first place I am unable to discover the least trace of collarette in *S. elegans*, whereas in *S. bipunctata* that structure, while not pronounced, is conspicuous. Then, the muscles in *S. bipunctata* are weak, the body is nearly transparent, the seizing jaws are not so numerous, and the general appearance is decidedly contrasted to that of *S. elegans*. The proportional measurements are, however, annoyingly alike, and altogether *S. elegans* resembles *S. bipunctata* more than any other species. However, from the fact that the few differences mentioned are so distinctive and the general appearance so radically different, it seems best to let *S. elegans* remain a valid species.

Sagitta tenuis Conant

Pl. 2, fig. 11.

Sagitta tenuis Conant (1896), p. 85.

The receipt of three specimens of *S. tenuis* from the United States National Museum made it possible to redescribe this species. The specimens are labeled as cotypes obtained from Jamaica, West Indies. They were all damaged, making it impossible to obtain as complete a description as desired.

Characters

Collarette present, but exceedingly small, as in *S. bipunctata*. Body semi-opaque and firm (pl. 2, fig. 11). Muscles strong. Body widest at about middle of its length. From this point it tapers gradually toward head, and more rapidly toward tail. Neck nearly absent. Constriction at tail-septum pronounced, as in *S. enflata*.

Anterior fin beginning on a level with ventral ganglion. Shorter than posterior fin. In length it varies from 12 to 13 per cent.

Posterior fin longer than anterior fin with less than 50 per cent of its length in front of tail-septum. It extends nearly, if not quite, to seminal vesicles. Interval from anterior fin to posterior fin is rather large, varying from 16 to 17 per cent.

Seizing jaws 8, *Anterior teeth* 5, *Posterior teeth* 9. The width of the fins could not be determined, owing to the fact that a considerable portion had been torn away. Furthermore, the vestibular ridge could not be seen without dissection, which was impossible under the circumstances.

The following measurements were made:

Length	5–5.5 mm.
Width	6 per cent
Tail	29 per cent
Anterior fin in length	12.7 per cent
Anterior to posterior fin	16.3 per cent
Posterior fin in length	25.6 per cent
Per cent of posterior fin in front of septum	43
Tail to ventral ganglion	68 per cent

Conant (1896, p. 85) found that *S. tenuis* resembled *S. hispida* very closely. He says: "Shape of fins, of seizing hooks, *corona ciliata*, accessory longitudinal septa in caudal segment, number of tactile prominences, and musculature of body,—as in *S. hispida*." That they are not the same species Conant (1896) recognized because *S. tenuis* attains sexual maturity at such a small size. In addition, it differs from *S. hispida* in that the anterior fins originate at the ventral ganglion, and that there is less than 50 per cent of posterior fin in front of tail-septum.

Ritter-Záhony (1910) places *S. tenuis* in the synonymy of *S. bipunctata*. The fact that there is more than 50 per cent of posterior fin in front of tail-septum, and that there is a considerable interval between anterior fin and ventral ganglion in *S. bipunctata* makes me skeptical of such synonymy. Add to this the fact of sexual maturity in *S. tenuis* at a length of 5 mm., and it becomes readily distinguishable from all other species, with the possible exception of *S. minima*.

BRIEF DESCRIPTIONS OF SPECIES NOT YET TAKEN FROM THE SAN DIEGO REGION

For the benefit of those future investigators who may have occasion to identify the Chaetognatha of this region, I have included brief descriptions of the species not yet taken from this vicinity. Such species are *Sagitta decipiens*, *S. sibogae*, *S. ferox*, *S. regularis*, *S. pulchra*, *S. bedoti*, *S. macrocephala*, *S.*

gazelle, *Eukrohnia pacifica* and *Spadella cephaloptera*. Owing to the inadequacy of descriptions, and the impossibility of obtaining authenticated specimens, *S. minima* is not considered.

Sagitta decipiens Fowler

Fowler (1905), p. 70, pl. 5, figs. 32-35.

Collarette present, but very short. Body transparent, firm, slender, and widest behind middle of length, tapering gradually toward each end. Neck not well marked. Anterior fin shorter and narrower than posterior fin, not extending to ventral ganglion. Posterior fin widest at or just behind tail-septum. More than 50 per cent of posterior fin in front of tail-septum. No diminution at tail-septum. Ovary short and thick. Ova large. Vestibular ridge prominent, with thick cuticle and long external process sometimes forked. Anterior teeth 5-10. Posterior teeth 12-18. Seizing jaws 5-6. Tail 25-40 per cent of total length.

Sagitta sibogae Fowler

Fowler (1906), p. 12, pl. 2, figs. 66-72.

Collarette present, but short. Body firm, opaque, and widest at middle point, tapering gradually forward and more rapidly backward. Head large. Neck large. Lateral fields medium. Muscles strong. Anterior fins longer and narrower than posterior fins, extending to ventral ganglion. Posterior fins widest at plane of tail-septum, with slightly more than 50 per cent in front of tail-septum. It never extends to seminal vesicles. Vestibular ridge with numerous large and fairly regular papillae. Anterior teeth 7-11, short with broad bases. Posterior teeth 13-23. Seizing jaws 5-7. Tail 21-33 per cent of total length.

Sagitta ferox Doncaster

Doncaster (1903), p. 212.
Fowler (1906), p. 10, pl. 1, figs. 18-23.

Collarette present, extending to anterior fins, and exceptionally wide. Head large. Lateral fields small. Muscles broad and thick. Body firm, broad, opaque, and nearly of uniform width from in front of ventral ganglion to tail-septum. Anterior fins longer than posterior fins, extending to ventral ganglion. Posterior fins about same width as anterior fins, extending to seminal vesicles. Less than 50 per cent of posterior fin in front of tail-septum. "Vestibular ridge strongly mammillated, terminating externally in a very blunt process." *Corona ciliata* long, commencing in front of eyes and terminating near ventral ganglion. Anterior teeth 4-10, closely set, and with broad bases. Posterior teeth 9-14, long, broad, closely set, and diverging distally. Seizing jaws 5-6. Tail 26-36 per cent of total length.

Sagitta regularis Aida

Aida (1897), p. 18, tab. 3, fig. 1.
Doncaster (1902b), p. 211.
Fowler (1906), p. 18, pl. 2, figs. 55-58.
Ritter-Záhony (1909b), fig. 7.

The similarity of this species to *S. neglecta* has already been considered in detail. Ritter-Záhony (1909b) says: "Bei gut erhaltenen Individuen ist allerdings die ausserordentlich mächtig entwickelte Collarette mit den stark vorspringenden Tasthügeln das beste Erkennungsmerkmal, haüfig bemerkt ich jedoch, dass sie infolge der Konservierung verloren gegangen oder stark geschrumpft war."

Collarette conspicuous, extending to anterior fins. Head small. Muscles broad and stout. Body firm, opaque, and of about the same width from ventral ganglion to seminal vesicles. Anterior fins shorter and narrower than posterior fins, extending nearly to ventral ganglion. Posterior fins widest behind tail-septum, and extending to seminal vesicles. Less than 50 per cent of posterior fin in front of tail-septum. Anterior teeth 2-4. Posterior teeth 2-7. Seizing jaws 6-9. Tail 28-40 per cent of total length.

Sagitta pulchra Doncaster

Doncaster (1902b), p. 213.
Fowler (1906), p. 17, pl. 2, figs. 49-54.

Collarette present. Body very transparent, slender, and firm. Widest about one-half to three-fourths distance from head to tail-septum, tapering gradually forward, and more rapidly backward. Anterior fins longer and narrower than posterior fins, the anterior fourth consisting of epidermic thickening with but few rays. Posterior fins widest at, or behind, tail-septum, barely extending to seminal vesicles. More than 50 per cent of posterior fin in front of tail-septum. Vestibular ridge with sharp, regular papillae, and provided with a very strong external process. *Corona ciliata* long, commencing between eyes and extending one-half distance from head to ventral ganglion. Anterior teeth 5-10. Posterior teeth 9-15. Seizing jaws 5-7. Tail 18-27 per cent of total length.

Sagitta bedoti Béraneck

Béraneck (1895), p. 137.
Fowler (1906), pp. 6-8, pl. 1, figs. 1-8.

Collarette absent. Head small. Lateral fields large. Muscles strong but narrow. Body firm, transparent, and widest at middle of length, with sudden diminution at tail-septum. Anterior fin longer than posterior fin, extending nearly to ventral ganglion. Posterior fins broader than anterior fins, widest behind tail-septum, and extend to seminal vesicles. Less than 50 per cent of posterior fin in front of tail-septum. Papillae of vestibular ridge regular and acute. External process long and sharp. Anterior teeth 5-13. Posterior teeth 16-32. Seizing jaws 5-7. Tail 21-35 per cent of total length.

Sagitta macrocephala Fowler

Fowler (1905), p. 65, pl. 5, figs. 16-21.

Collarette absent. Head unusually large. Neck narrow and prominent. Lateral fields small. Body slender, firm, opaque, and widest at middle of length. Anterior fins shorter and narrower than posterior fins, never extending to ventral ganglion. Posterior fins about equally divided between body and tail, but usually with more than 50 per cent in front of septum. Vestibular ridge with thick cuticle and provided with irregular papillae, which are fewer in number than posterior teeth. Anterior teeth 5-10. Posterior teeth 12-33. Seizing jaws 9-12, very sharply curved in the distal fourth. Tail 29-41 per cent of total length.

Sagitta gazelle Ritter-Záhony

Ritter-Záhony (1909c), p. 788.

The characters of this species have already been considered in connection with the description of *S. lyra* (pp. 32-39). As the description given by Ritter-Záhony is incomplete, I can add nothing to my former remarks.

Eukrohnia pacifica (Aida)

Aida (1897), pp. 19, 20, tab. 3, fig. 11.
Fowler (1906), p. 24, pl. 3, figs. 81-85.

Collarette absent. Head medium. Neck fairly evident. Body slender, about 5 per cent in width, but broader than in *E. subtilis.* Widest about midway between ventral ganglion and tail-septum, tapering gradually in both directions. Lateral fins arise nearly two-thirds distance from ventral ganglion to tail-septum, and terminate at seminal vesicles. Usually slightly less than 50 per cent of fin in front of tail-septum, its point of greatest width being behind septum. *Corona ciliata* short, clove-shaped, extending onto head but never reaching eyes. Teeth ''bayonet-shaped'' springing from a narrower neck than in *E. subtilis*, the number varying from 11 to 16. Seizing jaws, 6-9, with back of shaft made up of two curves, the junction of which makes an obtuse angle at a point about one-fourth the length of jaw proximad of tip. Tail 25-41 per cent of total length.

Spadella cephaloptera Busch

Busch (1851), pp. 93-100.
Hertwig (1880), pp. 66-67, taf. 1, fig. 6.
Fowler (1906), p. 34, pl. 3, figs. 95-99.

Collarette massive, widest just behind head, but less than half the width of body. Head medium. Neck evident. Collarette extends to tail-septum, where it becomes continuous with lateral fin. Body firm and opaque. Lateral fin more than five times longer than wide, extending to seminal vesicles. *Corona ciliata* confined to neck, its long axis being transverse to the body and extending over the collarette. Anterior teeth 3-4, irregularly set and blunt, the innermost being very long. Posterior teeth 3-4. Seizing jaws 8-9, slender and slightly saginate. Tail 50 per cent of total length.

PART II. DISTRIBUTION

EXPLANATION OF THE TABLES OF DISTRIBUTION

The data from which the following discussions and conclusions have been derived are printed in full. It is believed that, in connection with other plankton investigations, students of this Marine Biological Station will find the data advantageous for purposes of correlation. It is also probable that other students of distribution, after accumulating observations, may discover important relations suggested in these data.

For convenience the data are arranged in four sections. First, the surface catches are tabulated; second, those hauls made with horizontal closing nets; third, those made with vertical closing nets, and fourth, those made with open vertical nets. Temperature and salinity are not indicated in connection with closing net hauls because, till the present, it has been impossible to operate the water bottle and closing net at even approximately the same time. For records of relation between depth, temperature, and salinity see McEwen (1910). Temperature is recorded in Centigrade, depth in fathoms, and latitude and longitude to one-tenth of one minute measured from Greenwich.

The following symbols are employed to indicate the various nets used in making collections:

A. Surface net 000 XX mesh silk bolting cloth, orifice 97.5 cm. in diameter.

B. Kofoid closing net 000 XX mesh silk bolting cloth, orifice 37.0 cm. in diameter.

C. Nansen closing net 1 XX mesh silk bolting cloth, orifice 109.5 cm. in diameter.

F. Nansen closing net 000 XX mesh silk bolting cloth, orifice 45.2 cm. in diameter.

Method of Counting

If a haul seemed to contain under three hundred individuals of a species they were counted. When the number appeared greater, the following method was employed. After sorting the species, from sixty to one hundred specimens were removed with forceps and placed on filter paper to allow the fluid to drain off. This sample was then accurately weighed and counted. Dividing this weight by the number of specimens in the sample gave an average individual weight. A second sample was then treated likewise. The mean between the two average weights thus obtained was considered final, and the weight of the entire haul divided by this mean approximated the number of individuals contained. The usual error in this method has been calculated from twenty-five tests and amounts to about 5 per cent. In no instance was it over 10 or under 2 per cent.

TABLE 28

Distribution with Respect to Surface Hauls, Net A.

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day and Duration of haul	Temperature of water	Salinity of water	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. neglecta*	*S. planktonis*
	1904												
216	July 23	9:30 p.m.	....	....	32° 35'.0	117° 18'.8	....	....	....	....	50	....	....
275	Sept. 17	7:30 a.m.	....	....	32° 38'.6	117° 24'.0	....	2	....	....	2000	....	....
	1905												
411[1]	Feb. 25	....	15°.5	....	32° 40'.6	117° 30'.0	3500	....	....	1	75	9	....
412[2]	Feb. 25	....	15°.5	....	32° 40'.6	117° 30'.0	3100	4	....	1	64	75	....
473	April 29	....	16°.5	....	32° 45'.2	117° 23'.2	6	....	....	....	6	38	....
	1908												
1415	June 11	2:25 p.m.	....	....	32° 55'.6	117° 33'.0	....	....	....	....	5	....	....
1416	June 11	2:25 p.m.	....	....	32° 55'.6	117° 33'.0	1	....	....	....	1620	....	....
1417	June 12	12:00–12:20 p.m.	16°.5	33.380	32° 51'.0	117° 34'.0	....	....	....	....	3	....	....
1418	June 12	10:00–10:20 a.m.	16°.4	33.404	32° 51'.0	117° 34'.0	....	....	....	....	11	....	....
	1907												
1422	Nov. 2	5:00– 5:30 p.m.	....	....	32° 32'.0	117° 17'.0	....	....	....	....	9	....	1
1423	Nov. 3	8:25– 8:45 a.m.	....	....	32° 39'.0	117° 14'.2	....	....	....	....	135	....	....
1426	Nov. 3	9:20– 9:40 a.m.	....	....	32° 38'.1	117° 14'.1	....	....	....	10	1250	....	....

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[1] The single specimen of *Spadella draco* was obtained in this haul.

[2] Hauls 411, 412, and 473 began some time before 6:00 a.m. and ended sometime before 10:00 a.m.

TABLE 28—*Continued*

Data concerning each haul							Number of specimens obtained						
Haul number	Date 1908	Time of day and Duration of haul	Temperature of water	Salinity of water	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. neglecta*	*S. planktonis*
1438	June 16	11:00–11:40 a.m.	18°.5	33.558	32° 46′.9	117° 31′.8	....	....	....	....	25	....	....
1444	June 17	12:30– 1:00 p.m.	16°.5	....	33° 0′.1	117° 50′.0	....	....	....	....	25	....	....
1448	June 17	2:40– 3:20 p.m.	16°.5	....	32° 59′.5	117° 43′.6	....	....	....	....	50	....	....
1452	June 17	3:26– 3:39 p.m.	16°.5	33.432	33° 0′.1	117° 38′.9	....	....	....	....	1	....	....
1455	June 18	10:45–11:20 a.m.	16°.5	....	32° 57′.8	117° 46′.0	....	....	....	....	20	....	....
1460	June 18	1:40– 2:20 p.m.	17°.1	33.630	32° 49′.8	117° 46′.0	....	....	....	....	20	....	....
1465	June 19	7:45– 8:25 a.m.	17°.8	33.693	32° 57′.7	117° 22′.7	....	....	....	3	20	....	....
1471	June 19	10:20–10:40 a.m.	17°.5	34.069	32° 59′.0	117° 22′.3	....	2	....	20	10	....	....
1489	June 25	8:25– 9:15 a.m.	18°.6	33.630	32° 55′.2	117° 21′.4	....	....	2	7	127	....	....
1505	June 26	12:25–12:50 p.m.	20°.0	33.617	32° 38′.8	117° 29′.9	....	....	....	....	16	....	....
1509	June 27	5:58– 6:15 a.m.	18°.6	33.670	32° 54′.1	117° 21′.0	....	....	....	....	72	....	....
1512	June 27	6:20– 6:45 a.m.	18°.9	....	32° 54′.1	117° 21′.0	....	....	....	....	60	....	....
1530	July 2	11:40–12:00 a.m.	17°.5	....	32° 58′.3	118° 14′.7	....	....	2	....	....	....	....
1535	July 8	7:30– 7:50 a.m.	18°.9	....	32° 21′.9	118° 19′.1	....	2	....	....	3	....	....
1559	July 18	6:20– 6:30 a.m.	16°.5	....	32° 24′.2	119° 6′.2	....	....	....	....	2000	....	....
1560	July 18	7:20– 8:00 a.m.	16°.5	33.457	32° 24′.2	119° 6′.2	....	....	....	....	527	....	1
1562	July 18	8:00– 9:00 p.m.	19°.5	33.630	32° 47′.9	117° 51′.8	....	....	....	....	75	....	....
1568	July 21	2:45– 3:13 p.m.	22°.3	33.630	32° 49′.6	117° 28′.8	....	....	....	....	5	....	....
1579	July 22	7:30– 7:50 p.m.	20°.8	33.704	32° 51′.5	117° 21′.4	....	....	....	2	563	....	....

TABLE 28—*Continued*

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day and Duration of haul	Temperature of water	Salinity of water	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. neglecta*	*S. planktonis*
	1908												
1582	July 22	8:10– 8:35 p.m.	20°.5	33.646	32° 51'.9	117° 21'.6	....	....	....	7	600	....	....
1585	July 23	4:30– 4:53 a.m.	19°.8	33.646	32° 51'.5	117° 22'.0	....	....	....	....	15	....	....
1591	July 23	7:50– 8:12 p.m.	22°.2	33.646	32° 51'.7	117° 20'.7	....	....	....	5	200	....	....
1594	July 23	8:20– 8:42 p.m.	20°.5	33.574	32° 51'.8	117° 22'.0	....	....	....	....	150	....	....
1597	July 24	4:26– 4:46 a.m.	20°.5	33.549	32° 51'.4	117° 22'.2	....	....	....	....	75	....	....
1600	July 24	4:58– 5:18 a.m.	20°.5	33.603	32° 51'.5	117° 22'.6	....	....	....	....	3	....	....
1605	Aug. 26	7:00– 7:20 p.m.	19°.3	....	32° 18'.8	117° 27'.1	....	....	....	1	35	....	....
	1909												
1634	Feb. 19	5:50– 6:20 a.m.	13°.6	....	32° 44'.5	117° 39'.3	....	....	....	....	250	....	....
1643	June 15	11:45 a.m.–12:45 p.m.	18°.2	....	32° 52'.3	117° 31'.8	....	....	....	....	5	....	....
1650	June 16	5:10– 5:55 p.m.	18°.6	....	32° 51'.7	117° 32'.4	....	....	....	....	15	....	....
1653	June 16	6:10– 6:45 p.m.	18°.6	33.616	32° 51'.4	117° 32'.1	....	....	....	....	40	....	....
1655	June 16	6:55– 7:20 p.m.	....	....	32° 51'.0	117° 31'.9	....	....	....	....	75	....	....
1657	June 16	7:25– 8:00 p.m.	18°.4	33.670	32° 51'.0	117° 31'.9	....	....	....	....	5100	....	....
1659	June 17	5:00– 6:00 p.m.	18°.4	....	32° 51'.3	117° 16'.7	....	....	....	....	13	....	....
1661	June 17	6:45– 7:30 p.m.	18°.4	....	32° 51'.3	117° 16'.7	....	....	....	....	550	....	....
1673	June 21	6:00– 6:25 p.m.	18°.0	33.563	32° 51'.8	117° 30'.4	....	....	....	....	30	....	....
1680	June 21	7:00– 7:35 p.m.	15°.9	33.563	32° 52'.0	117° 32'.0	....	....	....	....	3600	....	....
1682	June 21	7:40– 8:15 p.m.	15°.9	33.563	32° 52'.1	117° 33'.1	....	....	....	....	80	....	....

TABLE 28—*Continued*

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day and Duration of haul	Temperature of water	Salinity of water	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. neglecta*	*S. planktonis*
	1909												
1686	June 22	4:00– 5:00 a.m.	17°9	33.574	32° 53′2	117° 36′5	....	1	....	....	1600	....	....
1689	June 22	5:16– 6:11 a.m.	17°9	33.563	32° 52′8	117° 35′7	....	....	....	....	475	....	....
1698	June 23	6:10– 6:50 a.m.	17°2	33.574	32° 52′0	117° 30′0	....	....	....	....	20	....	....
1703	June 23	7:00– 8:55 a.m.	17°2	33.534	32° 52′0	117° 30′0	....	....	....	....	105	....	....
1712	June 24	5:05– 6:15 p.m.	17°5	33.561	32° 52′0	117° 30′0	....	....	....	....	191	....	....
1716	June 24	6:20– 7:05 p.m.	17°5	33.563	32° 52′0	117° 30′0	....	....	....	1	50	....	....
1719	June 24	7:15– 8:23 p.m.	17°2	34.009	32° 52′0	117° 30′0	....	....	....	....	55	....	....
1728	June 25	5:10– 6:10 p.m.	17°7	33.534	32° 52′0	117° 30′0	....	....	....	....	72	....	....
1731	June 25	6:15– 7:00 p.m.	17°7	33.776	32° 52′0	117° 30′0	....	....	....	....	50	....	....
1734	June 25	7:03– 7:40 p.m.	17°7	33.534	32° 52′0	117° 30′0	....	....	....	....	103	....	....
1738	June 25	7:45– 8:41 p.m.	17°6	33.549	32° 52′0	117° 30′0	....	....	....	14	105	....	....
1744	June 28	5:00– 6:20 p.m.	19°2	33.648	32° 52′0	117° 30′0	....	....	....	....	2	....	....
1751	June 28	7:15– 8:00 p.m.	19°0	33.603	32° 52′0	117° 30′0	....	....	....	....	155	....	....
1754	June 28	8:10– 8:50 p.m.	19°0	33.603	32° 52′0	117° 30′0	....	....	....	....	1100	....	....
1767	June 30	4:00– 4:25 p.m.	19°1	33.630	32° 50′1	118° 3′1	....	....	....	....	1	....	....
1772	July 1	7:55– 8:23 a.m.	16°7	33.603	32° 52′5	118° 21′5	....	....	....	1	9	....	....
1784	July 2	4:50– 5:11 a.m.	18°7	33.648	32° 49′0	118° 21′0	....	....	....	....	618	....	....
1791	July 2	6:37– 7:00 a.m.	16°6	33.681	32° 48′0	118° 27′0	....	....	....	....	41	....	....
1815	July 7	4:50– 5:35 a.m.	19°0	33.811	32° 52′0	117° 30′0	....	....	....	....	46	....	....

TABLE 28—*Continued*

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day and Duration of haul	Temperature of water	Salinity of water	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. neglecta*	*S. planktonis*
	1909												
1836	July 7	7:55– 8:25 p.m.	19°.4	33.648	32° 52'.3	117° 20'.0	....	....	....	....	330	....	....
1850	July 9	3:30– 4:15 a.m.	18°.8	33.690	32° 52'.3	117° 20'.0	....	....	....	....	270	....	....
1854	July 9	4:20– 5:15 a.m.	18°.8	33.571	32° 52'.3	117° 20'.0	....	....	....	....	6	....	....
1860	July 9	5:18– 6:25 a.m.	18°.6	33.589	32° 52'.3	117° 20'.0	....	....	....	....	4	....	....
1868	July 9	7:03– 7:36 p.m.	19°.0	33.589	32° 52'.3	117° 20'.0	....	....	....	....	10	....	....
1872	July 9	7:40– 8:15 p.m.	18°.8	33.630	32° 52'.3	117° 20'.0	....	....	....	....	4300	....	....
1875	July 9	8:45–11:35 p.m.	19°.0	33.630	32° 52'.3	117° 20'.0	....	....	....	....	275	....	....
1883	July 10	12:55– 4:28 a.m.	19°.2	33.762	32° 53'.0	117° 18'.0	....	....	....	....	85	....	....
1888	July 10	4:35– 5:20 a.m.	19°.1	33.690	32° 53'.0	117° 18'.0	....	....	....	....	132	....	....
1892	July 10	5:25– 5:55 a.m.	19°.2	33.747	32° 53'.0	117° 18'.0	....	....	....	....	15	....	....
1902	Sept. 1	5:46– 6:06 a.m.	16°.6	....	32° 40'.0	117° 30'.0	....	....	....	....	12	....	....
1910	Sept. 2	5:52– 6:13 a.m.	18°.4	33.874	32° 37'.2	118° 37'.2	....	....	....	....	2	....	....
1915	Sept. 2	2:05– 2:27 p.m.	18°.2	33.675	32° 28'.0	119° 3'.0	....	....	....	....	8	....	....
1920	Sept. 3	6:00– 6:37 a.m.	19°.5	33.856	32° 48'.5	118° 20'.3	....	....	....	....	3	....	....
1931	Sept. 3	6:14– 6:43 p.m.	20°.1	33.793	32° 53'.9	117° 53'.2	....	....	....	....	170	....	....
1941	Nov. 2	6:00– 6:20 a.m.	17°.5	33.964	32° 52'.0	117° 30'.0	....	....	....	3	....	....	....
1954	Nov. 2	12:04–12:26 p.m.	18°.8	33.901	32° 52'.0	117° 30'.0	....	....	....	....	50	....	....
	1910												
1991	Feb. 17	6:20– 7:15 a.m.	13°.1	33.621	32° 39'.5	117° 31'.5	....	....	....	....	16	....	....

TABLE 28—*Continued*

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day and Duration of haul	Temperature of water	Salinity of water	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. neglecta*	*S. planktonis*
	1910												
1998	Feb. 17	7:30– 9:15 a.m.	13°.4	33.684	32° 39′.5	117° 31′.5	....	....	....	....	12	....	....
2010	Feb. 18	2:52– 4:25 p.m.	14°.2	33.811	32° 51′.2	117° 31′.5	....	....	....	....	55	....	....
2014	Feb. 18	4:50– 6:15 p.m.	13°.8	33.567	32° 51′.2	117° 31′.5	....	....	....	....	220	....	....
2024	Feb. 18	6:57– 7:54 p.m.	13°.8	33.558	32° 51′.2	117° 31′.5	....	....	....	....	165	....	....
2028	March 15	1:12– 1:50 p.m.	15°.4	33.486	32° 40′.4	117° 31′.0	....	....	....	....	3	....	....
2033	March 15	2:00– 2:43 p.m.	15°.8	33.558	32° 40′.4	117° 31′.0	....	....	....	....	3	....	....
2064	March 16	6:00– 6:55 p.m.	....	....	32° 40′.4	117° 31′.2	....	....	....	....	63	....	....
2070	March 17	1:30– 2:18 p.m.	14°.7	33.783	32° 50′.0	117° 30′.0	....	....	....	....	3	....	....
2078	March 17	2:20– 3:34 p.m.	14°.7	33.738	32° 50′.0	117° 30′.0	....	....	....	....	4	....	....
2082	March 17	3:40– 4:30 p.m.	17°.7	33.666	32° 50′.6	117° 29′.2	....	....	....	....	13	....	....
2085	March 17	4:45– 5:10 p.m.	14°.6	33.522	32° 50′.6	117° 29′.2	....	....	....	....	7	....	....
2096	March 17	6:15– 6:50 p.m.	14°.6	33.747	32° 50′.6	117° 29′.2	....	....	....	....	125	....	....
2101	March 17	6:55– 7:30 p.m.	14°.6	33.549	32° 50′.6	117° 29′.2	....	....	....	....	472	....	....
2109	April 19	8:30– 9:45 a.m.	16°.4	33.738	32° 23′.0	117° 20′.0	....	....	....	....	5	....	....
2123	April 20	4:45– 5:30 a.m.	....	....	32° 22′.3	117° 19′.0	....	....	....	....	10	....	....
2126	April 20	5:38– 6:10 a.m.	15°.8	33.603	32° 21′.6	117° 18′.5	....	....	....	....	31	....	....
2136	April 21	4:40– 5:05 a.m.	16°.2	33.802	32° 23′.5	117° 22′.2	....	....	....	....	224	....	....
2145	April 21	5:15– 5:35 a.m.	16°.2	....	32° 23′.5	117° 20′.0	....	....	....	....	140	....	....

TABLE 29

Data concerning Surface Hauls containing no Chaetognatha.

Haul number	Date		Time of day and Duration of haul	Temperature of water	Salinity of water	North Latitude	West Longitude
	1908						
1432	June	15	10:30–10:50 a.m.	18°.9	....	32° 39′.3	117° 30′.1
1436	June	16	9:30– 9:50 a.m.	16°.5	33.534	32° 48′.5	117° 34′.4
1478	June	23	4:45– 5:05 p.m.	18°.3	....	32° 41′.4	117° 30′.3
1499	June	25	3:45– 4:10 p.m.	19°.5	....	32° 51′.4	117° 21′.5
1518	June	30	9:50–10:05 a.m.	18°.5	....	32° 54′.4	117° 21′.5
1588	July	23	5:05– 5:30 a.m.	19°.7	33.617	32° 52′.1	117° 20′.2
	1909						
1660	June	17	6:00– 6:45 p.m.	18°.4	....	32° 51′.3	117° 16′.7
1662	June	17	7:30– 8:00 p.m.	18°.4	....	32° 51′.3	117° 16′.7
1667	June	19	8:45– 9:15 a.m.	....	....	32° 37′.1	117° 14′.5
1695	June	23	4:55– 6:00 a.m.	17°.6	33.574	32° 52′.0	117° 30′.0
1747	June	28	6:35– 7:11 p.m.	19°.0	33.603	32° 52′.0	117° 30′.0
1759	June	29	4:30– 4:50 a.m.	18°.6	33.571	32° 52′.0	117° 30′.0
1763	June	29	5:40– 6:35 a.m.	18°.7	33.735	32° 52′.0	117° 30′.0
1779	July	1	10:52 a.m.–12:40 p.m.	20°.4	33.778	32° 52′.6	118° 21′.5
1796	July	2	9:38–10:11 a.m.	17°.6	33.531	32° 44′.5	117° 53′.5
1800	July	2	12:45– 1:36 p.m.	20°.55	33.747	32° 41′.2	117° 32′.3
1804	July	2	4:23– 4:50 p.m.	20°.35	33.720	32° 40′.0	117° 26′.0
1810	July	2	6:15– 7:05 p.m.	20°.2	33.630	32° 40′.0	117° 26′.0
1812	July	7	4:10– 4:45 a.m.	....	....	32° 52′.0	117° 30′.0
1819	July	7	5:40– 6:35 a.m.	19°.0	33.690	32° 52′.0	117° 30′.0
1823	July	7	6:40– 7:36 a.m.	19°.0	33.690	32° 52′.0	117° 30′.0
1826	July	7	6:00– 7:00 p.m.	19°.2	33.733	32° 53′.3	117° 20′.0
1832	July	7	7:04– 7:50 p.m.	....	....	32° 53′.3	117° 20′.0
1837	July	8	10:20–11:05 a.m.	....	....	32° 51′.3	117° 18′.8
1864	July	9	6:15– 7:00 p.m.	19°.0	33.589	32° 52′.3	117° 20′.0
1881	July	10	11:35 p.m.–12:45 a.m.	18°.9	33.648	32° 52′.3	117° 20′.0
1906	Sept.	1	12:40–12:50 p.m.	18°.5	33.829	33° 0′.0	118° 41′.2
1967	Nov.	3	5:05– 5:45 p.m.	18°.0	33.865	32° 54′.1	117° 30′.1
1981	Nov.	5	11:50 a.m.–12:42 p.m.	17°.6	33.666	32° 40′.6	117° 30′.3
	1910						
2039	March	15	2:47– 4:03 p.m.	16°.2	33.774	32° 40′.4	117° 31′.0
2044	March	15	4:25– 5:20 p.m.	15°.6	33.585	32° 40′.4	117° 31′.0
2049	March	16	1:10– 1:50 p.m.	15°.5	33.675	32° 39′.2	117° 27′.0
2054	March	16	2:30– 3:22 p.m.	15°.4	33.693	32° 40′.4	117° 31′.2
2062	March	16	4:40– 5:50 p.m.	....	....	32° 40′.4	117° 31′.2
2091	March	17	5:30– 6:10 p.m.	14°.6	33.549	32° 50′.6	117° 29′.2
2114	April	19	9:55–10:45 a.m.	16°.5	33.657	32° 20′.9	117° 18′.5

TABLE 30

Distribution with Respect to Horizontal Closing Net Hauls.

Data concerning each haul							Number of specimens obtained						
Haul number	Date 1909	Time of day and Duration of haul	Net used	Depth in fathoms	North Latitude	West Longitude	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
1821	July 7	7:05– 7:35 a.m.	B	5	32° 52′.0	117° 30′.0	....	....	....	2	....	....	....
1827	July 7	6:40– 7:03 p.m.	C	5	32° 52′.3	117° 20′.0	....	....	....	190	....	....	....
1873	July 9	8:16– 8:26 p.m.	B	5	32° 52′.3	117° 20′.0	....	1	....	5	....	....	....
1879	July 10	12:27–12:37 a.m.	B	5	32° 52′.3	117° 20′.0	....	....	....	6	....	....	....
1889	July 10	5:19– 5:30 a.m.	B	5	32° 53′.0	117° 18′.0	....	....	....	1	....	....	....
1792	July 2	6:50– 7:10 a.m.	C	6	32° 48′.0	118° 27′.0	....	....	....	65	....	....	....
1798	July 2	1:10– 1:35 p.m.	C	6	32° 41′.2	117° 32′.3	....	....	....	14	....	....	....
1885	July 9	6:53– 7:03 p.m.	B	7	32° 52′.3	117° 20′.0	....	....	....	7	....	....	....
1833	July 7	7:05– 7:52 p.m.	C	9	32° 52′.3	117° 20′.0	....	....	....	12	....	....	....
1878	July 10	12:12–12:23 a.m.	B	10	32° 52′.3	117° 20′.0	....	....	15	......	....	....	....
1886	July 10	5:03– 5:15 a.m.	B	10	32° 53′.0	117° 18′.0	....	....	....	15	....	....	....
1872	Nov. 3	5:44– 5:54 p.m.	B	10	32° 54′.1	117° 30′.0	....	....	....	2	....	....	....
1789	July 2	6:36– 6:48 a.m.	C	12	32° 48′.0	118° 27′.0	....	....	....	18	....	....	....
1807	July 2	6:10– 6:35 p.m.	C	12	32° 40′.0	117° 26′.0	....	....	....	17	....	....	....
1834	July 7	7:51– 8:20 p.m.	B	15	32° 52′.3	117° 20′.0	....	....	....	7	....	....	....
1839	July 8	11:45–11:55 a.m.	B	15	32° 52′.0	117° 19′.2	....	....	....	30	....	....	....
1845	July 8	1:57– 2:10 p.m.	B	15	32° 52′.3	117° 18′.6	....	....	....	7	....	....	....
1852	July 9	4:55– 5:07 a.m.	B	15	32° 52′.3	117° 20′.0	....	....	....	23	....	....	....

TABLE 30—*Continued*

Data concerning each haul								Number of specimens obtained						
Haul number	Date		Time of day and Duration of haul	Net used	Depth in fathoms	North Latitude	West Longitude	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1909													
1862	July	9	6:38– 6:48 p.m.	B	15	32° 52′.3	117° 20′.0	....	....	....	17	....	....	....
1877	July	9	11:55 p.m.–12:05 a.m.	B	15	32° 52′.3	117° 20′.0	....	....	4	6	....	....	....
1885	July	10	4:45– 4:55 a.m.	B	15	32° 53′.0	117° 18′.0	....	....	....	14	....	....	....
1923	Sept.	3	8:32– 8:40 a.m.	B	15	32° 49′.4	118° 20′.3	....	....	....	3	....	....	....
1668	June	19	9:05– 9:30 a.m.	C	20	32° 37′.1	117° 14′.5	....	....	....	500	....	....	....
1770	July	1	7:25– 7:45 a.m.	C	20	32° 28′.1	118° 18′.3	....	....	....	9	....	....	....
1785	July	2	5:00– 5:23 a.m.	C	20	32° 49′.0	118° 21′.0	....	....	....	35	....	....	....
1802	July	2	4:23– 4:50 p.m.	C	20	32° 40′.0	117° 26′.0	....	....	....	18	....	....	....
1971	Nov.	3	5:33– 5:43 p.m.	B	20	32° 54′.1	117° 30′.0	....	....	....	14	....	....	....
1748	June	28	7:10– 7:35 p.m.	B	25	32° 52′.0	117° 30′.0	....	5	9	1	....	....	....
1761	June	29	5:55– 6:20 a.m.	B	25	32° 52′.0	117° 30′.0	....	1	....	1	....	....	....
1788	July	2	6:00– 6:35 a.m.	C	25	32° 48′.0	118° 27′.0	....	1	....	......	....	....	....
1793	July	2	8:38– 8:48 a.m.	C	25	32° 44′.5	117° 55′.5	....	....	....	20	....	....	....
1797	July	2	12:45– 1:05 p.m.	C	25	32° 41′.2	117° 32′.3	....	....	....	84	....	....	....
1851	July	9	4:33– 4:43 a.m.	B	25	32° 52′.3	117° 20′.0	....	....	7	2	....	....	....
1870	July	9	7:55– 8:05 p.m.	B	25	32° 52′.3	117° 20′.0	....	....	....	4	....	....	....
1876	July	9	11:30–11:45 p.m.	B	25	32° 52′.3	117° 20′.0	....	4	....	......	....	....	....
1984	Nov.	5	12:42–12:52 p.m.	B	25	32° 40′.6	117° 30′.3	....	....	1	......	....	....	....
1844	July	8	1:35– 1:45 p.m.	B	30	32° 52′.5	117° 19′.0	....	....	....	15	....	....	....

TABLE 30—*Continued*

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day and Duration of haul	Net used	Depth in fathoms	North Latitude	West Longitude	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1909												
1861	July 9	6:18– 6:30 p.m.	B	30	32° 52′.3	117° 20′.0	....	....	5	......	....	....	....
1858	July 9	6:10– 6:23 a.m.	B	35	32° 52′.3	117° 20′.0	....	....	2	1	....	....	....
	1908												
1476	June 21	11:00 a.m.	B	50	32°	117°	1	....	....	300	1	....	....
1603	July 24	12:33–12:41 p.m.	B	50	32° 51′.4	117° 18′.2	....	....	....	70	....	....	....
	1909												
1708	June 24	4:58– 5:15 p.m.	C	50	32° 52′.0	117° 30′.0	....	....	....	3	....	....	....
1760	June 29	5:25– 5:50 a.m.	B	50	32° 52′.0	117° 30′.0	....	....	3	......	....	....	....
1816	July 7	5:30– 5:55 a.m.	B	50	32° 52′.0	117° 30′.0	....	1	....	......	....	....	....
1828	July 7	6:55– 7:20 p.m.	B	50	32° 52′.3	117° 20′.0	....	....	....	3	....	....	....
1846	July 8	2:10– 2:20 p.m.	B	50	32° 52′.1	117° 18′.4	....	....	....	1	....	....	....
1857	July 9	5:05– 5:18 a.m.	B	50	32° 52′.3	117° 20′.0	....	....	6	......	....	....	....
1866	July 9	7:15– 7:25 p.m.	B	50	32° 52′.3	117° 20′.0	....	....	....	5	....	....	....
1929	Sept. 3	2:53– 3:12 p.m.	B	50	32° 53′.6	117° 53′.7	4	....	....	......	....	....	....
1966	Nov. 3	5:20– 5:28 p.m.	B	50	32° 53′.6	117° 30′.0	....	....	6	......	....	....	....
	1908												
1575	July 22	10:44–10:55 a.m.	B	75	32° 52′.8	117° 31′.8	....	....	76	65	....	....	....
	1909												
1928	Sept. 3	2:17– 2:40 p.m.	B	75	32° 55′.2	117° 54′.8	....	8	....	......	....	....	....

TABLE 30—*Continued*

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day and Duration of haul	Net used	Depth in fathoms	North Latitude	West Longitude	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1909												
1688	June 22	4:40– 5:20 a.m.	C	100	32° 52′.6	117° 36′.0	....	4	4	......	....	....	....
1691	June 23	4:55– 5:20 a.m.	C	100	32° 52′.0	117° 30′.0	....	....	20	......	....	....	....
1714	June 24	6:25– 6:45 p.m.	B	100	32° 52′.0	117° 30′.0	....	1	9	......	....	....	....
1725	June 25	4:45– 5:15 p.m.	C	100	32° 52′.0	117° 30′.0	....	....	....	2	....	....	....
1757	June 29	4:40– 4:50 a.m.	B	100	32° 52′.0	117° 30′.0	....	1	....	2	....	....	....
1813	July 7	4:25– 5:00 a.m.	B	100	32° 52′.0	117° 30′.0	....	2	12	......	....	....	....
1869	July 9	7:35– 7:45 p.m.	B	100	32° 52′.3	117° 20′.0	....	....	....	5	....	....	....
1947	Nov. 2	7:16– 7:30 a.m.	B	100	32° 50′.0	117° 30′.0	....	....	3	......	....	....	....
1965	Nov. 3	4:40– 4:50 p.m.	B	100	32° 53′.2	117° 30′.0	....	....	5	......	....	....	....
1979	Nov. 5	11:51–12:00 a.m.	B	100	32° 40′.6	117° 30′.3	....	1	30	......	....	....	....
1736	June 25	8:12– 8:32 p.m.	B	110	32° 52′.0	117° 30′.0	....	....	....	......	....	2	....
1927	Sept. 3	1:22– 1:39 p.m.	B	125	32° 52′.6	117° 55′.9	....	11	21	......	1	....	....
1756	June 28	8:50– 9:16 p.m.	B	150	32° 52′.0	117° 30′.0	....	....	2	......	....	....	....
1735	June 25	7:34– 7:54 p.m.	B	160	32° 52′.0	117° 30′.0	....	1	16	......	....	....	....
1690	June 22	6:35– 6:50 a.m.	B	200	32° 51′.9	117° 35′.6	....	....	10	......	....	....	....
1700	June 23	7:25– 7:45 a.m.	B	200	32° 52′.0	117° 30′.0	....	....	4	......	....	....	....
1745	June 28	6:28– 6:48 p.m.	B	200	32° 52′.0	117° 30′.0	....	....	3	......	....	....	....
1926	Sept. 3	12:21–12:52 p.m.	B	200	32° 52′.1	117° 57′.0	....	13	46	......	1	....	3
1948	Nov. 2	7:43– 8:03 a.m.	B	200	32° 50′.0	117° 30′.0	....	2	13	......	....	....	....

TABLE 30—*Continued*

Number of specimens obtained							Data concerning each haul						
Haul number	Date	Time of day and Duration of haul	Net used	Depth in fathoms	North Latitude	West Longitude	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1909												
1964	Nov. 3	4:20– 4:35 p.m.	B	200	32° 53.′2	117° 30.′0	....	....	40	......	....	....	....
1978	Nov. 5	11:25–11:35 a.m.	B	200	32° 40.′6	117° 30.′3	....	1	29	......	....	....	1
1732	June 25	6:53– 7:14 p.m.	B	220	32° 52.′0	117° 30.′0	....	1	13	......	....	....	....
	1908												
1557	July 17	1:45– 2:30 p.m.	B	250	32° 24.′2	119° 6.′2	....	50	24	......	....	....	....
	1909												
1729	June 25	6:13– 6:35 p.m.	B	250	32° 52.′0	117° 30.′0	....	2	17	......	....	....	....
1963	Nov. 3	2:53– 3:13 p.m.	B	300	32° 52.′0	117° 30.′0	....	....	....	......	....	2	....
	1908												
1550	July 16	11:45 a.m.–12:40 p.m.	B	350	32° 49.′2	118° 14.′9	....	2	....	......	3	....	....
1567	July 21	1:06– 1:19 p.m.	B	350	32° 49.′2	118° 14.′9	....	....	2	......	....	2	....

TABLE 31

Data concerning Horizontal Closing Net Hauls containing no Chaetognatha.

Haul number	Date		Time of day and Duration of haul	Net used	Depth in fathoms	North Latitude	West Longitude
	1909						
1842	July	8	12:55– 1:05 p.m.	B	5	32° 52′.5	117° 19′.5
1843	July	8	1:17– 1:28 p.m.	B	5	32° 52′.5	117° 19′.2
1856	July	9	5:27– 5:40 a.m.	B	5	32° 52′.3	117° 20′.0
1808	July	2	6:43– 7:05 p.m.	C	6	32° 40′.0	117° 26′.0
1865	July	9	6:53– 7:08 p.m.	B	7½	32° 52′.3	117° 20′.0
1841	July	8	12:40– 1:00 p.m.	C	7–8	32° 52′.2	117° 19′.3
1805	July	2	4:55– 5:25 p.m.	C	8	32° 40′.0	117° 26′.0
1820	July	7	6:32– 6:55 a.m.	B	10	32° 52′.0	117° 30′.0
1840	July	8	12:35–12:45 p.m.	B	10	32° 52′.2	117° 19′.3
1855	July	9	5:12– 5:22 a.m.	B	10	32° 52′.3	117° 20′.0
1794	July	2	9:52–10:09 a.m.	C	12	32° 44′.5	117° 53′.5
1801	July	2	1:38– 2:00 p.m.	C	12	32° 41′.2	117° 32′.3
1817	July	7	6:05– 6:25 a.m.	B	25	32° 52′.0	117° 30′.0
1830	July	7	7:25– 7:45 p.m.	B	25	32° 52′.3	117° 20′.0
1884	July	10	4:25– 4:40 a.m.	B	25	32° 53′.0	117° 18′.0
1930	Sept.	3	3:22– 3:37 p.m.	B	25	32° 53′.9	117° 53′.2
1944	Nov.	2	6:21– 6:41 a.m.	B	25	32° 52′.0	117° 30′.0
	1908						
1572	July	22	9:16– 9:29 a.m.	B	30	32° 51′.4	117° 33′.3
	1909						
1970	Nov.	3	5:20– 5:30 p.m.	B	30	32° 54′.1	117° 30′.0
	1908						
1542	July	9	6:45– 7:00 p.m.	B	50	33° 0′.2	118° 31′.3
1620	Aug.	29	10:30–11:14 a.m.	B	50	29° 8′.6	118° 16′.8
	1909						
1704	June	23	8:55– 9:17 a.m.	B	50	32° 52′.0	117° 30′.0
1739	June	25	8:41– 9:00 p.m.	B	50	32° 52′.0	117° 30′.0
1752	June	28	7:42– 8:05 p.m.	B	50	32° 52′.0	117° 30′.0
1909	Sept.	1	12:55– 1:25 p.m.	C	50	33° 0′.0	118° 41′.2
1946	Nov.	2	6:50– 7:05 a.m.	B	50	32° 52′.0	117° 30′.0
1980	Nov.	5	12:11–12:35 p.m.	B	50	32° 40′.6	117° 30′.3
	1908						
1621	Aug.	30	10:52–11:01 a.m.	B	100	29° 8′.6	118° 17′.5
	1909						
1753	June	28	8:15– 8:38 p.m.	B	100	32° 52′.0	117° 30′.0
1824	July	7	6:30– 6:50 p.m.	B	100	32° 53′.3	117° 20′.0
1684	June	21	9:20– 9:45 p.m.	B	150	32° 53′.0	117° 32′.7
1701	June	23	8:15– 8:25 a.m.	B	150	32° 52′.0	117° 30′.0
1764	June	29	6:30– 7:10 a.m.	B	150	32° 52′.0	117° 30′.0
	1908						
1576	July	22	12:33–12:46 a.m.	B	200	32° 55′.6	117° 30′.4
	1909						
1683	June	21	8:10– 8:40 p.m.	B	250	32° 52′.8	117° 33′.2
1699	June	23	6:35– 7:00 a.m.	B	250	32° 52′.0	117° 30′.0
	1908						
1578	July	22	1:52– 2:07 p.m.	B	300	32° 57′.6	117° 28′.8
	1909						
1726	June	25	5:00– 5:55 p.m.	B	300	32° 52′.0	117° 30′.0
1925	Sept.	3	10:41–11:11 a.m.	B	300	32° 51′.2	117° 59′.1

TABLE 32

Distribution with Respect to Vertical Closing Net Hauls.

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day[1]	Net used	Depth in fathoms	North Latitude	West Longitude	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1910												
2022	Feb. 18	8:00 p.m.	C	25– 10	32° 51′.2	117° 31′.5	....	....	......	4	....	....	....
2043	March 15	4:18 p.m.	C	25– 10	32° 40′.4	117° 31′.0	....	....	......	6	....	....	....
2047	March 15	5:26 p.m.	C	25– 10	32° 40′.4	117° 31′.0	....	....	13	....	....	....	....
2077	March 17	3:24 p.m.	C	25– 10	32° 50′.0	117° 30′.0	....	....	......	2	....	....	....
2104	March 17	7:34 p.m.	C	25– 10	32° 50′.0	117° 30′.0	....	....	20	4	....	....	....
1990	Feb. 17	7:03 a.m.	C	50– 25	32° 39′.4	117° 29′.9	....	....	1	....	....	....	....
2020	Feb. 18	7:35 p.m.	C	50– 25	32° 51′.2	117° 31′.5	....	....	1	....	....	....	....
2042	March 15	4:05 p.m.	C	50– 25	32° 40′.4	117° 31′.0	....	....	......	15	....	....	....
2060	March 16	4:20 p.m.	C	50– 25	32° 40′.4	117° 31′.2	....	....	......	10	....	....	....
2076	March 17	3:14 p.m.	C	50– 25	32° 50′.0	117° 30′.0	....	....	4	28	....	....	....
2100	March 17	7:24 p.m.	C	50– 25	32° 50′.0	117° 30′.0	....	....	12	4	....	....	....
2105	April 19	8:37 a.m.	F	50– 25	32° 23′.3	117° 19′.9	....	....	......	3	....	....	....
2118	April 20	3:00 a.m.	F	50– 25	32° 23′.3	117° 20′.0	....	....	......	2	....	....	....
2130	April 21	3:07 a.m.	F	50– 25	32° 23′.5	117° 22′.8	....	....	9	....	....	....	....
2141	April 21	6:12 a.m.	F	50– 25	32° 23′.5	117° 20′.9	....	....	......	3	....	9	....
2038	March 15	3:52 p.m.	C	75– 50	32° 40′.4	117° 31′.0	2	....	78	....	....	....	....
2059	March 16	4:08 p.m.	C	75– 50	32° 40′.4	117° 31′.2	....	....	......	43	....	....	....
2075	March 17	2:59 p.m.	C	75– 50	32° 50′.0	117° 30′.0	....	....	12	73	....	....	....
2099	March 17	6:53 p.m.	C	75– 50	32° 50′.0	117° 30′.0	....	....	78	....	....	....	....
2106	April 19	8:54 a.m.	F	75– 50	32° 22′.8	117° 19′.6	....	....	4	....	....	....	....
2119	April 20	3:15 a.m.	F	75– 50	32° 23′.0	117° 19′.9	....	1	4	....	....	....	....

TABLE 32—*Continued*

Data concerning each haul							Number of specimens obtained						
Haul number	Date 1910	Time of day[1]	Net used	Depth in fathoms	North Latitude	West Longitude	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
2131	April 21	3:21 a.m.	F	75– 50	32° 23′.5	117° 22′.7	....	....	5	....	....	....	....
2142	April 21	6:23 a.m.	F	75– 50	32° 23′.5	117° 20′.6	....	....	9	....	....	....	9
2037	March 15	3:35 p.m.	C	100– 75	32° 40′.4	117° 31′.0	....	3	40	....	....	....	....
2058	March 16	3:55 p.m.	C	100– 75	32° 40′.4	117° 31′.2	....	....	11	34	....	....	....
2074	March 17	2:43 p.m.	C	100– 75	32° 50′.0	117° 30′.0	....	1	263	....	....	....	....
2095	March 17	6:37 p.m.	C	100– 75	32° 50′.0	117° 30′.0	....	1	128	10	....	....	....
2107	April 19	9:09 a.m.	F	100– 75	32° 22′.5	117° 19′.4	....	....	......	3	....	....	....
2120	April 20	3:36 a.m.	F	100– 75	32° 22′.8	117° 19′.5	....	....	......	2	....	....	....
2132	April 21	3:36 a.m.	F	100– 75	32° 23′.5	117° 22′.6	....	....	......	3	....	....	....
1996	Feb. 17	8:27 a.m.	C	150–100	32° 39′.6	117° 31′.5	....	1	14	....	....	....	....
2018	Feb. 18	6:57 p.m.	C	150–100	32° 23′.3	117° 20′.0	....	....	44	....	....	....	....
2036	March 15	3:00 p.m.	C	150–100	32° 40′.4	117° 31′.0	....	....	206	....	....	....	....
2057	March 16	3:37 p.m.	C	150–100	32° 40′.4	117° 31′.2	....	3	170	34	....	....	....
2073	March 17	2:23 p.m.	C	150–100	32° 50′.0	117° 30′.0	....	....	156	....	....	....	....
2094	March 17	6:17 p.m.	C	150–100	32° 50′.0	117° 30′.0	1	....	165	....	....	....	....
2108	April 19	9:32 a.m.	C	150–100	32° 21′.9	117° 19′.0	....	....	15	....	....	....	....
2133	April 21	3:54 a.m.	F	150–100	32° 23′.5	117° 22′.5	....	....	3	....	....	....	....
2144	April 21	6:50 a.m.	F	150–100	32° 23′.5	117° 20′.0	....	....	......	3	....	....	....
1997	Feb. 17	9:35 a.m.	C	200–150	32° 39′.5	117° 31′.5	....	5	168	....	....	....	2
2017	Feb. 18	6:30 p.m.	C	200–150	32° 51′.2	117° 31′.5	....	....	15	....	....	....	....
2032	March 15	2:28 p.m.	C	200–150	32° 40′.4	117° 31′.0	....	11	248	....	....	....	....

TABLE 32—*Continued*

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day[1]	Net used	Depth in fathoms	North Latitude	West Longitude	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1910												
2053	March 16	3:08 p.m.	C	200–150	32° 40′.4	117° 31′.2	....	3	345	....	....	1	....
2069	March 17	2:02 p.m.	C	200–150	32° 50′.0	117° 30′.0	....	10	400	....	....	....	1
2090	March 17	5:58 p.m.	C	200–150	32° 50′.0	117° 30′.0	....	3	100	....	....	....	....
2112	April 19	9:55 a.m.	C	200–150	32° 20′.5	117° 18′.1	....	1	49	....	1	....	....
2122	April 20	4:33 a.m.	F	200–150	32° 22′.4	117° 19′.4	....	....	2	....	....	....	....
2134	April 21	4:20 a.m.	F	200–150	32° 23′.5	117° 22′.4	....	....	24	....	....	....	....
2001	Feb. 17	10:06 a.m.	C	250–200	32° 39′.0	117° 31′.4	....	2	140	1	2	4	....
2031	March 15	2:01 p.m.	C	250–200	32° 40′.4	117° 31′.0	....	3	190	....	3	....	3
2052	March 16	2:41 p.m.	C	250–200	32° 40′.4	117° 31′.2	....	6	240	....	1	1	10
2068	March 17	12:57 p.m.	C	250–200	32° 50′.0	117° 30′.0	....	9	715	....	....	....	11
2089	March 17	5:37 p.m.	C	250–200	32° 50′.0	117° 30′.0	....	5	129	....	....	....	1
2113	April 19	10:28 a.m.	C	250–200	32° 20′.4	117° 18′.0	....	1	21	....	....	....	....
2149	April 21	7:36 a.m.	F	250–200	32° 23′.5	117° 20′.0	....	....	2	....	....	1	....
2048	March 16	1:20 p.m.	C	300–250	32° 40′.4	117° 31′.2	....	6	264	....	....	....	....
2067	March 17	1:10 p.m.	C	300–250	32° 50′.0	117° 30′.0	....	5	478	....	2	1	2
2081	March 17	4:20 p.m.	C	300–250	32° 50′.0	117° 30′.0	....	11	316	....	6	....	3
2139	April 21	5:19 a.m.	F	300–250	32° 23′.5	117° 21′.6	....	....	1	....	....	....	....

[1] Hauls were all made at approximately the same velocity and therefore the time consumed or duration of haul varied from 2 to 5 minutes, depending upon distance of haul. For this reason the duration of each haul is not given.

TABLE 33

Data Concerning Vertical Closing Net Hauls Containing no Chaetognatha.

Haul number	Date	Time of day	Net used	Depth in fathoms	North Latitude	West Longitude
	1910					
1994	Feb. 17	7:17 a.m.	C	75– 50	32° 39′.6	117° 30′.5
1995	Feb. 17	8:07 a.m.	C	100– 75	32° 40′.0	117° 32′.0
2143	April 21	6:35 a.m.	F	100– 75	32° 23′.5	117° 20′.5
2121	April 20	3:59 a.m.	F	150–100	32° 22′.5	117° 19′.4
2135	April 21	4:47 a.m.	F	250–200	32° 23′.5	117° 22′.3
2027	March 15	1:32 p.m.	C	300–250	32° 40′.4	117° 31′.0

TABLE 34

Distribution with Respect to Open Vertical Net Hauls.

Data concerning each haul							Number of specimens obtained							
Haul number	Date	Time of day	Net used	Depth in fathoms	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1904													
236	Aug. 9	7:10 a.m.	A	2–0	32° 38′.7	117° 22′.3	....	....	....	......	250	1	....	....
217	July 23	9:30 p.m.	A	5–0	32° 35′.0	117° 18′.8	....	....	....	......	700	....	....	....
218	July 23	10:00 p.m.	A	5–0	32° 35′.0	117° 18′.8	....	....	....	......	800	....	....	....
234	Aug. 8	9:30 a.m.	A	5–0	32° 34′.1	117° 19′.7	1	....	....	......	375	....	....	....
219	July 23	9:30 p.m.	A	10–0	32° 35′.0	117° 18′.0	....	....	....	......	2100	....	....	....
235	Aug. 8	10:00 a.m.	A	10–0	32° 34′.1	117° 19′.7	5	....	....	......	2500	....	....	....
251	Aug. 27	7:10 a.m.	A	10–0	32° 36′.5	117° 30′.6	1	....	....	......	471	....	....	....
274	Sept. 17	7:00 a.m.	A	10–0	32° 38′.6	117° 24′.0	3500	....	....	......	2700	....	....	....
	1908													
1571	July 22	8:15 a.m.	A	10–0	32° 50′.6	117° 33′.8	....	....	....	......	5	....	....	....
1574	July 22	10:15 a.m.	A	10–0	32° 53′.3	117° 32′.3	....	....	....	......	1	....	....	....
	1910													
2023	Feb. 18	8:08 p.m	C	10–0	32° 51′.2	117° 31′.5	....	....	....	......	3	....	....	....
	1908													
1570	July 22	8:00 a.m.	B	20–0	32° 50′.1	117° 34′.0	....	....	....	......	10	....	....	....
	1909													
1838	July 8	11:05 a.m.	A	20–0	32° 51′.3	117° 18′.8	....	....	....	......	25	....	....	....
	1910													
2117	April 20	2:47 a.m.	F	25–0	32° 23′.3	117° 20′.0	....	....	....	......	6	....	....	....
2129	April 21	2:57 a.m.	F	25–0	32° 23′.5	117° 23′.2	....	....	....	2	....	....	....	....
2140	April 21	5:39 a.m.	F	25–0	32° 23′.5	117° 21′.0	....	....	....	......	5	....	....	....

TABLE 34—*Continued*

Data concerning each haul							Number of specimens obtained							
Haul number	Date	Time of day	Net used	Depth in fathoms	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
468	1905 April 22	6:00 a.m.	A	45–0	32° 34′.9	117° 16′.1	10	1	....	......	400	....	....	....
263	1904 Sept. 10	6:30 a.m.	A	50–0	32° 35′.0	117° 20′.8	....	....	....	......	3200	....	....	....
1677	1909 June 21	6:20 p.m.	C	50–0	32° 51′.7	117° 29′.7	....	....	....	......	50	....	....	....
1393	1907 June 24	7:00 a.m.	A	60–0	32° 53′.2	117° 17′.2	....	....	....	......	30	....	....	....
1398	July 3	10:00 a.m.	A	75–0	32° 53′.6	117° 17′.4	1	....	....	......	300	....	....	....
1402	July 9	9:00 a.m.	A	75–0	32° 53′.3	117° 18′.3	....	....	....	......	400	....	....	....
1848	1909 July 9	3:50 a.m.	B	75–0	32° 52′.3	117° 20′.0	....	....	3	6	10	....	....	....
1387	1907 June 17	7:00 a.m.	A	80–0	32° 53′.0	117° 18′.3	....	....	....	......	15	....	....	....
262	1904 Sept. 10	6:00 a.m.	A	90–0	32° 35′.0	117° 20′.8	....	....	....	......	1200	....	....	....
1495	1908 June 25	11:00 a.m.	A	100–0	32° 55′.2	117° 21′.4	....	....	....	......	1000	....	....	....
175	1904 July 12	8:30 a.m.	A	105–0	32° 34′.1	117° 19′.7	....	....	....	......	50	....	....	....

TABLE 34—*Continued*

Data concerning each haul							Number of specimens obtained							
Haul number	Date	Time of day	Net used	Depth in fathoms	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1905													
462	April 15	6:00 a.m.	A	110–0	32° 45′.3	117° 27′.2	1	4	.....	1	80	....	....	....
	1908													
1508	June 27	5:58 a.m.	A	150–0	32° 54′.1	117° 21′.0	....	....	12	48	43	2	....	....
1524	July 1	12:15 p.m.	A	150–0	33° 11′.3	118° 8′.1	....	....	....	......	20	....	....	....
	1904													
143	July 5	10:00 a.m.	A	200–0	32° 40′.1	117° 26′.5	....	....	....	......	8	....	....	....
	1908													
1492	June 25	10:10 a.m.	A	210–0	32° 55′.2	117° 21′.4	....	1	5	20	75	3	....	....
1494	June 25	11:00 a.m.	A	210–0	32° 55′.2	117° 21′.4	....	....	7	10	25	....	....	....
1516	June 30	9:20 a.m.	A	250–0	32° 54′.4	117° 21′.5	....	2	9	10	40	....	....	....
	1910													
2088	March 17	5:11 p.m.	C	250–0	32° 50′.0	117° 30′.0	....	....	8	382	2	3	1	3
	1908													
1483	June 24	10:00 a.m.	A	284–0	33° 5′.0	117° 29′.8	....	....	....	6	20	....	....	....
1468	June 19	9:35 a.m.	A	290–0	32° 58′.8	117° 22′.8	1	....	7	60	6	2	1	....
	1909													
1717	June 24	7:15 p.m.	B	300–0	32° 51′.0	117° 30′.0	....	....	1	13	8	....	1	....
	1908													
1527	July 2	11:20 a.m.	A	500–0	32° 58′.3	118° 14′.7	....	1	2	60	10	2	20	....

GENERAL DISCUSSION OF THE PROBLEMS OF DISTRIBUTION

Any interpretation of the data contained in the above tables depends on what we regard as adequate methods of collecting. The numerous methods employed may be distinguished according to the purpose in collecting. If we desire to study a single species from some morphological, physiological, or other special standpoint, or if we desire to study the number and range of species over extensive areas, we will employ any apparatus adapted to collecting the material. If, however, we desire to study quantitative relations among species, or the abundance of each in any region, we must employ specially constructed apparatus and collect with respect to the conditions affecting this abundance.

Most single expeditions have endeavored to increase our knowledge of the number and range of species over extensive areas. For instance, the monumental achievements of the "Challenger" expedition consist in having collected and described an enormous number of species representing nearly every class of animals. To determine the general environment of the species obtained from each locality, the hydrographic and meteorological conditions were investigated. The knowledge thus acquired is exceedingly valuable but, owing to the immense region explored, it is necessarily lacking in detail. The methods of collecting employed, while adequate for purposes of preliminary exploration, did not obtain sufficient data to permit interpretations respecting the abundance of each species collected. Such interpretations depend entirely on more special and detailed methods of collecting.

These special methods have been mainly developed under the auspices of the "Kiel Commission" by Hensen, Lohmann, Apstein, and other German investigators. They deserve much credit for originating the methods and inventing valuable apparatus for collecting plankton and analyzing the chemical and physical conditions of the sea. They have calculated filtration capacities, and coefficients of correction for a variety of nets, and have materially increased our mathematical and experimental knowledge concerned in quantitative estimates of plankton. Any one acquainted with Hensen's (1895) "Methodik der Untersuchung" knows how excellently this difficult and laborious work has been done.

From these important researches the "Kiel school" has drawn conclusions of vast significance which, however, are based on insufficient data. One illustration is enough. On the basis of 167 hauls made during the early spring of 1895 in the North Sea, Hensen and Apstein (1897) estimated that the surface waters contained 157,000,000,000 fish eggs. From a knowledge of the average number of eggs annually produced by each species these authors state that the number of mature food fishes in the North Sea may be estimated. As pointed out by Herdman (1906) this estimate is based on one successful haul (only 158 of the 167 hauls made contained fish eggs) for each 3,465,968,354 square meters, or approximately 133,800 square miles, of the sea. Concerning this estimate Johnstone (1908, p. 168) says: "Such an investigation presents fewer difficulties than are encountered in other quantitative researches." Probably Johnstone (1908) has reference to difficulties in calculating filtration capacities and various coefficients of correction for the nets used, but will even the simplest calculation justify such a "collossal conclusion" when based on only one haul from each 133,800 square miles of the sea?

Obviously the reliability of such results depends on uniformity in distribution of plankton over a large area. Are we warranted in assuming that this uniformity exists? Concerning this Herdman (1906, p. 35) says: "On the West Coast of Scotland I have seen large Copepoda so abundant for a mile or two that they seemed from the deck of a yacht to be dancing in crowds in the water . . . . in a few minutes we passed out of the swarm." Again (p. 36) he says: "In the Red Sea and on several occasions in the Indian Ocean I have seen *Trichodesmium erythraeum* forming a most conspicuous red-brown or tawny yellow-brown scum on the surface of the sea for, it might be, a few hundred yards up to a mile in width, and several or even many miles in length, while the sea at each side of the patch was entirely free from the organism." It is unnecessary to quote the numerous similar instances noted by many naturalists. Their significance in relation to the conclusions of the "Kiel school" is evident.

The data in this paper contain numerous examples of this lack of uniformity in distribution of the Chaetognatha of the San Diego region. Some of these examples are as follows:

1. On July 18, 1908, two surface hauls, 1559 and 1560, were made with the same net in the region of Cortez Banks at 32° 24′.2 N and 119° 6′.2 W. Haul 1559 was made at 6:20 a.m., lasted 10 minutes, and contained 2,000 specimens of *Sagitta bipunctata*. Haul 1560 was made at 7:20 a.m., lasted 40 minutes, and contained 527 of the same species. The temperature of the water during each haul was 16°.5 C. If, as indicated by the temperature, the current remained uniform during both hauls, then the net filtered four times more water during haul 1560 than during haul 1559. Consequently the number of *S. bipunctata* varied from 15 at 6:20 a.m. to 1 at 7:20 a.m. per unit volume of water.

2. On July 24, 1908, two surface hauls, 1597 and 1600, were made with the same net. The temperature during each haul was 20°.5 C., and the salinity varied from 33.549 during the first haul to 33.603 during the second. Haul 1597 was made at 4:26 a.m. at 32° 51′.4 N and 117° 22′.2 W. Haul 1600 was made at 4:58 a.m., and the position of the "Agassiz" was 0′.1 farther north and 0′.4 farther west. Each haul lasted 20 minutes. Haul 1597 contained 75 and haul 1600, 3 specimens of *S. bipunctata*. Thus the number of specimens varied from 25 to 1 per unit volume of water.

3. On June 17, 1909, two surface hauls, 1659 and 1661, were made with the same net *while the "Agassiz" was tied to its mooring*. Haul 1659 lasted from 5:00 to 6:00 p.m. and contained 13 specimens of *S. bipunctata*. Haul 1661 lasted from 6:45 to 7:30 p.m. and contained 550 specimens of the same species. Unless the current changed between 5:00 and 7:30 p.m., the net filtered one-fourth more water during haul 1659 than during haul 1661 and the number of specimens obtained per unit volume of water would be in the proportion of about 1 to 56. This difference is all the more striking when we consider that two other hauls were made with the same net at the same mooring on the

same evening, one from 6:00 to 6:45 p.m., the other from 7:30 to 8:00 p.m., which did not contain a single Chaetognath, and that the temperature of the water was 18°.4 C. during all four hauls.

4. On June 21, 1909, two surface hauls, 1680 and 1682, were made with the same net, the former at 32° 52'.0 N and 117° 32'.9 W, and the latter 0'.1 farther north and 0'.2 farther west. Haul 1680 began at 7:00 p.m., haul 1682 at 7:40 p.m., and each lasted 35 minutes. The former contained 3600 and the latter 80 specimens of *S. bipunctata.* Thus, within one hour the number of specimens varied from 45 to 1 per unit volume of water.

5. On June 28, 1909, four surface hauls, 1744, 1747, 1751, and 1754, were made with the same net at 32° 52'.0 N and 117° 30'.0 W. Haul 1744 lasted from 5:00 to 5:20 p.m., haul 1747 from 6:35 to 7:11 p.m., haul 1751 from 7:15 to 8:00 p.m., and haul 1754 from 8:10 to 8:50 p.m. The first haul contained 2 specimens of *S. bipunctata,* the second contained none, the third contained 155, and the fourth contained 1100. The temperature of the water was 19°.2 during haul 1744, and the salinity was 33.648 During the other three hauls the temperature was 19.2° and the salinity was 33.603. The number of specimens per unit volume of water bear the proportion of 1 to 0 to 128 to 1100.

6. On July 9, 1909, three surface hauls, 1850, 1854, and 1860, were made with the same net at 32° 52'.3 N and 117° 20'.0 W. The temperature of the water was 18°.8 C. during the first two hauls and 18°.62 during the third. The salinity was 33.690 during haul 1850, 33.570 during haul 1854, and 33.589 during haul 1860. Haul 1850 lasted from 3:30 to 4:15 a.m., haul 1854 from 4:20 to 5:15 a.m., and haul 1860 from 5:18 to 6:25 a.m. The first contained 270 specimens of *S. bipunctata,* the second contained 6, and the third contained 4. From 3:30 to 6:25 a.m. the number of specimens per unit volume of water varied from 135 to 1.

7. This example illustrates the rapid rate with which some physical conditions of the water may change. Surface haul 1868, made on July 9, 1909, from 7:03 to 7:36 p.m. at 32° 52'.3 N and 117° 20'.0 W, contained 10 specimens of *S. bipunctata.* A

second haul, 1872, made with the same net at the same location and lasting from 7:40 to 8:15 p.m. contained 4300 of the same species. In this instance the number of specimens per unit volume of water was approximately 1 to 430 but, during the first haul, the temperature of the water was 19° C. and the salinity 33.589, while during the second haul the temperature was 18?8 C. and the salinity 33.630. Obviously a change of 0?2 in temperature and 0.041 in salinity took place within 37 minutes, and these changes possibly involved an alteration in current and other physical conditions of the water.

Other instances might be cited, but enough have been given to show that the surface distribution of *S. bipunctata* is not constant for any length of time even in very small areas. The objection will be made that hydrographic and meteorological conditions change rapidly near the coast but remain constant on the high seas. I doubt the validity of such an objection. In the first place, owing to variations in wind, rain, light, barometric pressure, heat, etc., it is very improbable that hydrographic and meteorological conditions even approach constancy on the high seas. In the second place, some of the above examples show that *S. bipunctata* varied in abundance even when these conditions, so far as known, remained constant during the period within which the contrasted hauls were made.

Hydrographic and meteorological conditons of the region in which collections are made certainly affect the quantity of plankton present, but does this warrant the assumption that *other conditions* do not also affect it? According to Johnstone (1908), who has championed the cause of the "Kiel school," we are justified in making this assumption. He says (p. 157): "The validity of all conclusions as to the general abundance of microscopic life in the sea depends on the truth of the postulate, that wherever in the sea the *physical conditions* [italics mine] are uniform, there also the composition and abundance of the plankton is uniform."

The truth of this postulate depends upon what is implied by the term "physical conditions." Obviously Johnstone does not mean merely physical conditions for, without chemical and bacterial activity in the sea, plankton could not exist. If "physical conditions" mean *all conditons in the sea affecting the quantity of plankton*, then the postulate, while true, is meaningless, because it reduces to the statement that if all causes are uniform their effects will be uniform. Again, if the term includes only those conditions in the sea *not due to the behavior of organisms*, the postulate is not true, for it is apparent that rate of growth, rate of reproduction, and food-relations of marine fauna and flora do influence the quantity of plankton. Furthermore, the term may imply that physical conditions have a *more significant effect* than other conditions on the quantity of plankton, and that, consequently, we may disregard these other conditions in estimating its abundance. If this is true, the postulate rests on the assumption that the effects of these other conditions are known, for otherwise we could not distinguish *more significant* from *less significant* effects. It is, however, difficult to believe that all effects on the quantity of plankton in an area of 133,800 square miles could be discovered from evidence obtained during one haul. Finally the term may imply that, owing to a *perfect equilibrium* between all conditions affecting the quantity of plankton, knowledge of the effects of some may be regarded as an index to the effects of all. This supposition, however, involves the enormous assumption that such an equilibrium does exist, and this is certainly not justified by the present state of our knowledge.

Evidently the term "physical conditions" lacks meaning in the sense in which it is used, and consequently the above postulate collapses. Therefore, all calculations based upon this postulate necessarily lead to erroneous conclusions.

Any postulate concerning the abundance of plankton that fails to recognize the influence of organisms on this abundance is inadequate. This is well illustrated by the investigations of Herdman, Scott, and Dakin (1910) who have conducted a very extensive, as well as "intensive study of the marine plankton around the south end of the Isle of Mann." After very careful and excellent investigations they conclude (p. 295): "Some organisms show a remarkable regularity in their time of appearance. For example, the nauplii of *Balanus* began to appear on February 22nd in '07, on February 13th in '08, and on February 6th in '09. This is one of the cases where it is clear that the normal sequence of events in the life-history of the organism is the dominant factor in determining the constitution of the plankton at a definite time and place—the periodic reproduction of the *Balanus* causes the nauplii to appear in the plankton at a certain time.'' Again (p. 296): ''Many other swarms of neritic, and especially meroplanktonic, forms (such as crab zoeas and fish eggs) are similarly due to the succession of stages in the life history . . . .'' We are therefore compelled to acknowledge a very definite causal relation between rate of reproduction and variations in the quantity of plankton.

The influence of organisms on the abundance of plankton is illustrated further, and from quite a different standpoint, by the effects of ''red-water'' due to *Gonyaulax*, on various marine animals, which is discussed by Torrey (1902) in an article entitled ''An unusual occurrence of Dinoflagellata on the California Coast.' He says (p. 187): ''It was first noticed on July 7 as a red streak off the mouth of San Pedro Harbor. During the next few days it approached the shore, changing its shape and dividing into several patches, each many acres in extent. . . . The 'red-water' extended for two hundred miles at least along the coast, from the region of Santa Barbara to San Diego, and extended several miles to sea.'' On July 20 Torrey noticed a ''sickening odor'' arising from the ''red-water,'' and during the next few days he found the following animals on the beach, which were either dead or debilitated. Several hundred *Trachostoma arenata*, many smelts, *Petrolisthes cinctipes,* and *Cancer antennaius*, great numbers of *Hippa analoga,* a number of *Tevila crassatelloides*, and several *Mylobatis californicus*, *Urolophus halleri*, and octopi. It is also noted that ''wherever it [red-water] was seen the fishermen reported a scarcity of food fishes.'' While most of the animals known to have been affected are not included in what we call plankton, still it is improbable that the plankton was unaffected and, if so, we must acknowledge that the *abundance of plankton may be influenced by the occurrence of large numbers of Gonyaulax.*

It may be claimed that, if the physical and chemical conditions in the "red-water" area had not been what they were *Gonyaulax* would not have occurred in such large numbers and, consequently, the effect of *Gonyaulax* on the abundance of organisms was, after all, due to physical and chemical causes. However, is it not equally true that the effects of the physical and chemical condition of the water on the abundance of organisms were due to *biological causes?* Obviously, had *Gonyaulax* not been present, the physical and chemical condition of the water could not have disabled or killed the animals above mentioned. This tendency so frequently displayed by biologists to resolve biological activities into physical and chemical causes is based on the assumption that an organism is nothing but a physical and chemical complex. While this may be speculatively true, we should only be practically justified in saying that the effect which *Gonyaulax* had on the organisms in the vicinity of San Pedro was entirely due to physical and chemical causes, if we had learned to make this animal out of physical mixtures and chemical compounds.

To adequately estimate the quantity of plankton in a given area of the sea we must consider the influence of biological as well as physical and chemical conditions. In addition to the effects of wind, clouds, fog, rain, snow, ice, light, heat, time of day and season, depth, temperature, salinity, gas-content, and chemical composition of the water, this involves the effects of growth, reproduction, food-relations, and other activities of marine organisms. These factors are more or less correlated, but, as demonstrated by Kofoid (1903), there are variations in the quantity of plankton which are nearly, if not entirely, independent of the particular effects of hydrographic and meteorological conditions. Concerning this Kofoid (1903, p. 503) says: "Somewhat regular alternations of growth and rest, of fission and spore formation, or of parthenogenesis and sexual reproduction, are fundamentally the basis of cyclic movement in [plankton] production. The *amplitudes*, and to some extent the location and duration of the pulses, are plainly affected by the various factors of the environment . . . . by light, temperature, vegetation, tributary water, various hydrographic factors, and by food supply, and possibly, also, by chemical conditions not directly concerned in nutrition, but the available data fail completely to afford any satisfactory environmental factor or group of factors which stands in correlation, even remotely obvious with this cyclic movement in production. I therefore class this *periodic growth,* these *sexual cycles* which cause volumetric pulses, under the head of internal factors. The element of *periodicity* in itself does not seem to be consequent upon any known external factor.'' On the basis of these facts we must agree with Kofoid (1903) that ''If this cyclic movement in production be characteristic of the plankton generally, freshwater and even marine, it must follow that scattered and irregular collections, or those at intervals exceeding a week or at most a fortnight, may fail entirely to give adequate representation of the course of plankton production or relative fertility of a body of water. Chronological series throughout the whole seasonal range of climatic conditions and at close intervals—of one week or less—are necessary for any accurate delineation of production and fertility of water by the plankton method.'' This is obviously a laborious, time-consuming, and costly method, but it seems to be the only accurate one by which *definite* conclusions concerning the quantitative distribution of plankton can be obtained.

Before concluding these remarks on the problems of distribution, it is well to emphasize the importance of closing nets in obtaining definite knowledge concerning the vertical distribution of plankton. Their importance has been recognized by many investigators such as Chun, Peterson, Agassiz, Hensen, Apstein, Cori, Bergert, Bruce, Giesbrecht, Albert I of Monaco, and Kofoid, through whose researches and inventions the closing net has been developed to its present state of efficiency. However, excepting the Conseil International, ''Siboga,'' Biscayan, and a few other expeditions, most have depended mainly upon open vertical nets for collecting data relative to vertical distribution. Important conclusions have been based on evidence thus obtained, one of which is that the surface Chaetognatha of the Arctic seas would be found, if at all, in the mesoplankton of temperate and tropical regions. To test this statement I tabulated all accessible data, and discovered that it rested mainly on isolated observations and collections made with open vertical nets.

Data depending on collections made with these nets are of questionable value. This has been noted by Agassiz, Fowler, and others. In discussing the methods of collecting employed by the "Challenger" expedition Agassiz (1888, p. 35) says: "The old practice was employed of dragging for animal forms at intermediate depths by means of a tow-net, which, during the several operations of lowering, dragging, and hauling back remained open; this cannot be regarded as affording acceptable evidence of the habitat of such specimens as were obtained." Again Fowler (1905, p. 81), after pointing out that *S. furcata* was obtained abundantly in closing nets from 150 to 50 fathoms, and that below 200 to 100 fathoms the closing net failed to obtain the species, says: "The specimens recorded in open nets below 100 fathoms were therefore probably caught in the vertical journey upward; an instance of the deceptiveness of the method of open nets." To illustrate further the inadequacy of these nets I have selected the following instances from our data concerning the vertical distribution of the San Diego Chaetognatha.

1. During a period of four years 14 open net hauls were made below 110 fathoms, 15 from a variety of depths between 110 and 25 fathoms, and 13 from above 25 fathoms. Of the 14 hauls from below 110 fathoms 12 contained a total of 668 specimens of *S. serratodentata*. Of the hauls from between 110 and 25 fathoms, one from 75 fathoms contained 6, and one from 25 fathoms 2 specimens of the same species, while in the 13 hauls from above 25 fathoms no specimens were found.

2. During a period of four years *S. lyra* was obtained in 10 out of 21 open net hauls from or below 75 fathoms. During the same period 20 open net hauls were made from above 75 fathoms which failed to obtain the species.

Dare we conclude that *S. serratodentata* does not exist above 25 fathoms, or that *S. lyra* does not exist above 75 fathoms? Obviously such a conclusion is based on the absence of the species in open net hauls above these depths. However, how do we know that, in the hauls from below 110 fathoms containing *S. serratodentata* and in those from below 75 fathoms containing *S. lyra*, these species were not obtained from 5 or 10 fathoms, or even from the surface? Because they were not near the surface during 20 or even 10,000 hauls made above 25 or 75 fathoms *does not warrant the assumption that they were not near the surface during hauls made from below these depths.* This will be readily acknowledged when we learn that *S. serratodentata* was obtained in 25 out of 148 surface hauls, and in closing net hauls from 10 and 15 fathoms, and that *S. lyra* was obtained in 3 out of 148 surface hauls, and in closing net hauls from 5, 25, and 50 fathoms.

These data mean that conclusions based on open net hauls relate only to the usual manner in which each species is vertically distributed. The significance of this, however, depends on a knowledge of the *unusual* manner in which each is distributed. In other words, a correlation between the vertical distribution of each species and all varying conditions affecting this distribution cannot be made unless we know how the vertical distribution of each species varies. Herein lies the value of the closing net. It enables us to know the exact depth from which every specimen is obtained, and thus supplies knowledge concerning the *unusual* as well as the *usual* manner in which each species is distributed.

The first desideratum, then, for an adequate interpretation of the facts of vertical distribution is the frequent use of closing nets. Used in connection with Ekman's reversing bottles, and accurate deep-sea thermometers, the closing net supplies data the value of which can scarcely be exaggerated. However, in order to solve the problems of vertical distribution, the following precautions are necessary:

1. The area explored must be as small as possible, or the observations will be too scattered for comparison.

2. All conditions affecting the quantity, composition, and distribution of plankton in the region studied must be ascertained, and their effects determined so far as possible.

3. To accomplish this, hauls at all depths should be repeated as often, and under as great a variety of conditions as possible.

4. It is advisable, if not necessary, to plan all collecting with respect to one problem at a time; otherwise the data will be too indefinite to permit accurate conclusions.

5. Emphasis should be laid upon method of collecting rather than on quantity of plankton obtained, for an *ounce* of plankton collected systematically under known conditions, and with respect to definite problems means more than a *ton* otherwise obtained.

In conclusion, all the significant data concerning the distribution of the Chaetognatha so far obtained is condensed into the accompanying table, from which we may provisionally split the order into four groups according to temperature relations. These groups are as follows:

1. Eurythermal species, distributed irrespective of temperature. This group includes *S. bipunctata*, *S. hexaptera*, *S. planktonis*, *S. serratodentata*, and *E. subtilis*.

2. Cold water species, temperature 16°0 to 0°0 or less. This group includes *S. sibogae*, *S. macrocephala*, *S. elegans*, *E. hamata*, and possibly *S. lyra*.

3. Cool water species, temperature 19°0 to 9°5 This group includes *S. decipiens* and *Spadella cephaloptera*.

4. Warm water species, temperature 34°0 to 15°0. This group includes the remaining species, *S. enflata*, *S. pulchra*, *S. neglecta*, *S. regularis*, *S. bedoti*, *S. ferox*, *S. minima*, *S. tenuis*, *S. gazelle*, *S. hispida*, and *Spadella draco*.

It is to be noted that these groups are not sharply defined. *S. lyra*, for instance, while placed in the second group, might be placed in the first, although it has a greater tendency than the others to confine itself to cold water. *S. planktonis*, again is eurythermal regarding vertical distribution, but seems otherwise to be confined to temperate and tropical regions. It is quite possible that, after more extensive collecting with closing nets in the various latitudes, many of the species will be discovered to be eurythermal, with regard to vertical distribution, latitude, or both.

TABLE 35

Distribution of Chaetognatha with Respect to Latitude

Species	Neritic	Oceanic	Northern limit of distribution	Southern limit of distribution	Highest temperature	Lowest temperature	Atlantic Ocean										Indo-Australian Ocean				Pacific Ocean			
							Arctic		Sub-Arctic		North temperate		Tropical		South temperate		South temperate		Tropical		North temperate		Sub-Antarctic	
							Epiplankton	Mesoplankton	Epiplankton	Mesoplankton	Epiplankton	Mesoplankton	Epiplankton	Mesoplankton	Epiplankton	Mesoplankton	Epiplankton	Mesoplankton	Epiplankton	Mesoplankton	Epiplankton	Mesoplankton	Epiplankton	Mesoplankton
S. bipunctata[1]	*	*	74° N	28° S	33°.6	0°.2	*	....	*	....	*	*	*	*	*	....	*	....	*	....	*	....	....	....
S. hexaptera[2]	*	*	70° 30′ N	40° 4′ S	29°.0	6°.0	*	....	*	....	*	*	*	*	*	....	*	....	*	....	*	*	*	....
S. planktonis[2]	*	*	32° 45′ N	8° 30′ S	27°.0	4°.7	....	....	....	....	*	*	*	....	....	....	....	....	....	*	*	*	....	....
S. serratodentata[3]	*	*	60° 12′ N	53° S	32°.0	6°.5	....	....	*	....	*	*	*	....	*	....	....	....	*	....	*	....	*	....
E. subtilis[2]	*	*	60° 12′ N	29° 30′ S	30°.8	5°.3	....	....	....	....	*	*	*	*	*	....	*	....	*	*	....	*	....	....
S. lyra[4]	*	*	73° N	7° 33′ S	18°.6	—1°.1	....	*	*	*	*	*	?	?	....	....	....	....	....	....	*	*	....	....
E. hamata[5]	*	*	81° 30′ N	52° S	16°.0	—1°.1	*	....	*	*	*	*	....	*	....	....	....	....	....	*	....	*	*	....
S. siboga[6]	....	*	27° 4′ N	3° 58′ S	5°.5	......	....	....	....	....	....	—	....	*	....	....	....	....	....	*	....	....	....	....
S. macrocephala[6]	....	*	47° 10′ N	3° 20′ S	10°.0	2°.5	....	....	....	*	....	*	....	....	....	....	....	....	....	*	....	....	....	....
S. elegans[6]	*	*	81° 14′ N	39° 20′ N	11°.0	0°.3	*	....	*	....	....	*	....	....	....	....	....	....	....	....	....	....	....	....
S. decipiens[7]	....	*	47° N	......	11°.0	......	....	....	....	....	....	*	....	....	....	....	....	....	....	....	....	....	....	....
S. cephaloptera[7]	*	....	59° N	38° 10′ N	19°.0	9°.5	....	....	....	....	*	....	....	....	....	....	....	....	....	....	....	....	....	....
S. enflata[8]	*	*	40° 24′ N	34° 52′ S	32°.0	15°.5	....	....	....	....	*	....	*	....	*	....	*	....	*	....	*	....	....	....
S. pulchra[8]	*	....	47° 10′ N	39° S	29°.0	14°.0	....	....	....	....	....	....	....	....	....	....	....	....	*	....	*	....	....	....
S. neglecta[8]	*	....	35° N	9° S	29°.0	15°.5	....	....	....	....	....	....	....	....	....	....	....	....	*	....	*	....	....	....
S. regularis[8]	*	....	35° N	6° 30′ S	29°.0	21°.0	....	....	....	....	....	....	*	....	....	....	....	....	*	....	*	....	....	....
S. bedoti[8]	*	....	35° N	8° 30′ S	29°.0	21°.0	....	....	....	....	....	....	....	....	....	....	....	....	*	....	*	....	....	....
S. ferox[8]	*	....	6° N	9° S	29°.0	......	....	....	....	....	....	....	....	....	....	....	....	....	*	....	....	....	....	....
S. minima[8]	*	....	41° N	35° N	21°.0	19°.0	....	....	....	....	*	....	....	....	....	....	....	....	....	....	*	....	....	....
S. tenuis[8]	*	....	18° N	......	27°.0	......	....	....	....	....	....	....	*	....	....	....	....	....	....	....	....	....	....	....
S. gazelle[8]	....	*	39° S	45° S	......	......	....	....	....	....	....	....	....	....	....	....	....	....	*	....	....	....	....	....
S. hispida[8]	*	....	34° 15′ N	25° S	29°.0	21°.0	....	....	....	....	....	....	*	....	....	....	....	....	*	....	*	....	....	....
E. paciflca[8]	*	....	35° N	7° 30′ S	29°.0	......	....	....	....	....	....	....	*	....	....	....	....	....	*	....	*	....	....	....
S. draco[8]	*	*	41° 36′ N	41° 32′ S	29°.0	15°.5	....	....	....	....	*	....	*	....	*	....	....	....	*	....	*	....	*	....
Total 24	20	14					4	1	6	3	11	10	12	6	6	0	4	0	14	5	14	4	4	0

[1] Eurythermal, euryhyaline, cosmopolitan.
[2] Eurythermal.
[3] Eurythermal, stenobathic.
[4] Cold water, nearly eurythermal.
[5] Cold water, cosmopolitan.
[6] Cold water.
[7] Cool water.
[8] Warm water.

DISCUSSION OF VERTICAL DISTRIBUTION OF THE SAN DIEGO CHAETOGNATHA

In any accurate quantitative consideration of the vertical distribution of a species, all factors affecting the abundance of specimens obtained must be taken into account. Conditions of weather, currents, temperature, and salinity of the water, light, and season are some of these factors. In addition, each net used in collecting filters the water in a unique manner, and even the quantity of plankton obtained in two successive hauls with the same net usually varies. These net factors as well as the environmental factors affect the number of specimens obtained and their exact effect ought to be ascertained.

This problem of quantitative estimates would be much simpler if our engines and cables had permitted an earlier use of vertical closing nets. Being hauled a known distance at a known velocity and against gravitation, the pressure of water on such nets may be calculated and their filtering capacities determined. Furthermore the nets may be rapidly hauled so that the environmental conditions at each depth might be considered constant. These nets have, however, been used for only a few days during February, March, and April of 1910, and while the data obtained are valuable they are not sufficient to permit definite conclusions concerning the vertical distribution of the various species of this region.

Since we are compelled to depend mainly upon data obtained with surface nets and horizontal closing nets, it is almost impossible to estimate the effects of net and environmental factors on the number of specimens obtained in each haul. Obviously the pressure of water is greater on the lower portions of the net, and consequently each area of net surface filters the water at a different rate. The distance the net is hauled and the number, direction, and velocity of currents encountered have a marked effect on the quantity of plankton obtained, and our data supply practically no information regarding these factors. Furthermore, ten to twenty minutes is consumed in hauling, so it is questionable whether or not the environmental conditions of the water can be regarded as constant. For these reasons the amount of the water filtered during hauls made with different nets, or with the same net at different times, cannot be determined and consequently the number of specimens obtained in respective hauls cannot be accurately compared.

Owing to this impossibility of estimating the value of each horizontal haul, there is apparently only one practicable method of quantitatively considering the vertical distribution of the organisms. If hauls in each depth are numerous and distributed over considerable time, those environmental factors affecting the quantity of plankton obtained will not affect every haul alike. In fact their effects will tend to cancel one another. Now, if we consider the average number of specimens per haul obtained from each depth, we are justified in neglecting the effects of these factors. However, the time consumed during each haul has varied, so it is necessary to standardize the average number of specimens per haul with respect to time. A period of one hour is selected for this purpose. In the following discussion, therefore, the average number of specimens per hour-haul is regarded as the unit for quantitative comparison.

Had the same closing net always been used in collecting, this method, while not absolutely accurate, would yield a fair average estimate of the relative abundance of specimens from each depth. However, the Kofoid closing net and the Nansen closing net were used and this necessitates standardizing the hauls made by one net with those made by the other. While the nets are proportionally similar, the orifice of the former is 37.0 cm. in diameter, and that of the latter 109.5 cm. Since πr^2 equals the area of the orifice, it follows that the portion of a given volume of water filtered by the Kofoid net is to that filtered by the Nansen net as the square of the radius of the former is to that of the latter. In other words, if $r =$ the radius of the Kofoid net, $R =$ that of the Nansen net, $w =$ water filtered by the Kofoid net, and $W =$ that filtered by the Nansen net, then as the nets are proportionally similar, $w : W :: \pi r^2 : \pi R^2$ or $W = \frac{w\, \pi R^2}{\pi r^2} = \frac{w\, R^2}{r^2}$

Now $r = 18.5$ cm. and $R = 54.75$ cm., hence $W = \frac{(54.75)^2}{(18.5)^2} \times w$

or approximately $w \times 8$.

In this calculation it is assumed that both nets have the same size of mesh, but this is not true. The mesh of the Kofoid net is No. 000 and that of the Nansen net No. 1. Obviously, other things being equal, more water will be filtered by the net having the larger mesh, which means that W = less than w × 8. However, owing to the fact that the nets are towed horizontally, the exact effect of this difference in mesh on the amount of water filtered cannot at present be calculated. The number of specimens obtained from each depth by each net are, therefore, uncorrelated and in the following discussion allowance must be made for this fact.

Finally, it is obvious that a surface net of 000 mesh with an orifice of 97.5 cm. in diameter will filter more water than the Kofoid net would if hauled in place of the former. Theoretically the amount of water filtered during a given surface haul would be to that filtered by the Kofoid net as the square of the radius of the former is to that of the latter. In other words, to standardize the number of specimens obtained by the surface net with that obtained by the Kofoid net the number ought to be multiplied by $\frac{(18.5)^2 = \text{radius}^2 \text{ of Kofoid net}}{(48.75)^2 = \text{radius}^2 \text{ of surface net}}$ While this is theoretically required, the resulting fraction 1/7 is found empirically to be far too large. Because this calculation is misleading it seems best to allow for lack of correlation between surface and closing net hauls and regard the average number of specimens obtained per hour from the surface without attempting correction. It will be found that the effects of varying environmental conditions on the manner in which each species is distributed are apparent in spite of this lack of correction.

Although ten species of Chaetognatha were taken from the region of San Diego, lying between 32° 20′ and 33° 30′ N and extending from the coast to 119° W, the region is characterized by an enormous preponderance of one species. Including all hauls from all depths the number of specimens of each species is as follows:

S. bipunctata	51,670
S. enflata	10,127
S. serratodentata	6,575
S. lyra	271
S. neglecta	127

E. hamata	72
E. subtilis	50
S. planktonis	41
S. hexaptera	28
S. draco	1

Owing to the fact that *S. bipunctata* is the most abundant, it is best to consider its manner of distribution first.

VERTICAL DISTRIBUTION OF *SAGITTA BIPUNCTATA*.

Of the total number of this species obtained, 32,601 were taken from the surface, 17,144 in open vertical nets from depths varying from 2 to 500 fathoms, 303 in vertical closing nets from between 150 fathoms and the surface, and 1,322 in horizontal closing nets. Neglecting those obtained with open vertical and vertical closing nets, we find that from July 23, 1904, to April 21, 1910, 148 surface hauls were made, of which 108, or 72 per cent, obtained the 32,601 specimens mentioned. The horizontal closing nets obtained a total of 283 specimens in 7 out of 11 hauls made between 4 and 6 fathoms, 71 in 6 out of 15 hauls between 7 and 12 fathoms, 683 in 13 hauls between 15 and 20 fathoms, 128 in 8 out of 19 hauls between 25 and 35 fathoms, 147 in 6 out of 20 hauls between 40 and 75 fathoms, and 10 in 4 out of 19 hauls between 100 and 150 fathoms. Although 21 hauls were made between 160 and 350 fathoms, the species was not obtained. These data are shown to better advantage in the following table.

TABLE 36

Vertical Distribution of *S. bipunctata* based on Surface and Horizontal Closing Net Hauls

Depth in fathoms	Number of hauls[1]		Number of hours of hauling	Number of specimens		Frequency[2]
	Total	Successful		Total	Per hour	
0	136	96	96.7	29,696	307	70
4–6	11	7	3.3	283	92	64
7–12	15	6	4.6	71	15	40
15–20	13	13	3.5	683	195	100
25–35	19	8	5.3	128	24	42
40–75	20	6	5.7	147	26	30
100–150	19	4	6.5	10	2	21
160–350	21	0	9.0	0	0	0

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[1] The durations of hauls 216-1416 are unknown, and they are, therefore, not included in this table.

[2] By frequency is meant the percentage of hauls in which the species appeared without reference to abundance of specimens obtained.

This table marks a distinction between frequency and abundance of *S. bipunctata* at each depth. While it is most frequent in 15-20 fathoms it appears most abundant on the surface. It is fifth in frequency and sixth in abundance in 7-12 fathoms, sixth in frequency and fourth in abundance in 40-75 fathoms, and fourth in frequency and fifth in abundance in 25-35 fathoms. However, in 4-6 and 100-150 fathoms the frequency and abundance are parallel.

We should naturally expect complete parallelism between frequency and abundance, but we find it incomplete. What, then, does this lack of parallelism signify? Is it due to an insufficient number of hauls, to lack of correlation between hauls made with surface and closing nets, to an uneven distribution of hauls with respect to varying environmental conditions, or to a combination of all these influences?

It is obvious that accuracy of the percentage of successful hauls varies with the total number made. Thus the chance of error in the frequency of 100 based upon 13 hauls in 15-20 fathoms is much greater than that in the frequency of 70 based on 136 surface hauls. Had 136 hauls been made in each depth the frequencies noted in the table would undoubtedly be altered.

On the other hand, it was previously stated that the surface net was larger in orifice than the Kofoid closing net, and that the former, therefore, filtered more water per unit length of haul than the latter. Theoretically we estimated that the average number of specimens obtained per hour from the surface ought to be divided by 7 in order to correlate the number with that obtained from each depth by the closing nets. If this were done, however, the number would be reduced to 44, which is much too small to represent the relative number of specimens obtained. We can only be sure that the 307 specimens from the surface should be smaller. Possibly it should be less than 195.

Far more important than either an insufficient number of hauls or lack of correlation between surface and closing net hauls is the fact of their uneven distribution with respect to varying environmental conditions. Variations in temperature, salinity, currents, and light have all doubtless affected the number of specimens obtained in each haul. Consequently, an average based upon hauls irregularly distributed with respect to these factors is necessarily misleading.

These facts—insufficient number of hauls, lack of correlation between surface and closing net hauls, and irregular distribution of hauls—will explain the disagreement noted between frequency and abundance. However, we may safely conclude:

1. *S. bipunctata* is typically epiplanktonic,[1] occurring between the surface and 150 fathoms.

2. It is rarely found below 75 fathoms.

3. It is most frequent and abundant between the surface and 20 fathoms.

EFFECT OF DAY AND NIGHT ON THE VERTICAL DISTRIBUTION OF *SAGITTA BIPUNCTATA*

It has just been noted that, owing to irregularity in distribution of hauls with respect to varying environmental conditons, the average number of specimens per hour obtained from each depth is misleading. Because our data regarding day and night are more complete than those concerning other environmental factors, it is desirable to consider the influence of this factor on vertical distribution before undertaking to interpret the effects of variations in other factors.

By separating all hauls made between 6 a.m. and 6 p.m. from those made between 6 p.m. and 6 a.m., the *general* effect of day and night on vertical distribution may be considered. Such data are supplied in the following table:

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[1] Fowler (1906, p. 47) defines the terms epiplankton and mesoplankton as follows: Epiplankton includes all plankton above the region of 100 fathoms. Mesoplankton includes that between 100 fathoms and to within about 100 fathoms of the bottom.

TABLE 37

Table showing the effect of Day and Night on Distribution of *S. bipunctata*

Daylight, or 6 a.m. to 6 p.m.

Depth in fathoms	Number of hauls		Number of hours	Number of specimens		Frequency
	Total	Successful		Total	Per hour	
0	78	48	54.4	6,902	108	62
4–6	5	3	1.8	81	45	60
7–12	8	2	2.4	20	9	25
15–20	7	7	1.9	581	305	100
25–35	12	5	3.3	121	37	42
40–75	12	4	3.2	139	44	33
100–150	8	2	2.5	3	1	25
Night, or 6 p.m. to 6 a.m.						
0	58	48	42.3	22,794	539	83
4–6	6	4	1.5	202	136	67
7–12	7	4	2.2	51	23	57
15–20	6	6	1.6	102	64	100
25–35	7	3	2.0	7	3	43
40–75	8	2	2.6	8	3	25
100–150	11	2	4.1	7	2	18

This table shows that the ratios between the average number of specimens per hour obtained during the day and the average number obtained during the night are as follows: surface 1 to 5.0; 4-6 fathoms 1 to 3.0; 7-12 fathoms 1 to 2.6; 15-20 fathoms 4.8 to 1; 25-35 fathoms 12 to 1; 40-75 fathoms 14 to 1. Furthermore, the frequency in each depth during the day is to that during the night as 62 to 83 on the surface, 60 to 67 in 4-6 fathoms, 25 to 57 in 7-12 fathoms, 100 to 100 in 15-20 fathoms, 42 to 43 in 25-35 fathoms, and 33 to 25 in 40-75 fathoms. To sum up, these data show that during the night *S. bipunctata* is more frequent and abundant between the surface and 12 fathoms, while it is less so between 15 and 75 fathoms. This probably means that the species migrates in greatest number from all depths below 15 fathoms toward the surface during the night, while during the day it migrates in greatest number from all depths above 15 fathoms toward deeper water.

That there should be lack of parallelism between frequency and abundance in each depth, and why there should be such an abrupt drop in 7-12 fathoms is probably due to the following factors: (1) insufficient number of hauls, (2) impossibility of standardizing the filtering capacities of surface nets with closing nets, and (3) irregular distribution of hauls with respect to the effects of cloudy and foggy days, and moonlit nights. However, whatever effects these factors may have cannot offset the fact that a very evident difference between day and night distribution exists.

The question naturally arises, if this species migrates toward and away from the surface, at what time of day or night does it attain its maximum abundance in each depth? To determine this the specimens obtained from each depth have been segregated into groups according to two-hour periods as indicated in the following table:

TABLE 38

Number of specimens of *S. bipunctata* per hour obtained with respect to Time of Day.

		Equal intervals of time throughout day and night											
Depth		12-2 a.m.	2-4 a.m.	4-6 a.m.	6-8 a.m.	8-10 a.m.	10-12 a.m.	12-2 p.m.	2-4 p.m.	4-6 p.m.	6-8 p.m.	8-10 p.m.	10-12 p.m.
0	sp.	24	166	338	519	169	10	23	19	153	839	383	33
	min.	213	100	646	315	556	420	324	406	852	1154	337	90
4–6	sp.	36	......	3	80	......	......	18	......	......	254	30	....
	min.	10	0	24	50	0	0	46	0	0	45	10	0
7–12	sp.	0	......	41	31	0	......	0	......	3	23	......	....
	min.	11	0	22	35	17	0	52	0	40	97	0	0
15–20	sp.	36	......	96	27	908	180	......	32	52	102	17	....
	min.	10	0	45	20	33	10	0	13	37	10	39	0
25–35	sp.	......	......	3	1	52	......	138	0	0	1	.....	0
	min.	0	0	35	113	23	0	40	15	10	67	0	15
40–75	sp.	......	......	0	0	0	177	79	1	7	7	0	....
	min.	0	0	63	15	22	22	53	52	25	75	20	0
100–150	sp.	......	......	1	0	0	0	4	0	2	6	0	....
	min.	0	0	110	14	10	18	17	10	80	50	84	0

In this table sp. = number of specimens per hour, and min. = number of minutes consumed in hauling. Wherever number of specimens is not recorded no hauls have been made, but wherever hauls were made and no specimens obtained, a 0 indicates this fact.

From this table we learn that *S. bipunctata* appears in maximum abundance between 6 and 8 p.m. on the surface and in 4-6 fathoms, between 4 and 6 a.m. in 7-12 fathoms, between 8 and 10 a.m. in 15-20 fathoms, between noon and 2 p.m. in 25-35 fathoms, and between 10 a.m. and noon in 40-75 fathoms.

Furthermore, the data show two maxima in every depth above 20 fathoms. One occurs between 6 and 10 a.m. and the other between 6 and 8 p.m. Excepting the depth of 100-150 fathoms, only one maximum occurs in each depth below 25 fathoms and that between 10 a.m. and 2 p.m. What does this irregular distribution of maxima signify? Is it merely the effect of chance due to the small amount of hauling, or is some other explanation necessary?

The small number of hauls may have affected this distribution of maxima in some depths, but it will not explain the presence of two maxima on the surface. In correlating the number of *S. bipunctata* on the surface with time of day it is evident that the species increases in abundance from midnight till it reaches a *morning maximum* between 6 and 8 a.m., and after decreasing rapidly to a *minimum* between 10 a.m. and 4 p.m., it increases again till it reaches an *evening maximum* between 6 and 8 p.m. It then gradually decreases to a *midnight minimum*. As most of our collecting was done during June and July, these data teach us that the positions of these maxima approximately correspond to the time of sunrise and sunset. To be more exact, the species attains its morning maximum on the surface within an hour after sunrise, and its evening maximum within an hour after sunset. This indicates that the species migrates toward the surface during twilight and away during bright daylight and darkness.

If this is true, we should expect a greater abundance of specimens on the surface during evening than during morning twilight, for the light *increases* in intensity at dawn while it *decreases* during the evening. Consequently, if the species migrated to the surface during morning twilight its migration would soon be checked owing to the increasing intensity of light, while its migration during the evening would remain unchecked. The fact that the evening maximum is the larger harmonizes entirely with this hypothesis. Why the species should leave the surface so soon after attaining its evening maximum abundance is puzzling. It may be due to the small amount of collecting between 10 p.m. and 4 a.m., to possible cessation of activity or quiescence of the animals which would cause them to sink, since their specific gravity is greater than that of water, or more probably to the usual relatively high surface temperature (see p. 132).

It is obvious that when light increases in intensity the water nearest the surface is first affected, while when it decreases the reverse is true. During morning twilight, therefore, we should expect the species to ascend first from 4-6 fathoms, later from 7-12 fathoms, and still later from 15-20 fathoms. During evening twilight, however, we should expect migrations first from deeper water. Again, after the morning light becomes too intense, the animals ought to leave the surface first and the succeeding depths later. While our data are inconclusive owing to absence of closing net hauls during many periods of the day, still, when we endeavor to ascertain where the increasing number of specimens on the surface come from and where those leaving the surface go to, the following few facts extracted from table 38 are significant.

1. While an increase from 24 to 338 specimens per hour on the surface took place from midnight to 4-6 a.m. the number in 4-6 fathoms decreased from 36 to 3. Evidence of what happened in 7-12 fathoms is lacking, but in 15-20 fathoms the number increased from 36 to 96. This suggests that the intensity of twilight between 4 and 6 a.m. was sufficient to cause upward migrations from 4-6 but not from 15-20 fathoms.

2. While the number of specimens per hour on the surface increased from 338 between 4 and 6 a.m. to a morning maximum of 519 between 6 and 8 a.m., the number in 4-6 fathoms increased from 3 to 80, while that in 7-12 fathoms decreased from 41 to 31, and that in 15-20 fathoms from 96 to 27. This indicates that the intensity of light after sunrise was sufficient to cause upward migrations from 7-12 and 15-20 fathoms, some specimens reaching the surface while others accumulated in 4-6 fathoms.

3. Combined with a decrease from 519 specimens per hour on the surface between 6 and 8 a.m. to 169 between 8 and 10 a.m. and a decrease in 7-12 fathoms from 31 to 0, is an increase

in 15-20 fathoms from 27 to 908. Does this signify that the intensity of light above 15 fathoms caused the species to migrate downward, while that below 20 fathoms was subdued enough to cause them to migrate upward? The data are too incomplete to warrant such a conclusion, but it is suggested from the fact that the species attained its maximum abundance in 15-20 fathoms at this time.

4. During the next period, 10 a.m. to noon, the number of specimens on the surface decreased from 169 to 10 per hour, and that in 15-20 fathoms decreased from 908 to 180, while the species makes its first appearance in 40-75 fathoms, an average of 177 specimens per hour having been obtained. Owing to lack of collecting in 4-6, 7-12, and 25-35 fathoms at this time, the meaning of this is uncertain. However, it is probable that the intensity of light in 15-20 fathoms is much greater between 10 a.m. and noon than between 8 and 10 a.m., and if so we should expect downward migrations from this depth. Similarly between noon and 2 p.m. the maximum number of specimens was found in 25-35 fathoms and the next most abundant number in 40-75 fathoms.

5. From between 2 and 4, 4 and 6, and 6 and 8 p.m., the number of specimens per hour on the surface increased from 19 to 153 to 889. In 7-12 fathoms it increased from 3 between 4 and 6 p.m. to 23 between 6 and 8 p.m. In 15-20 fathoms it increased from 32 to 75 to 102. We should expect this evening increase to begin first in deeper water and appear last on the surface. Lack of hauling prevents determining this point, but, since this species was not taken below 150 fathoms, its occurrence in maximum abundance in from 25 to 75 fathoms between noon and 2 p.m. and in minimum abundance between 2 and 4 p.m. suggests that upward migration from these depths begins early in the afternoon.

These facts, while they do not prove that intense light causes downward and subdued light upward migrations, certainly point strongly in this direction.

Before leaving this question of the effect of light on the distribution of this species, it is well to consider evidence obtained from collections made at consecutive times during the same day. This will enable comparison of *actual* instead of *average* numbers of specimens obtained. Because our closing nets were rarely employed during consecutive times in the same depths, such evidence relates entirely to surface collections. Here are a few data.

1. On June 16, 1909, the sun set at 7:10 p.m. Four surface hauls (1650, 1653, 1655, and 1657) were made with the same net. The first lasted from 5:10 to 5:55 p.m., the second from 6:10 to 6:45 p.m., the third from 6:55 to 7:20 p.m., and the fourth from 7:25 to 8:00 p.m. The first haul contained 15, the second 40, the third 75, and the fourth 5100 specimens of *S. bipunctata.* Expressing these numbers with respect to hour-hauls, they are 20, 69, 180, and 8743. In other words, from two hours before until 50 minutes after sunset the number of specimens on the surface *increased 437 times* and, while the number *increased only 9 times during the first 2 hours and 10 minutes, it increased 48 times during the next 40 minutes.*

2. On the next day, June 17, 1909, sunset occurred between 7:10 and 7:11 p.m. From 5 to 6 p.m. one surface haul (1659) was made which contained 13 specimens, and from 6:45 to 7:30 p.m. a second haul (1661) was made which contained 550 specimens. Standardizing these numbers with respect to hour-hauls, we find that *S. bipunctata increased 56 times in abundance from 1 hour and 10 minutes before till 20 minutes after sunset.*

3. On June 21, 1909, the sun set at 7:12 p.m. One surface haul (1673) lasting from 6 to 6:25 p.m. contained 30, and a second haul (1680) lasting from 7 to 7:35 p.m. contained 3600 specimens. In other words, the number when standardized with respect to hour-hauls, *increased 86 times from 47 minutes before till 23 minutes after sunset.*

4. On June 24, 1909, sunset occurred at 7:13 p.m. Haul 1728 lasting from 5:10 to 6:10 p.m. contained 72, haul 1731 lasting from 6:15 to 7:00 p.m. contained 50, and haul 1734 lasting from 7:03 to 7:40 p.m. contained 103 specimens of *S. bipunctata.* Expressing these numbers according to hour-hauls they are 72, 67, and 167. Therefore, the number of specimens on the surface *increased threefold from 13 minutes before till 27 minutes after sunset.*

5. On June 28, 1909, the sun set at 7:12 p.m. Haul 1744 lasting from 5 to 6:20 p.m. contained 2, haul 1751 lasting from 7:15 to 8 p.m. contained 155, and haul 1754 lasting from 8:10 to 8:50 p.m. contained 1100 specimens of *S. bipunctata.* Expressed according to hour-hauls these numbers are 2, 207, and 1650. Here the number on the surface *increased 103 times from 52 minutes before till 48 minutes after sunset, while during the next 50 minutes it increased only 8 times.*

6. On July 9, 1909, sunset occurred at 7:10 p.m. Haul 1868 lasting from 7:03 to 7:36 p.m. contained 10, haul 1872 lasting from 7:40 to 8:15 p.m. contained 4300, and haul 1875 lasting from 8:45 to 11:35 p.m. contained 275 specimens. Expressing these numbers according to hour-hauls they are 18, 7371, and 97. Hence *between 26 minutes and 1 hour and 5 min-*

utes after sunset the number of specimens increased 409 times, and during the next 3 hours it decreased, which suggests that the species attains its maximum abundance within an hour after sunset.

7. On February 8, 1910, the sun set at 5:50 p.m. Three surface hauls (2010, 2014, and 2024) were made. The first, lasting from 2:52 to 4:25 p.m., contained 55, the second, lasting from 4:50 to 6:15 p.m., contained 220, and the third, lasting from 6:57 to 7:54 p.m., contained 165 specimens. Expressed according to hour-hauls these numbers are 35, 155, and 174. This means that *from 3 hours before till 25 minutes after sunset the number increased fourfold, while it increased but slightly during the next hour and 49 minutes.*

8. On March 17, 1910, the sun set at 6:10 p.m. Six surface hauls (2070, 2078, 2082, 2085, 2096, and 2101) were made. They lasted respectively from 1:30 to 2:18 p.m., 2:20 to 3:34 p.m., 3:40 to 4:30 p.m., 4:45 to 5:10 p.m., 6:15 to 6:50 p.m., and 6:55 to 7:30 p.m. They contained respectively 3, 4, 13, 7, 125, and 472 specimens. Expressed according to hour-hauls these numbers are 4, 3, 16, 17, 214, and 809. Hence, *during the period of 4 hours before sunset the number of specimens only quadrupled, while an hour after sunset found the number 13 times larger, and during the succeeding 40 minutes the number quadrupled again.*

The following instances (9 to 13) concern variation in abundance relative to sunrise.

9. On June 27, 1908, sunrise occurred at 4:53 a.m. Two surface hauls (1509 and 1512) were made which lasted respectively from 5:58 to 6:15 a.m. and 6:20 to 6:45 a.m. The former contained 72 and the latter 60 specimens of *S. bipunctata*. Expressed according to hour-hauls these numbers are 306 and 120, which means that the number of specimens on the surface 1 hour and 52 minutes after sunrise *was approximately one-third of that present 30 minutes earlier.* In this instance the first haul began an hour after sunrise, so it is probable that the morning maximum occurred before the time of hauling.

10. On July 24, 1908, the sun rose at 5:08 a.m. Two surface hauls (1597 and 1600) lasted respectively from 4:26 to 4:46 a.m. and 4:58 to 5:18 a.m. The former contained 75 and the latter 3 specimens of *S. bipunctata*. Expressed accordng to hour-hauls the numbers are 229 and 9. This means that *22 minutes before sunrise the animals were 25 times more abundant than at 10 minutes after sunrise.*

11. On July 2, 1909, the sun rose at 4:55 a.m. Haul 1784 lasting from 4:50 to 5:11 a.m. contained 618, and haul 1791 lasting from 6:37 to 7:00 a.m. contained 41 specimens of *S. bipunctata*. Expressed according to hour-hauls the numbers are 1769 and 104. In other words, the number of specimens on the surface *16 minutes after sunrise was 17 times greater than that 1 hour and 40 minutes later.*

12. On July 9, 1909, the sun rose at 4:59 a.m. Three surface hauls (1850, 1854, and 1860) lasting respectively from 3:30 to 4:13 a.m., 4:20 to 5:15 a.m., and 5:18 to 6:25 a.m. were made. The first contained 270, the

second 6, and the third 4 specimens of *S. bipunctata.* Expressed according to hour-hauls the numbers are 360, 6, and 4. Thus, *from 44 minutes before till 16 minutes after sunrise the number of specimens on the surface decreased in the proportion of 90 to 1.*

13. On July 10, 1909, the sun rose at 4:59 a.m. Haul 1888 lasting from 4:35 to 5:20 a.m. contained 132, and haul 1892 lasting from 5:25 to 5:55 a.m. contained 15 specimens of *S. bipunctata.* Expressed according to hour-hauls the numbers are 176 and 30. Hence, *from 39 minutes before till 56 minutes after sunrise the number of specimens on the surface decreased in the proportion of 6 to 1.*

To emphasize the bearing of the thirteen instances just cited I have condensed the data into the following table.

TABLE 39

Actual Distribution of *S. bipunctata* based on Surface Hauls made with the same net during the same days.

Instances cited	Haul number	Time and duration of haul	Number of specimens			Latitude	Longitude	Temperature	Salinity
			Actual	Per hour	Ratio				
Four hauls made on June 16, 1909. Sunset 7:10 p.m.									
1	1650	5:10–5:55 p.m.	15	20	1	32° 51′.0	117° 31′.9	18°.6	?
	1653	6:10–6:45 p.m.	40	69	3	32° 51′.0	117° 31′.9	18°.6	33.616
	1655	6:55–7:20 p.m.	75	180	9	32° 51′.0	117° 31′.9	?	?
	1657	7:25–8:00 p.m.	5100	8743	437	32° 51′.0	117° 31′.9	18°.4	33.670
Two hauls made on June 17, 1909. Sunset 7:10 p.m.									
2	1659	5:00–6:00 p.m.	13	13	1	32° 51′.3	117° 16′.7	18°.4	?
	1661	6:45–7:30 p.m.	550	733	56	32° 51′.3	117° 16′.7	18°.4	?
Two hauls made on June 21, 1909. Sunset 7:12 p.m.									
3	1673	6:00–6:25 p.m.	30	72	1	32° 51′.8	117° 30′.4	18°.0	33.563
	1680	7:00–7:35 p.m.	3600	6171	86	32° 52′.0	117° 32′.9	15°.9	?
Three hauls made on June 24, 1909. Sunset 7:13 p.m.									
4	1728	5:10–6:10 p.m.	72	72	1	32° 52′.0	117° 30′.0	17°.7	33.534
	1731	6:15–7:00 p.m.	50	67	1	32° 52′.0	117° 30′.0	17°.7	33.776
	1734	7:03–7:40 p.m.	103	167	3	32° 52′.0	117° 30′.0	17°.7	33.534
Three hauls made on June 28, 1909. Sunset 7:12 p.m.									
5	1744	5:00–6:20 p.m.	2	2	1	32° 52′.0	117° 30′.0	19°.2	33.647
	1751	7:15–8:00 p.m.	155	207	103	32° 52′.0	117° 30′.0	19°.0	33.603
	1754	8:10–8:50 p.m.	1100	1650	825	32° 52′.0	117° 30′.0	19°.0	33.603
Three hauls made on July 9, 1909. Sunset 7:10 p.m.									
6	1868	7:03–7:36 p.m.	10	18	1	32° 52′.3	117° 20′.0	19°.0	33.589
	1872	7:40–8:15 p.m.	4300	7371	409	32° 52′.3	117° 20′.0	18°.8	33.630
	1875	8:45–11:35 p.m.	275	97	5	32° 52′.3	117° 20′.0	19°.0	33.630

TABLE 39—*Continued*

Actual Distribution of *S. bipunctata* based on Surface Hauls made with the same net during the same days.

Instances cited	Haul number	Time and duration of haul	Number of specimens			Latitude	Longitude	Temperature	Salinity
			Actual	Per hour	Ratio				
Three hauls made on February 18, 1910. Sunset 5:50 p.m.									
7	2010	2:52–4:25 p.m.	55	35	1	32° 51′.2	117° 31′.5	14°.2	33.811
	2014	4:50–6:15 p.m.	220	155	4	32° 51′.2	117° 31′.5	13°.8	33.567
	2024	6:57–7:54 p.m.	165	174	5	32° 51′.2	117° 31′.5	13°.8	33.811
Six hauls made on March 17, 1910. Sunset 6:10 p.m.									
8	2070	1:30–2:18 p.m.	3	4	1	32° 50′.0	117° 30′.0	14°.7	33.783
	2078	2:20–3:34 p.m.	4	3	1	32° 50′.0	117° 30′.0	14°.7	33.738
	2082	3:40–4:30 p.m.	13	16	4	32° 50′.6	117° 29′.2	14°.7	33.666
	2085	4:45–5:10 p.m.	7	17	4	32° 50′.6	117° 29′.2	14°.6	33.522
	2096	6:15–6:50 p.m.	125	214	53	32° 50′.6	117° 29′.2	14°.6	33.747
	2101	6:55–7:30 p.m.	473	809	202	32° 50′.6	117° 29′.2	14°.6	33.549
Two hauls made on June 27, 1908. Sunrise 4:53 a.m.									
9	1509	5:58–6:15 a.m.	72	306	3	32° 54′.1	117° 21′.0	18°.6	33.670
	1512	6:20–6:45 a.m.	60	120	1	32° 54′.1	117° 21′.0	18°.9	?
Two hauls made on July 24, 1908. Sunrise 5:08 a.m.									
10	1597	4:26–4:46 a.m.	75	225	25	32° 51′.4	117° 22′.2	20°.5	33.549
	1600	4:58–5:18 a.m.	3	9	1	32° 51′.5	117° 22′.6	20°.5	33.603
Two hauls made on July 2, 1909. Sunrise 4:55 a.m.									
11	1784	4:50–5:11 a.m.	618	1769	17	32° 49′.0	118° 21′.0	18°.7	33.647
	1791	6:37–7:00 a.m.	41	104	1	32° 48′.0	118° 27′.0	16°.6	33.681
Three hauls made on July 9, 1909. Sunrise 4:59 a.m.									
12	1850	3:30–4:15 a.m.	270	360	90	32° 52′.3	117° 20′.0	18°.8	33.690
	1854	4:20–5:15 a.m.	6	6	1	32° 52′.3	117° 20′.0	18°.8	33.571
	1860	5:18–6:25 a.m.	4	4	1	32° 52′.3	117° 20′.0	18°.6	33.589
Two hauls made on July 10, 1909. Sunrise 4:59 a.m.									
13	1888	4:35–5:20 a.m.	132	176	6	32° 53′.0	117° 18′.0	19°.1	33.690
	1892	5:25–5:55 a.m.	15	30	1	32° 53′.0	117° 18′.0	19°.2	33.747

While the above instances evidence considerable variation in the rates of increase and decrease in abundance, as expressed in the column of ratios, the data demonstrate that marked *decrease occurs about the time of sunrise* and marked *increase directly after sunset.* These facts strikingly confirm our former inference that *S. bipunctata* migrates toward the surface during subdued light and away during intense light and darkness.

To summarize, the facts and inferences respecting light are:

1. During the night this species is most abundant between the surface and 15 fathoms, while during the day it is most abundant below 15 fathoms.

2. The species appears in maximum abundance on the surface and in 4-6 fathoms between 6 and 8 p.m., in 7-12 fathoms between 4 and 6 a.m., in 15-20 fathoms between 8 and 10 a.m., in 25-35 fathoms between noon and 2 p.m., and in 40-75 fathoms between 10 a.m. and noon.

3. In all depths above 20 fathoms the species attains two maxima in abundance during the twenty-four hour day, one occurring between 6 and 10 a.m., and the other between 6 and 8 p.m. Below 20 fathoms only one maximum occurs and that between 10 a.m. and 2 p.m.

4. On the surface the species attains its morning maximum within an hour after sunrise and its evening maximum within an hour after sunset.

5. It is probable that the species migrates toward that depth in which twilight conditions are found.

VARIATION IN DISTRIBUTION OF *S. BIPUNCTATA* DUE TO TEMPERATURE

A variation in surface temperature from 13°1 to 22°3 C. is noted in our data. During February it varied from 13°1 to 15°5, during March from 14°6 to 15°8, during April from 15°8 to 16°4, during June from 15°9 to 19°5, during July from 17°5 to 22°3, during August and September from 16°6 to 19°5, and during November from 17°5 to 18°5. Hauls were not made nor temperatures taken during January, May, October, and December. The variations noted, however, indicate that a minimum in temperature occurs in the winter months and a maximum in June and July.

These monthly variations in temperature are evidently due to seasonal influences. Consequently, unless some definite period of the year is selected as a basis for determining the effects of variation in temperature on distribution, our interpretations may be misleading. Because the greatest number of collections were made during June and July I have selected these months for this purpose.

While during these months the temperature varied irregularly from 15°9 to 22°3 the number of hauls made in water of known temperature are too few to permit considerations of the effects of small changes in temperature on the number of specimens obtained. I have, therefore, segregated the hauls into three groups according to whether the temperature varied from 15°9 to 17°5, 17°6 to 19°5, or 19°6 to 21°5. I have not considered the only hauls (1568 and 1591) made in water having temperatures above 21°5 because, on the basis of two hauls, it is impossible to eliminate the effects of light on the number of specimens obtained. The following table, therefore, supplies data concerning the relation between temperature and abundance of *S. bipunctata* with respect to the months of June and July.

TABLE 40

Surface Distribution of *S. bipunctata* with Respect to Temperature

Temperature in Centigrade	Number of hauls		Number of hours	Number of specimens		Frequency
	Total	Successful		Total	Per hour	
15°9–17°5	21	19	12.4	6818	549	91
17°6–19°5	53	36	42.8	16274	380	68
19°6–21°5	12	7	6.4	1422	222	58

This table shows clearly that the average number of specimens obtained per hour from the surface is greatest when the temperature of the water is least. It also shows that the frequency is greatest when the temperature is least.

It may be objected that, on the basis of so few hauls, the effect of their uneven distribution with respect to intensity of light might account for the results contained in the above table.

This objection would be justified if the greatest number of hauls in water varying from 15°9 to 17°5 had been made during morning and evening twilight, while those in water varying from 19°6 to 21°5 had been made during intense daylight. However, as frequency means the percentage of hauls in which the species appears without reference to number of specimens obtained, its parallelism with abundance indicates that the hauls were evenly distributed. This is true because, if the species occurred at all, uneven distribution of hauls with respect to light would affect an increase or decrease in abundance but not in frequency. To demonstrate that hauls were evenly distributed, the following table is supplied, which includes only those hauls made during daylight.

TABLE 41

Surface Distribution of *S. bipunctata* between 6 a.m. and 6 p.m.

Temperature in Centigrade	Number of hauls		Number of hours	Number of specimens		Frequency
	Total	Successful		Total	Per hour	
15°9–17°5	17	15	9.7	3033	312	88
17°6–19°5	21	12	14.4	395	27	57
19°6–21°5	4	1	3.5	16	25	25

These data show that, during daylight, the species is most abundant and frequent in water having a temperature between 15°9 and 17°5. It further shows that the decrease in both frequency and abundance is significantly greater than that found in table 40. This is exactly what would be expected if intensity of light affects the distribution of this species. In the former table, where twilight hauls are included, the effect of higher temperatures in decreasing the abundance of specimens is, to some extent, counteracted by the effect of twilight in increasing it. In table 41, however, only a minimum of twilight hauls are included, and both the effects of more intense light and higher temperatures tend to decrease the abundance.

Still, this greater decrease in abundance and frequency during daylight is possibly affected by an uneven distribution of hauls throughout the various times of day. Our data show that, while three of the four hauls in water having a temperature between 19°6 and 21°5 were made between 10 a.m. and 2 p.m., only three of the twenty-one hauls in water having a temperature between 17°6 and 19°5, and six of the seventeen hauls in water having a temperature between 15°9 and 17°5 were made during this period. Now we have learned that *S. bipunctata* is on the surface in minimum numbers between 10 a.m. and 2 p.m. It will be interesting, therefore, to see what effect low and high temperatures have on the abundance of the species during this period of greatest light intensity.

TABLE 42

Distribution of *S. bipunctata* during the time of Minimum Abundance

(10 a.m. to 2 p.m.)

Temperature in Centigrade	Number of hauls		Number of hours	Number of specimens		
	Total	Successful		Total	Per hour	Frequency
15°9–17°5	6	5	2.4	69	29	83
17°6–19°5	3	2	2.0	30	15	67
19°6–21°5	3	1	3.06	16	5	33

The number of hauls included in this table are too few to determine fully the abundance of specimens with respect to temperature. These data, however, indicate that, even when the species migrates in maximum numbers from the surface, more specimens remain when the temperature is low than when it is high. However, the effect of higher temperatures in decreasing the abundance and frequency of the species is not so great as shown in the preceding table. I believe this means that, when most intense, light has more effect in causing downward migrations from the surface than low temperatures have in causing the species to remain. This cannot be proven but, if true, it suggests that the reverse is also true, namely, that subdued light has more effect in causing upward migrations to the surface than high temperatures have in preventing such migrations. In examining the following two tables evidence of this fact is not wanting.

TABLE 43

Surface Distribution of *S. bipunctata* during Night (6 p.m. to 6 a.m.)

Temperature in Centigrade	Number of hauls		Number of hours	Number of specimens		
	Total	Successful		Total	Per hour	Frequency
15°9–17°5	4	4	3.05	3785	1241	100
17°6–19°5	32	24	26.6	15459	581	75
19°6–21°5	8	6	2.9	1404	484	75

TABLE 44

Surface Distribution of *S. bipunctata* during the time of Maximum Abundance (6 to 10 p.m.)

Temperature in Centigrade	Number of hauls		Number of hours	Number of specimens		
	Total	Successful		Total	Per hour	Frequency
15°9–17°5	4	4	3.05	3785	1241	100
17°6–19°5	19	14	15.1	12208	808	74
19°6–21°5	8	6	2.9	1404	484	75

In table 43 all four hauls in water having a temperature between 15°9 and 17°5 were made betwen 6 and 10 p.m., while practically half the hauls in water having higher temperatures were made during this period. This means that the 1241 specimens obtained per hour when the temperature was 15°9-17°5 are not strictly comparable with the numbers obtained from water having higher temperatures. While the table shows that abundance and frequency decreases as the temperature increases, the amount of decrease is less than that found during the twelve hours of daylight (table 41). Finally table 44 shows that the amount of decrease is still less during the time when the species migrates in maximum numbers to the surface. In fact, the table shows an actual reversal in abundance and frequency relative to temperatures between 17°6-19°5 and 19°6-21°5. This reversal is probably due to the small number of hauls, but it is significant that the effect of high temperature on abundance and frequency of this species is less during twilight than during any other period of the day.

It was noted on page 121 that the number of specimens on the surface decreases abruptly after evening twilight vanishes. The above relations discovered between temperature and dis-

ERRATUM

TABLE 44.—The last line should read

19°.6–21°.5	4	3	1.6	1313	821	75

tribution leads me to suggest that the species migrates downward after twilight because, *the cause of upward migration being removed, it seeks deeper water where the temperature is lower.* Unfortunately this suppositon cannot be adequately tested because practically no closing net hauls were made with respect to temperature.

To summarize, it is demonstrated that, whether the data concern day, night, time of maximum abundance with respect to light, or time of minimum abundance, *S. bipunctata* is more abundant and frequent on the surface when the temperature is low than when it is high. It is further suggested that low surface temperatures *retard downward* and *aid upward* migrations, and that high surface temperatures *retard upward* and *aid downward* migrations.

VARIATION IN DISTRIBUTION OF *S. BIPUNCTATA* DUE TO SALINITY

From June 12, 1908, to April 21, 1910, 101 surface hauls were accompanied by water samples of which the salinities were computed. The salinity varied mainly from 33.549 to 33.693, although our data show a few instances outside these limits, the extremes being 33.381 and 34.069. Of the 101 hauls, 31 were scattered over the months of February, March, April, September, and November, while the remaining 70 were made during June and July. Now the salinities corresponding to the 31 hauls just mentioned average above 33.693. It is therefore advisable, owing to possible seasonal effects on distribution, to confine the following discussion to June and July data.

In attempting to correlate small changes in salinity with variations in the distribution of *S. bipunctata*, our data are not extensive enough to eliminate the effects of light and temperature. Consequently I have segregated the 70 June and July hauls into three groups according to whether the corresponding salinities were less than 33.605, between 33.605 and 33.648, or greater than 33.648. The surface distribution with respect to these groups is given in the following table.

TABLE 45

Surface Distribution of *S. bipunctata* with Respect to Salinity.

	Number of hauls		Number of hours	Number of specimens		Frequency	Average temperature
Salinity	Total	Successful		Total	Per hour		
33.604 or less	27	22	19.4	7243	373	81	17°.7
33.605–33.648	19	16	12.5	6941	555	84	19°.4
33.649 or more	24	16	21.0	7409	352	67	18°.8

These data indicate that, other things being equal, *S. bipunctata* accumulates on the surface in greater numbers when the salinity of the water is between 33.605 and 33.648. It may be objected that other things are not equal, that the average temperature corresponding to each salinity group differs, and that consequently the variations in abundance and frequency noted in the table are due to temperature and not to salinity. However, it has already been shown that the species is more abundant and frequent when the temperature is low. Therefore, if salinity has no effect, we should expect, as shown by temperature averages given in the table, the species to have been most abundant and frequent when the salinity was less than 33.605 and least abundant and frequent when it was between 33.605 and 33.648. This is obviously not the case. In fact the relations shown between temperature averages and salinity suggest that the effect of temperature is antagonistic to that of salinity. If this is true, then, by including only those hauls made when the temperature varied from 17°.6 to 19°.5 we should expect greater difference in abundance and frequency with respect to the three salinity groups than that found in the above data. The following table demonstrates that this is true.

TABLE 46

Effect of Salinity on Distribution of *S. bipunctata* when the Temperature varied from 17°.6 to 19°.5

	Number of hauls		Number of hours	Number of specimens		Frequency
Salinity.	Total	Successful		Total	Per hour	
33.604 or less	14	10	11.1	2430	219	71
33.605–33.648	9	8	8.2	6073	753	89
33.649 or more	18	13	16.1	6781	421	72

Comparing this with the preceding table, we see that the frequency and abundance corresponding to salinities less than

33.605 is much less in table 46 than in table 45. Now the average temperature corresponding to this salinity group is 17°7, which means that more hauls were made when the temperature was below 17°6 than when it was above 19°5. In fact during only two of the 27 hauls was the temperature above 19°5, while during 11 it was below 17°6. The effect of low temperatures, then, affords an explanation of why a reduction occurred in abundance from 373 to 219, and in frequency from 81 to 71.

Comparison of the two tables also shows that the frequency and abundance corresponding to salinities between 33.605 and 33.648 are much greater in table 46 than in table 45. As the temperature average corresponding to this salinity group is 19°4, we should infer that more hauls were made when the temperature was over 19°5 than when it was under 17°6. In fact the temperature during eight of the 19 hauls was above 19°5, while during only two hauls was it below 17°6. Hence, because high temperatures are detrimental to the accumulation of specimens on the surface, the reason is evident why the frequency increased from 84 to 89, and the abundance from 555 to 753.

Again, comparison of the two tables shows that the abundance and frequency corresponding to salinities greater than 33.648 increased respectively from 352 and 67 as given in table 45 to 421 and 72 as given in table 46. The temperature during four of the 24 hauls was more than 19°5, while during two hauls it was less than 17°6. This not only explains why the abundance and frequency increased, but also why the amount of increase is less than that corresponding to the second salinity group, and less than the amount of decrease corresponding to the first salinity group.

Finally, these tables demonstrate that salinity has a marked effect on the distribution of *S. bipunctata*. While the effect is evident in table 45, it is much greater when the antagonistic effects of variable temperatures are eliminated from the data, as in table 46. This means, then, that the species is most abundant and frequent on the surface when the salinity of the water varies between 33.605 and 33.648, that it is less when the salinity is over 33.648, and still less when the salinity is below 33.605. It would be interesting to tabulate data concerning salinity with respect to temperatures varying from 15°9 to 17°5, and from 19°6 to 21°5, but the few hauls made under these conditions make this impossible.

In spite of the apparent significance of these data it may be argued that the hauls were distributed irregularly with respect to light. Consequently, if more night hauls were made when the salinity varied from 33.605 to 33.648 than when it was outside these limits, the greater abundance and frequency noted might be due to the effect of light and not to that of salinity. The following tables indicate that this is not so.

TABLE 47

Effect of Salinity on Distribution of *S. bipunctata* with respect to Night (6 p.m. to 6 a.m.)

	Number of hauls		Number of hours	Number of specimens		Frequency	Average temperature
Salinity	Total	Successful		Total	Per hour		
33.604 or less	15	12	10.3	6284	610	79	18°9
33.605–33.648	13	11	9.2	6763	735	85	19°6
33.649 or more	13	10	12.1	7264	600	77	19°1

TABLE 48

Including only hauls made when Temperature varied from 17°6 to 19°5

	Number of hauls		Number of hours	Number of specimens		Frequency
Salinity	Total	Successful		Total	Per hour	
33.604 or less	10	7	7.7	2329	302	70
33.605–33.648	7	6	6.95	5945	841	86
33.649 or more	11	9	10.6	6646	627	81

From these tables we see that, after day hauls are eliminated from consideration, *S. bipunctata* still persists in being more abundant and frequent on the surface when the salinity varies from 33.605 to 33.648. Furthermore, after the antagonistic effects of variable temperatures are eliminated by tabulating only those night hauls made when the temperature was between 17°6 and 19°5, table 48 shows *increased correlation* between abundance and frequency of the species and salinity of the water.

There is still a possibility that a maximum number of hauls corresponding to salinities between 33.605 and 33.648 were made during twilight, and a maximum number corresponding to salinities outside these limits during darkness. Now of the ten hauls corresponding to salinities less than 33.605 and temperatures between 17°6 and 19°5, four were made during *evening twilight* (6 to 10 p.m.), and six during *morning twilight* (4 to 6 a.m.). Concerning salinities in the second group, all seven hauls were made during *evening twilight.* Finally of the eleven hauls corresponding to the third salinity group, four were made during *evening twilight*, four during *morning twilight*, and three during *darkness* (10 p.m. to 4 a.m.).

The distribution of hauls does show irregularity with respect to twilight, which may partly explain why the maximum abundance and frequency corresponds to the second salinity group. However, because of the three hauls made during *darkness*, which correspond to salinities more than 33.648, and the fact that the species maintains a *relative minimum* on the surface during darkness, we should expect both abundance and frequency to be less than that corresponding to salinities below 33.605. This is obviously not the case. It would seem, therefore, that while irregular distribution of hauls with respect to twilight has probably affected the relation between abundance and frequency of the species and salinity of the water, the data included in the above tables cannot be adequately explained without involving the effect of variations in salinity.

Finally, it is well to consider data based on daylight hauls. Such data are tabulated below.

TABLE 49

Effect of Salinity on Distribution of *S. bipunctata* with respect to Daylight (6 a.m. to 6 p.m.)

Salinity	Number of hauls		Number of hours	Number of specimens		Frequency	Average temperature
	Total	Successful		Total	Per hour		
33.604 or less	12	10	9.0	949	105	83	17°2
33.605–33.648	6	6	3.3	178	54	100	18°9
33.649 or more	11	5	8.9	145	16	22	18°9

The distribution with respect to salinity, as shown in this table, is not parallel with that shown in the preceding tables. However, since the temperature average corresponding to the first salinity group is the *lowest*, it is certain that the abundance of 105 is too large for comparison with the 54 of the second, and the 16 of the third salinity group. Again, the hauls were unevenly distributed with respect to light. Corresponding to the first group, four hauls were made between 6 and 8 a.m., the time of *morning maximum abundance*, two between 4 and 6 p.m., and six between 8 a.m. and 4 p.m. Corresponding to the second group, five hauls were made between 8 a.m. and 4 p.m., one between 4 and 6 p.m., and *none between 6 and 8 a.m.* Concerning the third group, five hauls were made between 6 and 8 a.m., two between 4 and 6 p.m., and four between 8 a.m. and 4 p.m.

From these facts it follows that the hauls included in the above table were so distributed that both effect of light and temperature were antagonistic to that of salinity. Therefore, if the data were corrected with respect to these factors, the effect of variations in salinity ought to be more apparent. By including only data relative to hauls made between 8 a.m. and 4 p.m. the antagonistic effect of light may be mostly eliminated. The results of such elimination are shown in the following table.

TABLE 50

Effect of Salinity on the Surface Distribution of *S. bipunctata* based on Hauls between 8 a.m. and 4 p.m.

Salinity	Number of hauls		Number of hours	Number of specimens		Frequency	Average temperature
	Total	Successful		Total	Per hour		
33.604 or less	6	4	2.4	40	16	67	17°0
33.605–33.648	5	5	2.9	177	61	100	18°9
33.649 or more	4	2	3.6	30	8	50	19°05

Because only four of the entire fifteen hauls were made when the temperature of the water was between 17°6 and 19°5, it is impossible to standardize the data with respect to temperature. However, from the average temperatures recorded in the table, we can be sure that the abundance of 16 corresponding to the first salinity group is larger, and that of 8 corresponding to the third salinity group smaller than it would be if the effect of temperature could be eliminated. In spite of the antagonistic effects of temperature the table shows that, when disturbing light factors are eliminated, the maximum abundance and frequency of the species is correlated with salinities between 33.605 and 33.648.

It is possible that the evidence in all the above data may be due merely to insufficient hauling. However, if this is true, it is difficult to see why the data *in every case indicate maximum abundance and frequency corresponding to salinities between 33.605 and 33.648.* This is true whether the data are tabulated with respect to temperature and light or not. Were such results due merely to chance or insufficient hauling we should expect such a variety of tabulation to introduce contradictions, but it does not. Consequently, it seems legitimate to conclude that, other things being equal, *S. bipunctata* is most abundant and frequent on the surface when the salinity of the water is between 33.605 and 33.648.

What this relation between salinity and distribution signifies is indeed puzzling. We know that salinity increases, somewhat irregularly, with the depth, and we also know that *S. bipunctata* is most abundant and frequent during the greater part of day and night in 15-20 fathoms. Are these facts correlated? Unfortunately June and July salinities corresponding to this depth have not been determined. We do know, however, that, while the average of the 70 surface salinities considered is 33.641, 31 were below 33.605, 14 between 33.605 and 33.648, and 25 above 33.648, which means that the salinity *most characteristic* of the surface is below 33.605. Now in 50 to 75 fathoms, while the average salinity is about 33.964, it is usually below 33.874. It is, therefore, obvious that between the surface and 50 fathoms a depth occurs in which the salinity is *normally* between 33.605 and 33.648. If this depth should prove to be 15-20 fathoms, the meaning of the above data would be much clearer. This speculation, however, proves nothing, but it does suggest a possible explanation of the correlation between salinity and distribution.

SEASONAL VARIATION IN THE DISTRIBUTION OF *S. BIPUNCTATA*

In discussing this question it is necessary to confine attention to surface hauls, for our closing nets were not employed sufficiently throughout the seasons to warrant adequate interpretations of the data obtained by them. Furthermore, the surface collecting with respect to season was so irregular and fragmentary that the meaning of the data is very obscure. Six hauls were made during each of the months of February, April, and September, 7 during November, 15 during March, 42 during July, and 53 during June. During August only one haul was made, and during January, May, October, and December none were made. In the following table the data for each month during which collections were made are given.

TABLE 51

Monthly Variation in Distribution of *S. bipunctata.*

Month	Number of hauls		Number of hours	Number of specimens		Frequency	Average temperature	Average Salinity	Distribution of hauls with respect to time of day					
	Total	Successful		Total	Per hour				4-6 a.m.	6-8 a.m.	8 a.m.-4 p.m.	4-6 p.m.	6-10 p.m.	10 p.m.-4 a.m.
February	6	6	7.25	718	93	100	13°6	33.540	1	1	2	1	1	0
March	15	9	12.2	733	60	60	15.1	33.641	0	0	7	5	3	0
April	6	5	4.1	410	100	79	16.1	33.700	4	0	2	0	0	0
June	53	40	35.5	10672	301	75	17.9	33.608	4	5	19	8	17	0
July	42	26	30.3	10357	341	62	18.9	33.641	10	7	8	1	13	3
August	1	1	0.33	35	105	100	18.3	?	0	0	0	0	1	0
September	6	5	2.3	195	85	83	18.5	33.877	1	2	2	0	1	0
November	7	4	3.4	1444	424	57	17.9	33.848	0	1	4	2	0	0

It is evident from this table that the hauls were too unevenly distributed with respect to temperature, salinity, and especially time of day, to permit any significant comparison of the abundance and frequency of the species during the various months. Except for one November haul made between 8 and 10 a.m., which obtained 1240 specimens, the largest number obtained in any one haul during this month was 135. This indicates that the November abundance of 424 is too large to represent the usual abundance during this month. With this exception the months of June and July are apparently those of maximum abundance, although this appearance may be entirely due to the greater number of twilight hauls made during these months. Until more collecting is accomplished with respect to season it will be impossible to determine its effect on the distribution of this species.

EFFECT OF LOCALITY ON THE DISTRIBUTION OF *S. BIPUNCTATA*

As in the case of seasonal collecting, our closing nets were not employed at all stations. Consequently a consideration of the effect of locality, or distance from the coast, on distribution limits us to surface collections. While definite seasonal effects on distribution could not be discovered, it is very probable that some such effect exists. It seems, therefore, advisable to restrict this consideration to June and July data. These data are summarized in the accompanying table.

From this table we find that conditions of salinity, temperature, and time of day under which the hauls were made varied from station to station. With such an amount of variation no significant effect of locality on distribution can be detected. From the table we see that those stations where the abundance of specimens is greatest are those where the most twilight hauls were made. This indicates that very little, if any, difference in distribution exists with respect to distance from the coast. At any rate, until more definite collecting regarding this problem is accomplished, no definite conclusions are possible.

TABLE 52

Surface Distribution of *S. bipunctata* with Respect to Locality.

Station	Latitude	Longitude	Number of hauls		Number of hours	Number of Specimens		Distribution of hauls with respect to time						Average temperature	Average Salinity	Distance from coast.
			Total	Successful		Total	Per hour	4-6 a.m.	6-8 a.m.	8 a.m. to 4 p.m.	4-6 p.m.	6-10 p.m.	10 p.m. to 4 a.m.			
1	32°(30′–40′)	117°(20′–30′)	2	1	0.9	16	19	0	0	2	0	0	0	20°0	33.617	Bet. 10 & 20 miles from coast.
2	(30′–40′)	(30′–40′)	1	0	0.3	0	0	0	0	1	0	0	0	18.9	(?)	Bet. 20 & 30 miles from coast.
3	(40′–50′)	(20′–30′)	3	1	1.8	5	3	0	0	3	0	0	0	21.0	33.699	Bet. 10 & 20 miles from coast.
4	(40′–50′)	(30′–40′)	4	1	2.3	25	11	0	0	3	1	0	0	18.4	33.601	Bet. 20 & 30 miles from coast.
5	(40′–50′)	(40′–50′)	1	1	0.7	20	30	0	0	1	0	0	0	17.1	33.630	Bet. 30 & 40 miles from coast.
6	(40′–50′)	(50′–60′)	2	1	1.55	75	48	0	0	1	0	1	0	18.5	33.580	Bet. 40 & 50 miles from coast.
7	(40′–50′)	118°(20′–30′)	3	2	1.7	659	387	1	1	1	0	0	0	19.2	33.652	Bet. 5 & 10 miles from San Clemente.
8	(50′–60′)	117°(10′–20′)	7	4	7.6	782	103	2	0	1	0	3	1	18.8	33.733	Bet. 0 & 5 miles from La Jolla.
9	(50′–60′)	(20′–30′)	29	19	19.2	7090	368	7	4	5	0	11	2	19.3	33.657	Bet. 10 & 20 miles from coast.
10	(50′–60′)	(30′–40′)	30	25	22.3	14662	657	4	3	4	4	14	0	17.8	33.594	Bet. 20 & 30 miles from coast.
11	(50′–60′)	(40′–50′)	2	2	1.25	70	56	0	0	2	0	0	0	16.5	(?)	Bet. 30 & 40 miles from coast.
12	(50′–60′)	118°(0′–10′)	1	1	0.4	1	2	0	0	0	1	0	0	19.1	33.630	Bet. 50 & 60 miles from coast.
13	(50′–60′)	(10′–20′)	1	0	0.3	0	0	0	0	1	0	0	0	17.5	(?)	Bet. 10 & 20 miles from San Clemente.
14	(50′–60′)	(20′–30′)	2	1	1.3	9	7	0	0	2	0	0	0	18.5	33.690	Bet. 5 & 10 miles from San Clemente.
15	33°(0′–10′)	117°(30′–40′)	1	1	0.2	1	5	0	0	1	0	0	0	16.5	33.432	Bet. 10 & 20 miles from coast.
16	(0′–10′)	(40′–50′)	1	1	0.5	25	50	0	0	1	0	0	0	16.5	(?)	Bet. 20 & 30 miles from coast.
17	(10′–20′)	118°(0′–10′)	1	0	0.3	0	0	0	0	1	0	0	0	(?)	(?)	Bet. 10 & 20 miles from Catalina.
18	(20′–30′)	(10′–20′)	1	0	0.3	0	0	0	0	1	0	0	0	(?)	(?)	Bet. 5 & 10 miles from Catalina.
19	32°(20′–30′)	(10′–20′)	1	1	0.4	3	7	0	1	0	0	0	0	18.9	(?)	Bet. San Clemente and Cortez banks.
20	(20′–30′)	119°(0′–10′)	2	2	0.8	2527	3032	0	2	0	0	0	0	16.5	33.457	On Cortez banks.

SIGNIFICANCE OF THE DATA CONCERNING THE DISTRIBUTION OF *S. BIPUNCTATA.*

In the foregoing pages it is demonstrated that *S. bipunctata* is most abundant on the surface during twilight when the temperature of the water is between 15°9 and 17°5, and the salinity between 33.605 and 33.648. Furthermore, we found the species confined to the upper 150 fathoms of water, and mainly above 75 fathoms. Our data also indicate that during darkness and intense light the species is most abundant and frequent in 15-20 fathoms, migrating to the surface only during the hours of twilight. In other words, the region of 15-20 fathoms is probably the center from which the species migrates. Now what do these facts taken together signify?

Let us assume that the *usual* conditions of light, temperature, and salinity occurring in 15-20 fathoms are those which determine the migrations of this species. On this assumption, if the intensity of the light in this depth during the day approximates twilight, the migration of the species toward the surface is readily explained. Again, if the temperature in 15-20 fathoms is *normally* between 15°9 and 17°5, or less than 15°9, and the salinity between 33.605 and 33.648, the tendency of the species to remain on the surface in greater numbers when these conditions are realized is also readily explained.

What, then, are the usual conditions of light, temperature, and salinity occurring in 15-20 fathoms? Concerning light, we know its intensity below the surface rapidly decreases as the depth increases, and it is generally agreed that it is very subdued below 100 or 200 fathoms. Now, since the species begins to accumulate on the surface at sundown and sunrise, it is certain that the *earlier* or *brighter* evening twilight and the *later* or *brighter* morning twilight initiates the upward migrations. This fact, together with the time of day in which we found the maximum number of specimens in the various depths, indicates that during the greater part of the day *bright twilight* conditions normally occur in 15-20 fathoms. Again, with respect to temperature, while observations were not taken in connection with closing net hauls, our records show that the usual June and July temperature in 15-20 fathoms is approximately 15°-16°. Finally, while salinity determinations for 15-20 fathoms were not made, sity it is possible, as pointed out on page 139, that the salinity is usually between 33.605 and 33.648.

Our data, then, seem to justify the truth of the above assumption. To prove it, however, would require carefully planned collecting with all conditions of light-intensity in each depth recorded, as by an automatic light meter, systematic closing net hauls with corresponding temperature observations in each depth, and salinity determinations corresponding to each haul in each depth.

Notwithstanding that these more accurate methods of collecting were not employed, from what data we have the following conclusions may be drawn:

1. The region of 15-20 fathoms is the center from which the species migrates or, in other words, it is the depth in which the greatest number of optimum conditions favorable to this species are found.

2. It migrates to the surface at sundown and sunrise because the conditions of light intensity at these times are *similar* to those occurring in 15-20 fathoms during the greater part of the morning and afternoon.

3. Other things equal, it remains on the surface in greater numbers when the temperature of the water is between 15°9 and 17°5, because this is approximately the normal temperature occurring in 15-20 fathoms.

4. It remains on the surface in greater numbers when the salinity of the water is between 33.605 and 33.648 because this approximates the normal salinity in 15-20 fathoms. This, at present, is *barely suggested* by our data; it still remains to be proven.

5. The animals leave the surface at night because the light incentive which caused them to migrate upward is absent, and they presumably return to the region of 15-20 fathoms where optimum temperature and other conditions occur.

6. Probably light has more pronounced effect on vertical distribution than temperature or salinity because its variations are more regular and periodic.

7. All individuals do not react toward light, temperature, and salinity in the same way. While the majority migrate toward the surface during twilight hours, and toward deeper water during intense light and darkness, *a few almost always remain in deeper water during twilight, and on the surface during intense light and darkness.* Similar individual differences occur with respect to temperature and salinity. This means that those optimum conditions favorable to the species as a whole are not favorable to each individual or, in other words, the characteristic organization, constitution, or physiological state of each individual modifies the effect of light, temperature, and salinity on its behavior.

DISTRIBUTION OF *S. SERRATODENTATA.*

Of the 6,499 specimens of this species obtained, 76 were taken from the surface, 676 in open vertical nets from depths varying from 500 to 25 fathoms, 5,299 in vertical closing nets from between 300 and 10 fathoms, and 448 in horizontal closing nets. The 76 obtained from the surface were distributed in 14 or 9.5 per cent of the 148 hauls made. Of 68 vertical closing net hauls 46 or 68 per cent obtained some specimens, while of the 118 horizontal closing net hauls 33 or 18 per cent were successful, and of 41 open vertical net hauls 14 or 34 per cent obtained the species. More complete data concerning the surface and closing net hauls are given in the following tables.

TABLE 53

Vertical Distribution of *S. serratodentata* based on Surface and Horizontal Closing Net Hauls.

Depth in fathoms	Number of hauls		Number of hours	Number of specimens		Frequency
	Total	Successful		Total	Per hour	
0	136	12	96.7	74	1	9
4–6	11	0	3.3	0	0	0
7–12	15	1	4.6	15	3	7
15–20	13	1	3.5	4	1	8
25–35	19	5	5.3	15	3	26
40–75	20	5	5.7	91	16	25
100–150	19	9	6.5	106	17	47
160–220	10	9	3.1	174	56	90
250–350	11	5	5.4	43	8	27

TABLE 54

Vertical Distribution of *S. serratodentata* based on Vertical Closing Net Hauls.

Depth in fathoms	Number of hauls		Distance of haul in fathoms	Number of specimens		Frequency
	Total	Successful		Total	Per 50 fathom haul	
0–10	11	0	10	0	0	0
10–25	5	2	15	33	22	40
25–50	10	5	25	27	5	50
50–75	9	7	25	190	44	78
75–100	9	4	25	442	98	45
100–150	10	8	50	773	77	80
150–200	9	9	50	1351	150	100
200–250	8	7	50	1439	179	88
250-300	5	4	50	1057	211	80

It is significant that the data in both tables agree that this species is mainly mesoplanktonic, and that the depth of maximum abundance and frequency is below 150 fathoms. They disagree in detail but, owing to very different methods of collecting, and of different depths considered, this is to be expected. From the fact that the frequency and abundance are more nearly parallel in the former than in the latter table, the data in the former are probably more reliable.

In arranging the above data with respect to day and night, the following table suggests that the species migrates upward during the night.

TABLE 55

Day and Night Distribution of *S. serratodentata* based on Surface and Horizontal Closing Net Hauls.

Daylight or 6 a.m. to 6 p.m.

Depth in fathoms	Number of hauls		Number of hours	Number of specimens		Frequency
	Total	Successful		Total	Per hour	
0	78	6	54.4	48	1	8
4–6	5	0	1.8	0	0	0
7–12	8	0	2.4	0	0	0
15–20	7	0	1.9	0	0	0

TABLE 55—*Continued*

Daylight or 6 a.m. to 6 p.m.

Depth in fathoms	Number of hauls		Number of hours	Number of specimens		
	Total	Successful		Total	Per hour	Frequency
25–35	12	2	3.3	3	1	16
40–75	12	2	3.2	82	28	16
100–150	8	4	2.5	59	26	50
160–220	6	5	1.8	132	73	83
250–350	9	2	5.1	26	5	22

Night or 6 p.m. to 6 a.m.

Depth in fathoms	Number of hauls		Number of hours	Number of specimens		
	Total	Successful		Total	Per hour	Frequency
0	58	6	42.3	30	1	10
4–6	6	0	1.5	0	0	0
7–12	7	1	2.2	15	7	14
15–20	6	1	1.6	4	2	16
25–35	7	3	2.0	21	10	43
40–75	8	2	2.6	9	3	25
100–150	11	5	4.1	47	11	45
160–220	4	4	1.3	42	32	100
250–350	2	1	0.3	17	57	50

This table shows clearly that the species was practically never obtained during daylight above 40 fathoms, while during the night it occurred above this depth. While the difference between day and night distribution is not so striking as in the case of *S. bipunctata*, the data point in exactly the opposite direction to those of Fowler (1905). In the Biscayan plankton he found *S. serratodentata* more frequent on the surface during daylight. He has, however, regarded the day as including twilight, while I have regarded the night as including it. This, together with the fact that in table 55 we find very little distinction between day and night surface distribution, and that the number of specimens is so small, may explain the difference noted.

In connection with day and night distribution it is significant to discover that, when data obtained with vertical closing nets are segregated as in table 56, similar variation is found.

TABLE 56

Day and Night Distribution of *S. serratodentata* based on Vertical Closing Net Hauls.

Daylight or 6 a.m. to 6 p.m.

Depth in fathoms	Number of hauls		Distance of haul in fathoms	Number of specimens		Frequency
	Total	Successful		Total	Per 50 fathom haul	
0–10	7	0	10	0	0	0
10–25	3	1	15	13	14	33
25–50	6	2	25	5	1	33
50–75	6	4	25	103	34	66
75–100	6	3	25	314	105	50
100–150	6	5	50	561	93	83
150–200	6	6	50	1310	218	100
200–250	7	7	50	1439	205	100
250–300	3	3	50	1056	352	100
Night or 6 p.m. to 6 a.m.						
0–10	4	0	10	0	0	0
10–25	2	1	15	20	33	50
25–50	4	3	25	22	11	75
50–75	3	3	25	87	58	100
75–100	3	1	25	128	86	33
100–150	4	3	50	212	53	75
150–200	3	3	50	41	14	100
200–250	1	0	50	0	0	0
250–300	2	1	50	1	1	50

While these data are not strictly comparable to those obtained with horizontal nets, they show clearly that during daylight the species is less numerous above 75 fathoms than it is during the night.

In the data concerning vertical closing net hauls one instance is found where two similar series of hauls were made with the same net on the same day at approximately the same location. One series was made between 1:10 and 3:24 p.m. and the other between 4:20 and 7:34 p.m. It will be interesting, therefore, to compare the *actual* number of animals obtained from each depth during the afternoon and evening series. Such data are given in the following table.

TABLE 57

Two Series of Hauls containing *S. serratodentata* made with the Nansen Closing Net on March 17, 1910, at 32° 50′.0 N and 117° 30′.0 W.

Hauls made between 1:10 and 3:24 P.M.					Hauls made between 4:20 and 7:34 P.M.				
			Number of specim'ns					Number of specim'ns	
Haul number	Time	Depth	Total	Per 50 fathoms	Haul number	Time	Depth	Total	Per 50 fathoms
2077	3:24 p.m.	25–10	0	0	2104	7:34 p.m.	25–10	20	66
2076	3:14 p.m.	50–25	4	8	2100	7:24 p.m.	50–25	12	24
2075	2:59 p.m.	75–50	12	24	2099	6:53 p.m.	75–50	78	156
2074	2:37 p.m.	100–75	263	526	2095	6:37 p.m.	100–75	128	256
2073	2:23 p.m.	150–100	156	156	2094	6:17 p.m.	150–100	165	165
2069	2:02 p.m.	200–150	400	400	2090	5:58 p.m.	200–150	100	100
2068	1:57 p.m.	250–200	715	715	2089	5:37 p.m.	250–200	129	129
2067	1:10 p.m.	300–250	478	478	2081	4:20 p.m.	300–250	316	316

This table shows that the species was most abundant above 75 fathoms during late afternoon and early evening, while below this depth it was most abundant during early afternoon. It is significant that this result is very similar to that derived from consideration of the average number of specimens obtained by both horizontal and vertical nets. It is quite certain, therefore, that the species migrates toward the surface when light is subdued. Owing to the small number of animals obtained it is impossible to determine accurately its center of migration, but the data suggest that this center is between 100 and 200 fathoms.

All our data show that the species was rarely found above 10 fathoms, which suggests the question: Why did it occur on the surface? Of the fourteen hauls in which it appeared, six were made between 6 and 10 p.m., one between 10 a.m. and noon, three between 8 and 10 a.m., and four between 6 and 8 a.m. It seems, therefore, that their occurrence on the surface was not correlated with intensity of light, or time of day. Again, fifty-four specimens were obtained when the temperature of the water was between 15°.5 and 17°.8, eight when it was between 18°.6 and 19°.3, and fourteen when it was between 20°.5 and 22°.2. This possibly means that low temperatures caused them to remain in greater numbers on the surface, but it can not explain what brought them there. Finally, the salinities corresponding to the fourteen hauls varied from 33.563 to 34.069 so that it seems impossible that this was a factor. Their occurrence on the surface was undoubtedly due to some unusual surface conditions. Low temperature was possibly one, but what the others were is not apparent in our data.

Considering all the data, the following conclusions may be drawn:

1. *S. serratodentata* occurs mainly in the mesoplankton.

2. It is maximum in abundance and frequency in the region of 200 fathoms.

3. It is rarely taken above 40 fathoms during daylight, but occurs above this depth at night.

4. The species probably migrates toward the surface when twilight is very subdued, but rarely ascends above 10 fathoms.

5. Its center of migration, or the depth in which the greatest number of optimum conditions are found, is probably between 100 and 200 fathoms.

6. Its exceptional occurrence on the surface is probably correlated with some unusual surface conditions, of which low temperature may be one.

DISTRIBUTION OF *S. LYRA*

Of the 272 specimens of this species only four were obtained from the surface. Open vertical nets obtained 61 from a variety of depths below 75 fathoms, horizontal closing nets obtained 112 from below 25 fathoms, and vertical closing nets obtained 94 from below 50 fathoms. All these data agree that the species occurs very rarely near the surface. The exact way in which the number of specimens obtained with surface and horizontal closing nets were distributed with respect to depth is given in the following table:

TABLE 58

Vertical Distribution of *S. lyra* based on Surface and Horizontal Closing Net Hauls.

	Number of hauls		Number of hours	Number of specimens			Frequency
Depth	Total	Successful		Total	Per hour	Per 10 hrs.	
0	136	2	96.7	4	1—	1—	1.4
4–6	11	1	3.3	1	1—	3	9.0
7–12	15	0	4.6	0	0	0	0
15–20	13	0	3.5	0	0	0	0
25–35	19	4	5.3	11	2+	21	21
40–75	20	2	5.7	9	2—	15	10
100–150	20	6	6.5	20	3+	31	30
160–220	10	4	3.1	17	6—	57	40
250–350	11	3	5.4	54	10	100	27

The per 10 hour column is supplied in order to eliminate the fractions which occur when the number of specimens is expressed according to one hour hauls.

This table shows clearly that the species rarely occurs above 25 fathoms, and that it increases in abundance and frequency at least down to 250 fathoms. In 25-35 fathoms, however, there is an irregularity in the increase and it is interesting to notice that when the night hauls are eliminated this irregularity disappears This is shown in table 59.

TABLE 59

Daylight Distribution of *S. lyra* (6 a.m. to 6 p.m.) based on Surface and Horizontal Closing Net Hauls.

	Number of hauls		Number of hours	Number of specimens			
Depth	Total	Successful		Total	Per hour	Per 10 hrs.	Frequency
0	78	2	54.4	4	1—	1—	2.5
4–6	5	0	1.8	0	0	0	0
7–12	8	0	2.4	0	0	0	0
15–20	7	0	1.9	0	0	0	0
25–35	12	2	3.3	2	1—	9	17
40–75	12	1	3.2	8	2+	25	8
100–150	8	2	2.5	12	5—	48	25
160–220	6	3	1.8	16	8+	88	50
250–350	9	2	5.1	52	10+	102	22

TABLE 60

Night Distribution of *S. lyra* (6 p.m. to 6 a.m.) based on Surface and Horizontal Closing Net Hauls.

	Number of hauls		Number of hours	Number of specimens			
Depth	Total	Successful		Total	Per hour	Per 10 hrs.	Frequency
0	58	0	42.3	0	0	0	0
4–6	6	1	1.5	1	1—	7	17
7–12	7	0	2.2	0	0	0	0
15–20	6	0	1.6	0	0	0	0
25–35	7	2	2.0	9	4+	45	29
40–75	8	1	2.6	1	1—	4	13
100–150	11	4	4.1	8	2—	19	36
160–220	4	1	1.3	1	1—	8	25
250–350	2	1	0.3	2	6+	66	50

Table 59 shows that during daylight the species occurs rarely above 40-75 fathoms, and that it increases regularly in abundance from nine in 25-35 fathoms to 102 in 250-350 fathoms. The increase in frequency is more irregular, but this is to be expected because so few successful hauls were made. When compared with the night distribution, as shown in table 60, the species is found less abundant above and more abundant below 40 fathoms during the day. While the data do not prove nocturnal migration toward the surface they indicate that such migration occurs.

Of the 94 specimens obtained with vertical closing nets one was taken from between 50 and 75 fathoms, five between 75 and 100 fathoms, seven between 100 and 150 fathoms, 33 between 150 and 200 fathoms, 26 between 200 and 250 fathoms, and 22 between 250 and 300 fathoms. Expressing these numbers according to unit distance of haul they are 2, 11, 7, 36, 33, and 55. (In this instance, in order to avoid fractions of animals, 500 instead of 50 fathoms is considered as the unit distance of haul.) The frequencies corresponding to these numbers are 11, 33, 30, 66, 75, and 60. This means that the species did not occur above 50 fathoms, and that it increased in abundance from two in 50-75 fathoms, to 55 in 250 to 300 fathoms, and in frequency from 11 in 50-75 fathoms to 75 in 200-250 fathoms.

When vertical closing net hauls are segregated with respect to day and night, it appears that only one specimen was obtained at night. Now we learn from table 56 that the number of night hauls in each depth was very small. This together with the fact that the total number of specimens was only 94, will possibly explain why the animals were not obtained at night. However, whatever the reason may be, it seems certain, from data concerning horizontal closing net hauls, that the absence of the species was not due to light.

Hence, when all the data are considered, we find that, while the species does not occur abundantly in the San Diego region, the following conclusions are suggested:

1. The species is typically mesoplanktonic.
2. It occurs very rarely above 25 fathoms and is most abundant and frequent between 200 and 300 fathoms.
3. It occurs in greater numbers within 35 fathoms of the surface during the night than during the day.
4. It is very possible that nocturnal migrations toward the surface occur, although their meaning is obscure.
5. Its center of migration is probably below 200 fathoms.

DISTRIBUTION OF OTHER SPECIES

Distribution of S. hexaptera

Of 28 specimens obtained, 11 were taken from the surface, five with horizontal closing nets, three with vertical closing nets, and nine with open vertical nets. All our data concerning the distribution of these specimens are given in the following table.

TABLE 61

Data concerning the Distribution of *S. hexaptera.*

Haul number	Date	Time of Day	Depth	Number of specimens	
				Total	Number per 10 hrs. hauling
	Horizontal Net Hauls.				
	1904				
275	Sept. 17	7:30 a.m.	0	2	1+
	1905				
412	Feb. 25	6:00 a.m.	0	4	
	1908				
1417	June 19	10:20 a.m.	0	2	
1535	July 8	7:30 a.m.	0	2	
	1909				
1686	June 22	4:00 a.m.	0	1	
	1908				
1476	June 2	11:00 a.m.	50	1	10—
	1909				
1929	Sept. 3	2:53 p.m.	50	4	
	Vertical Closing Net Hauls				
	1910				
2038	Mar. 15	3:52 p.m.	75–50	2	
2094	Mar. 17	6:17 p.m.	150–100	1	
	Open Vertical Net Hauls.				
	1905				
468	Apr. 22	6:00 a.m.	45	1	
462	Apr. 15	6:00 a.m.	110	4	
	1908				
1492	June 25	10:10 a.m.	210	1	
1516	June 30	9:20 a.m.	250	2	
1527	July 2	11:20 a.m.	500	1	

From these data we see that this species is irregularly distributed. So few specimens were obtained that it is difficult to tell whether it typically occurs in the mesoplankton or not. However, excepting at the surface it has not been obtained above 45 fathoms, and even those from the surface when expressed in terms of number per 10 hours of hauling become insignificant beside those taken in 50 fathoms. It is probable, therefore, that the species occurs mainly in the mesoplankton or lower epiplankton.

Distribution of S. planktonis

Of the 36 specimens obtained, two were taken from the surface, six with horizontal closing nets, 15 with vertical closing nets, and 13 with open vertical nets. All data concerning this species are given in the following table.

TABLE 62

Data concerning the Distribution of *S. planktonis*.

Haul number	Date	Time of Day	Depth	Number of specimens	
				Total	Number per 100 hour-haul
	Horizontal Net Hauls.				
	1907				
1422	Nov. 2	5:00 p.m.	0	1	1+
	1908				
1560	July 18	7:20 a.m.	0	1	
1476	June 21	11:00 a.m.	50	1	18+
1927	Sept. 3	1:22 p.m.	125	1	15+
1926	Sept. 3	12:21 p.m.	200	1	32+
1550	July 16	11:45 a.m.	350	3	56—
	Vertical Closing Net Hauls				Per 500 fathom haul
	1910				
2112	Apr. 19	9:55 a.m.	200–150	1	1+
2001	Feb. 17	10:06 a.m.	250–200	2	7+
2031	Mar. 15	2:01 p.m.	250–200	3	
2052	Mar. 16	2:41 p.m.	250–200	1	
2067	Mar. 17	1:10 p.m.	300–250	2	16
2081	Mar. 17	4:20 p.m.	300–250	6	
	Open Vertical Net Hauls				
	1904				
236	Aug. 9	7:10 a.m.	2	1	
	1908				
1508	June 27	5:58 a.m.	150	2	
1492	June 25	10:10 a.m.	210	3	
	1910				
2088	Mar. 17	5:11 p.m.	250	3	
	1908				
1468	June 19	9:35 a.m.	290	2	
1527	July 2	11:20 a.m.	500	2	

These data indicate that this species occurs mainly below 100 fathoms, although at times it is found on the surface. We may only conclude, therefore, that the species is typically mesoplanktonic and that it is apparently most abundant in the region of 300 fathoms.

Distribution of S. enflata

This species was obtained in only four surface hauls, which yielded a total of 6607 specimens. Of this number 6600 were obtained in two hauls (411 and 412) made on February 25, 1905. Six of the remaining seven were obtained on April 26, 1905, and the other specimen on June 11, 1908. In addition to the surface hauls, the open vertical net obtained 3520, but both horizontal and vertical closing nets failed to obtain a single specimen. This may be due to the fact that no specimens were obtained since June 19, 1908, before which date very few closing net hauls were made. All data regarding the species are contained in the following table.

TABLE 63

Data concerning the Distribution of *S. enflata.*

Haul	Date	Time of day	Depth	Temperature	Number of specimens
	1905				
411	Feb. 25	6:00 a.m.(?)	0	15°5	3500
412	Feb. 25	6:00 a.m.(?)	0	15°5	3100
473	Apr. 29	6:00 a.m.(?)	0	16°5	6
	1908				
1416	June 11	2:25 p.m.	0	?	1
		Open Vertical Net Hauls.			
	1904				
234	Aug. 8	9:30 a.m.	5	?	1
235	Aug. 8	10:00 a.m.	10	?	5
251	Aug. 27	7:10 a.m.	10	?	1
274	Sept. 17	7:00 a.m.	10	?	3500
	1905				
468	Apr. 22	6:00 a.m.	45	?	10
	1907				
1398	July 3	10:00 a.m.	75	?	1
	1905				
462	Apr. 15	6:00 a.m.	110	?	1
	1908				
1468	June 19	9:35 a.m.	290	?	1

From these data we may be sure that this species is strictly epiplanktonic. It can not be regarded as typical of the San Diego region, and since it occurs elsewhere on the surface when the temperature of the water is as high as 34°, it seems probable that it was carried into this region by currents from the more tropical seas. We have, however, found it to occur in midwinter when the temperature of the water was as low as 15°5, which, on the above supposition, makes its distribution decidedly puzzling.

Distribution of S. neglecta

This species, like *S. enflata*, can scarcely be considered typical of this region. It seems to be confined strictly to the surface, for it was not obtained in either open vertical nets or horizontal or vertical closing nets. Furthermore, of 127 specimens obtained, all but five were taken in three hauls made during February and April, 1905. Like *S. enflata*, the species is typical of the epiplankton of tropical seas, and its occurrence in the region of San Diego during the winter when the temperature of the water was 15°5 is likewise puzzling. Were it not for the low temperature noted, I should believe the species was carried here by currents from the tropics. It is possible, of course, that this species, as well as *S. enflata*, normally occurs here during the winter months and that it was not obtained in greater numbers because practically no winter collections were made. This, however, seems hardly probable. Our data warrant but one conclusion, namely: *S. neglecta*, when it occurs at all in this region, is confined to the upper epiplankton.

Distribution of Spadella draco

But one specimen was obtained, and that one in surface haul 411. Like *S. enflata* and *S. neglecta*, this species occurs typically in the warmer water of the more tropical seas, and the reason why it occurred in this region remains obscure.

Distribution of Eukrohnia hamata

Of 61 specimens obtained, six were taken in horizontal closing nets below 100 fathoms, 16 in vertical closing nets below 25 fathoms, and 39 in open vertical nets below 250 fathoms. None were found on the surface. These data agree that this species is typically mesoplanktonic, that it occurs occasionally above 100 fathoms, but not above 25 fathoms. Owing to the small number of specimens obtained any further conclusions are impossible.

Distribution of E. subtilis

Of 50 specimens obtained, two were taken with horizontal closing nets from 160 fathoms, and four from 200 fathoms. The vertical closing nets obtained nine from between 75 and 50 fathoms, two between 200 and 150 fathoms, 25 between 250 and 200 fathoms, and five between 300 and 250 fathoms. Finally, the open vertical net obtained three in a haul from 250 fathoms to the surface. From these data it is apparent that this species occurs in greatest number between 200 and 250 fathoms. It has never been taken above 50 and rarely above 150 fathoms. We can be sure, therefore, that this species is mesoplanktonic and that its probable center of migration is between 200 and 250 fathoms.

GENERAL SUMMARY AND CONCLUSIONS.

We have taken ten species of Chaetognatha from the vicinity of San Diego, none of which are new. They are *Sagitta bipunctata, S. serratodentata, S. lyra, S. hexaptera, S. planktonis, S. enflata, S. neglecta, Spadella draco, Eukrohnia hamata*, and *E. subtilis*. Of these only *S. bipunctata* was obtained in large enough numbers and frequently enough to permit extensive analysis of its manner of distribution. Concerning it we found:

1. It is typically epiplanktonic, occurring between the surface and 150 fathoms.

2. It is rarely found below 75 fathoms, and it is most frequent and abundant between the surface and 20 fathoms.

3. Between 6 p.m. and 6 a.m. the species is most abundant above 15 fathoms, while between 6 a.m. and 6 p.m. it is most abundant below 15 fathoms.

4. The species appears in maximum abundance on the surface and in 4-6 fathoms between 6 and 8 p.m., in 7-12 fathoms between

4 and 6 a.m., in 15-20 fathoms between 8 and 10 a.m., in 25-35 fathoms between noon and 2 p.m., and in 40-75 fathoms between 10 a.m. and noon.

5. In all depths above 25 fathoms the species attains maximum abundance twice during the day, one maximum occurring between 6 and 10 a.m., and the other between 6 and 8 p.m. Below 25 fathoms only one maximum occurs in each depth, and that one between 10 a.m. and 2 p.m.

6. The species attains its morning maximum on the surface within an hour after sunrise and its evening maximum within an hour after sunset.

7. Other conditions constant, the species is most frequent and abundant on the surface when the temperature of the water is between 15°9 and17°5.

8. It also tends to remain on the surface in greater numbers when the salinity is between 33.605 and 33.648.

9. No significant correlation between season and variations in distribution could be detected.

10. No significant correlation between locality, or distance from the coast, and variations in distribution were found.

From these facts we concluded:

1. It is probable that the region of 15-20 fathoms is the center from which the species migrates or, in other words, it is the depth where the greatest number of optimum conditions favorable to the species are found.

2. It migrates to that depth in which the intensity of light is similar to that occurring throughout a large part of the day in 15-20 fathoms, and it remains in greater numbers in that depth when the temperature and salinity of the water, and probably other unknown conditions, are similar to those typical of 15-20 fathoms.

3. This explains why the species occurs in maximum number on the surface during morning and evening twilight, why the evening maximum is the largest, why it leaves the surface so quickly after it becomes dark, why it is more abundant on the

surface when the temperature is below 17°5, and possibly why it is more abundant when the salinity is between 33.605 and 33.648.

Concerning *S. serratodentata* we found:

1. It is typically mesoplanktonic, being most abundant and frequent in the region of 200 fathoms.

2. It is rarely taken above 40 fathoms and practically never above 10 fathoms, and is obtained from these depths only at night.

3. It is probable that the species migrates toward the surface when twilight is very subdued.

4. Its exceptional occurrence on the surface is undoubtedly correlated with some unusual surface conditions, of which low temperature may be one.

5. Its center of migration, or the depth in which the greatest number of optimum conditions are found, is probably between 100 and 200 fathoms.

Concerning *S. lyra* we found:

1. It is typically mesoplanktonic, rarely occurring above 25 fathoms, and irregularly increasing in abundance and frequency at least to 250 fathoms.

2. It occurs in greater numbers within 35 fathoms of the surface during the night than during the day, which indicates that nocturnal migrations toward the surface probably occur.

3. Its center of migration is probably below 200 fathoms.

Concerning the remaining species we found:

1. *S. planktonis* is entirely confined to the mesoplankton because it was not obtained above 100 fathoms. Its center of migration is probably in the region of 300 fathoms.

2. *S. hexaptera* probably belongs in the mesoplankton or lower epiplankton, although it occurs to a certain extent in 75, 50, and 45 fathoms, and on the surface.

3. *Sagitta enflata*, *S. neglecta*, and *Spadella draco* cannot be regarded as typical of the San Diego region. They were all taken from above 10 fathoms, and are, therefore, strictly epiplanktonic.

4. *Eukrohnia hamata* is typically mesoplanktonic. It has, however, been taken above 100 but not above 25 fathoms.

5. *E. subtilis* was not taken above 50 and only rarely above 150 fathoms. The species is, therefore, mesoplanktonic and its center of migration is probably between 200 and 250 fathoms.

6. Comparison of the distribution of all the species shows conclusively that manner of distribution is correlated with the organization of the species. In other words, the distinctive manner in which each species is distributed is as much a *specific character* as is its structure.

Such evidence as was obtained, especially concerning *S. bipunctata*, can not be regarded as *proving* the conclusions advanced in this paper. To prove would require much more collecting with respect to light, temperature, salinity, gas content, season, location, and other factors. It would further require special apparatus for determining the amount of light throughout day and night in the various depths, and the number, direction, velocity, and alterations of currents in all depths. It would also require determination of net coefficients, or better, the use of nets of similar size, mesh, and filtering capacities in collecting in all depths. To call attention to this necessity for improved and more complete methods in collecting is one of the greatest values of this paper. However, in spite of the less adequate methods employed, the data strongly support the conclusions made.

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BIBLIOGRAPHY

Abric, P.

1905. Sur la systématiques des Chétognathes. C. R. Acad. Sc. Paris, **141**, 222-224.

Agassiz, A.

1866. On the young stages of a few Annelids. Ann. Lyc. New York, **8**, 303-304, 3 pls.

1888. Three cruises of the United States Coast and Geodetic Survey steamer "Blake" in the Gulf of Mexico, in the Carribean Sea, and along the Atlantic Coast of the United States from 1877 to 1880. (Vol. 1.) Bull. Mus. Comp. Zool. Cambridge, **14**, 314 pp., 194 figs.

Aida, T.

1897. The Chaetognatha of Misaki Harbor. Annot. zool. japon., **1**, 79-81, pl. 4

Apathy, St. V.

1902. Die drei verscheidenen Formen von Lichtzellen bei Hirudeneen. Verh. intern. Zool. Congr., **5**, 707-728, 2 pls.

Apstein, C.

1906. Plankton in Nord-und Ostee auf den deutschen Terminfahrten. Wiss. Meeresuntersuch. N. F. Abt. Kiel, **9**, 1-25, 14 figs.

Aurivillius, C. W. S.

1896. Das Plankton der Baffins Bay und Davis Strait. Eine thiergeographische Studie. Festschr. Lilljeborg; 179-212, 1 pl.

1898. Vergleichende tiergeographische Untersuchungen über die Plankton-fauna des Skageraks in den Jahren 1893-1897. Svenska Vet. Akad. Handl., **30**, No. 3, 426 pp.

1899. Animalisches Plankton aus dem Meere zwischen Jan-Mayen-Spitzbergen-K. Karlsland und der Nordküste Norwegens. Svenska Vet. Akad. Handl., **32**, No. 6, 77 pp., 5 figs.

Aurivillius, C. W. S. und Cleve, P. T.

1896. Das Plankton des Baltischen Meeres. Bih. svenska Vet. Akad. Handl., **21**, No. 8, 79 pp., 1 pl., 1 chart.

Béraneck, E.

1895. Les Chétognaths de la Baie d'Amboine. Rev. Suisse Zool., **3**, 137-159, pl. 4.

Broch, H.

1906. Ueber die Chätognathen des Nordmeeres. Nyt Mag. Naturv., **44**, 145-150, pls. 2-3.

Browne, E. T.

1905. Notes on the pelagic fauna of the Firth of Clyde. Proc. R. Soc. Edinburgh, **25**, 779-791.

Browne, E. T. and Vallentin, R.

1904. On the marine fauna of the Isles of Scilly. Journ. R. Inst. Cornwall, **50**, 120-132.

Bütschli, O.

1873. Zur Entwicklungsgeschichte der *Sagitta*. Zeitschr. wiss. Zool., **23**, 409-413, 1 pl.

Busch, W.

1851. Beobachtungen über Anatomie und Entwickelung einiger wirbellosen Seethiere. Berlin, 4to., p. 93-100.

Busk, G.

1856. An account of the structure and relations of *Sagitta bipunctata*. Quart. Journ. Micr. Sc., (1), **4**, 14-27.

Car, L.

1902. Planktonproben aus dem adriatischen Meere und einigen süssen und brackischen Gewässern Dalmatiens. Zool. Anz., **25**, 601-605.

Cleve, P. T.

1899. Plankton collected by the Swedish expedition to Spitzbergen in 1898. Svenska. Vet. Akad. Handl., **32**, No. 3, 51 pp. 4 pls.

1900. Report on the Plankton collected by the Swedish expedition to Greenland in 1899. Svenska Vet. Akad. Handl., **34**, No. 3, 21 pp.

1900-02. The seasonal distribution of Atlantic plankton organisms. Göteborg. Vetensk. Vitterhets-Samhäll. Handl. F. **4**, Häft 3, No. 3, 368 pp.

1901. Plankton from the Indian Ocean and the Malay Archipelago. Svenska Vet. Akad. Handl., **35**, No. 5, 58 pp., 8 pls., 2 figs. in text.

1902. The plankton of the North Sea and the Skagerak in 1900. Svenska Vet. Akad. Handl., **35**, No. 7, 49 pp., 1 fig.

1903. Plankton researches in 1901 and 1902. Svenska Vet. Akad. Handl., **36**, No. 8, 53 pp.

Conant, F. S.

1895. Descriptions of two new Chaetognaths. J. Hopkins Univ. Circ., 14:77-78, pl. 1; also in Ann. Mag. Nat. Hist., (6), **16**, 288-292, figs. 1-2.

1896. Notes on the Chaetognaths. J. Hopkins Univ. Circ., **15**, 82-85, figs. 1-5; also in Ann. Mag. Nat. Hist. (6), **18**, 201-213, figs. 1-5.

Costa, A.

1869. Di un nuovo genere di Chetognati. Ann. Mus. Zool. Univ. Napoli, **1865**: 54-57.

Darwin, C.

1844. Observations on the structure and propogation of the genus *Sagitta*. Ann. Mag. Nat. Hist., (1), **13**, 1-6.

Delap, M. and Delap, C.

1905. Notes on the plankton of Valencia Harbor from 1899 to 1901. Rep. Sea Inland Fish. Ireland, 1902-03, Pt. 2:3-19.

Doncaster, L.

1902a. On the development of *Sagitta,* with notes on the anatomy of the adult. Quart. Journ. Micr. Sc., (N), **46**, 351-398, pls. 19-21.

1902b. Chaetognatha, with a note on the variation and distribution of the group. Fauna and Geogr. Maldive-Laccadive Archip., **1**, 209-218, pl. 13, figs. 39-40 in text.

Ehlers, E.

1881. On the Vermes collected by H. von Henglin in the Sea of Spitzbergen. Ann. Mag. Nat. Hist., (4), **8**, 53-61.

Ekman, V. W.

1905a. On the use of insulated water bottles and reversing thermometers. Cons. perman. Intern. Explor. Mer., Publ. Circ., No. **23**, 28 pp., 2 pls., 8 figs.

1905b. Kurze Beschreibung eines Propell-Strommessers. *Ibid.*, No. **24**, 4 pp., 1 pl.

Fol, H.

1879. Récherches sur la fécundation et le commencement de l'hénogénie chez divers animaux. Mém. Soc. phys. nat. Geneve, **26**, 35-38, 109-112, 193-197.

Fowler, G. H.

1896. Contributions to our knowledge of the plankton of the Faroe Channel. Proc. Zool. Soc. London, **1896**, 991-996, pl. 1.

1905. Biscayan plankton collected during a cruise of H. M. S. ''Research'' 1900. Part 3.—The Chaetognatha. Trans. Linn. Soc. London, (2), **10**, 55-87, pls. 4-7.

1906. The Chaetognatha of the ''Siboga'' expedition, with a discussion of the synonymy and distribution of the group. Siboga Exped. Monogr. No. **21**, 86 pp., 3 pls., 6 maps.

Gamble, F. W.

1900. The fauna and flora of Valencia harbor on the west coast of Ireland. Proc. Irish Acad., (3), 5, 67-854, 3 pls.

Gegenbaur, C.

1854. Ueber die Entwicklung von *Doliolum* der Schreibenquallen und von *Sagitta*. Zeitschr. wiss. Zool., 5, 13-16.

Giard, A.

1875. On the position of *Sagitta* and on the convergence of types by pelagic life. Ann. Mag. Nat. Hist., (4), 16, 81-90.

Giard, A, et Barois, J.

1875. Note sur un Chaetosome et suive quelques réflexions sur la convergence des types par la vie pélagique. Rev. Sc. nat. Montpellier, 3, 513-532.

Gough, L. H.

1905. Report on the plankton of the English Channel in 1903. Rep. North Sea Fish. invest. Comm., 1902-03, 325-377, 7 figs., 16 maps.

Gourret, P.

1884. Considérations sur la faune pélagique du Golfe du Marseille suives d'une étude anatomique et zoologique de la *Spadella marioni*. Ann. Mus. nat. Hist. Marseille, 2, No. 2, 167 pp., 5 pls.

Graeffe, E.

1905. Uebersicht der Fauna des Golfes von Triest nebst Notizen über Vorkommen, Lebenweise,' Erscheinungs und Laichzert der einzelnen Arten. Arb. zool. Inst. Wein, 15, 317-332.

Grassi, B.

1881. Intorno ai Chetognati. Atti Inst. Lombard, (2), 14, 193-213.

1885. I Chetognati. Fauna u. Flora Golfe Neapel, Monogr. No. 5, 126 pp., 13 pls.

Günther, R. T.

1903. On the distribution of midwater Chaetognatha in the north Atlantic during the month of November. Ann. Mag. Nat. Hist., (7), 12, 334-337, pl. 24.

1907a. The Chaetognatha or primitive Mollusca, with a bibliography. Quart. Journ. Micr. Sc., 51, 357-394, 10 figs.

1907b. Die Stellung der Chätognathen im System. Zool. Anz., 32, 71-72.

Haddon, P.

1886. Marine worms from S. W. Ireland. Proc. Irish Acad., (2), 4, 621-662.

HAUPT, H.

1904. Am Ufer der Schwarzen Meeres. Natur u. Haus, 12, 193-196, 6 figs.

HENSEN, V.

1895. Methodik der Untersuchung bei der Plankton Expedition. Ergebn. Plankton-Exped., 1, No. B, 200 pp., pls., 1-12.

HENSEN, V., UND APSTEIN, C.

1897. Die Nordsee Expedition 1895 des deutschen Seefischerei-Vereins. Ueber die Eimenge der im Winter laichenden Fische. Wiss. Meeresuntersuch. N. F. Abt. Kiel, 2, 1-97, pls., 1-20.

HERDMAN, W. A.

1906. Some problems of the sea. 20th Ann. Rep. mar. biol. sta. Port Erin, Appendix A, 25-147.

HERDMAN, W. A., AND SCOTT, A.

1908. Plankton problems in the Irish Sea. An intensive study of the marine plankton around the south end of the Isle of Man. Trans. biol. Soc. Liverpool, 22, 94-197, 13 figs.

HERDMAN, W. A., SCOTT, A., AND DAKIN, W. J.

1910. An intensive study of the marine plankton around the south end of the Isle of Man. Part 3. Rep. Lancashire Sea Fish. Lab., 1909, No. 18: 193-297, pls. A-B, figs. 1-21 in text.

HERDMAN, W. A., THOMPSON, I., AND SCOTT, A.

1897. On the plankton collected continuously during two traverses of the north Atlantic in the summer of 1897, with descriptions of two new species of Copepoda, and an appendix on dredging in Puget Sound. Trans. biol. Soc. Liverpool, 12, 33-90, 4 pls., 4 figs.

HERTWIG, O.

1880. Die Chätognathen. Monogr. Jena, 111 pp., 6 Taf. Also in Zeitschr. Med. Naturw. Jena, 14, 196-302, pls. 9-15.

HUXLEY, T. H.

1851. Observations on the genus *Sagitta*. Rep. Brit. Ass., 1851, 77-78.

JOHNSON, G.

1865. A catalogue of the non-parasitical worms in the collection of the British museum. London, 8vo., 366 pp., 20 pls.

JOHNSTONE, J.

1908. Conditions of life in the sea. (Cambridge Univ. Press). 326 pp., 29 figs.

JOURDAIN, M. S.

1892. Sur l'embryogénie des *Sagitta*. Ann. Mag. Nat. Hist., (6), **9**, 415-416.

KEFFERSTEIN, W.

1862. Untersuchungen über niedere Seethiere. Einige Bemerkungen über *Sagitta*. Quart. Journ. Micr. Sc., (N), **3**, 134-136.

KENT, W. S.

1870. On a new species of *Sagitta* from the south Pacific. Ann. Mag. Nat. Hist., (4), **5**, 268-272, fig. 1.

KOFOID, C. A.

1903. The plankton of the Illinois River, 1894-1899, with introductory notes upon the hydrography of the Illinois River and its basin. Part I.—Quantitative investigations and general results. Bull. Ill. Lab. Nat. Hist., **6**, 95-629, tab. 1-15, pls. 1-50.

1905. A self-closing water bucket for plankton investigations. Cons. perman. Intern. Explor. Mer, Publ. Circ., No. **32**, 10 pp., 4 figs.

1907. The coincident distribution of related species of pelagic organisms as illustrated by the Chaetognatha. Amer. Nat., **41**, 241-251.

1911. On a self-closing plankton net for horizontal towing. Univ. Calif. Publ. Zool., **8**. (In press.)

KOWALEVSKI, A.

1871. Embryologische Studien an Würmern und Arthropoden. Mém. Acad. Sc. St. Petersbourg, (7), **16**, No. 12, 10 pp., 12 pls.

KROHN, A.

1844. Anatomische physiologische Beobachtungen über die *Sagitta bipunctata*. Ann. Nat. Sc. (3), **3**, 102-116, pl. 1.

1853. Nachträgliche Bemerkungen über den Bau der Gattung *Sagitta*, nebst der Beschreibung einiger neuen Arten. Arch. Naturgesch., **19**, No. 1: 266-277.

KRUMBACH, T.

1903. Ueber die Greifhaken der Chätognathen. Zool. Jahrb. Abt. System., **18**, 579-646, figs. A-U in text.

LANGERHANS, P.

1878. Das Nervensystem der Chätognathen. Monatsber. Acad. Berlin, **1878**, 189-193.

1880. Die Wurmfauna von Madeira. 3. Zeitschr. wiss. Zool., **34**, 132-136.

LANKASTER, R.

1873. Notes on embryology and classification. Quart. Journ. Micr. Sc., (N), **17**, 399-455.

LEE, A. B.

1888. La spermatogenèse chez les Chétognathes. La Cellule, **4**, 107-133, pls. 1-2.

LEIDY, J.

1882. *Sagitta falcidens.* Ann. Mag. Nat. Hist., (5), **10**, 79-80.

LEUCKART, R., UND PAGENSTECHER, H. A.

1858. Untersuchung über niedere Seethiere. Arch. Anat. Physiol. wiss. Med., **1858**, 593-600.

LEVINSON, G. M. R.

1883. Systematisk geografisk Oversit over de nordiske Annulata, Gephyra, Chaetognathi, og Balanoglossi. Vid. Med. nat. Hist., **1883**, 160-251.

LOBIANCO, S.

1903. Le pesche abissali eseguite da F. A. Krupp col Yacht ''Puritan'' nelle adiacenze di Capri ed altre localita del Mediteraneo. Mitth. zool. Sta. Neapel, **16**, 109-279, 3 pls.

1904. Pelagische Tiefseefischerei der ''Maja'' in der Umgebung von Capri (Beiträge zur Kenntnis des Meeres und seiner Bewohner, Bd. 1), Jena. Gust. Fisher, 8vo., 7, 91 pp., 42 pls., 1 chart.

MCEWEN, G. F.

1910. Preliminary report on the hydrographic work carried on by the Marine Biological Station of San Diego. Univ. Calif. Publ. Zool., **6**, 189-204, 1 fig., 1 map.

MEISSNER, G.

1857. Bericht über die Fortschritte der Anatomie und Physiologie im Jahre 1856. Zeitschr. nat. Med., **1**, 637-640.

METSCHNIKOFF, E.

1867. Beiträge zur Naturgeschichte der Würmer. Zeitschr. wiss. Zool., **17**, 539.

MICHAEL, E. L.

1908. Notes on the identification of the Chaetognatha. Biol. Bull., **15**, 67-84, pl. 1, figs. 1-10 in text, 1 table.

MÖBIUS, K.

1875. Vermes. Die Expedition zur physicalisch-chemischen und biologischen Untersuchung der Nordsee im Sommer 1872. Wiss. Meeresuntersuch. N. F. Abt. Kiel, **2**, 158-159.

MOLTSCHANOFF, L. A.

1907. Die Chätognathen des zoologischen Museums der kaiserlichen Akademie der Wissenschaften in St. Petersbourg. Ann. Mus. St. Petersbourg, 12, 204-209.

MOLTSCHANOV, L.

1907. Ein Beitrag zur Klassification der Chätognathen. Zool. Anz., 31, 861-862.

NORGAARD, O.

1899. Undersögelser i fjorden ved Bergen 1897-1898. Bergens Mus. Aarb., **1898**, No. 10, 20 pp., 2 pls.

OERSTED, A. S.

1850. Et Bidrag till at besvare det Spoengsmaal hvilken Plado Slaegton *Sagitta* boer indtage i Systemet. Forieps Tagsber, Forsch. nat. Heilkunde, Abt. Zool. Paleon., **1**, 201-202.

D'ORBIGNY, A.

1843. Voyage dans l'Amérique méridonale. Paris, 4to., **5**, 140-144.

PAGENSTECHER, H. A.

1862. Untersuchungen über niedere Seethiere aus Cette. Zeitschr. wiss. Zool., **12**, 308-310.

1863. Notes on the Anatomy of *Sagitta*. Quart. Journ. Micr. Sc., (N), 3:192-193. Also in Zeitschr. wiss. Zool., **8**, 308.

PAULSEN, O.

1904. Plankton investigations in the waters round Iceland in 1903. Medd. Komm. Havundersögelser (Plankton), **1**, No. 1, 40 pp., 12 figs., 2 charts.

QUOY, J. R. C., ET GAIMARD, P.

1827. Observations zoologiques faites à bord de l'"Astrolabe" en Mai, 1826, dans le détroit de Gibralter. Ann. nat. Sc., **10**, 232-233, pl. 8, fig. C in text.

REDCKE, H. C., EN VAN BREEMAN, P. J.

1903. Plankton en Bodemdieren in de Noordzee verzameld van 1-6 Augustus, 1901, mit de "Nelly." Tijdschr. nederl. dierk. Vereen., (2), **8**, 118-147.

VON RITTER-ZÁHONY, R.

1908. Chätognathen. Ber. Comm. Erforsch. östl. Mittelmeer, Zool. Ergebn., **14**, 18 pp., 1 pl.

1909a. Zur Anatomie des Chätognathenkopfes. (Ber. Comm. Erforsch. östl. Mittelmeer). Denkschr. Akad. Wiss. Wien Math. Nat. Cl., **84**, 33-41, 1 pl.

1909b. Expeditionen S. M. Schiff "Pola" in das Rote Meer nördliche und südliche Hälfte 1895-96, 1897-98. Ber. Comm. ozeanogr. Forsch., Zool. Ergebn., **27,** 12 pp., 4 figs.

1909c. Die Chätognathen der "Gazelle" Expedition. Zool. Anz., **34,** 783-793, fig. 1.

1910. Die Chätognathen. Fauna Arctica., **5,** 251-288, pl. 5.

Scharff, R. F.

1902. Gephyrea. Chaetopoda, Rotifera, Nematoda, Nemertinea, Platyhelmia. Chaetognatha. Rep. Brit. Assn., **1902,** 226-231.

Scott, T.

1891. The food of *Sagitta.* Ann. Scott. Nat. Hist., **1,** 142-143.

1893. The food of *Sagitta.* Ann. Scott. Nat. Hist., **3,** 120.

1896. Additions to the fauna of the Firth of Forth. Ann. Rep. Fish Board Scotland, **14,** 158-166.

1897. Notes on the animal plankton from H. M. S. "Research." Ann. Rep. Fish. Board Scotland, **15,** 305-315.

Shipley, A. E.

1896. Nemathelminthes and Chaetognatha. The Cambridge Nat. Hist., **2,** 121-194, 44 figs.

Steinhaus, O.

1896. Die Verbreitung der Chätognathen in südatlantischen und indischen Ozean. Inaug. Diss. Kiel, **5,** No. 13, 49 pp., 1 pl., 2 charts.

1900. Die Chätognathen. Ergebn. Hamburg. Magalhaens Sammelr., **5,** No. 2, 10 pp.

Stevens, N. M.

1903. On the ovogenesis and spermatogenesis of *Sagitta bipunctata.* Zool. Jahrb. Abt. Morph., **18,** 227-240, pls. 20-21.

1905. Further studies on the ovogenesis of *Sagitta.* Zool. Jahrb. Abt. Morph., **21,** 243-252, pl. 16.

Strodtmann, S.

1892. Die Systematik der Chätognathen und die geographischen Verbreitung der einzelen Arten im nordatlantischen Ozean. Inaug. Diss. Kiel, **2,** No. 10, 47 pp., 2 pls.

1905. Die Chätognathen. Nordisches Plankton, **3,** 10-17, 12 figs.

Thiele, J.

1907. Sind die Chätognathen als Mollusken aufzufassen? Zool. Anz., **32,** 428-430.

THOMPSON, D. A. W.

1885. A bibliography of the Protozoa, Sponges, Coelenterates, and Worms for the years 1861 to 1883. (Cambridge, Univ. Press), viii + 284.

THOMPSON, I. C.

1898. Report on a small collection of Antarctic plankton from the neighborhood of South Shetland Islands collected by the staff of a Dundee whaler in 1892-1893. Trans. Biol. Soc. Liverpool, **12**, 291-297, 12 pls.

TORREY, H. B.

1902. An unusual occurrence of Dinoflagellata on the California coast. Amer. Nat., **36**, 187-192, figs. 1-3.

ULJANIN, B.

1871. Materialien zur Fauna des schwarzen Meeres. Trans. nat. Soc. Moscou, **9**, 77.

VERRILL, A. E.

1871-2. Report on the invertebrate animals of Vineyard Sound and adjacent waters. Rep. U. S. Fish Comm., **1871-72**, 295-798, pls. 1-38.

1879. The Invertebrates of the N. E. coast of North America. Proc. U. S. Nat. Mus., **2**, 165-205, 227-232.

1883. Results of the explorations made by the steamer "Albatross" off the northern coast of the U. S. in the year 1883. Rep. U. S. Fish Comm., **1883**, 503-699, pls. 1-44.

EXPLANATION OF PLATES

Figures on plates 1 and 2 are intended primarily to represent specific differences in transparency and general appearance. Drawings were made on Ross stipple board, nos. 5 and 8, black.

All figures drawn with the camera lucida.

PLATE 1

Fig. 1. *Sagitta enflata* Grassi. × 3.

Fig. 2. *Sagitta hexaptera* d'Orbigny. × 3.

Fig. 3. *Sagitta lyra* Krohn. × 3.

Fig. 4. *Sagitta serratodentata* Krohn. × 3.

Fig. 5. *Sagitta bipunctata* Quoy et Gaimard. × 3.

Fig. 6. *Sagitta planktonis* Steinhaus. × 3.

ABBREVIATIONS

col.—collarette.
int.—intestine.
ov.—ovary.
seiz. j.—seizing jaws.
sem. v.—seminal vesicle.
vent. g.—ventral ganglion.

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E. L. M., del. ad nat. Lith. Gottschalk, S. F.

PLATE 2.

Fig. 7. *Sagitta neglecta* Aida. × 3.

Fig. 8. *Eukrohnia hamata* (Möbius). × 3.

Fig. 9. *Eukrohnia subtilis* (Grassi). × 3.

Fig. 10. *Spadella draco* Krohn. × 8.

Fig. 11. *Sagitta tenuis* Conant. × 8.

Fig. 12. *Sagitta elegans* Verrill. × 3.

Fig. 13. *Sagitta arctica* Aurivillius. & 3.

ABBREVIATIONS

col.—collarette.
int.—intestine.
ov.—ovary.
seiz. j.—seizing jaws.
sem. v.—seminal vesicle.
vent. g.—ventral ganglion.

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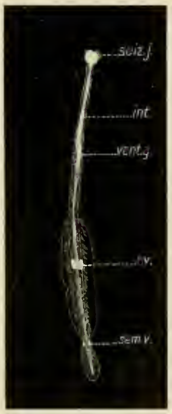

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PLATE 3.

Fig. 14. Left vestibular ridge of *Sagitta enflata*. × 240.

Fig. 15. Left vestibular ridge of *Sagitta hexaptera*. × 80.

Fig. 16. Left vestibular ridge of *Sagitta lyra*. × 80.

Fig. 17. Left vestibular ridge of *Sagitta gigantea* Broch. Specimen from Norwegian North Atlantic. × 80.

Fig. 18. Left vestibular ridge of *Sagitta bipunctata*. × 240.

Fig. 19. Double vestibular ridge of *Sagitta bipunctata*. × 240.

Fig. 20. Left vestibular ridge of *Sagitta serratodentata*. × 240.

Fig. 21. Left vestibular ridge of *Sagitta planktonis*. × 80.

Fig. 22. Left vestibular ridge of *Sagitta neglecta*. × 240.

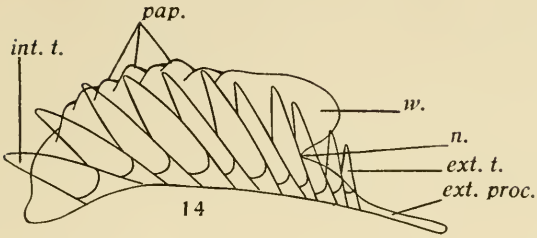
Fig. 23. Left vestibular ridge of *Spadella draco*. × 240.

Fig. 24. Left vestibular ridge of *Sagitta elegans*. × 240.

Fig. 25. Teeth of *Eukrohnia subtilis*. × 240.

ABBREVIATIONS.

b.—barbs.
ext. proc.—external process.
ext. t.—external tooth.
int. t.—internal tooth.
n.—notch.
pap.—papillae.
w.—wing of ridge.



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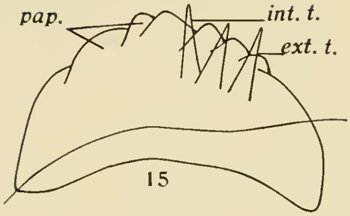

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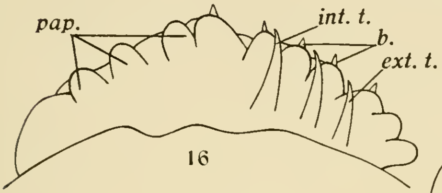

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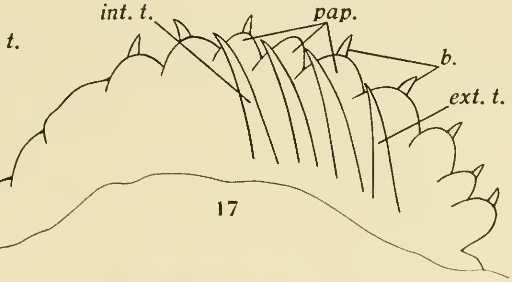

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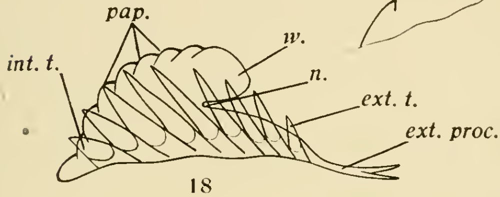

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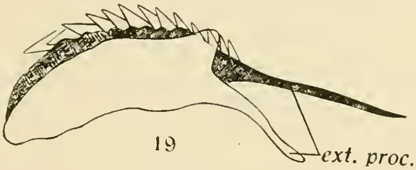

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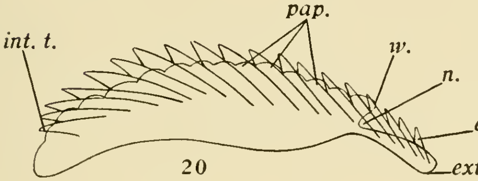

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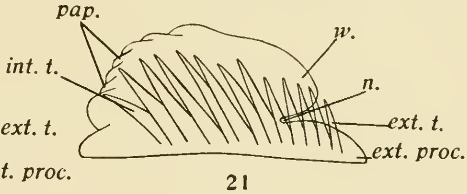

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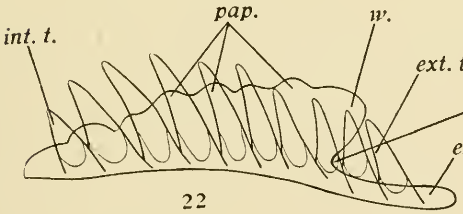

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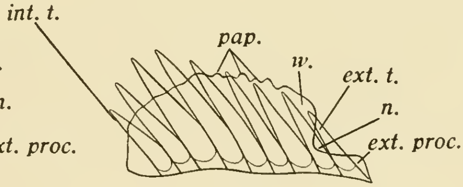

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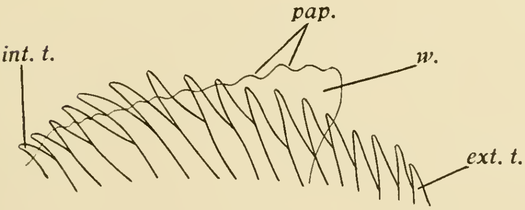

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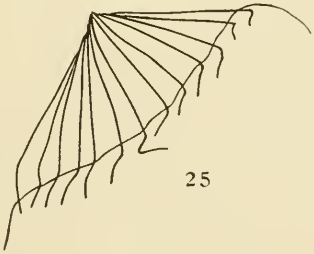

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PLATE 4.

Fig. 26. Upper part of seizing jaw of *Sagitta enflata.* × 1130.

Fig. 27. Upper part of seizing jaw of *Sagitta hexaptera.* Old jaw. × 1130.

Fig. 28. Upper part of seizing jaw of *Sagitta hexaptera.* Young jaw. × 1130.

Fig. 29. Upper part of seizing jaw of *Sagitta lyra.* × 1130.

Fig. 30. Upper part of seizing jaw of *Sagitta serratodentata.* × 1130.

Fig. 31. Upper part of seizing jaw of *Sagitta bipunctata.* Old jaw. × 1130.

Fig. 32. Upper part of seizing jaw of *Sagitta bipunctata.* Young jaw. × 1130.

Fig. 33. Upper part of seizing jaw of *Sagitta planktonis.* × 1130.

Fig. 34. Upper part of seizing jaw of *Sagitta neglecta.* × 1130.

Fig. 35. Upper part of seizing jaw of *Eukrohnia hamata.* × 1130.

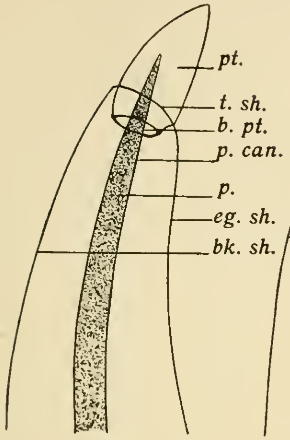
Fig. 36. Upper part of seizing jaw of *Eukrohnia subtilis.* × 1130.

Fig. 37. Upper part of seizing jaw of *Spadella draco.* × 1130.

Fig. 38. Upper part of seizing jaw of *Sagitta elegans.* × 1130.

ABBREVIATIONS.

b. pt.—base of point.
bk. sh.—back of shaft.
cr.—crest.
eg. sh.—edge of shaft.
p.—pulp.
p. can.—pulp canal.
pt.—point.
ser.—serrations.
sw.—swollen place in pulp.
t. sh.—top of shaft.



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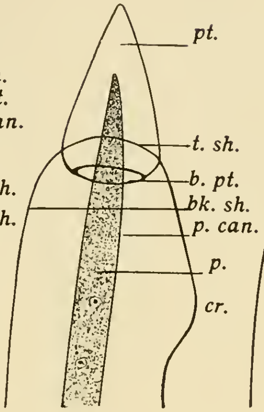

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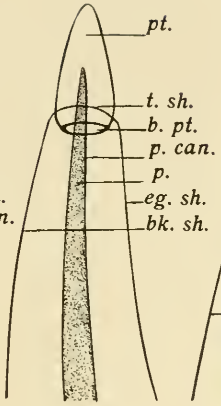

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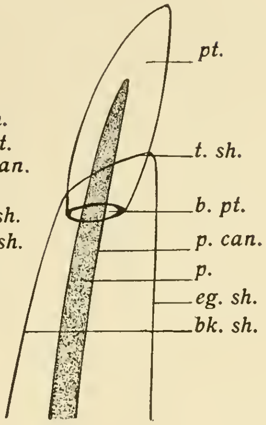

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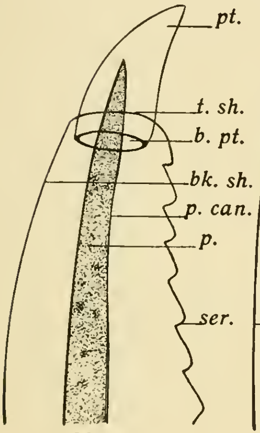

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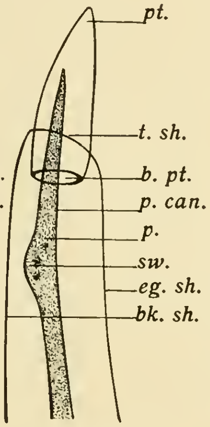

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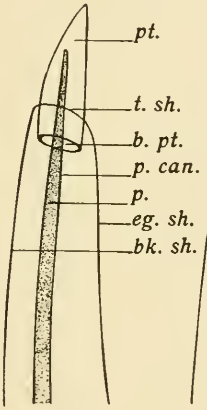

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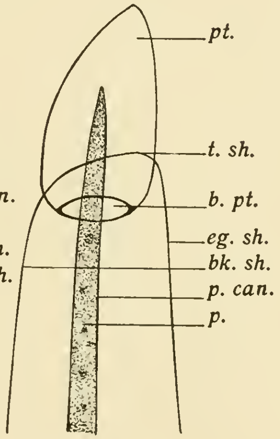

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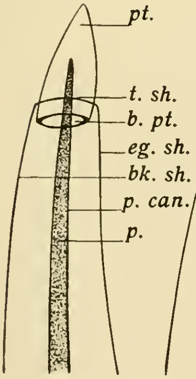

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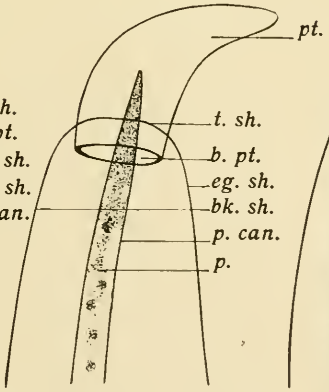

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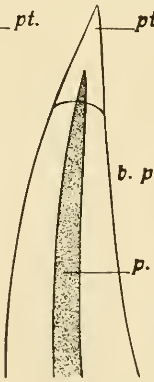

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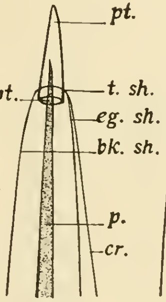

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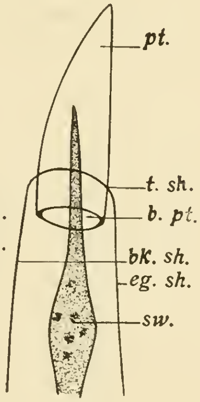

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PLATE 5.

Fig. 39. Posterior end of *Sagitta enflata.* × 14.

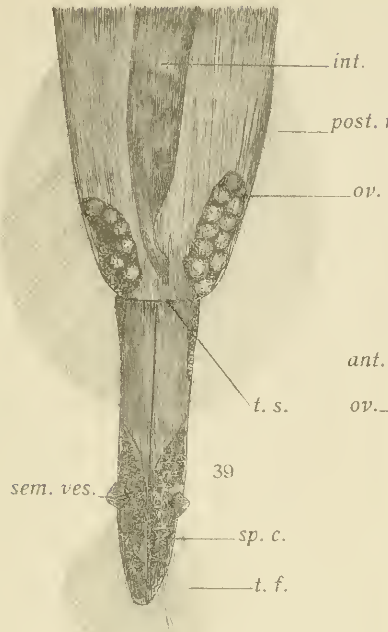
Fig. 40. Posterior end of *Sagitta bipunctata.* × 14.

Fig. 41. Posterior end of *Sagitta serratodentata.* × 14.

Fig. 42. Posterior end of *Sagitta planktonis.* × 14.

ABBREVIATIONS.

ant. f.—anterior fin.
int.—intestine.
ov.—ovary.
post. f.—posterior fin.
sem. rec.—seminal receptacle.
sem. ves.—seminal vesicle.
sp. c.—sperm cells.
t. f.—tail fin.



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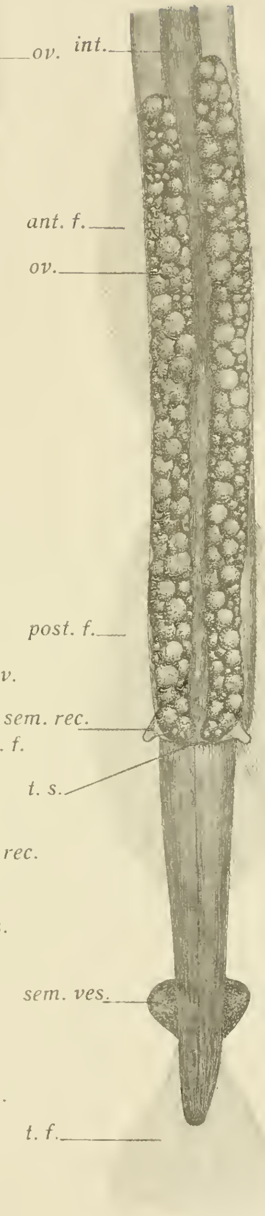

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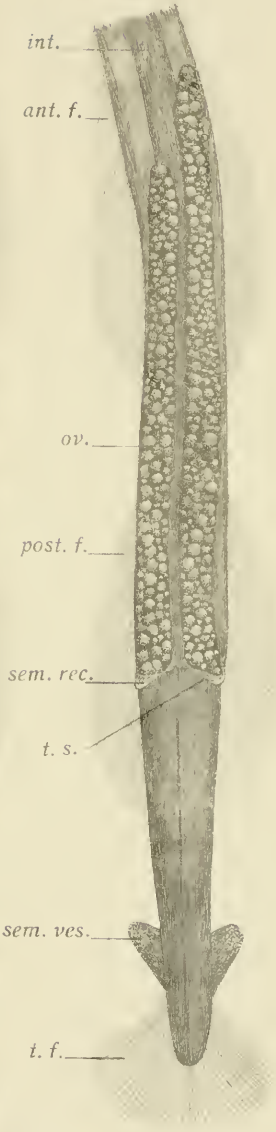

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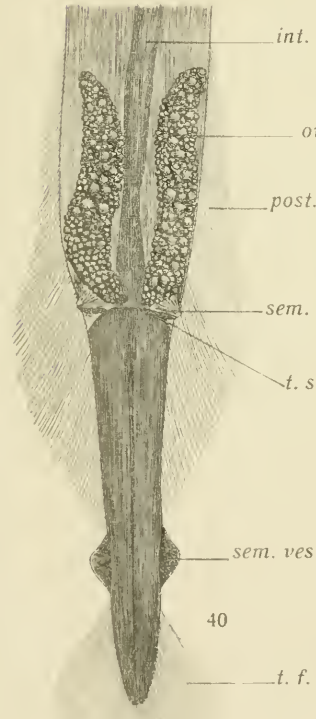

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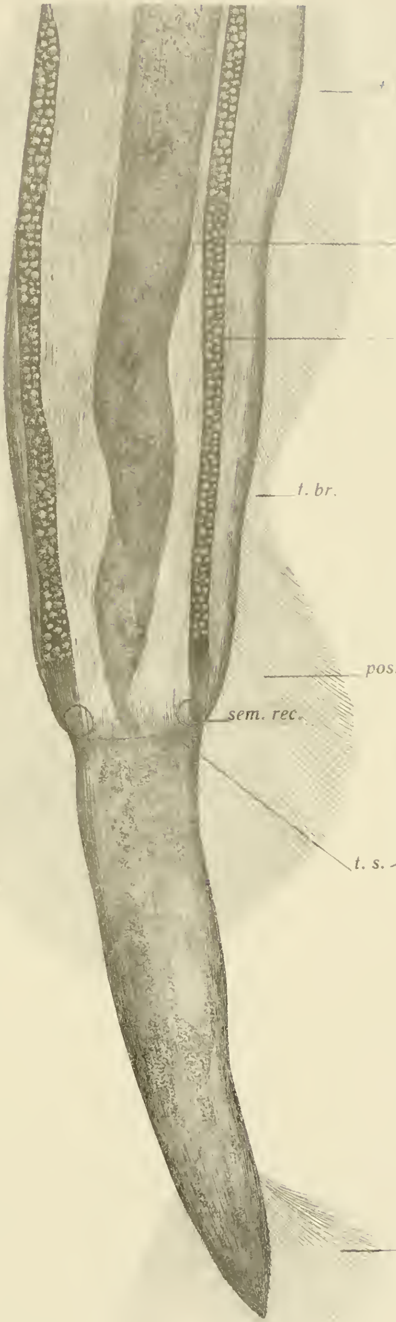
PLATE 6.

Fig. 43. Posterior end of *Sagitta lyra.* × 6.

Fig. 44. Posterior end of *Sagitta hexaptera.* × 6.

ABBREVIATIONS.

ant. f.—anterior fin.
f. br.—fin-bridge.
int.—intestine.
ov.—ovary.
post. f.—posterior fin.
sem. rec.—seminal receptacle.
sem. ves.—seminal vesicle.
t. f.—tail fin.



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E. L. M. del. ad nat.

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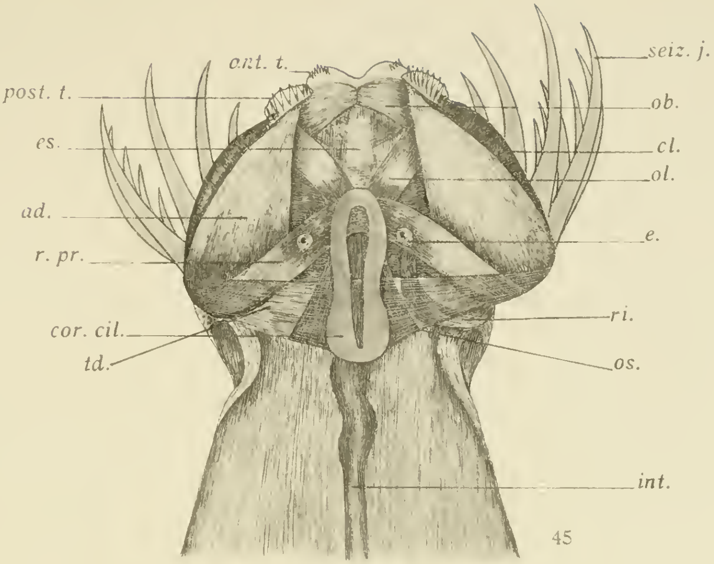
PLATE 7.

Fig. 45. Head of *Sagitta enflata.* Dorsal view. × 40.

Fig. 46. Head of *Sagitta planktonis.* Dorsal view. × 40.

ABBREVIATIONS.

ad.—M. adductor uncinorum.
ant. t.—anterior teeth.
cl.—M. complexus lateralis.
col.—collarette.
cor. cil.—corona ciliata.
e.—eye.
es.—M. expansus superior.
int.—intestine.
ob.—M. obliquus capitis brevis.
ol.—M. obliquus capitis longus.
os.—M. obliquus superficialis.
post. t.—posterior teeth.
ri.—M, rectus colli internus.
r. pr.—M. retractor praeputii.
seiz. j.—seizing jaws.
td.—M. transversus dorsalis.



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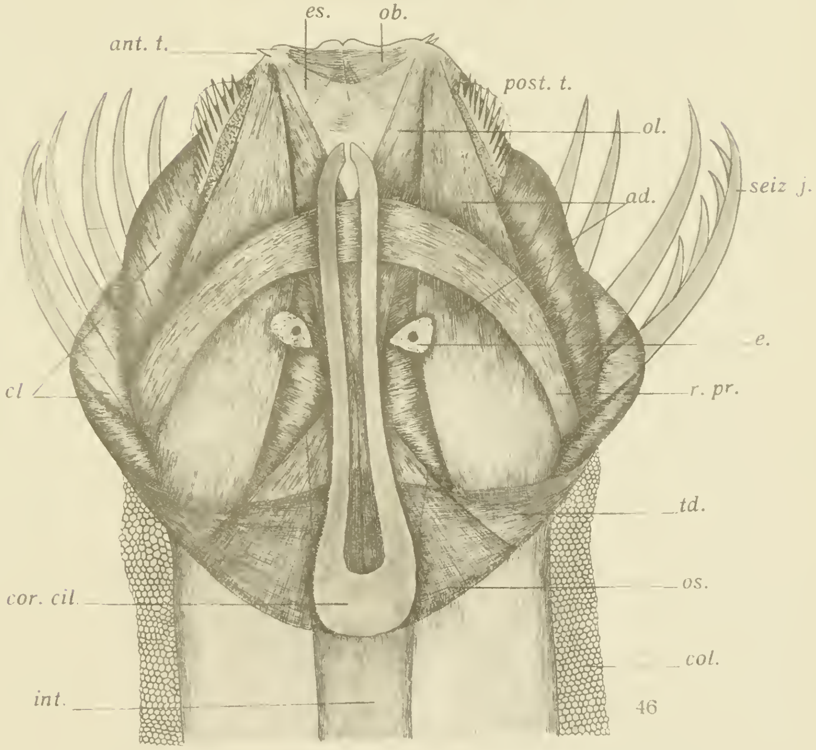

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PLATE 8.

Fig. 47. Head of *Sagitta enflata*. Ventral view. × 40.

Fig. 48. Head of *Sagitta planktonis*. Ventral view. × 40.

ABBREVIATIONS.

ant. t.—anterior teeth.

cl.—M complexus lateralis.

co. a.—M. constrictor oris alter.

col.—collarette.

co. p.—M. constrictor oris primus.

dv. e.—M. dilator vestibuli externus.

ei.—M. expansus inferior.

es.—M. expansus superior.

int.—intestine.

m.—mouth.

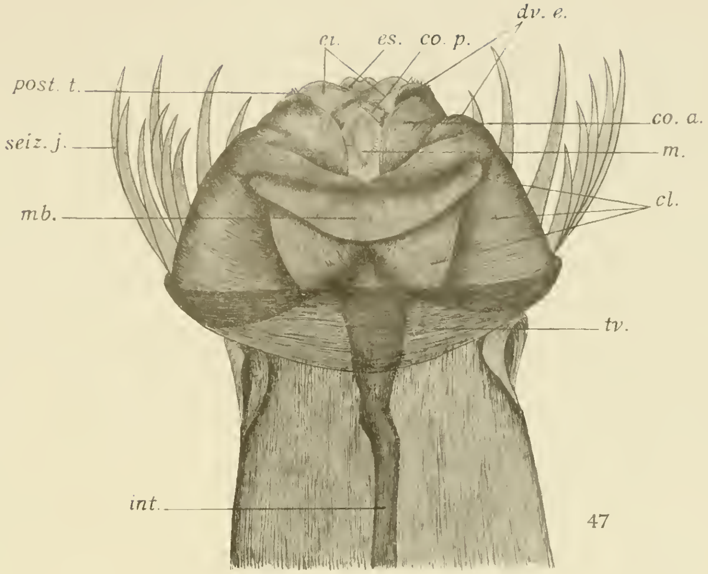
mb.—M. bicornis.

post. t.—posterior teeth.

p. pr.—M. protractor praeputii.

seiz. j.—seizing jaws.

tv.—M. transversus ventralis.



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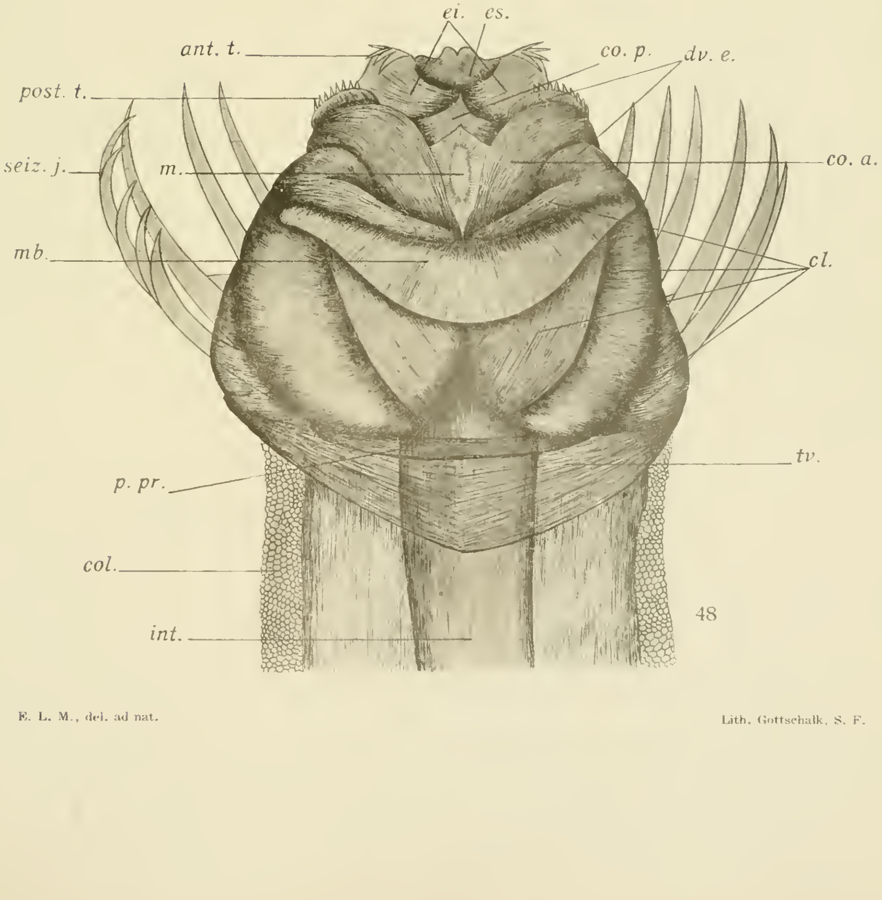

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9. (XIV) Ostracoda of the San Diego Region. II. Littoral Forms, by Chancey Juday. Pp. 135-156, plates 18-20.
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BY

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BY

CHARLES ATWOOD KOFOID

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DINOFLAGELLATA OF THE SAN DIEGO REGION, IV. THE GENUS *GONYAULAX*, WITH NOTES ON ITS SKELETAL MORPHOLOGY AND A DISCUSSION OF ITS GENERIC AND SPECIFIC CHARACTERS

BY

CHARLES ATWOOD KOFOID

(Contributions from the Laboratory of the Marine Biological Association of San Diego)

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A. INTRODUCTION

The genus *Gonyaulax* is one of the most widely represented of the dinoflagellates, occurring in boreal, temperate and tropical seas and in both brackish and fresh waters. It is also at times exceedingly abundant in coastal waters, appearing in numbers so great as to discolor the sea. *Gonyaulax polyedra* is the cause of periodical outbreaks of "red water" along the coasts of southern California in middle and late summer which are accompanied by remarkable displays of phosphorescence. The outbreaks occasion the destruction of great numbers of the fish of the shallow waters and of the invertebrates such as the holothurians, annelids, sipunculids, and some of the mollusks [see Torrey (1902)]. It is cast upon the sands along shore by the breakers and its decay there, together with that of the animals killed by its abundance, causes a stench which suggests that of the Nile which in Hebrew writings is recorded as having turned to blood. It is not improbable that the phosphorescence and red water reported by Darwin (1871) off the coast of South America and by Streets (1878) in the Gulf of California, was caused by this species or some related dinoflagellate.

Present Status

Although widely distributed and at times abundantly represented in the plankton, this genus has remained in a state of imperfect definition and has been a great source of uncertainty and a cause of oft recurring confusion in the matter of its characters and its limits. Very few of the species assigned to it, even in recent years, have been accurately defined in the matter of their skeletal morphology, and a number of older species of the genus have been variously interpreted by later writers with the result that it has become increasingly difficult to determine with what species an author is dealing, unless his work is accompanied by figures and in some cases not even these relieve the confusion which reigns in this genus. Another and very fundamental reason for this confusion lies in the fact that a wide range of material is often necessary to determine the limits of variation within the species of the genus. This wide range in variation coupled with the very dissimilar appearances which even the same individual may present from different points of view, make the interpretation of the older literature, and some of the more recent, exceedingly difficult, and usually force the investigator to a re-examination of pertinent material before he can come to any conclusion that does not rest all too much upon conjecture.

B. MATERIAL

This paper is based primarily upon the examination of the plankton collected off the coast of southern California by the San

Diego Marine Biological Station during the past ten years, and upon certain collections made in Alaska in the summer of 1905 by the U. S. Bureau of Fisheries Str. "Albatross." Permission to use the data from the latter source has been kindly granted by Hon. Geo. M. Bowers, U. S. Commissioner of Fisheries.

Grateful acknowledgments are here made to the San Diego Marine Biological Association for its continuous interest in and support of this work, to the Smithsonian Institution for the privileges of their research table at the Naples Zoological Station in 1908, and to Mr. R. W. Harvey, Miss Ethel Abeel, and especially to Mrs. Josephine R. Michener for drawings.

The plankton from the coast of California at my disposal is primarily oceanic, but this is supplemented by neritic collections from San Diego Bay, San Pedro Harbor, and from San Francisco Harbor, while that in the collection from Alaska is primarily neritic. The southern oceanic plankton taken off San Diego from deeper levels (50-100 fathoms) contains considerable moribund plankton of northern (Alaskan) facies.

In addition to the material above noted the writer has had at his disposal, but not included in the scope of the present paper, the very extensive collections of the expeditions of the Str. "Albatross" to the Eastern Tropical Pacific of 1904-1905 and to the Northern Pacific in 1905-1906, as well as numerous collections from European waters made during his tour of the biological stations of Europe in 1908-1909. The material upon which this study is based is therefore both extensive and representative. My especial thanks are tendered to Dr. Andrew Scott of Piel-in-Barrow, for a collection rich in Dinoflagellata, from the Faeroes Channel.

The collections of plankton made during the past ten years mainly at San Diego and San Pedro and in the California Current off these ports are distributed through all seasons of the year, but more especially during the summer and in mid-winter. Nearly every collection contains one or more species of *Gonyaulax*.

In all fourteen species have been recorded. Of these four are new, *G. alaskensis*, *G. diegensis*, *G. sphaeroidea* and *G. scrippsae*.

Four are at times fairly common, *Gonyaulax polyedra, G. digitale, G. diegensis* and *G. polygramma;* of the remainder, *G. alaskensis, G. kofoidi, G. pacifica, G. scrippsae, G. spinifera, G. triacantha,* and *G. turbynei* are rare, and *G. fragilis, G. birostris* and *G. sphaeroidea* very rare. The winter plankton of tropical facies brings *G. birostris, G. pacifica, G. kofoidi, G. sphaeroidea, G. polygramma* and *G. turbynei* to the coasts of southern California. *G. alaskensis* is a northern form drifting southward in the deeper plankton. *G. scrippsae* and *G. diegensis* were found in the neritic plankton, the remainder in both neritic and oceanic plankton. *Gonyaulax triacantha* has thus far been found only in neritic plankton from Alaska, and the distribution of *G. spinifera* (*sensu stricto*) is imperfectly known at present, not having been distinguished from *G. digitale* during the progress of the work.

C. GENERAL DISCUSSION OF THE GENUS

I. Generic Characters

1. HISTORICAL DISCUSSION

The genus *Gonyaulax* was first defined by Diesing (1866) for the single species (*Peridinium spiniferum*) which Claparède and Lachmann (1858-1861) had previously assigned to the genus *Peridinium,* but in their description placing special emphasis upon the helicoidal form of the transverse furrow. No mention is made by them of an extension of the longitudinal furrow to the apex upon the epitheca. Diesing's generic diagnosis is likewise based upon the marked displacement of the girdle which results in the helicoidal form of the transverse furrow and he has embodied the idea in his generic name *Gonyaulax* (γόνυ [knee] αὖλαξ [furrow]). Diesing's diagnosis which follows contains no reference to the extension of the longitudinal furrow upon the apex.

Gonyaulax Diesing

Peridinii spec. Claparède

"Animalcula solitaria libera symmetrica. Corpus immutabile, ovatum, ecaudatum, ciliatum, lorica, tabulata, sulco, hiante transversali in pagina dorsali obliquo in pagina ventrali bis geniculato et altero longitudinali, ab anfractu anteriore sulci transversalis ad extremitatem anticam excurrente, tripartita inclusum, ciliis e sulcis prominentibus. Os terminale. Flagellum unum pone os. Anus . . . . Ocellus nullus. Partitio ignota. Maricolae.''

In Stein's (1883) great monograph, the text for which was unfortunately never completed, he notes (p. 12) his observation at Kiel of ''*Perid. spiniferum* Cl. Lach., auf welches bereits Diesing eine neue Gatt. *Gonyaulax* gegründet hat, die wohl berechtigt ist, aber ganz anders characterisirt werden muss.'' The modifications which Stein made were (1) a correct orientation with the pointed end anterior, (2) designation of a narrow area from the proximal end of the girdle to the apex as an extension of the longitudinal furrow, (3) an analysis of the thecal plates in two species, with three apicals (Frontalien), five precingulars (Basalien), five postcingulars (Basalien) and two ''Endplatten'' one of which is the antapical and the other the posterior accessory.

Later monographers, Bütschli (1885b), Schütt (1896), and Paulsen (1908), all follow Stein in his interpretation of an extension of the longitudinal furrow anteriorly to the apex. Bütschli finds six precingulars (in *Gonyaulax polyedra*) and later discoveries of new species have necessitated some modifications in the range in form of body and number of apical plates found in the genus. In essential particulars Stein's diagnosis has stood with but minor additions to the present time.

2. MODIFICATIONS RESULTING FROM NEW DATA

As a result of my investigations on this genus certain fundamental modifications are necessary in the generic diagnosis of *Gonyaulax*.

(1) The form of the body is exceedingly varied and affords no basis for diagnosis. It ranges from an almost perfectly spherical form such as is seen in *G. sphaeroidea*, to polyhedral species such as *G. polyedra* and *G. ceratocoroides*, and to elongated types such as *G. birostris* and *G. jolliffei*. In the development of spines, we find conditions ranging from the smooth, spine-free *G. sphaeroidea* to the spinous *G. triacantha*, and to *G. ceratocoroides* with its long processes resembling those of *Ceratocorys*. In like manner no particular type of surface markings is prevalent. The surface

may be smooth or reticulate, and the mesh may be predominantly linear, vermiculate, polygonal or irregular. None of these features affords any satisfactory criterion for a genuine diagnosis.

(2) The displacement of the girdle in a descending spiral with the distal end one or more girdle widths posterior to the proximal occurs in all species of the genus. It is this character primarily which distinguishes *Gonyaulax* from *Amphidoma* in which the displacement is at the most but slight.

(3) The longitudinal furrow should not be considered as extending, as Stein (1883) supposed, anteriorly upon the epitheca to the apex. There is no basis in the skeletal morphology for this interpretation, and there is no suggestion of such an extension of the furrow in the external appearance in a number of species which belong in this genus. The midventral apical plate (*1′* fig. A) in *Gonyaulax* which is homologous with the diamond-shaped "Rautenplatte" of *Peridinium*, extends from the apex posteriorly until it meets an anterior extension of the ventral area (*v. a.*, figs. A and B) and thus separates the precingular series in the midventral line between precingulars *1″* and *6″*. In most but not all species of *Gonyaulax* this ventral apical *1′* is a narrow plate. When suture lines are marked by thickenings of the wall, as for example in *G. ceratocoroides* [see Murray and Whitting (1899, pl. 30, fig. 6)] this plate, in consequence of these thickenings, lies at the bottom of a depression between elevated ridges. This, however, does not occur in all species and the trough thus formed is not a part of the furrow in which the longitudinal flagellum lies any more than are similar depressions between ridges elsewhere on the thecal wall. (See Murray and Whitting's figures).

(4) There is no trace of evidence whatever that this so-called anterior extension of the longitudinal furrow to the apex ever functions as a longitudinal furrow; that is, that it serves as a trough for the longitudinal flagellum, whose normal position is in the furrow running posteriorly from the flagellar pore.

To regard this plate as a part of the longitudinal furrow is thus to assign to it a function which it does not have, and to obscure its morphological relations. Furthermore, to make this mistaken interpretation the basis of generic diagnosis as Stein and his followers have done is to exclude from the genus species, such as *G. sphaeroidea*, whose skeletal morphology would otherwise compel their inclusion in the genus. It is therefore necessary to eliminate this interpretation, and to confine the designation of longitudinal furrow (or the more widely applicable term, ''ventral area,'' which seems desirable on account of conditions in *Ceratium*) to that part of the thecal wall in which the flagellum is found extending posteriorly between the two ends of the girdle. This term ventral area was proposed by me (1909) for this region in *Peridinium* and appears to be widely applicable in other genera.

(5) The plates of the genus (Figs. A and B) are not as heretofore described, but, in all species which I have thus far examined they are as follows: apicals, 3 to 6; anterior intercalaries, 0 to 3; precingulars, 6; girdle, 6; postcingulars, 6; posterior intercalary, 1; antapical, 1. The ventral area contains one anterior plate indenting the epitheca, in the posterior margin of which lies the flagellar pore, a group of about four small intermediate plates and a large posterior plate.

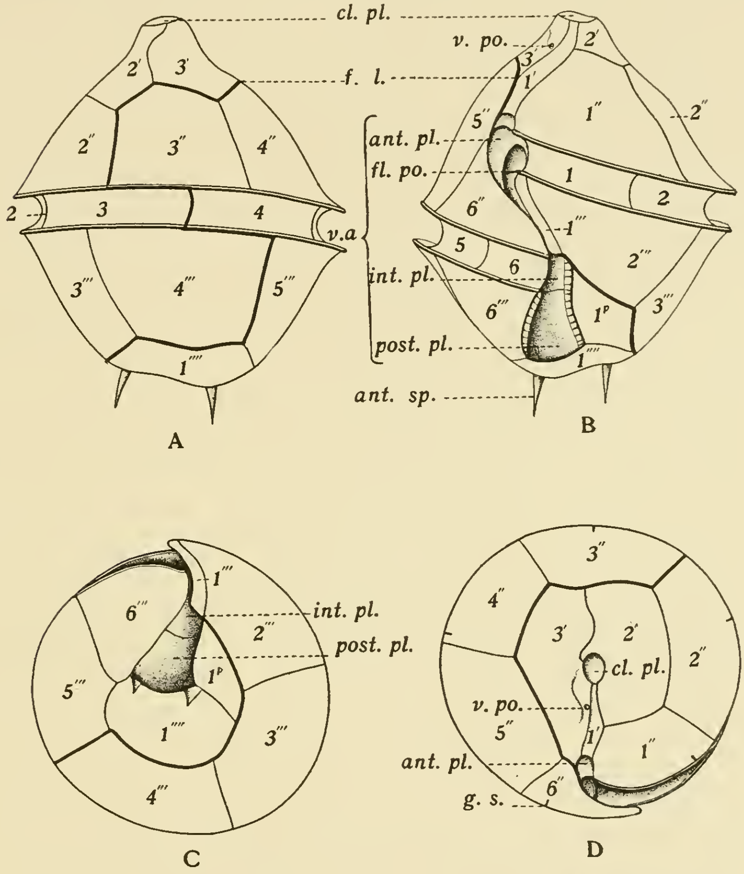
3. SKELETAL PLATES OF *GONYAULAX*

The *apical plates* (*1′-6′*) are those in contact with the apex. This *does not have an open pore* as sometimes indicated, but is closed by a minute closing platelet (*cl. pl.*, fig. A) which often adheres to the top of apical *1′* and covers the truncate apex. The number of the apicals varies from three to six in different species. At least three have been found in all species analyzed. It is probable that plate *1′* has been overlooked in cases where two apicals have been reported. Bifurcated and trifurcated apices such as Murray and Whitting (1899, pl. 30, figs. 1-3) have described in their inverted figures are due to the parting of the apicals, a phenomenon very commonly observed in many species of the genus, preparatory to ecdysis or the escape of the contents.

In some cases as in *G. apiculata* and *G. polyedra* one or more of the plates in the apical region are crowded away from contact with the apex. Such plates I have designated as *anterior inter-*

calarics (*1^a–3^a*), as well as other plates lying between the apical and precingular series.

The *precingular plates* (*1″–6″*, fig. A) are invariably six in number in the species which I have examined. Stein (1883)



Figs. A-D. Plates of thecal skeleton of *Gonyaulax spinifera* (Clap. et Lach.) Diesing × 1000. A, dorsal view; B, ventral view; C, antapical view; D, apical view. *1–6*, girdle series of plates; *1′–3′*, apical series; *1″–6″*, precingular series; *1‴–6‴*, antapical series; *1^p* posterior intercalary; *1⁗*, antapical plate; *ant. pl.*, anterior plate of ventral area; *ant. sp.*, antapical spine; *cl. pl.*, closing platelet of apex; *f. l.*, fission line along which skeleton parts in cell division; *fl. po.*, flagellar pore; *int. pl.*, intermediate plates (usually four in number, hidden in constricted region of ventral area); *post. pl.*, posterior plate of ventral area; *v. a.*, ventral area ("longitudinal furrow" of other writers in part); *v. po.*, ventral pore.

reported five and though Bütschli (1885b) later reported six in *G. polyedra*, no one has presumed to question the accuracy of Stein's observations, so great has been the confidence placed in his work which as a rule is extremely detailed and reliable. Lemmermann (1907) figures and describes six precingular (Praeaequatorialplatten) in *Gonyaulax palustris*.

The *girdle plates* (*1-6*) are six in number and may be disarticulated from one another with comparative ease.

The *postcingular plates* (1‴–*6‴*, fig. B) are invariably six in number, plate *1‴* of the series lying immediately adjacent to the ventral area (on its left edge) as a slender linear structure. This plate has hitherto been overlooked, though Entz (1904, fig. 4a, f) delineates it but does not otherwise note its presence or significance. Paulson (1904) indicates it in his figure of *G. triacantha* but does not otherwise note its presence. Lemmermann (1907) figures six postcingulars in *G. palustris* (in his fig. 5) but states that there are five "Postaequatorialplatten," no one of which can, however, be homologized with the narrow postcingular *1′* of my nomenclature.

The *posterior intercalary* (*1^p*) and *antapical* (*1⁗*, fig. B) are invariably present without change in number in the different species and the latter constitutes the most ready means of separation of this genus from most of the genera of the Peridinidae.

II. Generic Diagnosis

Gonyaulax Diesing emend.

Body variously shaped, spheroidal, polyhedral, broadly fusiform, elongated with stout apical and antapical prolongations, or dorso-ventrally flattened. Apex rounded or truncate symmetrically or asymmetrically, never acutely symmetrically pointed. Antapex rounded, flattened, or pointed symmetrically or asymmetrically. Girdle usually equatorial, descending, displaced distally one to seven times its own width, and sometimes with slight overhang. Transverse furrow impressed or not; longitudinal furrow usually slightly indenting the epitheca, often flaring distally, well developed, reaching to or approaching the antapex. Thecal wall (text figs. A-D) consisting of one to six apical plates (*1′–6′*), none to three anterior intercalaries (1^a–3^a), six precingulars (*1″–6″*), six girdle plates (*1–6*), six postcingulars, (*1‴–6‴*), one posterior intercalary (1^p), and one (*1⁗*) antapical. The longitudinal furrow occupies the whole of the ventral area (*v. a.*) which slightly indents the epitheca and consists of one anterior, about four intermediate and one posterior plate. The midventral plate (*1′*) of the apical series is usually a narrow plate extending posteriorly to a junction with the anterior plate of the ventral area, thus parting precingulars *1″* and *6″*. When guarded by lateral ridges it simulates an anterior extension of the longitudinal furrow. It bears at its apex a delicate extension, the closing platelet which covers the apical region.

Surface smooth or rugose with major thickenings along suture lines and minor ones on plates forming a regular or irregular polygonal mesh of varying size, often with vermiculate, longitudinal elements predominating, sometimes spinulate. Furrows with or without lists which in many species are ribbed or spinulate. One or more antapical spines sometimes present, rarely with sheathed spines of the *Ceratocorys* type. Plates porulate, with pores in centers, angles or nodes of the mesh. A peculiar large ventral pore (*v. po.*) occurs to the right of the midventral line usually near the suture between apical *1′* and the plate to its right. Theca divided obliquely in fission. Ecdysis frequently seen. Chromatophores yellow to dark brown, often dense. In fresh, brackish and marine waters from boreal to tropical regions.

III. COMPARISONS WITH OTHER GENERA

The presence in *Gonyaulax* of a single large antapical plate separates this genus at once from *Pyrophacus* and *Podolampas* (4 antapicals), *Goniodoma*, *Protoceratium*, and *Blepharocysta* (3 antapicals), and from *Diplopsalis* and *Peridinium* (2 antapicals). The hypotheca of *Gonyaulax* is identical with that of *Steiniella* and *Ceratocorys* [see Kofoid 1910] in its skeletal elements. The epitheca of the latter genus is distinguished by having five instead of six precingulars as in *Gonyaulax*.

Steiniella, however, has its epitheca also of the same skeletal constitution as that of *Gonyaulax* and should on this ground be included therein. The fact that the apex (region of the closing platelet) is carried over on the dorsal face scarcely suffices as a generic character, as it is almost realized in some species of *Gonyaulax*, as for example in *G. alaskensis* and *G. hyalina*, and the gap between the two genera is practically obliterated. Recognizing the fundamental identity of the skeletal formula in these two genera and finding it difficult to apply consistently any set of morphological distinctions between the two as the number of species ascribed to them has increased, I feel constrained to include *Steiniella* Schütt (1895) in the older genus *Gonyaulax*, according it therein only a subgeneric status.

The differences between the valid species of *Steiniella* (*S. fragilis*, *S. mitra*, and *S. inflata*) and *Gonyaulax* are no greater, if indeed as great, as those now found between species within *Gonyaulax* itself. A marked tendency to fall to pieces on the part of the theca, the predominance of vermiculate-linear markings, and an elongated apex overlapping the dorsal edge of the anterior end of the body are the only available characters upon which to found the genus *Steiniella*, and no one of them affords an adequate basis for separation since they are all to be found in varying degrees within *Gonyaulax* itself. They are, moreover, purely superficial characters such as are subject to great modifications in many of the larger genera of the dinoflagellates.

The species of *Steiniella* thus far described which should be transferred to *Gonyaulax* are the following:

Gonyaulax (*Steiniella*) *fragilis* Schütt. See Schütt (1895).
G. (*Steiniella*) *mitra* (Schütt). See Schütt (1895).
G. (*Steiniella*) *inflata* (Kofoid). See Kofoid (1907a).

Certain other species have been described in the genus *Steiniella* which have previously been otherwise assigned. *Steiniella* (?) *punctata* described by Cleve (1900a) was assigned by me (1907a) to the new genus *Murrayella*, while Cleve's (1903) *Steiniella* (?) *complanata* was in the same paper referred by me to another new genus *Centrodinium*. *Steiniella cornuta* described by Karsten (1907) is identical with the larger forms of

Gonyaulax pacifica described by me in the same year (April 13, 1907), but prior to the publication of Karsten's paper (December, 1907). It may therefore be dismissed as a synonym of *G. pacifica.*

A homonym (in botanical nomenclature) of *Steiniella* Schütt was established by Bernard (1908) for a single species, *S. Graevenitzii* (*Protococaceae*) for the reception of which I here propose the generic name *Steinedesmus* nom. nov.

The relations of *Amphidoma* and *Murrayella* to *Gonyaulax* are intimate, but our present knowledge of their skeletal morphology is insufficient for final conclusions as to their standing. In so far as our data go they are both generically distinct. The apical and antapical regions in both are difficult of analysis on account of the small size of the plates and their firm adhesion one to another. *Amphidoma* is distinguished from *Gonyaulax* by six apicals and no precingulars, by the form of the apices, by the feebly developed longitudinal furrow, equatorial, and non-displaced, horizontal girdle; *Murrayella* by its five postcingulars, the absence of a truncate apex, and by the form of the longitudinal furrow.

The genus *Ceratocorys* is distinguished by its five precingulars, three apicals and one anterior intercalary and by the anteriorly located girdle.

The genus *Spiraulax* Kofoid founded on *Gonyaulax jolliffei* Murray and Whitting differs from *Gonyaulax* in the shortened apical *1′* (rhomb plate of various authors), the junction of precingular *1″* and anterior intercalary 1^a across the midventral line, in the presence of a ventral notch in apical *1′*, and in the absence of a ventral pore. See Kofoid (1911c).

IV. Skeletal Fission

Cell division in the genus *Gonyaulax* may take place in thecate individuals and in this case it involves the division of the enveloping theca. Fission of the cell mass which has rid itself of its skeleton by ecdysis is possible especially in such species as *G. polyedra* where this phenomenon is often seen, but no conclusive evidence of cell division in the naked stage has thus far been observed by me. In the fission of thecate individuals the parental skeleton parts along uniformly definite sutures as in *Ceratium* (see Kofoid, 1909a) in an irregular plane at approximately right angles to the major axis of the spindle of the dividing cell. This plane parts the antero-sinistral moiety from the postero-dextral one. Chain formation occurs in conjunction with thecal fission, in so far as my own observations and the literature indicate, only in *Gonyaulax catenata* (Levander) Kofoid, and in *G. series*, as I have elsewhere shown (1911c). Chain formation of the plasma mass followed by skeletal formation *de novo* occurs in *Gonyaulax series* (see Kofoid, 1911a).

The anterior moiety (see text-figures A–D and pl. 10, figs. 9, 10) receives from the ancestral skeleton all of the apical series, and interior intercalaries when these are present, precingulars *1″* and *2″*, girdle plates *1–3*, and postcingulars *1‴–4‴*. The posterior moiety receives precingulars *3″–6″*, girdle plates *4–6*, postcingulars *5‴–6‴*, posterior intercalary 1^p, and the antapical *1⁗*. The fission line appears to pass through the flagellar pore and the greater part, if not the whole, of the ventral area goes with the posterior moiety. The path of the fission plane along the sutures is clearly shown in text figures A–D. The precise location of the fission line in the ventral area has not been accurately determined as yet. The figure of Entz (1905, fig. 58) suggests that this line passes through the flagellar pore and separates the anterior plate of the ventral area from the intermediates. Since he does not distinguish the subdivisions of this area, or indeed in his figures the other plates of the thecal wall, he has left the matter still in some uncertainty.

V. SUBGENERA AND SPECIES OF GONYAULAX

For convenience the species of *Gonyaulax* may be grouped in three subgenera based upon the general form of the body. It is somewhat difficult to define these groups in such a way as to make the assignment of every known species to one of the three perfectly evident. A few aberrant species are in consequence included in the larger subgenera. As a result of my examination of extensive material of this genus and of a critical review of the literature the following species are recognized as valid and are grouped as follows. Pertinent bibliographical references are appended in each case.

1. Subgenus **Gonyaulax** (Diesing) Kofoid subgen. nov.

Body spheroidal or polyhedral, not greatly elongated, apical closing platelet not carried over upon the dorsal side. This includes the non-fusiform species of the genus as heretofore defined. Here belong:

Gonyaulax apiculata (Penard) Entz (1904), p. 11, fig. 4a–i.
  Syn. *Peridinium apiculatum* Penard (1891), p. 51, pl. 3, figs. 3–13.
    G. clevei Ostenfeld (1901), p. 133, fig. 2.
    G. apiculata var. *clevei* Ostenfeld (1908), p. 164, pl. 5, figs. 59, 60.
G. catenata (Levander) Kofoid (1911b). Described as *Peridinium catenatum* by Levander (1894a), pp. 1–18, pl. —, figs. 1–11.
G. diegensis, sp. nov. See p. 217.
G. digitale (Pouchet) (1883), p. 433, pl. 18/19, fig. 14 as *Protoperidinium digitale*. See p. 214 of this paper.
G. kofoidi Pavillard (1909), p. 278, fig. 1, A, B.
G. pacifica Kofoid (1907b), p. 308, pl. 30, figs. 37–39.
G. palustris Lemmermann (1907), pp. 296–297, figs. 1–5.
G. polyedra Stein (1883), pl. 4, figs. 7–9.
G. polygramma Stein (1883), pl. 4, fig. 15. See *G. steini* Lemmermann, in list of indeterminate species on p. 203 for the remainder of Stein's figures.
G. scrippsae, sp. nov. See p. 228.
G. series Kofoid (1911a), pp. —, pls. 1–2, figs. 1–6. (In press.)
G. sphaeroidea, sp. nov. See p. 206.
G. spinifera (Claparède et Lachmann) Diesing (1886), p. 96. Originally described by Claparède and Lachmann (1858–1859), p. 405, pl. 20 figs. 4, 5, as *Peridinium spiniferum.*
G. triacantha Jörgensen (1899), p. 35. See Kofoid (1906b), pp. 102–105, figs. 1–3.
G. turbynei Murray and Whitting (1889), p. 323, pl. 28, figs. 4a, b.

2. Subgenus **Fusigonyaulax**, subgen. nov.

Body elongated, usually fusiform, often with an elongated apical and antapical horn. Here belong:

Gonyaulax birostris Stein (1883), p. 4, fig. 20.
G. glyptorhynchus Murray and Whitting (1899), p. 324, pl. 28, fig. 3a–c.
G. highleii Murray and Whitting (1899), p. 324, pl. 28, fig. 2a, b.

G. jolliffei Murray and Whitting (1899), p. 324, pl. 28, figs. 1a, b, which might be placed here, is described by me (1911c) as in a new genus, *Spiraulax*.

3. Subgenus **Steiniella** (Schütt) Kofoid, subgen. nov.

Body rounded, spheroidal or subpolyhedral, exceedingly fragile, closing platelet of apex carried over upon dorsal side. Surface markings tending to longitudinal direction.

Gonyaulax alaskensis, sp. nov. See p. 249.

Gonyaulax hyalina Ostenfeld og Schmidt (1901), p. 172, figs. 24 a-d.

Gonyaulax fragilis (Schütt), described as *Steiniella fragilis* by Schütt (1895), p. 6, figs. 26_{1-14}.

Gonyaulax inflata (Kofoid). Described as *Steiniella inflata* by Kofoid (1907a), pp. 168–169, pl. 2, fig. 15.

Gonyaulax mitra (Schütt). Described as *Steiniella mitra* by Schütt (1895), pl. 7, figs. 27_{1-3}. Possibly not a *Steiniella*.

4. Subgenus **Acanthogonyaulax** subgen. nov.

Characterized by spines upon the hypotheca with axial cores similar to those of *Ceratocorys*. Girdle premedian. Plates of apical region numerous (6 in *G. ceratocoroides*). Contains one species *G. ceratocoroides* (Murr. and Whitt.) Kofoid (1910, p. 182).

For convenience in reference I append herewith (1) a list of species of *Gonyaulax* regarded by me as synonyms, (2) a list of described species which I regard as indeterminable and therefore invalid, (3) a list of species originally described in other genera which are here included in the genus *Gonyaulax*, and (4) species referred to *Gonyaulax* but belonging to other genera.

VI. ANNOTATED LIST OF SPECIES OF GONYAULAX REGARDED HERE AS SYNONYMS

Gonyaulax apiculata var. *clevei* Ostenfeld (1908), p. 164, pl. 5, figs. 59, 60 = *G. apiculata* (Penard) Entz.

G. clevei Ostenfeld (1901), p. 133, fig. 2 = *G. apiculata* (Penard) Entz (1904), p. 14, fig. 4.

G. grani Henckel (1909), p. 118, pl. 30, figs. 1–16 = *G. digitale* (Pouchet) Kofoid.

G. globosa Stüwe (1909), p. 275, pl. 2, fig. 7 = *G. kofoidi* Pavillard (1909), p. 278, fig. 1 A, B. Doubtfully listed here.

G. levanderi (Lemmermann) Paulsen (1907), p. 8, fig. 8 = *G. spinifera* (Clap. et Lachm.) Diesing. See p. 213 of this paper.

G. mangini Fauré-Fremiet (1908), p. 230, fig. 16, pl. 16, fig. 19 = *G. spinifera* (Clap. et Lachm.) Diesing.

VII. INDETERMINATE SPECIES, NAMES WHICH SHOULD BE REGARDED AS APPLIED TO UNRECOGNIZABLE SPECIES

Gonyaulax caspicus Henckel (1909), pl. 29, figs. 6–15. No description published. On p. 187 as *G. caspicum.*

G. obliqua (Gourret) Lemmermann (1899), p. 368. Figure and description of *Roulea obliqua* Gourret (1883), p. 87, pl. 2, figs. 39, 39a, too indefinite to permit reidentification. Possibly a synonym of *G. spinifera.*

G. polygramma var. Stein (1883), pl. 4, figs. 16, 17.

G. schuetti Lemmermann (1899, p. 367), based on *G. polygramma* Stein var. of Schütt (1895), pl. 8, figs. 33b $_{1-3}$ Probably an early stage in the reformation of the theca following ecdysis in some indeterminable species.

G. steini Lemmermann (1907), p. 298, based on part (pl. 4, figs. 16, 17) of Stein's (1883) *G. polygramma.* (''Eine Varietät mit zugespitzer Endplatte.'') This is plainly different from Stein's figure 15, which is a typical *G. polygramma,* but the ''variety'' has been figured in such oblique positions as to render reidentification wholly conjectural.

Roulea spinifera Gourret (1883), pp. 86–87. Assigned by Lemmermann (1907), p. 298, to synonomy of *G. spinifera.* Specific relations indeterminable.

VIII. SPECIES OF *Gonyaulax* DESCRIBED IN OTHER GENERA, OR ASSIGNED TO SPECIES IN OTHER GENERA, WHICH BELONG IN *Gonyaulax*

Amylax lata Meunier (1910), pp. 51–52, pl. 3, figs. 24–27 = *Gonyaulax triacantha* Jörg. (1899), p. 35.

Amylax nivicola Meunier (1910), p. 53, pl. 3, figs. 35, 36. Probably *Gonyaulax.* Generic and specific status problematical.

Amylax perpusilla Meunier (1910), p. 53, pl. 3, fig. 37. Probably *Gonyaulax.* Generic and specific status problematical.

Amylax catenata Meunier (1910), p. 52, pl. 1 bis, figs. 46, 47; pl. 3, figs. 28–34 = *Gonyaulax catenata* (Levander) Kofoid (1911b), pp. 287–294, pl. 18.

Ceratium hyperboreum Cleve (1900a), p. 14, pl. 8, fig. 14 = *Gonyaulax triacantha* Jörgensen (1899), p. 35. Quoted by Lemmermann (1907), p. 298, as *Ceratium hyperboreum* and by Linko (1907), pl. 91, as *Geratium hyperboreum.*

Ceratocorys spinifera Murray and Whitting (1899), p. 329, pl. 30, figs. 6a, b, e = *G. ceratocoroides* Kofoid (1910), p. 182. The remaining figures, 6c, d, are of *Ceratocorys.*

C. [*cratocorrys!*] *spinifera,* Schröder (1906), p. 329 = *Gonyaulax spinifera.* Lapsus.

Goniodoma milneri Murray and Whitting (1899), p. 325, pl. 27, figs. 2a–d = *Gonyaulax milneri* (Murr. and Whitt.) Kofoid.

Heterodinium triacantha (Jörgensen) Kofoid (1906a), p. 354 = *Gonyaulax triacantha*. See Kofoid (1906b), p. 102.

Peridinium apiculatum Penard (1891), p. 51, pl. 3, figs. 3–13 = *Gonyaulax apiculata* (Penard) Entz (1904), p. 11, figs. 4a–i.

Peridinium catenatum Levander (1894a), pp. 1–18, pl. figs. 1–11 = *Gonyaulax catenata* (Levander) Kofoid (1911b), pp. 287–294, pl. 18.

Peridinium digitale, Lemmermann (1899), p. 369 = *Gonyaulax digitale* (Pouchet) Kofoid. See p. 214 of this paper.

Peridinium levanderi Lemmermann (1900), p. 120, based on Levander's (1894a), p. 50, pl. 2, fig. 21, of *Peridinium sp.* = *G. spinifera*.

Peridinium pyrophorum, Lemmermann (1899), p. 369 = *Gonyaulax polygramma* Stein.

Peridinium spiniferum Claparède et Lachmann (1858-1859), p. 405, pl. 20, fig. 4, 5 = *G. spinifera* (Clap. et Lachm.) Diesing (1866), p. 96.

Protoperidinium digitale Pouchet (1883), p. 433, pl. 18/19, fig. 14 = *G. digitale* (Pouchet) Kofoid. See p. 214 of this paper.

Protoperidinium pyrophorum Ehrbg. See Pouchet (1883), p. 433, pl. 18/19, fig. 15 = *G. polygramma* Stein (1883), pl. 4, fig. 15. Pouchet's form is not that of Ehrenberg (1838), p. 133, pl. 1, fig. 1, which is fossil.

Roulea obliqua Gourret (1883), p. 87, pl. 2, figs. 39, 39a = *G. obliqua* (Gourret) Lemmermann (1899), p. 368. Indeterminable.

Roulea spinifera Gourret (1883), pp. 86–87, pl. 2, fig. 43. Assigned by Lemmermann (1907), p. 298, to synonomy of *G. spinifera*. Indeterminable.

Steiniella cornuta Karsten (1907), pp. 348, 420, pl. 53, figs. 7a-c = *Gonyaulax pacifica* Kofoid (1907b), p. 308, pl. 30, figs. 37–39.

Steiniella fragilis Schütt (1905), pl. 6, figs. 26_{1-14} = *G. fragilis* (Schütt) Kofoid.

Steiniella inflata (Kofoid) (1907a), pp. 168-169, pl. 2, fig. 15 = *G. inflata* (Kofoid).

Steiniella mitra Schütt (1905), pl. 7, figs. 27_{1-3} = *G. mitra* (Schütt) Kofoid.

IX. DESCRIBED OR CITED SPECIES OF *GONYAULAX* WHICH BELONG IN OTHER GENERA

Gonyaulax fimbriatum Murr. and Whitt. See Schröder (1906), p. 329, lapsus (?) for *Goniodoma fimbriatum* = *Ceratocorys armatum* (Schütt) Kofoid (1910), p. 181.

D. SPECIES OF *GONYAULAX* FROM THE COAST OF CALIFORNIA

The species of *Gonyaulax* included in the following key have been found along the Pacific coast between southern Alaska and

San Diego. Skeletons or moribund individuals of Alaskan species may be expected in the deeper plankton (ca. 50-100 fathoms) as far south as San Diego and are therefore included in this key. It is to be expected that the further examination of the plankton of subtropical facies occurring at San Diego during late autumn and early winter will bring to light additional species normal to warmer seas. No fresh-water species has as yet been reported from California.

I. KEY TO SPECIES OF *Gonyaulax* IN CALIFORNIA WATERS

1. Body elongated, fusiform, length 1.5 transdiameters or more........ 2
1. Body not elongated, length less than 1.5 transdiameters.................. 3
2. Antapex decidedly asymmetrical 4
4. Very large, length over 100μ, body deeply excavated, antapex in ventral view broadly rounded ....**pacifica**
4. Large, length less than 100μ, not so deeply excavated, antapex obliquely truncate ....**kofoidi**
2. Antapex nearly symmetrical 5
5. Length less than 2 transdiameters........**Spiraulax jolliffei** gen. nov.
5. Length more than 2 transdiameters.............................**G. birostris**
3. Apex extended over to dorsal face 6
3. Apex not extended on to dorsal face 7
6. Body elongated, surface vermiculate ....**G. fragilis**
6. Body rotund, surface reticulate ....**G. alaskensis**
7. Body spheroidal ....**G. sphaeroidea**
7. Body not decidedly spheroidal 8
8. Antapical spines not present 9
8. With one or more antapical spines 10
9. Body polyhedral, surface reticulate ....**G. polyedra**
9. Body ellipsoidal, with longitudinal striae predominant 11
11. Girdle with considerable displacement and overhang .... **G. scrippsae**
11. Girdle with little displacement and overhang..................**G. turbynei**
10. Apical horn 0.4 transdiameter, 5 antapical spines....**G. triacantha**
10. Apical horn not so well differentiated, fewer antapical spines...... 12
12. Surface with longitudinal striae predominant...........**G. polygramma**
12. Surface with polygonal recticulations 13
13. Large species, length $60–100\mu$, apical horn moderately differentiated ....**G. diegensis**
13. Medium-sized species, $40–50\mu$, apical slightly differentiated.. **G. digitale**
13. Small species, $30–40\mu$, apical scarcely differentiated .... **G. spinifera**[1]

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[1] Sometimes without antapical spines.

II. Descriptions of Species of *Gonyaulax* Diesing, With Notes on Synonomy, Variation, and Distribution

1. Subgenus **Gonyaulax** subgen. nov.

The California representatives of this subgenus fall into several groups of species of unequal coherence and content; to wit, the *spinifera, polygramma, polyedra,* and *sphaeroidea* groups. The *spinifera* group consists of four species, *G. spinifera, G. digitale, G. diegensis* and *G. triacantha.* The first three form a series of increasing size, of closely related species, from which the fourth differs widely in form of body, surface markings and distribution of the antapical spines, the possession of which forms the main character linking it to this group.

a). The *Sphaeroidea* Group

Characterized by spheroidal form, smooth or feebly reticulated surface, girdle and ventral area scarcely impressed.

Here belong *Gonyaulax sphaeroidea* sp. nov. and *G. palustris* Lemm.

1. **Gonyaulax sphaeroidea** sp. nov.

Pl. 16, figs. 41, 42

Diagnosis—A medium-sized species with spheroidal body, no apical horn or with one which is but slightly differentiated, girdle displaced 1.5 to 2 times its width, anterior intercalary plate present, surface smooth or faintly reticulate, rather sparingly punctate. Hyaline lists on both sides of longitudinal furrow.

Description: *Body* spheroidal, major axis slightly exceeding equatorial (1.12 transdiameters), no apical horn differentiated in specimen figured. *Epitheca* slightly exceeding hypotheca, each nearly hemispherical. Section at girdle with only a trace of flattening on ventral face.

The *girdle* is equatorial, slightly postmedian, descending, displaced distally 1.5 to 2 girdle widths, and has an overhang of less than 0.5 girdle width. It is not impressed and has low hyaline, non-ribbed lists.

The *ventral area* or longitudinal furrow is slightly curved to the left opposite the distal end of the girdle, and flares posteriorly to more than a girdle width. It is guarded on either side by salient membranous, non-ribbed lists which increase in height posteriorly. Anteriorly the ventral area slightly indents the epitheca.

The *plate formula* is $3'$, 1^a, $6''$, 6, $6'''$, 1^p, $1''''$. The *apical* plates, $1'$ to $3'$ surround the apex. Apical $1'$ is a slender plate reaching to the ventral area, separating plates $1''$ and $6''$ of the precingular series and bearing at its apex the elliptical closing platelet, a thin scale-like structure which covers the so-called apical pore, and when the plates are parted often remains attached to the slender midventral apical plate $1'$. Plates $2'$ and $3'$ are nearly bilateral and placed saddle fashion upon the anterior end. The *anterior intercalary* is a small plate not touching the apical region and lying to the right (of body, left of figure) of apical $1'$, and between the apical and precingular series. It bears on its median margin a conspicuous pore, which is present throughout the genus *Gonyaulax,* and has not been noted heretofore, which I call the ventral pore. The six *precingulars* $1''$–$6''$ are all prominent plates, $6''$ being quadrangular. It is triangular in most species which have widely displaced girdles. The girdle plates are normally six in *Gonyaulax* but were not separated in this species as the material at command was limited. The six *postcingulars* are typical; postcingular $1'$ being, as usual, a narrow plate partially hidden on the left margin of the longitudinal furrow. The *posterior intercalary* 1^p is a wide plate at the left of the longitudinal furrow, touching neither the girdle nor the antapex. The single *antapical* $1''''$, is a large pentagonal plate whose ventral margin is slightly indented by the ventral area.

The *ventral area* includes those plates of the thecal wall which are involved in the longitudinal furrow. There are as many as six of these in some species of *Gonyaulax.* Only the most anterior one is to be seen in the figure.

The *surface* of the San Diego specimen was perfectly smooth and was sparsely porulate with rather large scattered pores. There were no surface markings or reticulations and the lists along the furrows were without ribs.

Cell contents unknown.

DIMENSIONS: Length, 43μ; transdiameter, 38μ; dorsoventral diameter the same; girdle width, 4.5μ.

COMPARISONS: Its spherical form and smooth surface at once distinguish it from all described species of the genus.

Described from an empty theca taken in surface plankton off San Diego, November 26, 1904. The composition of the plankton in this collection indicates its oceanic and subtropical origin as shown by the presence of such species as *Pyrophacus horologicum, Ceratocorys armatum, C. horrida, Gonyaulax turbynei, Ceratium reticulatum* and *Podolampas palmipes.*

b). The *Spinifera* Group

A group of rotund species characterized by the presence of one or more antapical spines, more or less widely displaced girdle and slightly differentiated apical horn. Plate formula $3'$ (or $4'$), 0 (or $2)^a$, $6''$, 6, $6'''$, 1^p, $1''''$. No longitudinal striae.

One of the most puzzling cases of confusion which exists among the Peridinidae is that which involves *Gonyaulax spinifera*, due, in my opinion, to the defective figure of Claparède and Lachmann (1858-1859) who originally described the species as *Peridinium spiniferum*, to Stein's (1883) error in failing to distinguish between the form he described as *G. spinifera* and that of Claparède and Lachmann, and to the non-acceptance by subsequent writers of Pouchet's (1883) *Protoperidinium digitale* as distinct from the species originally described as *spiniferum*. The acceptance on the part of later workers of the application of the name *spinifera* to Stein's species has led to the re-description of the minute original form as a new species by Paulsen (1907), Fauré-Fremiet (1908), Henckel (1909) and possibly to repeated appearance of *Gonyaulax* spp. in the plankton records of the International Commission for the Investigation of the Sea. See Ostenfeld (1906, 1909).

The examination of a wide range of material, and an inspection of all published figures have convinced me that there are two somewhat similar forms but distinct species of *Gonyaulax* widely distributed in the neritic and in the oceanic plankton to some extent. These are, (1) the minute form with widely displaced, overhanging girdle and usually two, rarely several, small antapical spines, and (2) a larger form with less displacement and overhang and two larger spines. This first is the original *G. spinifera*, the type species of the genus, known in later literature as *G. levanderi* (Lemmermann) Paulsen, *G. mangini* Fauré-Fremiet, and possibly *G. caspica* Henckel. Doubtless it has sometimes been confused with and often combined with the other common species, *G. digitale* (Pouchet) (described as *Protoperidinium digitale*).

The other species is the larger and, it seems from all the evidence obtainable, is the more abundant one, has less displacement and less overhang of the girdle, is often more rugose, and has two prominent antapical spines. It was first described, as above stated, by Pouchet (1883, July-August) and several months later referred by Stein (1883, November) to *G. spinifera* (Clap. et Lachm.) Diesing, a reference widely followed by subsequent workers. The date of publication of Stein's (1883) monograph is stated in a letter to me from the publisher to have been the latter part of November.

To these two forms I here add a third and still larger species *G. diegensis*, distinguished by its still larger size, widely displaced but not much overhanging girdle, usually three antapical spines, by its wide intercalary bands, and by the presence of four apical plates.

These three species form a series of increasing size comparable with that formed in the *polygramma* group by *G. turbynei*, *G. scrippsae*, *G. polygramma*, *G. kofoidi*, and *G. pacifica*, and as in the case of that series, showing more or less intergradation.

The possibility that they form merely a growth series is excluded by their distribution, for in the case of the *polygramma* series, *G. kofoidi* and *G. pacifica* are tropical and oceanic, and the other two do not occur together with them in such numbers as the growth relation demands. The possibility that they are geographical (temperature) species or "races" is suggested by the present incomplete data of their distribution, but it is by no means conclusively determined. All three, *spinifera*, *digitale*, *diegensis*, occur, perhaps together, in the San Diego region. Their predominant centers of distribution must be determined to solve this problem. In my opinion from data at present available they are distinct species.

The inclusion of *G. triacantha* in the *spinifera* group is an arbitrary assignment, based primarily on the presence of several antapical spines. Here also may be placed *G. apiculata* (Penard) Entz, and its variety *clevei* (Ostenfeld).

2. **Gonyaulax spinifera** (Claparède et Lachmann) Diesing

Pl. 10, figs. 8–10; pl. 16, fig. 39, and text figs. A–D.

Peridinium spiniferum Claparède et Lachmann (1858–1859), p. 405, pl. 20, figs. 4, 5.

Gonyaulax spinifera (Clap. et Lachm.) Diesing (1866), p. 96.

Peridinium sp. Levander (1894b), p. 50, pl. 2, fig. 21.

Peridinium vexans Murray and Whitting (1899), p. 327, pl. 29, figs. 7a, b. See discussion of synonomy below.

P. levanderi Lemmermann (1900), p. 120.
Gonyaulax sp. Van Breeman (1905), p. 42.
C. [*eratocorrys*] *spinifera*, Schröder (1906), p. 329. Lapsus.
Gonyaulax levanderi, Paulsen (1907), p. 8, fig. 8.
G. levanderi, Ostenfeld (1908), p. 165, pl. 5, figs. 54–58.
G. levanderi, Paulsen (1908), p. 30, fig. 38.
G. mangini, Fauré-Fremiet (1908), pp. 213, 230; fig. 6, pl. 16, fig. 19.

Diagnosis: A minute rotund species somewhat elongated anteriorly, with relatively wide oblique girdle with considerable overhang; epitheca with convex sides, with or without two or more small antapical spines. Longitudinal furrow not flaring much posteriorly, often abruptly widened opposite distal end of girdle. Line joining ends of girdle makes an angle of 27°-40° with major axis. Surface lightly marked. Length 24-50μ.

Description: *Body* small, length, excluding spine 1.14–1.25 transdiameters; rotund, girdle section subcircular. *Epitheca*, subconical, more rotund than in *G. digitale*, apex subsquarely truncate, nearly a girdle width across; apical horn not much differentiated or barely suggested; sides slightly convex, greatest altitude, 0.6 to 0.7 transdiameter. *Hypotheca* subhemispherical, greatest altitude, 0.6 transdiameter, antapex broadly rounded or sub-truncate between spines, with one, two or more usually short antapical spines, rarely with none. The spines shown in plate 10, figures 9 and 10, are exceptionally long.

The *girdle* is the most striking characteristic of this species. It is relatively very wide, one-sixth of the transdiameter across, descending, displaced twice its width (2.2–3) or more, with an overhang of 1 to 2 girdle widths. It is deeply indented, with low ridges, sometimes salient, and without lists.

The *ventral area* (*v.a.*, text fig. B.) is very oblique anteriorly, slightly indents the epitheca, is laterally compressed almost to closure between the overhanging ends of the girdle and is nearly straight posteriorly with a slight deflection to the left side of the body. It is not expanded posteriorly as in *G. digitale* (Pouchet), its distal end being about 1.4 wider than at the distal posterior girdle ridge. The most marked and fairly constant feature is its abrupt almost rectangular expansion to the left just opposite to the distal end of the girdle, a feature not prominent in *G. digitale* or *G. diegensis*. This expansion is better shown in plate 10, figure 10, than in plate 16, figure 39.

Plate formula is $3'$, 0^a, $6''$, 6, $6'''$, 1^p, $1''''$. Apical $1'$ is curved with large ovate or elliptical closing platelet (*cl. pl.*, pl. 10, figs. 8, 9). Apical $3'$ bears a faint trace (pl. 16, fig. 39, and text fig. B) of a curved marking resembling a suture line which marks off the apical-median part of the plate in somewhat the same fashion in which apical $4'$ is delimited in *G. diegensis*. I have not been able to separate this as a plate in *G. spinifera* and the marking is often absent. Ventral pore (*v. po.*) is on median edge of apical $3'$, about one-half of the distance from the apex to the apical-precingular suture. *Precingular 1″* is vertically displaced anteriorly the whole length of 6″, separated by ventral area from plate 6″, which is nearly triangular (pl. 10, fig. 10). *Postcingular 1‴* is very small, linear, overhanging oblique part of ventral area. *Posterior intercalary* is 1 to 1.3 girdle widths across.

The plates of the *ventral area* (*v. a.*, pl. 10, fig. 8) are much obscured by the obliquity and overhang of the girdle. The anterior plate (*ant. pl.*) slightly indents the epitheca, is not crossed by the anterior girdle ridge and bears on its postmargin the anterior edge of the flagellar pore. The intermediate plates (*int. pl.*, pl. 10, fig. 10) must be small as they are more or less hidden in the oblique part of the longitudinal furrow. The posterior plate (*post. pl.*) is large and extends anteriorly almost to the level of the distal end of the posterior girdle ridge. Its posterior end roundly indents the antapical plate.

The *surface* is smooth, sparingly porulate with large pores, especially near suture lines which are marked by faint lines. A faint reticulum about the pores is sometimes developed. Ridges along girdle and ventral area heavier, continued on either side in short spinules which are rather nearer together than in *G. digitale,* being about 1.5 girdle widths apart. Often but a single spine, the right one, is present, and sometimes none at all is found. In the brackish water form of this species described as *G. levanderi,* Paulsen (1907, fig. 8a), has figured these spines as posterodorsal to the end of the ventral area and also finds several small accessory spinules. The two spines in our material are located near the points where the ventral area indents the antapical, a position which the antapical spines often occupy in this genus. Lists on the spines are rare in this species. Chromatophores often dark yellowish brown. *Contents* dense, occasionally pale and translucent.

DIMENSIONS: Length, 24 to 50μ, generally 35 to 40μ; transdiameter, 21 to 33μ. In the Aral Sea Ostenfeld (1908) records forms referable tentatively to this species, 40 to 50μ in length and 32 to 44μ wide. A few of our marine forms approaching this size have been found by me.

The following table of measurements gives the range in dimensions observed in San Diego material and recorded elsewhere.

Measurements of *Gonyaulax spinifera*
(Dimensions in Microns)

Locality	Date	Length	Transdiameter
San Pedro Harbor, Calif.,	May 31, 1901	44	35
San Pedro Harbor, Calif.,	May 31, 1901	35	31
San Pedro Harbor, Calif.,	May 31, 1901	40	35
San Pedro Harbor, Calif.,	May 31, 1901	45	39
Off San Diego, Calif.,	June 28, 1904	48	37
Off San Diego, Calif.,	June 28, 1904	41	23

Locality	Date	Length	Trans-diameter
Off San Diego, Calif.,	June 28, 1904	40	30
Off San Diego, Calif.,	Dec. 2, 1904	38	30
Off San Diego, Calif.,	Dec. 2, 1904	38	35
Loring, Alaska,	Sept. 15, 1905	40	34
Loring, Alaska,	Sept. 15, 1905	45	40
Claparède and Lachmann	(1858–1859), p. 405, pl. 20, fig. 4.	30–40	20–26(?)
Murray and Whitting	(1899), pl. 29, fig. 7a.	39	33
Fauré-Fremiet	(1908), p. 230, pl. 16, fig. 19.	40	33
Ostenfeld	(1908), pl. 5, figs. 54–58.	40–50	32–44

Variation: Quite variable in amount of overhang (1 to 2 girdle widths) and displacement of the girdle (2.2–3 girdle widths), number and development of antapical spines, from none to two main ones with accessory spinules, and in development of surface markings.

Comparisons: Most like *G. digitale* with which it has been more or less confused and not with certainty always separable from it. In material from the Faeroes, Irish Sea, Naples, and Alaska which I have examined there seem to be fairly constant differences between the two species which, however, are in some cases difficult to apply.

From *G. diegensis* it is distinguished at once by its much smaller size, absence of intercalary striae, and its smaller antapical spines. The table below summarizes the important points of difference in the three species.

Species Characters in *Spinifera* Group

	Spinifera	*Digitale*	*Diegensis*
Length	24–50μ	45–75μ	60–100μ
Width	20–37μ	34–50μ	45–82
Antapical spines	0–2, small	2 (4)	1–3, usually 3
Angle made with major axis by line joining ends of girdle	27°–40°	5°–18° (26°)	0°–8° (15°)
Displacement of girdle in girdle widths	2.3–3	1.5–2.5	3–5
Overhang of girdle ends, in girdle widths	1.5–2	0.5–1.25	0–1
Form of longitudinal furrow	Widens abruptly opposite distal end of girdle	Not abruptly widened	Not abruptly widened
Apical 4′	Not separated	Not separated	Separated

SYNONOMY: The species originally described by Claparède and Lachmann (1858–1859) as *Peridinium spiniferum* was clearly a small one (40μ) with widely displaced overhanging girdle, as is evident in both the figures and description. This Diesing (1866) made the type (only species) of his genus *Gonyaulax.* It is equally evident that Stein's (1883) figure is of a form with less displacement and overhang and probably (exact magnifications are not given) of larger size. An examination of extensive material from tropical and northern waters from the Atlantic, Pacific and Mediterranean has convinced me that there are two distinct and separable forms confused more or less under the name *G. spinifera.* Others have evidently labored under the same opinion and have sought to escape from it by renaming either the smaller or larger form according as the name *spinifera* was applied to Stein's or the original describer's figures. Pouchet (1883), who had Claparède and Lachmann's paper (1858-1859) at hand distinguished the larger form which Stein (1883) a few months later published as *G. spinifera*, as *Protoperidinium digitale.* Later workers finding the smaller form with oblique and overhanging girdle have recognized its distinctness from the *G. spinifera* of Stein (1883). Levander (1894b) called it *Peridinium* sp. Lemmermann named it *P. levanderi;* Van Breeman (1905) recognized its distinctness from *G. spinifera* of Stein and left it unnamed and Paulsen (1907, 1908) and Ostenfeld (1908) have called it *G. levanderi*, while retaining Stein's name for the larger form, and Fauré-Fremiet names it *G. mangini.* The distinctions between the two forms have evidently been widely recognized though Paulsen cautiously says of *G. levanderi* "Vielleicht eine Hungerform von *G. spinifera.*"

There can be no doubt of the fact that if the two forms are distinct the older name *spinifera* should remain with the small form originally described by Claparède and Lachmann and that the larger form figured by Stein should bear another name. Pouchet's (1883) name *digitale* is the proper one for the larger species. It is quite probable that Murray and Whitting's *Peridinium vexans* is *Gonyaulax spinifera*, for it agrees with it in size and structural features in so far as represented in their figures. The only disturbing feature in this interpretation is the overrun of the apex upon the dorsal side, perhaps the result of the oblique view suggested by curvature of girdle and occlusion of spines in their figure. It is plainly a *Gonyaulax* and evidently close to *G. spinifera* as shown by the size (40μ), overhang and displacement of girdle, and flare of longitudinal furrow opposite distal end of girdle. The fins on the antapical spines are unusual.

Distribution: Any discussion of the distribution of this species in the present confused state of records of occurrence is futile. Statements of occurrences can be based only on figures which are plainly *G. spinifera sensu stricto* or upon records of *G. levanderi*. Its distribution in California waters is not as yet fully determined since all of our earlier records include *G. digitale* and to some extent *G. diegensis* under the single caption of *G. spinifera*.

It is known to occur in San Pedro Harbor, May 31, 1901 (No. 505); in collections made off San Diego, June 28 (Nos. 130, 133) and December 2 (No. 342), 1904; and at Loring, Alaska, September 15, 1905. Claparède and Lachmann (1858-1859) describe it from the western coast of Norway. It is reported as *Peridinium* sp. from the Gulf of Finland by Levander (1894) and by Van Breeman (1905) as *Gonyaulax* sp. from the Zuider Sea. It is reported by Paulsen (1907) from the eastern Baltic and Iceland, and by Ostenfeld (1908) from the Aral Sea. It is described by Fauré-Fremiet (1908) as *G. mangini* from the Baie de la Hougue on the northern coast of France.

Evidently neritic, and predominantly in northern and temperate waters.

3. **Gonyaulax digitale** (Pouchet) Kofoid

Pl. 9, figs. 1–5.

Protoperidinium digitale, Pouchet (1883), p. 443, pls. 18–19, fig. 14.
Gonyaulax spinifera, Stein (1883), pp. 13, 16, pl. 4, figs. 10–14.
G. spinifera, Schütt (1887), pp. 366–367, pl. 18, figs. 7–11; (1895), pl. 9, figs. 34_{1-2}.
Peridinium digitale, Lemmermann (1899), p. 369.
Gonyaulax spinifera, Van Breeman (1905), pp. 41–42, figs. 10 a-b.

G. spinifera, Entz (1907), pp. 11–19, pl. 2, figs. 5–6; (1909), pp. 247–256, pl. 8, figs. 5–6.

G. spinifera, Paulsen (1907), pp. 7–8, fig. 6; (1908), pp. 28–29, fig. 37.

G. Granii, Henckel (1909), p. 118, pl. 30, figs. 1–16.

Diagnosis: Larger than *G. spinifera*, less rotund, with less overhang. Epitheca subconical, shoulders often slightly angled, generally two stout antapical spines. Line joining ends of girdle makes an angle of 13°–18° with major axis; longitudinal furrow not abruptly widened opposite distal end of girdle; surface usually heavily reticulated.

Description: Based largely on material from the Faeroes. *Body* subrotund, sometimes subangular at precingular suture, with short, stout apical horn one to two girdle widths in length and 1 to 1.5 widths at apex, rising from slightly angled shoulders of the subconical epitheca; its length 1.1–1.17 (in Stein's figure 12, 1.5) transdiameters. Little if any convexity in sides of epitheca, except at approaching fission(?), its greatest altitude 1.45 transdiameters. Altitude of the *hypotheca* 0.55 transdiameter. The latter more rotund than epitheca, contracted to a broad antapex somewhat less than 0.5 transdiameter across.

Girdle equatorial, descending, displaced 2 to 2.5, with an overhang of 1 to 1.25 girdle widths. Furrow deeply impressed with stout marginal ridges bearing a low ribbed fin. Longitudinal furrow slightly sigmoid, laterally compressed nearly to closure between girdle ends, oblique to the major axis in this region 13°–18°, rarely 26°, expanding posteriorly. This expansion is more apparent than real for the left side of the middle part of the furrow is encroached upon by the thickened reticulate fin (*f.*, pl. 9, fig. 5) arising from the median margin of the posterior intercalary plate 1^p), which simulates the thecal wall in its structure and gives the longitudinal furrow of heavily reticulated thecae an appearance of constriction anteriorly or expansion posteriorly which is not found in less heavily reticulated individuals such as those from Southern Alaska waters (pl. 9, fig. 4). The *ventral area* slightly indents the epitheca in a small angular area. The longitudinal furrow of this species lacks the markedly abrupt expansion immediately opposite the distal end of the girdle which characterizes *G. spinifera*.

The *plate formula* is $3'$, 0^a, $6''$, 6, $6'''$, 1^p, $1''''$. *Apical* $1'$ (pl. 9, fig. 5) is very slender with a slight median expansion to the left and bears a large closing platelet at its apex. Apical $3'$ bears the ventral pore (*v. po.*) on its median margin toward the base of the apical horn. *Precingular* $6''$ is almost triangular. *Postcingular* $1'''$ is very narrow and is curved over into the longitudinal furrow. The *antapical* $1''''$ is large, and is barely indented by the ventral area. The plates of the *ventral area* (pl. 9, fig. 5) are an anterior plate (*ant. pl.*) crossed by the anterior girdle ridge, a large posterior one (*post. pl.*) reaching to the level of the posterior girdle ridge and several intermediate (*int. pl.*) ones hidden in the compressed longitudinal furrow.

The *surface* of northern forms (Faeroes, pl. 9, figs. 1–3, 5) is deeply and coarsely reticulate with central pores in the mesh, 4 to 6 meshes on the side of a precingular plate. Ribs are faintly or strongly marked along sutures and those adjacent to both furrows bear lists which along the girdle are ribbed. Two stout subequal antapical spines 1 to 1.5 girdle widths in length and about 2 apart are often provided with fins which may bear accessory spinules. In some cases these (pl. 9, fig. 4) become as large as the two main spines. In exceedingly rugose individuals (pl. 9, fig. 5), the fin and spines (*ant. sp.*) are converted into a recticulate structure resembling the thecal wall.

Dimensions: Length (37) 50–75μ; transdiameter, 34–50μ; width of girdle, 5μ; length of antapical spines, 3 to 10μ.

Table of Measurements of *Gonyaulax digitale*

Locality	Date	Length in microns excluding spines	Width
Faeroe Channel	August, 1907	42	35
Faeroe Channel	August, 1907	57	48
Faeroe Channel	August, 1907	68	48
Faeroe Channel	August, 1907	52	43
Faeroe Channel	August, 1907	37	30
Faeroe Channel	August, 1907	40	37
Faeroe Channel	August, 1907	53	45
Faeroe Channel	August, 1907	56	48
Faeroe Channel	August, 1907	54	44
Faeroe Channel	August, 1907	67	60
Bay of Naples	April 4, 1909	60	48
Off San Diego	June 22, 1905	60	50
Loring, Alaska	Sept. 15, 1905	42	35
Loring, Alaska	Sept. 15, 1905	43	35
Loring, Alaska	Sept. 15, 1905	40	35

Variation: Varies principally in surface markings from excessively rugose to nearly smooth forms, in the overhang and displacement of the girdle, and overgrowth of the longitudinal furrow by its lateral walls which is much greater in rugose specimens, in the development of spines and fins, and in size (37–75μ).

Comparisons: See *G. spinifera.* The wide heavy form (compare pl. 9, fig. 2) figured by Van Breeman (1905, fig. 10b) probably represents a condition brought about by an expansion at the apical-precingular sutures possibly preparatory to fission.

Alaskan forms (pl. 9, fig. 4) are smaller, more rotund and less rugose than those from the Faeroes.

SYNONOMY: See *G. spinifera.* It is highly probable that *G. spinifera* of many writers is in reality *G. digitale* as here defined. The possibility also of the inclusion of *G. spinifera* as above defined, together with *G. digitale*, is excluded only in case of those writers, e.g., Paulsen, who have noted the distinctness of *G. levanderi*, or in those papers accompanied by diagnostic figures. The sketches published by Henckel (1909) of *G. grani* from the Caspian Sea seem to be referable to *G. digitale*. In any event this supposed new species from the Caspian Sea requires a more critical diagnosis before its distinctness from *G. digitale* can be recognized.

DISTRIBUTION: This species occurred rather frequently in plankton taken in the harbor at Loring, Alaska (55° 40′ N, 131° 35′ W), September 15, 1905 (see pl. 9, fig. 4), and a few specimens have been recognized in the plankton of the San Diego region taken in early summer (No. 919, June 22, 1905), which seem to be referable to this species. They are possibly of northern origin, carried southward in the California current. Full data as to the occurrence of this species in the San Diego region are not available since the species was not distinguished from *G. spinifera* during the examination of most of the collections. Essentially a northern species but not confined to neritic plankton though favoring coastal region, Faeroes, Iceland, North Sea, Concarneau, Naples, Caspian Sea, coasts of Alaska and California. In the absence of figures it is wholly conjectural to base reports of the occurrence of this species upon records of *G. spinifera*, as upon those of Cleve (1901a), though it is extremely probable that many records of the aforesaid species are, especially in northern waters, in reality referable to *G. digitale* wholly or in part.

4. **Gonyaulax diegensis** sp. nov.

Pl. 13, figs. 21–24; pl. 16, fig. 40.

Gonyaulax spinifera, Schütt (1895), pl. 9, figs. 34_{1-2}. Reference here problematical.

G. spinifera, Wright (1907), p. 5, pl. 1, fig. 14.

G. polygramma, Meunier (1910), pp. 54–55, pl. 3, figs. 5–13.

DIAGNOSIS: A large robust species with short stout apical horn, elongated apex, two or three antapical horns, widely displaced (3 to 6 girdle widths) girdle with little overhang, longitudinal furrow not abruptly widened opposite distal end of girdle. Apical *4′* separable. Reticulate surface with wide reticulate intercalary bands.

Description: *Body* elongate-spheroidal, its length nearly 1.2 transdiameters, slightly flattened on ventral face. *Epitheca* exceeds hypotheca. Epitheca contracted to stout apical horn 2 to 4 girdle widths in height and 3 to 4 across at the base and 1.1 to 2 at the apex, with broadly and regularly rounded shoulders, its greatest altitude 0.85 transdiameter, flaring a little at the girdle. *Hypotheca* also flaring at girdle, its greatest altitude 0.6 transdiameters, antapex wide but very broadly rounded bearing two or three short, stout, close-set spines.

The *girdle* is equatorial, descending, displaced distally 3 to 6 girdle widths, and with rarely more than 1 of overhang. Furrow very deeply impressed with salient heavy ridges of thecal wall. In ventral view both portions appear curved, the distal one sweeping in a regular curve (pl. 13, fig. 24) from the margin posteriorly so that its distal end lies nearly midway between the proximal end and the antapex. It is thus one of the most widely displaced girdles in the whole genus.

The *ventral area* or longitudinal furrow is spoon-shaped with slight irregularities in its course. It is nearly closed by lateral compression between girdle ends and flares posteriorly to a maximum width of four girdle widths, rounding at the postmargin which indents the antapical slightly. It is guarded by fins on either side, each at times (pl. 13, fig. 24) with a few heavy ribs. There is no marked expansion as in *G. spinifera* opposite the distal end of the girdle. Anteriorly the ventral area indents the epitheca for a distance of about three girdle widths ending in a rounded margin, a girdle width across, which abuts directly against the posterior end of the midventral apical *1′*.

Plate formula $4'$, 0^a, $6''$, 6, $6'''$, 1^p, $1''''$. The *apical* series consists of a midventral apical *1′*, a very slender plate with sinuous sides to whose apex is attached a much elongated, curved, concave, elliptical closing platelet (pl. 13, fig. 22, and *cf. pl.*, figs. 23 and 24). This platelet extends a trifle beyond the apex upon the dorsal side as in the subgenus *Steiniella* and is marked with a marginal row of pores. Plate *2′* has the upper end carried around to the right beyond the middorsal line as in many other species (*G. triacantha*, *pacifica*, *digitale*) of this genus. The third plate, *3′*, just barely touches the apex in a point adjacent to *2′*, the remaining part of the apical margin being occupied by a small plate, *4′* (pl. 13, fig. 23), apparently cut out of the top of plate *3′* by a curved suture. This suture line is not prominent and separates with difficulty as do also the other sutures on this shoulder of the theca. It has been separated, however, several times in my material. A region similar to plate *4′* is suggested by surface markings in *G. spinifera* and is marked off in several other species, for example, in *G. polygramma*, but it is not separable in them. The median margins of plates *3′* and *4′* are in contact with plate *1′* and the anterior angle of the former bears the ventral pore (*v. po.*, pl. 13, fig. 23) which in this species is quite large and often elongated. The *precingular* plates are all large, except plate *6″*, which is small and triangular in form. In a few cases observed its apex is truncated but the length of the fourth side thus formed is not over a girdle width. *Postcingular* plate *1‴* is about 1 girdle width across and 3 to 5 in length. The *posterior intercalary*, *1p*, is an elongated pentagonal plate to the left of the furrow. The single *antapical*, *1⁗*, is relatively small, and is not deeply indented by the ventral area.

The anterior plate (*ant. pl.*, pl. 13, fig. 23) of the *ventral area* is greatly elongated in this species (4 girdle widths), expands anteriorly and is deeply notched at its postmargin by the flagellar pore (*fl. po.*) The intermediate plates (*int. pls.*, pl. 13, fig. 21) are obscured in the depths of the longitudinal furrow between girdle ends. The posterior plate (*post. pl.*) is a rounded quadrilateral reaching anteriorly nearly to the level of the distal end of the girdle.

The *surface* of this species is most characteristic, its whole area usually being reticulate with subregular polygonal mesh but not uniformly so. Polygonal areas in each of the precingular and postcingular plates contiguous on one side to the girdle are more heavily marked (pl. 16, fig. 40). The more lightly marked margins bear the some relation to the plates that intercalary bands do, and they are probably of this nature. These intercalary bands vary in width in different individuals and the contrasted markings vary greatly in relative distinctness and in degree of development in different individuals. In the more heavily marked forms (pl. 13, fig. 24) the central reticulations are coarse and heavy and are less sharply delimited from the lighter margins. In more lightly marked forms the intercalary bands are very sharply marked off from the more densely pitted or reticulate central regions. In some cases (pl. 16, fig. 40) the intercalary bands are quite free from all but the faintest reticulations. The pores are large, sparsely distributed over the more reticulated central parts of the plates and located in the nodes of the mesh rather than in the center of the enclosed areas. There are no girdle lists, but those of the longitudinal furrow on plates *1‴* and *1p* are heavily ribbed. The spines on the antapex arise near the middle of the antapical plate and not from the nodes of the sutures. They are usually two, occasionally but one, and quite often three, the third being on the right side. The spines are usually finned. The girdle is heavily reticulate except where crossed by intercalary bands.

The contents are prone to escape through the parted apicals as in *G. polygramma* and *G. polyedra*. There is a centrally located ellipsoidal nucleus with moniliform chromatin network. The irregular chromatophores are of a yellowish brown color. The plasma is not especially dense.

DIMENSIONS: Length (60) 75 to 100μ; transdiameter (45) 70 to 82μ; width of girdle 4.5 to 5μ. The following measurements apply to material from the San Diego region, and to figures referable to the species.

Measurements of *Gonyaulax diegensis*

Locality	No. collection	Date	Length in microns excluding spines	Trans-diameter
Schütt (1905) Naples(?)		....	65	43
Wright (1907) Grand River, Gulf of St. Lawrence		....	75	45
Off San Diego, Calif.	62	June 8, 1904	60	43
Off San Diego, Calif.	73	June 8, 1904	82	65
Off San Diego, Calif.	73	June 8, 1904	95	74
Off San Diego, Calif.	120	June 23, 1904	90	75
Off San Diego, Calif.	120	June 23, 1904	60	43
Off San Diego, Calif.	128	June 23, 1904	65	45
Off San Diego, Calif.	141	June 30, 1904	98	78
Off San Diego, Calif.	141	June 30, 1904	74	55

Ten individuals taken in surface plankton June 27, 1905, off San Diego, were respectively 70, 75, 75, 80, 80, 83, 87. 90, 92, and 100μ in length.

Variation: This species varies greatly in size, in girdle displacement (3 to 6 girdle widths) and overhang (0 to 1.5), in the degree to which reticulations are developed and thickened, and in the widths of the intercalary bands and the distinctness with which they are marked out. In all individuals which I have examined, however, the bands are definitely discernible. The smaller forms (60 by 45μ) are found in the same collections with the largest ones and seems to represent merely the extremes in variation, though the most of the individuals are 75μ or more in length.

Synonomy: It seems possible but by no means certain that the form figured by Schütt (1895) is this species, since it has the size, the general form, the color and the three antapicals characteristic of it. Wright's (1907) figure is open to a similar interpretation. Neither has, however, indicated the intercalary bands usually apparent on the less heavily marked specimens of the species.

Meunier (1910) figures as *G. polygramma* a form which is not even remotely like that species, though he comments upon the resemblance to *G. spinifera*. His magnification is unfortunately not given. In proportions, girdle, and surface markings his form is so remarkably like *G. diegensis* that I am constrained to include it in the synonomy of that species. This is the only species which he refers to *Gonyaulax*.

Comparisons: This species is a member of the *G. spinifera* group, related to *G. digitale* (Pouchet), differing from it in its size, in its more pronounced rotundity, its broad intercalary bands, and in having few pores located sparingly in the nodes of the fine reticulum instead of many centrally located in the openings of the mesh, and in three finned antapical spines, whereas *G. spinifera* usually has two spines, without fins. It differs from *G. spinifera* in much greater size, less overhang of girdle, and absence of expansion of longitudinal furrow opposite the distal end of the girdle.

Distribution: In neritic plankton of spring and summer at San Diego. Less abundant in oceanic plankton. Many empty thecae were taken in plankton off kelp zone in 1904 with *Gonyaulax spinifera*, *G. polyedra*, *Dinophysis homunculus* and *Ceratium pentagonum*. The abundance of empty thecae in this region may be due to the discharge of skeletons in faeces of the abundant sessile plankton-feeding fauna of the kelp zone, or to adverse local conditions about this zone leading to ecdysis.

5. **Gonyaulax triacantha** Jörgensen

Pl. 11, figs. 11–15.

Gonyaulax(?) triacantha Jörgensen (1899), no. 6, p. 35.
Ceratium(?) hyperboreum Cleve (1900a), 1, pp. 14–15, pl. 18, fig. 14.
Ceratium(?) hyperboreum Cleve (1901a), p. 223.
Gonyaulax hyperborea (Cleve) Paulsen (1903), p. 90.
Gonyaulax triacantha, Paulson (1904), pp. 21–22, fig. 5a-d.
Heterodinium triacantha (Jörg.) Kofoid (1906a), p. 354.
Gonyaulax triacantha, Kofoid (1906b), pp. 102–105, figs. 1-3.
Ceratium hyperboreum, Lemmermann (1907), p. 298.
Geratium hyperboreum, Linko (1907), p. 91.
Amylax lata Meunier (1910), pp. 51–52, pl. 3, figs. 24–27.

Diagnosis: A small species (50μ) with rotund hypotheca, epitheca with concave faces, and obliquely truncated apex. Girdle slightly displaced, ventral area spreading posteriorly to the right, five to seven spreading antapical spines, surface finely reticulate. Northern neritic species.

Description: *Body* rotund posteriorly, concave anteriorly, flattened ventrally, girdle postmedian. The length (excluding spines) 1.16 to 1.20 transdiameters, dorso-ventral diameter 0.5 to 0.6 transdiameter, girdle section reniform (pl. 11, figs. 11, 12) of empty thecae. The usual form is more rotund (see Paulson, 1904, fig. 5d). *Epitheca* flaring at the base into the spreading girdle, its altitude 0.75 transdiameters, its sides contracted in a sweeping concave curve into the well-developed apical horn with a slight hump at the apical-precingular suture. Apical horn 0.35 transdiameters in height, very obliquely truncated with acute termination on its right margin. *Hypotheca* broadly rounded posteriorly, its altitude nearly 0.4 transdiameter, excavated ventrally. *Girdle* postmedian, descending, displaced distally one furrow width. Furrow deeply impressed with stout ridges of body wall. *Ventral area* is exceptionally wide in this species: it indents the epitheca about a furrow width, flaring posteriorly to the left immediately behind the girdle to 2 and at the slightly convex post margin to 3.8 furrow widths.

Plate formula, 3′, 2^a*, 6″, 6, 6‴,* 1^p*, 1⁗. Apical* region (pl. 11, figs. 11–15) consists of a midventral apical (Rautenplatte) *1′* widened in its middle to the left to nearly two girdle widths, a short plate on the left dorsal face of the apical horn which cuts off the two anterior intercalaries (1^a, 2^a) from contact with the apex, and the right ventral apical *3′*. The circular closing platelet (*cl. pl.*, pl. 11, fig. 12) is attached to apical *1′*. *Precingular 6″* is quadrilateral and is separated by apical *1′* and the anterior plate of the ventral area (*ant. pl.*) from precingular *1′*. *Postcingular 1‴* is a narrow and sometimes very short plate on the left of the longitudinal furrow; postcingular *3‴* is narrower than other members of the series. *Posterior intercalary* 1^p is concave on its right margin, expanding posteriorly. *Antapical 1⁗* is 0.75 transdiameter from right to left but narrow dorso-ventrally. The *ventral area* (*v. a.*, pl. 11, figs. 11–13) is composed of a triangular anterior plate (*ant. pl.*) crossed in the middle by the anterior girdle ridge and notched posteriorly by the flagellar pore (*fl. po.*, fig. 13). Behind this lie four intermediate plates (*int. pl.*) and the spreading posterior plate (*post. pl.*).

The *surface* is minutely and quite regularly reticulated with a mesh which sometimes shows a tendency toward a quadrilateral pattern. Pores not demonstrated. Ventral pore (*v. po.*) near apex on right margin of plate *4′*. Girdle without hyaline lists, a very wide (1–1.5 furrow widths) hyaline, faintly reticulated, list on left side of ventral area (pl. 11, fig. 13), arising from suture along posterior intercalary, decurrent posteriorly, with an antapical spine (*a*) on the node where this suture joins the antapical suture. The largest antapical spine (*f*), 0.33 transdiameter in length, arises from the right antapex from the surface of the antapical plate, and a somewhat shorter one (*c*) from the left antapex. Three or four additional spines (*b*, *d*, *e*) arise at or near the nodes of the antapical suture. The areolation of the surface of the plates extends for a short distance upon the base of the spines. They are, however, solid.

Contents exceedingly dense, obscuring thecal structure; chromatophores thickly packed.

Dimensions: Length, excluding spines, 58 to 60μ; transdiameter, 34 to 35μ; dorso-ventral diameter, 20μ (diameters measured on empty theca, those with contents are less flattened);

length of longest spine 12 to 15μ; width of furrow, 4μ; Paulsen (1908) gives length (without spine ?) as 72 to 84μ. Cleve's (1900) figure is 70μ without spines. Alaskan specimens appear to be smaller than those of European waters.

VARIATION: This species varies in the number of spines. Five can usually be found, and as many as seven sometimes appear. The surface markings are more pronounced in some individuals than in others and linear striae are sometimes more evident than in the individual figured (pl. 11, fig. 13). Postcingular *1‴* is subject to considerable variation in length.

COMPARISONS: *Gonyaulax triacantha* is one of the best defined and most isolated species in the genus. It is remarkable both in form and in the development of the antapical spines as well as in the character of the surface markings. It is not structurally nearly related to any other species and its inclusion in the *spinifera* group is justified mainly on the ground of its antapical spines. Two dorsal intercalaries still further distinguish it.

SYNONOMY: First described but without figures by Jörgensen (1899) who questionably referred it to the genus *Gonyaulax* and later by Cleve (1900) as *Ceratium hyperboreum*. It was first figured by Paulsen (1904) who analysed the plates incompletely but verified Jörgensen's conjecture that it belonged in *Gonyaulax*. It was later referred by me (1906a) to my new genus *Heterodinium* on account of certain structural features found in Paulsen's incomplete figures, but this error on my part was corrected a few months later (1906b) upon examination of material from Alaska, which enabled me to extend the analysis of the thecal plates. A fuller knowledge of the genus enables me in the present paper to correct and supplement certain interpretations and deficiences in my earlier analysis. These are the correct analysis of the apical region showing 3 apicals (*1′*, *2′*, *3′*) and two dorsal intercalaries (1^a, 2^a) instead of 3 apicals (Kofoid, 1906b, fig. 1, pls. 1, 2, 3); six precingulars (*1″–6″*) instead of 5 (*1–8*), and 6 postcingulars (*1‴–6‴*), instead of 5 (*9–13*). Paulsen's figure (1904, fig. 5a) was correct in suggesting the presence of the small plate, my postcingular 1‴, though it was not delimited therein from the posterior intercalary.

Judging from the obliquity of the ventral area (longitudinal furrow plate) and the location of the small postcingular *3'''*, Paulsen's (1904) figure 5d is evidently not an "antapical view" of the hypotheca as stated, at least not *from* the antapex but rather from the direction of the apical pole. He shows five postcingulars and a furrow plate, but does not represent in this figure the small postcingular *1'''* (of my nomenclature). It is also evident that the two plates on the ventral side to the right of the doubled suture line (in his figure *d*) both belong to the ventral area and that the direction of their boundaries should be somewhat modified. In other respects this figure harmonizes with my findings. His double suture line is evidently the fission line, as will be seen on comparing his figure, as interpreted above by me, with the fission line of text figures A-D.

Meunier (1910) has created a new genus, *Amylax,* for this species and certain other inadequately defined forms, basing the genus solely upon the presence of starch grains in the cytoplasm. He includes in this genus a species which he calls *A. lata*, which is, however, undoubtedly *Gonyaulax triacantha* Jörg. I cannot agree that the species he figures is not *triacantha.* In girdle, spines, surface markings, and dorso-ventral compression it is a typical representative of the species. The outline of the epitheca of the specimens he figures is more convex than in my figures, which are of a skeleton from which cell contents had escaped, and hence its sides are more concave than in his figures. The generic basis he proposes is also, in my opinion, quite inadequate, and might lead to endless confusion if followed. In skeletal structure his *A. catenata* (= *Gonyaulax catenata* (Levander) Kofoid) is also referable to the genus *Gonyaulax.* Since skeletal structure has been generally utilized in generic characters in the dinoflagellates, it seems logical and advisable to follow it in this instance. I therefore reject his genus *Amylax* and refer the species in it to *Gonyaulax.*

Distribution: Fairly abundant in plankton from Alaska, Yes Bay and Loring (55° 40′ N, 131° 35′ W) taken by U. S. Steamer "Albatross" of the Bureau of Fisheries, September 15, 1905. It is to be expected in coastal plankton drifting southward in deeper levels, along the coast of California.

Reported by Jörgensen (1899) from Herlö fiord, by Cleve (1900a) from Spitzbergen, by Paulsen (1904) as abundant in fiords in Iceland, from Shetland and the Faeroes, and by Paulsen (1907) as rare in the North Sea, Skagarak and Cattegat. It is plainly a neritic northern species. It appears in the records of the International Commission for the Investigation of the Sea (see Ostenfeld, 1906, 1909), from the North Atlantic, North and Baltic Seas, and the Gulfs of Bothnia and Finland as present in small numbers.

c). The *Polygramma* Group.

This group is represented in the plankton of the San Diego region by five species, *G. turbynei* Murr. and Whitt., *scrippsae* sp. nov., *polygramma* Stein, *kofoidi* Pavillard, and *pacifica* Kofoid, which form a series of increasing size, characterized by linear markings with a predominantly longitudinal direction. In the order named the species represent stages in increase in size, elongation of body and increase in antapical asymmetry. Owing to the considerable variability in proportions and in surface markings, a wide range of material and a large series of carefully executed drawings are desirable for a critical comparison of the species in this group. Plate formula $3'$, 0^a, $6''$, 6, $6'''$, 1^p, $1''''$.

6. **Gonyaulax turbynei** Murray and Whitting

Pl. 17. fig. 44

Gonyaulax Turbynei Murray and Whitting (1899), pp. 323–324, pl. 28, figs. 4a, b.

G. polygramma Stein (1883), in part, pl. 4, fig. 19 only.

G. Turbinei, Schröder (1906), pp. 329, 340.

Glenodinium ovatum Fauré-Fremiet (1908), p. 214–5, pl. 15, fig. 2. Provisionally referred here.

Diagnosis: A small ovoid species, with equatorial girdle displaced 1 to 1.5 girdle widths, without marked overhang, with linear markings more or less well developed.

Description: *Body* ovoid, length 1.16 transdiameters, girdle section circular. Epitheca and hypotheca subequal. *Epitheca* a low cone with somewhat convex sides, its altitude 0.6 transdiameter. No apical horn, apical region elliptical, flattened, sloping ventrally. *Hypotheca* subhemispherical with very slight ventral depression.

Girdle equatorial, descending, displaced distally 1 to 1.5 girdle widths, with very little if any overhang, deeply impressed, without lists or prominent ridges.

Ventral area does not indent the epitheca, its anterior part much restricted, the middle region very narrow, and the posterior part elliptical, the whole having the shape of a short-handled spoon with a sigmoid handle. The narrow apical *1'* appears to continue the ventral area to the apical region.

The *plate formula* is *3'*, 0^a, *6''*, 6, *6'''*, 1^p, *1''''*. The ventral *apical 1'* is very slender about 0.3 girdle width across, bent to the right in the middle of its course. It bears a median line of pores and carries at its apex an elliptical closing platelet. The ventral pore is an elliptical structure on the median margin of plate *3'*. Plates *2'* and *3'* are almost bilaterally arranged upon the left and right sides of the apex. *Precingular 6''* is displaced posteriorly nearly to the level of the proximal end of the anterior girdle list and is plainly quadrilateral in form. *Postcingular 1'''* is very short, scarcely a girdle width in length. *Posterior intercalary* 1^p widens posteriorly to nearly two girdle widths. *Antapical 1''''* is deeply indented by the ventral area. The anterior plate of the *ventral area* is small, not indenting the epitheca and bearing the flagellar pore on its posterior margin. The intermediate plates are hidden in the constricted part of the area. The posterior plate is elliptical with a group of pores at its posterior part.

The *surface*, in well-developed thecae, is rather strongly marked by prominent longitudinal striae which stand out from the minor mesh work most clearly in the precingular series of plates, and less so in the apical region and the distal part of the postcingular zone. About ten major lines may be counted across the ventral face. Between these lines a minor network breaks up the surface into irregular polygons, or areoles in a few of which pores of irregular sizes may be detected. The number of pores is ten to fifteen in each major plate of the precingular and postcingular series. The girdle plates are coarsely and unevenly porulate. Faint traces of intercalary bands may sometimes be detected. There are no spines or lists on this species, as a rule.

DIMENSIONS: Length, 47μ; transdiameter, 37μ; width of girdle 5μ. Murray and Whitting (1899, pl. 28, fig. 4) figure an individual 35 by 28μ.

VARIATION: Varies considerably in the development of surface markings, in the width of precingular 6'', and somewhat in the development of an apical elevation, all features tending toward *G. polygramma*, the next member of the series in this group.

COMPARISONS: The linear markings and absence of apical horn and of antapical spines distinguish it from members of the *G. spinifera* group, and the last two characteristics and its smaller size serve to separate it from *G. polygramma.* The absence of overhang separates it from *G. scrippsae.*

SYNONOMY: The form described by Fauré-Fremiet (1908) from St. Vaast as *Glenodinium ovatum* is quite similar in form, proportions and size to this species but lacks wholly both sutures and surface markings. It possibly bears the same relation to this species that Schütt's (1895, pl. 8, figs. 33b $_{1-3}$) *G. polygramma* Stein var. (= *G. schuetti* Lemm.) does to *G. polygramma*, that is, it is the result of recent ecdysis, only taken at an earlier stage in the growth of the theca.

The status of the small form with hyaline finely and abundantly striate theca figured by Stein (1883, pl. 4, fig. 19) as a "Panzer eines sehr jungen Individuums noch ohne Spur von Täfelung und Sculptur" is still somewhat problematical. I find it at times in the summer plankton at San Diego. It is uniformly smaller than *G. polygramma*. It differs from *G. schuetti* Lemm. (= *G. polygramma* var. Schütt) in the presence of numerous fine striae and in smaller size. In fact *G. schuetti* appears to be only a *G. polygramma* which has recently shed the thecal wall by ecdysis, and has acquired an early phase of a new theca. It differs decidedly from *G. scrippsae* in its but slightly displaced not overhanging girdle. If not an immature or early phase in thecal development following ecdysis it is possibly some as yet unknown type of sporulation, in *turbynei* or some related species. It may be designated as forma *longistriata* forma nova.

It is obvious that the apical horn in this form is more developed than in the typical *G. turbynei* (compare Stein's pl. 4, fig. 19, and my pl. 17, fig. 44). This feature is, however, characteristic in the thin theca following ecdysis in *G. spinifera* and *G. polygramma* (See Stein 1883, pl. 4. figs. 11 and 13, and Schütt 1895, pl. 8, fig. 33b, pl. 9, fig. 34) and might therefore be expected to find some expression also in the corresponding stage in the more rotund *G. turbynei*.

Distribution: Taken in surface plankton July 12, 1904, in California current off San Diego. Probably common but escaping readily through the meshes of the plankton net. Occurrence in other collections of San Diego material not yet determined. Reported as yet only by Murray and Whitting (1899) from the tropical Atlantic in 16°–44° N and 19°–69° W at temperatures of 55°–80°, and by Schröder (1906) from the Indian Ocean south of Ceylon.

7. **Gonyaulax scrippsae** sp. nov.

Diagnosis: A small very rotund species with small apical horn, much displaced girdle, surface with fine striations principally in the longitudinal direction.

Description: *Body* subspheroidal, its length 1.12–1.15 transdiameters. Dorso-ventral diameter equal to transdiameter. *Epitheca* subhemispherical, contracted abruptly at the apex to a short apical horn whose altitude and diameter are each less than a girdle width, with an oblique apex tilted toward the ventral face. Its greatest altitude is 0.6 to 0.7 transdiameters. Its sides are regularly convex without trace of angulation at the shoulders. The *hypotheca* is nearly hemispherical, its greatest altitude is about 0.6 transdiameter. There is no angulation at the antapex.

The *girdle* is equatorial, descending, displaced 2 to 3 girdle widths with an overhang of 0.1 to 1 girdle width. The *furrow* is deeply indented with marginal ridges scarcely elevated above the body contour and without lists. The *ventral area* or longitudinal furrow is sigmoid, rather narrow. The ventral area makes a shallow rounded indentation into the epitheca, is compressed almost to closure in its oblique course between the girdle ends and widens beyond the girdle to 1.4 girdle widths. Its posterior end is rounded and barely indents the antapical plate.

The *plate formula* is $3'$, 0^a, $6''$, 6, $6'''$, 1^p, $1''''$. *Apical 1′* is a slender plate expanded toward the apex at the apical-precingular suture and bears at the apex the elliptical closing platelet (*cl. pl.*, pl. 13 fig. 27). Apical *3′* bears the ventral pore (*v. po.*) very near the apex. *Precingular 6″* is triangular and postcingular *1‴* almost linear in form. *Posterior intercalary* 1^p is a relatively small plate in this species. The plates of the *ventral area* in the intermediate region are obscured in the narrow furrow. The anterior plate (*ant. pl.*) is partially crossed by the anterior girdle ridge and notched in its left ventral edge by the flagellar pore (*fl. po.*). There are suggestions of several intermediate plates (*int. pl.*) and a well-defined posterior plate (*post. pl.*) some distance behind the distal end of the girdle.

The *surface* is very characteristically marked with fine subparallel lines which are mainly longitudinal but in some places are parallel to the intercalary bands which are formed in all specimens I have seen along the sutures. In cases of lightly marked specimens these lines are regularly punctate (pl. 13, figs. 26, 27). In other cases the markings are more of the vermiculate-reticulate type of heavier pattern though still of delicate tracery and with more of a mesh work developed, especially distally and on the hypotheca (pl. 16, fig. 38). Pores are not evident except two marginal rows of minute ones just within the girdle ridges. Sutures are very faint, marked by intercalary bands. No lists or fins have been seen though in some cases two minute spinules (pl. 16, fig. 38) appear on the antapex at junction points of the ventral area and antapical plate. The girdle is abundantly marked by numerous parallel ribs which connect the pores on its two sides.

Dimensions: Length, 29 to 39μ; transdiameter, 27 to 34μ; dorsoventral diameter the same; width of girdle, 4 to 5μ.

Variation: Varies in surface markings and in girdle displacement and overhang as above stated.

Comparisons: Its small size and peculiar markings combined with its considerable displacement serve adequately to characterize this species. It might be easily confused when full of contents with *G. spinifera,* in young stages with small spines, but is more rotund with characteristic surface markings. It is also somewhat similar to *G. turbynei* but has greater displacement of the girdle and much finer markings.

Distribution: Found thus far mainly as empty thecae in neritic summer plankton at San Pedro and San Diego, California.

Named for Miss Ellen B. Scripps whose interest in marine biology has made possible the foundation of the San Diego Marine Biological Station.

8. **Gonyaulax polygramma** Stein

Pl. 10, figs. 6, 7; pl. 17, fig. 47

Protoperidinium pyrophorum Pouchet (1883), p. 433, pl. 18/19, fig. 15. In explanation of plates (p. 455) as *P. prophorum.* This is not *Peridinium pyrophorum* (also as *Peridinium ?* (*Glenodinium ?*) *pyrophorum* in explanation of plates) of Ehrenberg (1836), p. 133, pl. 1, fig. 1, iv; (1854), p. 17, pl. 37, vii, figs. 3, 4.

Gonyaulax polygramma Stein (1883), pl. 4, fig. 15. It is possible that figs. 16 and 17 (= *G. polygramma* var. Stein = *G. steini* Lemmermann 1907) represent another and indeterminable species.

G. polygramma Stein var. Schütt (1895), fig. 33 $_{1-3}$.

G. polygramma Stein var. Schütt (1895), fig. 33 $_{1-3}$.

G. polygramma, Delage et Hérouard (1896), p. 383, fig. 662.

Peridinium pyrophorum, Lemmermann (1889), p. 369. "Ob zu *Gonyaulax* gehörend!"

Gonyaulax Schuettii Lemmermann (1899), p. 367, based on Schütt (1895), pl. 8, fig. 33.

G. polygramma, Entz (1905), pp. 110, 138–142, figs. 58–59; (1907), pp. 11–22, pl. 3, figs. 1–3, 5–6; (1909), pp. 247–260, pls. 9, figs. 1–3, 5–6.

G. polygramma, Paulsen (1907), pp. 7–8, fig. 7; (1908), pp. 28–29, fig. 36.

G. polygramma, Okamura (1907), p. 132, pl. 13, figs. 13a–d.

Diagnosis: A medium-sized species of slightly elongated form, symmetrically rounded hypotheca, girdle displaced posteriorly a little more than its width, narrow ventral apical, spreading longitudinal furrow, usually with two or more short unequal antapical spines, rarely but one or none; theca with three apicals and no intercalary and ten to fifteen longitudinal striae.

DESCRIPTION: *Body* elongated, its length 1.5 to 2 transdiameters, subcircular in cross-section at the girdle, flattened ventrally. Epitheca exceeds hypotheca. *Epitheca* subconical, broadly angled at apical-precingular suture, its altitude 0.6 to 0.95 transdiameters, contracted to a stout apical horn one girdle width across and one to two in height. *Hypotheca* broadly and symmetrically rounded, its altitude 0.5–0.6 transdiameters. *Girdle* postmedian, descending, displaced distally 0.1 to 1.5, or even 2, girdle widths, with very little overhang if any; furrow deeply impressed with stout ridges, rarely with very low lists. *Ventral area* on longitudinal furrow widening on the right distally to 2 girdle widths, very narrow between girdle ends. The anterior plate (*ant. pl.*, pl. 10, fig. 7) of the ventral area indents the epitheca somewhat more than a girdle width, and is squarely truncate anteriorly.

The *plate formula* is *3′*, 0^{a}, *6″*, *6*, *6‴*, 1^{p}, *1⁗*. The ventral *apical, 1′*, is slender, widening posteriorly on the left, slightly excavated. It is attached to the elliptical closing platelet (*cl. pl.*, pl. 10, fig. 7), which contains an elongated hyaline area. Apicals *2′* and *3′* are wide plates, the anterior dorsal angle of *2′* being continued in a small point to the right (pl. 10, fig. 6). The upper end of apical *3′* sometimes has a small pore-free area set off from the rest of the plate by a well-marked oblique curved rib, as in *G. spinifera*. The area thus enclosed corresponds in position and relationships to a larger area in *G. areolata* and to the small separable apical plate in *G. diegensis*. It is not in our experience, separable in *G. polygramma*. It might be regarded as an incipient plate, the separation of which in *G. polyedra* and *G. diegensis* is fully realized. There is no ventral notch, but the ventral pore (*v. po.*) can usually be found on the median margin of *3′* a short distance above the apical-precingular suture. It is sometimes a mere notch in the margin of the plate. *Precingular 6″* is quadrangular, its anterior face being nearly two girdle widths across. *Postcingular 1‴* is very narrow, overhanging the furrow. The *posterior intercalary* is very large, two girdle widths across, and the *antapical 1⁗* relatively small, and indented by the rounded end of the *ventral area*. This area has its anterior plate (*ant. pl.*) deeply notched for the flagellar pore and its posterior plate broadly rounded posteriorly. Between the two the four or five narrow subdivisions of the intermediate plate (*int. pl.*, pl. 10, fig. 7) can be made out in some specimens.

The *surface* of the theca is very characteristically marked by a series of 10–15 linear ridges with subparallel longitudinal arrangement, continued from one plate through the next and across the girdle from epitheca into hypotheca with more or less continuity. The ventral area and the posterior intercalary plate are not thus marked. Lemmermann's (1907) statement that in his *G. steini* (= *G. polygramma* var. Stein) ''Zwischenplatten zahlreich'' is doubtless based upon a misconception of the relation of these striae to suture lines. The intermediate regions between the striae are freely areolated or sometimes reticulated, with scattered pores with a tendency to linear grouping along the ribs. The ribs lie on suture lines in some cases, but several ribs may appear on one plate. The ventral area is sparingly porulate. The girdle ridges may be faintly armed with lists, and low denticulate lists may guard the longitudinal furrow. At its posterior end the denticulations become finned antapical spines sometimes 1.5 girdle widths in length and 1–3 in number. There is often none, and the single one or the largest where several are present is at the left. The suture lines are sometimes marked by narrow intercalary bands.

Contents dense, chromatophores crowded, yellowish to dark brown, elliptical or sausage-shaped, sometimes linear and radiating from the center of the cell mass. The theca is frequently opened by parting of the apical plates and the contents escape in a membranous envelope which is soon differentiated into a new theca. In this stage it is faintly and abundantly striate longitudinally and has been designated by Lemmermann (1899) as *G. schuetti* on the basis of Schütt's (1895) figures.

DIMENSIONS: Length, 42–75μ; transdiameter, 38–48μ; length of longest antapical spine, 2–8μ; width of girdle, 4–5μ.

VARIATION: This widely distributed species varies toward both *G. turbynei*, the next smaller member of the series, and toward *G. kofoidi* and *G. pacifica*, the larger ones. This variation is expressed in a shorter or longer apical region, in suppression or extension of the antapical spines, and in increasing development of the left antapical spine. There is also great variation in the development of surface markings. In highly striated forms the number of major lines seems to be fairly constant and in the main the species is one of the most easily recognized ones in the genus.

SYNONOMY: Originally described by Stein (1883) from the Atlantic and Pacific. Prior to the appearance of Stein's paper (November, 1883), Pouchet (July–August, 1883) published a figure of a *Gonyaulax* which is undoubtedly *G. polygramma* under the name of *Protoperidinium pyrophorum* and indicated in his discussion that it was provisionally regarded as identical with Ehrenberg's (1836) fossil *Peridinium* (?) *Glenodinium* (?) *pyrophorum*. It is, however, wholly different and Stein's name becomes applicable. Lemmermann's (1899) designation, as a distinct species, of the thin-shelled sutureless forms following ecdysis figured by Schütt (1895), should be dismissed, but his later (1907) designation of Stein's figures 16 and 17 as *G. steini* on the ground of the difference in proportions and antapex should be accepted in so far as the removal of the two figures from the species *polygramma* is concerned. Stein's two figures are, however, so drawn that no one has ever recognized this "Varietät" in material. Lemmermann's (1907) statement that *G. steini* is from the "Pacific" is not verifiable in Stein's work. The figures are oblique views, lack critical details and are not diagnostic. This "variety" possibly represents extreme variants either of *G. polygramma* or *G. kofoidi* and it is impossible to determine which. It should be relegated along with Lemmermann's name to the category of indeterminate species. His recognition of Pouchet's *Protoperidinium pyrophorum* as a valid species of *Peridinium* may also be dismissed as a synonym of *Gonyaulax polygramma.*

Comparisons: This common species and *G. turbynei* are at once distinguished from all others except *kofoidi* and *pacifica* by their linear markings. From *G. turbynei* it is distinguished by its better developed apical horn, and presence of antapical spines. The three species with antapical spines may be distinguished readily by the following complexes of characters:

Comparisons of Species

Species	*polygramma*	*kofoidi*	*pacifica*
Length	42–75μ	77–110μ	106–179μ
Axial ratio	1.25–1.5	1.5–2	1.5–1.75
Girdle section	Circular	Circular	Obliquely reniform
Antapex	Symmetrically rounded	Obliquely asymmetrical	Asymmetrically rounded
Width of posterior intercalary in transdiameters	0.22	0.148	0.08

It is also more pronounced in its linear markings and generally more rugose than these other species.

Stein's (1883) figure 15 is somewhat more angular and has a less sloping epitheca than is usually found in the species, while that of Delage and Hérouard (1896) constructed after Schütt has certain obvious defects. Paulsen's (1907–1908) figure is evidently from a tilted specimen and does not show the typical linear markings in full.

Distribution: This species occurs in the coastal and oceanic plankton of the San Diego region, but never in numbers. Its periods of greatest relative abundance appear to coincide with that of the plankton of semi-tropical facies in November-January. It is also sparingly present in June–September, especially at times of outbreaks of red water.

Judging from the reported occurrences of this species it is generally rare but widely distributed in tropical waters. It is reported from the Atlantic by Murray and Whitting (1899), and found occasionally, according to Cleve (1901a) as far north as 60° N. It is also reported by Cleve (1901b), and by Karsten (1907) from the Indian Ocean, by Schröder (1900) from Naples, by Entz (1902) from the Adriatic, by Ostenfeld and Schmidt (1901) from the Red Sea, and by Schmidt (1901) from the Gulf of Siam, by Nishikawa (1901) and Okamura (1907) from Japanese waters, and by Zacharias (1906) from the South Pacific off Antofagasta, Chili.

9. **Gonyaulax kofoidi** Pavillard

Pl. 14, fig. 30

Gonyaulax kofoidi Pavillard (1909), p. 278, fig. 1.

G. globosa Stüwe (1909), p. 275, pl. 2, fig. 7. Doubtfully assigned here.

Diagnosis: A large species with elongated body, tapering apical horn, asymmetrical antapex and prominent left antapical spine, with coarsely porulate longitudinally striate surface.

Description: Body elongated, length, excluding spine, 1.65 transdiameters, girdle section subcircular, flattened ventrally. *Epitheca* exceeds hypotheca its altitude 0.9 to 1.1 transdiameter, conical, with slight angulation on left shoulder, and abruptly changing to a tapering apical horn 0.4 to 0.5 transdiameter in length, 2 to 2.5 girdle widths wide at the base and 1.5 at the truncate apex. *Hypotheca* with nearly straight sides and obliquely truncate antapex. The oblique postmargin is 0.3 transdiameter in length; altitude of hypotheca 0.75 transdiameter.

Girdle descending, displaced distally 2 to 2.25 girdle widths, its ends lacking at least 0.5 of a girdle width of completing the circuit. Both proximal and distal ends curve posteriorly. It is deeply impressed, with salient heavy ridges of thecal wall. The anterior plate of the *ventral area* (pl. 14, fig. 30) indents the epitheca for 1.5 girdle widths, ending in an obliquely truncate margin. The region of the intermediate plates is almost completely buried between the girdle ends. The ventral area curves to the right and in its distal half flares widely, mainly to the right to 3 girdle widths, the wide porulate posterior plate reaching the postmargin. It is guarded on the right side anterior to the distal end of the girdle and on the left, posterior to its proximal end, by a hyaline fin or list, passing posteriorly to the base of the single antapical spine.

The *plate formula* is $3'$, 0^a, $6''$, 6, $6'''$, 1^p, $1''''$. *Apical 1′* is a slender ribbon-like plate bearing the elliptical closing platelet at its apex and passing posteriorly to junction with the oblique margin of the anterior plate of the ventral area, thus parting precingulars *1″* and *6″*. Apical *2′* bears an apical lobe to the right resting in a terminal excavation in apical *3′*, which bears near its posterior end on the median margin the circular ventral pore. *Precingular 6″* is quadrangular. *Postcingular 1″* is minute, 1 girdle width wide and 2 in length, and *posterior intercalary* 1^p is a large plate 2 to 3 girdle widths wide and 0.5 to 0.6 transdiameter in length. *Antapical 1″″* is wholly exposed on the dorsal face.

The *surface* is coarsely, regularly and heavily porulate and sparingly marked with heavy longitudinal striae, about seven in dorsal view on the precingular plates and a like number on the postcingular, and four on the apicals. In ventral view the striae are less regular. There are seven on the hypotheca and five or six on the epitheca. The girdle bears two rows of marginal pores and is crossed by irregular striae. The antapical spine is 1.5 to 2 girdle widths in length, finned on both sides and bears a basal reticulation.

Dimensions: Length, excluding spine, 100 to 110μ; transdiameter, 62 to 65μ; dorso-ventral diameter about the same; length of antapical spine, 8 to 10μ.

Variation: Varies in extension of apical horn, length of apical spine, obliquity of postmargin, and development of fins, and prominence of the pores.

Synonomy: About the same time that Pavillard (1909) described *G. kofoidi* Stüwe (1909) published a brief diagnosis and a simple figure of a form he calls *G. globosa*. In his description he distinctly specifies an absence of parallel markings. These characterize *G. kofoidi*. In size, however, it approaches *G. kofoidi*, and in outline in ventral view *G. pacifica*, but is much smaller than the latter and has a conical instead of a flattened epitheca and thus approaches *G. kofoidi*. It occurred in several collections in the North Atlantic. It is possible that it is only a smooth form of *G. kofoidi*, and if so, it falls into the synonomy of that species. Stüwe's figures and descriptions are not sufficiently diagnostic to be of much assistance. It has not been possible as yet to determine the exact dates of publication of Pavillard's and Stüwe's papers and thus settle the matter of priority. I provisionally adopt Pavillard's name, as certainly applying to the species here described, and probably having priority.

COMPARISONS: See *G. polygramma* (p. 229). Distinguished readily from *G. polygramma* by its larger size, greater antapical asymmetry and elongation of apical region; from *G. pacifica* by its smaller size, greater rotundity at girdle and oblique antapex.

DISTRIBUTION: Taken at San Diego, November 12, 1904, in surface plankton seven miles WNW of Point Loma. This collection contained also *G. pacifica*, *Ceratium trichoceros* and *Ceratocorys armatum*, all tropical species. Reported by Pavillard (1909) in the winter plankton of the Gulf of Lyons.

10. **Gonyaulax pacifica** Kofoid

Pl. 15, fig. 35

Gonyaulax pacifica Kofoid (1907), p. 308, pl. 30, figs. 37–39.
Steiniella cornuta Karsten (1907), pp. 348, 420, pl. 53, fig. 7.

DIAGNOSIS: An exceedingly large species, resembling *G. polygramma* Stein, asymmetrically flattened and excavated on the ventral face, in ventral view more rounded especially on post margin than in *G. kofoidi* Pavillard, linear markings less regular and usually less developed than in *G. polygramma*, posterior intercalary very narrow, its length five to seven times its width. Proximal end of girdle curved posteriorly.

DESCRIPTION: The largest known species of the genus, its outline varying greatly with the point of view. Seen in ventral view the body resembles *G. polygramma* and *G. kofoidi* but is usually more rotund posteriorly, the sides of both epitheca and hypotheca being convex, with some contraction near the apex. Occasional specimens have straight or concave or even slightly angled slopes of the epitheca. The striking feature of the species is the broad, deep asymmetrical excavation of the ventral face, principally upon its right side, which extends posteriorly to the thin postmargin giving almost the shape of a scoop to deeply excavated individuals and an asymmetrically reinform cross-section at the girdle, as well as a much modified lateral profile. Because of this asymmetry it is rather difficult to get strictly ventral or lateral views of the theca, our figure (pl. 15, fig. 35) giving an obliquely ventral view with greater exposure of the left face. *G. polygramma* and *G. kofoidi* approach more nearly to a circular cross-section at the girdle. In this species the dorso-ventral diameter is from 0.6 to 0.75 of the transdiameter.

The length, excluding spine, is 1.6 to 2 transdiameters (used in this description for the greatest diameter at the girdle which is somewhat oblique to the true transdiameter). The *epitheca* is contracted distally to a short, scarcely differentiated apical horn about two girdle widths in length and obliquely truncated. It is deeply and abruptly concave above the girdle on the ventral face. Its altitude is from 0.78 to 1.16

transdiameters. The *hypotheca* has, in ventral view, a broadly rounded postmargin whose even contour is interrupted by the asymmetry adjacent to the base of the antapical spine. In lateral view it is a rather abruptly contracted cone, especially on the ventral face. Its altitude is 0.6 to 0.8 transdiameters.

The *girdle* is postmedian, descending, displaced distally 1.5 to 3 girdle widths, with a sharply curved proximal end, far more than in either *G. polygramma* or *G. pacifica,* without overhang. Furrow relatively very narrow, its width 0.1 to 0.05 transdiameters, very deeply impressed and with projecting shelf-like ridges of thecal wall, which occasionally bear very low lists. The *ventral area* or longitudinal furrow somewhat obscured by asymmetrical ventral excavation in which it lies, is relatively wide, gradually spreading posteriorly to four girdle widths. The *ventral area* indents the epitheca with a slender extension of the anterior plate with oblique end, and posteriorly the wide posterior plate broadly invades the antapical plate. In some cases this end of the ventral area is at the postmargin of the body. In others it lies somewhat anterior to it so that the antapical plate is exposed in the ventral view as in our figure.

The *plate formula* is $3', 0^a, 6'', 6, 6''', 1^p, 1''''$. Ventral *apical 1′* is very slender and is attached at the apex to a closing platelet. Apical *2′* is asymmetrically extended in the apical region in an apical lobe which crowds in between the apex and the top of apical *3′*. There is no apical notch as in *Spiraulax jolliffei* and the small inconspicuous ventral pore is borne at the posterior corner of apical *3′*. *Precingular 6″* is quadrilateral its anterior margin being convex and about four girdle widths long. *Postcingular 1‴* is very small, and the *posterior intercalary* very long and narrow. The plates were not correctly interpreted in my earlier (1907) description. The *ventral area* consists of a narrow anterior plate against the lower half of which the furrow abuts, which is deeply notched posteriorly by the flagellar pore. The large posterior plate has a broadly rounded postmargin. Between these two plates there are at least three plainly marked off intermediate plates, the anterior one of which is notched by the flagellar pore.

The *surface* is marked by striae which follow longitudinal suture lines and occasionally transverse ones also, in bands of one to four closely set parallel elements. They are better developed on the pre- and postcingular plates, are often incomplete and show a tendency to follow lines of pores. Intercalary bands of varying width may follow the main suture lines. The wall is generally rather thin and hyaline with minute, sparsely distributed pores in rather vague lines. We have not seen coarsely or heavily reticulated individuals, though faint reticulations are sometimes present (pl. 15, fig. 35). The furrow is often heavily ribbed. There are sometimes very low hyaline girdle lists and low denticulate lists with abundant spinules arise from the sutures between the posterior intercalary 1^p and the ventral area, and between the latter and the antapical. The solid antapical spine is relatively short, from 1 to 3 girdle widths in length. It is tapering, sometimes finned on both sides and arises from the left angle of the antapical plate.

Dimensions: Length, excluding spine, 148 to 167μ; greatest diameter, 72 to 88μ; dorso-ventral (oblique), 53 to 76μ; length of antapical, 4 to 18μ; width of furrow, 5 to 8μ.

Variation: An exceedingly variable species in size, shape of epitheca, development of surface markings, especially in number and extent of longitudinal striae, width of intercalary bands, and finer surface markings. This added to the change in outline and proportions with change in orientation, and an adequate description becomes exceedingly difficult.

Synonomy: Karsten (1907, December), has described as *Steiniella cornuta* an organism which exhibits the form, proportions, linear markings, and ventral excavation characteristic of this species (Kofoid, 1907, April 11, 13).

Comparisons: See *G. polygramma* (p. 229). The earlier figures (see Kofoid, 1907b, pl. 30, figs. 37–39) of this species are of a more rugose specimen which, owing to escape of contents, is somewhat collapsed and it therefore fails adequately to show the typical rotundity of this species, or its usual delicacy of surface markings. It varies towards *G. kofoidi* Pavillard, but is separable by the proximal curvature of the girdle, the ventral excavation and the more rounded antapical outline. It is not in our experience merely an accumulation of extreme variants of the *polygramma-kofoidi* series, but a well-established species with relatively few individuals which exhibit intergradations.

Distribution: Sparingly present in the autumn (October to January) in oceanic plankton of semitropical facies. Associated with *Ceratium reticulatum*, *C. trichoceros* and *Ornithocercus magnificus*. Reported by Pavillard (1909) in the winter plankton of the Gulf of Lyons, where it has its maximum in January. Reported also by Karsten (1907) as *Steiniella cornuta*, from the Indian Ocean, 9° 6′ N, 53° 41′ E in catch from 200 m.

d). The *Polyedra* Group

Characterized by polyhedral form, with angled sutures, rugose surface, without longitudinal striae. No apical horn. Plate formula $4'$, 2^a, (or $5'$, 0^a), $6''$, 6, $6'''$, 1^p, $1''''$.

Here belong *Gonyaulax polyedra* Stein and *G. milneri* (Murray and Whitting) Kofoid, originally described by Murray and

Whitting (1899) as *Goniodoma milneri.* It has, however, a plate formula identical with that of *Gonyaulax polyedra* and does not exhibit the three antapicals characteristic of the genus *Goniodoma. Gonyaulax ceratocoroides* is closely related in plating to this group, but because of its peculiar antapical spines is placed in the subgenus *Acanthogonyaulax.*

11. **Gonyaulax polyedra** Stein

Pl. 12, figs. 16–20; pl. 14, figs. 28, 29, 31; pl. 17, fig. 43.

Blepharocysta splendor maris Ehrenberg (1873), in part, pp. 3–4 (of reprint), pl. 1, figs. 11, 12 only.

Gonyaulax polyedra Stein (1883), p. 13, pl. 4, figs. 7–9.

G. polyedra Bütschli (1885a), p. 545, pl. 26, figs. 20, 21; (1885b), pp. 932–933, 950–953. 1020, pl. 52, figs. 3a, b.

G. polyedra, Schütt (1896), p. 21, fig. 29.

Gonyaulax sp., Torrey (1902), pp. 187–192, figs. 1–3.

G. polyedra, Okamura (1907), p. 132, pl. 5, figs. 35a–c (= *Goniodoma acuminatum* Stein).

G. polyedra, Paulsen (1907), pp. 7–8, fig. 5; (1908), pp. 28, 31, 33, fig. 40.

Diagnosis: A small, angular, polyhedral species, with ridges along sutures, equatorial girdle displaced 1–2 girdle widths, regularly pitted, rugose surface, four apical and two intercalary plates, the right apical $4'$ minute.

Description: *Body* polyhedral, subconical anteriorly, truncated posteriorly, its length 1.15 transdiameters, the ventral face scarcely excavated. The *epitheca* has both shoulders angled at the apical-precingular suture; its greatest altitude is about 0.6 transdiameters. There is no distinct apical horn. The *hypotheca* is more angular, sides straight or nearly so, contracted regularly to a broadly truncated antapex 0.4 transdiameter in width, its greatest altitude almost 0.5 transdiameter. The girdle section is nearly circular.

The *girdle* is nearly equatorial descending, displaced distally 1 to 2 girdle widths, without overhang, and in some cases even parted 0.5 girdle width, deeply impressed, guarded by low ridges with coarsely and abundantly ribbed lists. Its ends are sometimes slightly curved posteriorly in some individuals.

The *ventral area* or longitudinal furrow is broad, not deeply excavated, widening posteriorly to 1.5 girdle widths, its rounded posterior margin slightly indenting the antapex. It is nearly straight.

The *plate formula* is $4'$, 2^a, $6''$, 6, $6'''$, 1^p, $1''''$. The formula here given for the *apical* region differs from that given by Bütschli (1885a, 1885b), Torrey (1902), and Paulsen (1907, 1908), in that here as in other species of *Gonyaulax* and Peridinidae generally we designate as apicals (see Kofoid 1909b) only those plates which reach the apex and as intercalaries those between these plates and the precingulars; and also in the fact that two additional plates are here defined for the apical region for the first time. A minute but perfectly distinct plate, 4^p, lies between the two intercalaries, 1^a, 2^a, and the apex. This plate appears in the figures of Bütschli (1885b) and Torrey (1902) but is not treated as a separate plate by them. When the structure of the apical region of *G. polyedra* is considered in the light of that of other species of the genus, the homologies of the parts are clearly as follows: the so-called anterior extension of the longitudinal furrow is a ventral apical *1'*, homologous with the diamond-shaped plate of *Peridinium.* The *intercalary* region of the right shoulder contains two plates instead of one as in *Spiraulax jolliffei.* *Gonyaulax sphaeroidea* and *G. apiculata,* the adjacent apical region is greatly reduced in size and the territory which is occupied by apical *3'* in such species as *G. polygramma,* a typical *Gonyaulax* with three apicals, is subdivided into two plates, one of which, *3'*, on the right dorsal shoulder is of some size while the other, *4'*, is the minute plate in question. It is quite probable that the extra intercalary, 1^a, adjacent to apical *4'* has been split off from its lower edge and also belongs in the territory of apical *3'* of several species of the *polygramma* and *spinifera* groups, where its presence is suggested by the surface markings indicative of an incipient suture. The position and relations of the two large plates on the right shoulder are those of the intercalaries and the small plate is plainly one of the apical series. The disposition of the plates here proposed enables us to homologize the plates of the apical region of *polyedra* with those of other species of the genus.

There is some variation in size of apical *4'* (compare plate 14, figure 28, and plate 12, figure 20), which gives rise to certain modifications of the relations of the plates to the elliptical apical area which contains the closing platelet (*cl. pl.*, pl. 12, fig. 20). Ordinarily the plate designated as anterior intercalary 2^a does not come into contact with this apical region (pl. 12, figs. 18 and 20). In one case (pl. 14, fig. 29) of a reduced apical *4'* this intercalary impinges upon the apical region.

In another instance a third right dorsal anterior intercalary plate (*x*, pl. 14, fig. 28) appears as an extra plate which seems to have developed at the expense of the equatorial ends of apical *3'* and intercalary 1^a. This is the only instance thus far detected in any species of the genus *Gonyaulax* of a variation in the number of plates. The genus exhibits a noteworthy rigidity in this respect.

Apical 1' is much wider than figured by Stein (1883) and is somewhat irregular in outline, widening at the apical-intercalary suture (pl. 12, fig. 20). An apical notch has not been found but the ventral pore (*v. po.*) in the right margin of apical *1'* opposite the middle of intercalary 2^a was noted. At its apical end plate *1'* appears to include the region designated in other species as the closing platelet (*cl. pl.*, pl. 12, fig. 20). It contains a minute hyaline oblong area. Apical *2'* is large, covering the left apex. *Precingulars 1''* and *6''* are parted by the ventral area and apical *1'* which are joined in the midventral line. *Precingular 6''* is pentagonal. *Postcingular 1'''* is a very slender plate at the edge of the ventral area and has been overlooked in all previous accounts of the species. The *posterior intercalary, 1p,* is a rather large quadrangular plate and the *antapical 1''''*, a subregular pentagonal plate indented at the midventral angle by the rounded margin of the ventral area (pl. 12, fig. 19).

The *ventral area* (pl. 17, fig. 43) indents the epitheca for half a girdle width, the anterior plate being squarely truncate anteriorly and deeply notched posteriorly by the flagellar pore (*fl. po.*). The posterior plate is exceptionally large, extending anteriorly well toward the distal end of the girdle. Three intermediate plates in addition to the hyaline scale of the pore region have been isolated.

The *surface* is uniformly but not closely porulate with rather large pores about which on a high focus a coarse reticulation may be seen. In some cases the reticulum is finer than the porulation and some meshes have no pores (pl. 14, fig. 31). In some cases no reticulum is visible or merely a faint areolation. A regular line of pores follows each margin of the girdle plates and in reticulate thecae the reticulum between these resembles a columnar arcade. The ventral area in young specimens (pl. 17, fig. 43) is also porulate in its peripheral parts only. On the whole, the large size of the pores and feebly developed reticulum gives the impression of a porulate rather than a reticulate type of theca in this species. There are no free spines or lists other than those about the girdle, which are low with stout denticulations rising from the basal ridge. The theca of this species is rather fragile and is easily and quickly shed, in fact ecdysis seems to be normal and frequent, judging by the number of empty thecae and isolated plates found in the plankton wherever the species is abundant. It also occurs very frequently in crowded or moribund plankton collections. A thin pellicle surrounds the cell body within the theca, the apical and precingular plates spread apart along the longitudinal sutures, especially those in the sagittal plane, and the *Gymnodinium*-like cell body escapes and presumably its thin pellicle is differentiated into a new theca.

The *cell contents* are very dark orange-brown and the chromatophores are densely packed together. When present in great numbers, as they often are, they give the sea a reddish color, and cause magnificent displays of phosphorescence at night. Oil droplets abound in the cytoplasm and it gives off a rank odor upon decay.

DIMENSIONS: Length, 50 (43 to 54)μ; transdiameter, 45.6 (37 to 53)μ; dorso-ventral diameter about the same; width of girdle, 4 to 5μ. Ten individuals measured.

VARIATION: There is considerable variation in size, in angularity, in porulation, development of reticulum and girdle lists. The displacement of the girdle varies from one to nearly two girdle widths. The adjustment of apical plates to each other also exhibits some irregularities in the lengths of the different lines. Apical *4'* varies considerably in size and one instance of three anterior intercalaries has been recorded (pl. 14, fig. 28).

COMPARISONS: *Gonyaulax polyedra* is quite distinct from all other species of the genus except *G. milneri*, in the character of its apical plates and in the presence of two anterior intercalaries. The absence of linear markings and the four apical plates distinguish it at once from *G. polygramma*, its common associate in subtropical waters, and the absence of antapical spines and shorter, more angular epitheca, as well as four apicals, mark it off from the *G. spinifera* group, with species of which it is often found. The other species (*ceratocoroides*, *milneri*), with four or more apicals, either have no anterior intercalary, or at the most but one.

SYNONOMY: This species is so well marked that it has rarely been confused with others. Okamura's (1907) figure assigned to this species is *Goniodoma acuminatum* Stein.

Ehrenberg (1859) described as *Peridinium splendor maris,* a highly phosphorescent dinoflagellate from the plankton in August at Naples and later (1873, pl. 1, figs. 7–18) figured it, and in the explanation of the plate suggested the new generic name *Blepharocysta* for this organism. The description and the figures in both cases are entirely inadequate for certain reidentification. Stein (1883) admirably figures an organism which he assigns to Ehrenberg's "*Blepharocysta splendor maris* (z. Theil)" noting particularly in his brief text "Ehrenberg warf damit noch andere unklare Formen zusammen." Stein does not, however, state which of the several forms figured by Ehrenberg he regards as the part of the agglomeration equivalent to *B. splendor maris.* Jörgensen (1899) criticizes Stein's procedure on the ground that Ehrenberg's figures show an impressed girdle while the *B. splendor maris* of Stein's figures entirely lacks impression of the girdle into the contour of the body. He further notes the fact that two of Ehrenberg's figures (figs. 11 and 12) evidently belong to *Gonyaulax polyedra,* to which I agree. However, I see no ground, beyond the *statement* in the original description and in the explanation of Ehrenberg's plate that there are three end plates in each half of the theca, for accepting Jörgensen's suggestion that Ehrenberg's figures 7 to 10 are possibly referable to *Goniodoma acuminatum* Stein. No one of these figures *shows* the angular body, or three "Endplatten" characteristic of the genus *Goniodoma.* Jörgensen seems to have overlooked the fact that Stein assigns only a part of Ehrenberg's complex to his emended *Blepharocysta splendor maris.* While Ehrenberg's figures 11 and 12 are in all probability *Gonyaulax polyedra*, the other figures are unmistakably not *Goniodoma* and might better be crudely drawn *Blepharocysta* than *Gonyaulax polyedra.* It seems best, therefore, in the absence of any valid criterion for determining what Ehrenberg actually had, to accept *Blepharocysta splendor maris* Ehrbg. in part (figs. 11, 12) as a synonym of *Gonyaulax polyedra* and to allow Stein's emended *Blepharocysta splendor maris* to stand for the well-figured organism to which he attached the name proposed by Ehrenberg, and therefore to leave the name also attached to the plainly unrecognizable figures 7–10, 15–18, of Ehrenberg's original delineation of the species.

Distribution: Very abundant in the San Diego region in the summer plankton, July–September, when it causes local outbreaks of "red water" which extend along the coast of Southern and Lower California. The northern limit of the region of excessive abundance is approximately Santa Barbara and the southern one is at present unknown, though inadequate data (Darwin, 1871, Streets, 1878), suggest at least local outbreaks along South American coasts and in the Gulf of California. Torrey (1902) records reports of an outbreak off Tomales Bay, north of San Francisco, about forty years ago.

The seaward extension of the discolored areas is quite irregular, ranging from one-half to three miles. The local distribution within the "red water" itself, as seen from the mast head or from Mt. Soledad (elevation 822 feet), near La Jolla, is exceedingly irregular, areas of deeply discolored water of varying size and intensity being interspersed with areas of clearer water. In the early part of August, 1907, with the University of California dredging party in the launch "Elsie," I ran by night from San Diego to San Pedro, a distance of about one hundred miles, through the discolored coastal zone. The depth of discoloration, the brightness of the phosphorescence by night, varied greatly at different points along the coast, being especially marked off La Jolla, Point San Juan, Newport, and San Pedro. This irregularity may be due to the configuration of the coast and of the bottom, especially to the sunken valleys which may serve as conduits for upwelling waters. It is quite possible that the local and periodical enrichment of coastal waters by the nitrogen-bearing waters from the depths along the coasts of California, is one of the primary causes for the occurrence of these outbreaks of "red water" and in part for the irregularities of their appearance and inequalities in their local distribution.

This species upon stimulation by the movement of the water as in the breakers along shore, or in the path of a moving fish, gives forth a brilliant greenish-blue flash of phosphorescence of an instant's duration, which bathes the breakers or white caps in a foam of fire, and outlines the path of fishes, seals and porpoises or the wake of a steamer with a luminous trail which lingers for some seconds, or even minutes, as the motion of the water dies down.

The decay of countless millions of these organisms in the water and upon the beaches where they are continually stranded by the receding waves, creates a nauseous and penetrating stench of most disagreeable nature. The products of decay (and metabolism ?) of these organisms are toxic to many marine organisms, which die in great numbers (see text figure E) and are cast up by the tide upon the beaches.

Not all organisms are equally affected (See Torrey, 1902), by these adverse conditions but mainly bottom forms which cannot retreat into places of safety, such as the holothurians, sipunculids and bottom-feeding fish, such as the sting ray (*Urolophus halleri*) and guitar fish (*Rhinobatis productus*) and littoral crustaceans, such as *Hippa analoga* and *Cancer antennarius*. The organisms of the plankton, both large and small, and the widely ranging fishes, seem not to be affected adversely, at least to a fatal degree. It is obvious that the bottom-dwelling forms would be overwhelmed by the accumulation upon the bottom in shallower waters of organic debris from the excessive development of the plankton of the "red water," principally *Gonyaulax poly-*

edra, and this localization of a region of fermentation is doubtless the immediate cause of the destruction of the large numbers of the representatives of the bottom fauna.

Fig. E. Shore at East San Pedro, California, in August, 1907, during an outbreak of red water, showing dead fishes and invertebrates stranded on the shore at low tide. Photograph by Professor W. R. Coe.

This species is the most abundant dinoflagellate of the San Diego region during summer months and is found in small numbers throughout the year in both oceanic and neritic plankton. It is found at least as far north as San Francisco along the coast of California.

It is widely distributed in temperate and subtropical waters of coastal regions, but apparently is not common in the more strictly oceanic plankton. The extensive records of Cleve (1901a, 1902) for the Atlantic do not contain this species, and it appears in the many collections of the International Commission for the Investigation of the Sea (see Ostenfeld, 1906, 1909) only (unless it be as *Gonyaulax* sp.) from Danish waters where Aurivillus (1898), Cleve (1900b) and also Paulsen (1907) report it. Jörgensen (1899, 1905) reports it rare in Norwegian fiords and Ostenfeld (1899, 1900, 1903) from the neritic plankton at the Faeroes, in adjacent waters north of Scotland (60° N, and 4°–6° W) and in the North Atlantic at about 60° N, 31° W. Later Ostenfeld and Paulsen (1904) report other occurrences along the route of Danish steamers going to Greenland in the North Atlantic along the parallel of 60° N at 1°, 13° and 27° W, and in all cases as rare. Stein (1883), Bütschli (1885) and others have found it at Kiel, Schröder (1900) at Naples, Entz (1902) in the Adriatic at Quarnero, and Pavillard (1905) in the Gulf of Lyons, Whitelegge (1891) reports it at Port Jackson, Australia, during an outbreak of discolored water which he attributes mainly to *Glenodinium rubrum*, a new species which he describes from the red water. This form looks suspiciously like the contents of *Gonyaulax polyedra* after ecdysis. Okamura's (1907) record of this species from Japanese waters is to be rejected, since his figure is plainly that of *Goniodoma acuminatum*. Karsten (1906) reports it once in the Valdivia Collections from Station 55, 2° 36′ N, 3° 27′ E, in the Gulf of Guinea, in a locality which is perhaps within the reach of neritic influences.

The species exhibits as a whole marked preferences for a neritic distribution, with rare occurrences in territory invaded by oceanic currents which may carry occasional individuals away from neritic regions, as in the case of records in the North Atlantic and Gulf of Guinea. Both in local distribution and relative numbers it is remarkably erratic, varying, in seemingly similar regions where other cosmopolitan dinoflagellates occur with greater regularity and uniformity, from an entire absence of all records of occurrence up to overwhelming numbers, which completely mask the other dinoflagellates, and in fact all the microplankton and even exterminate the bottom fauna. The indications are that *Gonyaulax polyedra* is a species in a peculiarly susceptible physiological condition in which the reproductive and growth processes may be more than usually sensitive to stimulus by favorable conditions in the environment.

2. Subgenus **Fusigonyaulax** subgen. nov.

Sectio *Fusiformes*, Lemmermann (1907), p. 299.

Body elongated, fusiform, with centrally located well differentiated apical and antapical horns. Girdle not displaced more than 3 furrow widths. Usually three (rarely two or four) apicals and no (rarely one) anterior intercalary. Usually from tropical or warm temperate waters.

This subgenus may be divided for convenience in treatment into two groups, the *birostris* group with elongation exceeding two transdiameters, and the *acuta* group, with elongation less than two transdiameters and therefore containing the stouter, more robust members of the subgenus.

e). The *birostris* Group

Characterized by a length exceeding two transdiameters, an apical horn equaling or exceeding a transdiameter in length, and a finned central antapical spine of nearly equal length and by a subglobular or ellipsoidal midbody. Surface pitted or areolated.

This group contains *Gonyaulax birostris* Stein, *G. highleii* Murray and Whitting, and *G. glyptorhynchus* Murray and Whitting. This group of species is in need of careful revision, for it is desirable that distinctions between the species be more clearly defined.

Represented at San Diego by *G. birostris* Stein.

12. **Gonyaulax birostris** Stein

Gonyaulax birostris Stein (1883), pl. 4, fig. 20

DIAGNOSIS: Body elongated fusiform, with abruptly swollen midbody, girdle displaced 1.5 furrow widths, apical precingular suture oblique. Apical *1′* very narrow. Antapical spine equaling transdiameter in length.

A single individual referable to this rare species was taken in surface collection (No. 679) made September 24, 1904, ten miles WNW of Point Loma. It was somewhat shorter than the specimen shown in Stein's (1883) figure and had the areolations on the surface well developed. Neither drawing nor full description was obtained.

This species was described by Stein (1883) from the Pacific and has since been reported by Murray and Whitting (1899) from the temperate and tropical Atlantic between 4° and 42° N and 20° to 66° W; by Zacharias (1906) from the Gulf of Naples, by Entz (1907) from Quarnero, and by Karsten (1907) from the northwestern part (9° N, 54° E) of the Indian Ocean. It is apparently a rare oceanic species of the warmer seas.

3. Subgenus **Acanthogonyaulax** subgen. nov.

Represented by *Gonyaulax ceratocoroides* Kofoid, a tropical species described by Murray and Whitting as *Ceratocorys spinifera*. See Kofoid (1910). Not as yet found at San Diego, but to be expected in the winter plankton.

4. Subgenus **Steiniella** (Schütt) Kofoid

Steiniella Schütt (1895, p. 151, pl. 6, fig. 26; 1896, p. 19, fig. 26. Not *Steiniella* Bernard (Protococcaceae) (1908, p. 189).

Characterized by a laterally compressed apex which is carried over on to the dorsal face of the epitheca. Large rotund body with very fragile theca, often faintly marked with longitudinal vermiculations. Three or four apicals and no anterior intercalary. Ventral pore sometimes absent (?).

This subgenus falls into three groups of unequal content: the *fragilis* group, rotund, without constriction behind girdle, the *bispinosa* group, with marked constriction, containing *G. bispinosa* Kofoid and Michener, and the *mitra* group, greatly elongated and laterally compressed, containing *G. mitra* (Schütt) Kofoid. Only representatives of the first named group have as yet been discovered in the San Diego region.

g). The *Fragilis* Group

Characterized by rotund form of body, with no differentiated apical horn, no constriction immediately behind the girdle, and predominantly longitudinal markings.

Here belong *G. fragilis* (Schütt), *G. hyalina* Ostenfeld and Schmidt, and *G. alaskensis* sp. nov.

13. **Gonylaulax fragilis** (Schütt)

Pl. 15, figs. 33, 34, 36, 37; pl. 13, fig. 25.
Steiniella fragilis Schütt (1895), pl. 6, figs. 26_{1-14}.

Diagnosis: Length, 1.14 to 1.35 transdiameters. Epitheca conical, hypotheca asymmetrically rounded, girdle displaced 3 girdle widths. No spines.

Description: *Body* rotund, somewhat elongated, slightly flattened on ventral face. Epitheca and hypotheca subequal. *Epitheca* a low cone, 0.66 transdiameters in middorsal altitude, its sides slightly convex. No apical horn. Apical region extending a short distance on dorsal face. *Hypotheca* sac-like, its middorsal altitude 0.72 transdiameter, abruptly and asymmetrically rounded at antapex, the left side being a trifle the fuller. *Girdle* slightly premedian, descending, displaced distally 3 girdle widths, without overhang, proximal end curved posteriorly, furrow not deeply impressed, with scarcely any salient ridges and no lists. Ventral area indenting the epitheca scarcely a girdle width, widening posteriorly to the right and then to the left.

Plate formula $3'$, 0^a, $6''$, 6, $6'''$, 1^p, $1''''$. *Apical* $1'$ slender, about 0.5 girdle width across, slightly sigmoid, with elongated closing platelet which extends upon the dorsal face at its anterior end. It joins the anterior plate of the ventral area posteriorly. Apicals $2'$ and $3'$ surround the apex in saddle fashion. *Precingular* $6''$ triangular. *Postcingular* $1'''$ long and slender, expanding anteriorly less than a girdle width across. *Posterior intercalary* 1^p, two girdle widths across. *Antapical* $1''''$ deeply indented by the posterior end of the ventral area. The *ventral area* is about 0.5 girdle width across between girdle ends, flaring asymmetrically posteriorly to at least 3 girdle widths and carried well under the antapex into the antapical plate, and usually without lists. The surface is nearly smooth, with feeble or more pronounced vermiculations running in short, sinuous longitudinal lines. They run posteriorly from the pores about which they take their origin. (See Schütt, 1895, pl. 6, fig. 26_2.) Often two originate from the same pore. Suture bands are finely areolated. The arrangement of surface markings, of pores and of chromatophores all give the organism an appearance of longitudinal striation. In some specimens the vermiculations coalesce (pl. 13, fig. 25) to form a semistriate meshwork with pores at the nodes. *Chromatophores* ellipsoidal, irregular, or linear, in peripheral or radial arrangement, several large anteriorly located pusules and posteriorly located ellipsoidal nucleus.

Dimensions: Length, $82–105\mu$; transdiameter, $65–80\mu$; dorsoventral diameter, $60–65\mu$; width of furrow, 5μ.

Variation: I have noted some variation in form of antapex, surface markings, and shape of ventral area, which is usually not so wide as figured by Schütt (1895).

Comparisons: Distinguished from *G. alaskensis* by its more elongated body, more linear markings and absence of antapical spines. From *G. hyalina* it differs in its less rotundity and less pronounced linear markings. In this species the length and transdiameter are about equal. From *G. inflata* it differs in its less expanded girdle region, less sloping hypotheca and smaller size.

Synonomy: Originally described by Schütt (1895) in his new genus *Steiniella*, but in all skeletal characters a typical *Gonyaulax*.

Distribution: Taken sparingly in the plankton of the inner harbor, at San Pedro, Calif. (No. 505), May 31, 1901; evidently carried in by tidal currents with the oceanic plankton from the outside.

Reported by Ostenfeld (1900) as very rare in Gulf Stream waters north of Scotland 59° N, 2°–9° W, and by Cleve (1901a) from the Atlantic 29°–47° N and 9°–23° W. Also by Schröder (1900) from Naples and by Entz (1902) from Quarnero on the Adriatic.

14. **Gonyaulax alaskensis** sp. nov.

Pl. 17, figs. 45, 46; pl. 14, fig. 32.

Diagnosis: A very large polyhedral species with much displaced (4 girdle widths) girdle, apex dorsally extended, coarse reticulations often of predominantly longitudinal elements with scattered pores at the nodes. Longitudinal furrow flaring widely at antapex; two short antapical spines. The ventral area reaches nearly half the distance from girdle towards apex.

Description: *Body* polyhedral with rounded angles, its length 1.05–1.12 transdiameters, nearly circular in equatorial cross-section with some flattening on ventral face of hypotheca. *Epitheca* approximately equal to hypotheca, low, conical, its greatest altitude 0.66 transdiameter, slightly angled at the apical-precingular sutures. No apical horn, apex small, elongated, extending dorsally beyond the summit, less than a girdle width across and 2.5 in length, sloping obliquely toward the ventral face. *Hypotheca* subhemispherical, its altitude 0.6 transdiameter with convex sides swelling at the girdle, contracted to a proportionally small antapex less than 0.3 transdiameter across, bearing two small, stout, widely separated spines.

The *girdle* is equatorial, descending with little (0.5 to 1.5 girdle widths) overhang, but relatively great displacement (4 girdle widths).

The two ends are both sometimes curved posteriorly and the distal end declines steadily in a long slope from the right side of the body. The furrow is relatively narrow, very deeply impressed with salient ridges bearing low, abundantly ribbed fins of 0.5 girdle width in height. The anterior plate (*ant. pl.*, pl. 14, fig. 32) of the ventral area indents the epitheca nearly half way to the apex. The *ventral area* or longitudinal furrow is much compressed laterally between the ends of the girdle where it makes an angle of 25° with the major axis. The salient right mid-ventral region with the distal end of the furrow crowds the furrow to the left and (pl. 17, fig. 45) overhangs it. Posteriorly it flares very abruptly to the right side to 3 girdle widths at the postmargin.

The *plate formula* is $3', 0^a, 6'', 6, 6''', 1^p, 1''''$. *Apical 1'* is a short plate 0.2 transdiameters in length and 0.5 to 0.8 girdle width across bearing at its apex the elongated elliptical closing platelet (*cl. pl.*, pl. 14, fig. 32). Apical *3'* bears in its median margin less than a girdle width below the apex the conspicuous ventral pore (*v. po.*). *Precingular 6''* is quadrangular. *Postcingular 1'''* relatively broad, 1 to 2 girdle widths across; *posterior intercalary* very wide; *antapical 1''''* rather widely and deeply invaded by posterior plate of ventral area. *Ventral area* with long, slender anterior plate (*ant. pl.*, pl. 14, fig. 32) nearly 3 girdle widths in length, partially crossed by the anterior girdle ridge, with a shallow notch at its postmargin for flagellar pore. Intermediate plates obscured. Posterior plate beginning about two girdle widths behind the distal end of girdle and flaring rapidly and principally to the right side, expanding from one girdle width anteriorly to three at the postmargin.

The *surface* is very characteristically marked with a light tracery of delicate meshwork made up predominantly of longitudinal or semi-detached vermiculate elements with which transverse or irregular bars form an incomplete mesh. In some specimens the mesh work is predominantly polygonal, especially on the hypotheca and near sutures. On others the longitudinal pattern predominates especially on pre- and postcingular plates and along suture lines (pl. 17, figs. 45, 46). The low fin on the girdle lists is very abundantly ribbed as are also the low fins on plates *1'''*, *6'''*, and 1^p which overhang the longitudinal furrow. The low fin between the two antapical spines is likewise minutely and abundantly ribbed. In fact the fins throughout are all low and abundantly ribbed, the distance between the thickenings in their substance corresponding remarkably well with the diameter of the polygonal meshwork upon the shell, suggesting the action of a similar physical factor determining both. The only fin showing an unusual development is the one on plate *1'''*. In most species of *Gonyaulax* no fin appears here or at the most it is a very low list. In this species it almost completely covers over the furrow. In one specimen (pl. 17, fig. 46) the girdle lists are lacking and there is no fin on the postmargin between the antapical spines. The two antapical spines are short (0.6 girdle width), stout, and finned on both sides, or entirely lacking fins.

The pores are sparingly distributed, in rows along sutures, in the girdle where the two rows are joined by vertical ribs as in *G. scrippsae*, and in certain nodes of the meshwork on the plates. They are of small size and inconspicuous.

The *cell contents* are not dense. In addition to the ellipsoidal nucleus there is in some individuals a very large dense yellowish chromosphere, nearly 0.4 transdiameters across similar to those often seen in *Oxytoxum.*

DIMENSIONS: Length, 65 to 77μ (4 measured); transdiameter, 65 to 74μ; girdle width, 4μ; antapical spines, 3 to 4μ.

VARIATION: Varies in size, fin development, and degree to which the linear type of markings is realized.

COMPARISONS: Belongs to the subgenus *Steiniella.* The characters in which it resembles *Steiniella fragilis* are (1) the surface markings which are slightly of the linear-vermiculate type so well developed in that species, (2) the overrun of the apex upon the dorsal side, and the elongation of the closing platelet and (3) the fragility of the theca. In none of these characters, however, does it attain the degree realized in other species of the subgenus *Steiniella.* It may be distinguished from other members of the *G. fragilis* group by its two antapical spines.

It is a very well defined species easily recognizable by reason of its elongated anterior plate of the ventral area; its wide postcingular *1‴*, its widely separated antapical spines, and by its characteristic surface markings.

DISTRIBUTION: Taken thus far but twice at San Diego, first on June 9, 1904 (No. 65) in a haul from 75 fathoms several miles off San Diego, and a second time in a vertical haul from 170 fathoms, about ten miles off San Diego on June 23, 1904 (No. 120). A number of specimens have been observed in a surface collection made in the evening (7 p.m.) at Loring, Alaska, September 15, 1905, by Mr. F. M. Chamberlain of the U. S. Bureau of Fisheries, S.S. "Albatross." Permission to use this material has been kindly granted by Hon. Geo. M. Bowers, Commissioner, U. S. Bureau of Fisheries.

E. GENERAL DISCUSSION OF GENERIC AND SPECIFIC CHARACTERS IN *GONYAULAX*

The oft repeated and long continued close scrutiny of numerous groups of individuals of related species such as has been the basis of the preparation of this paper affords an exceptional opportunity not only for the appreciation and detection of minute details of structural differences upon which the concept of species is customarily built, but also for an ever growing realization that other phases of the organism which may be designated broadly as physiological or functional, rather than structural, are just as profoundly and truly characteristic of species as are those other concrete indications of activity of the living substance which are recorded in more or less permanent expression in form. It may be useful to sum up here both the morphological and functional data and to give the impressions which this study has made upon me with reference to the nature and relations of both generic and specific characters.

The generic characters of *Gonyaulax* are the displacement of the girdle and the constant number of skeletal elements in the hypotheca, girdle, and precingular series of plates, in all a constancy in not less than twenty of the twenty-three to twenty-six skeletal elements characteristic of the different species, and the form and relations of apical *1′*. If we divide the skeleton into zones or belts of plates, as follows (a) apicals, three to five; (b) anterior intercalary (incomplete), none to two; (3) precingulars, six; (4) postcingulars, six; (5) posterior intercalary (incomplete), one; (6) antapical, one, we discover that the posterior half of the skeleton, the girdle, and precingular belt are constant, while the plates of apical region and adjacent intercalary region are variable in number and position. The generic characters thus inhere in the skeleton in and adjacent to the girdle and longitudinal furrow (ventral area of this paper), structural features moulded by the two flagella, the prime ordinal characters of the Dinoflagellata. They thus express, in so far at least as the maintenance of constant number is concerned, conservative ancestral tendencies in the organism, and are directly related to the regions of major activity.

These characters are maintained with remarkable constancy amidst a great diversity of external form, ranging from the spherical as seen in *G. sphaeroidea* (pl. 16, figs. 41, 42), to the greatly elongated seen in *G. birostris*, or the polyhedral in *G. polyedra* (pl. 17, fig. 43).

The ventral pore is also found throughout the genus, but this is present, though not hitherto described, in other genera, such as *Amphidoma*, *Goniodoma*, *Pyrophacus*, and *Centrodinium*. It therefore can not be regarded as a generic character.

I. SPECIES CHARACTERS

1. The Extent of Differences between Species

The specific characters which differentiate the thirty-six or more species of this genus are of greatest variety and affect, in one species or another, practically all the structural elements which make up the organism (see Kofoid, 1906c). Not only is this true for the genus as a whole, but it is also true to a large degree for each species as a unit. It differs from its congeners not merely in certain easily detected and quickly defined structural features which strike the eye at once, but in manifold minor details which are less easily comprehended and can only be described by a mass of minutiae and often accurately expressed only by statistics of proportional measurements. These become evident as one works over the material, in spite of increasing evidences of variation, which on the novice too often leave the impression of inextricable confusion. Just as in the case of the Gadidae, where Williamson (1910) has so clearly demonstrated that the species are profoundly differentiated not only in surface characters such as scalation and fin rays, but by internal visceral and skeletal structures as well, so also in the Dinoflagellata specific characters extend throughout the organism but are more easily comprehended in the less labile skeletal structures. To this the work of Schmidt (1905, 1906) upon the young stages of the various species of cod in the North Atlantic and North Sea has added equally striking evidence of the specific distinctness of the eggs and fry, differences in dimensions, oil drops, pigmentation, and the like, which the experienced eye soon learns to utilize as an infallible guide to the separation of these organisms in the early stages of their development. In a like direction the work of the various divisions of the International Commission for the Investigation of the Sea has brought to light the fact that sharply defined differences based on salinities, temperature, and currents delimit the seasons and spawning territories of the adults of the various species of the Gadidae.

Distinguishing characters of a type not unlike in essential nature to that found among the Gadidae may also be demonstrated between the various species of *Gonyaulax*. It will suffice for illustration to compare two common species, *G. spinifera* and *G. polygramma* (compare figs. A-D, pl. 16, fig. 39 and pl. 17, fig. 47), species of about the same size, often found in the same waters. They differ in size, proportions, in displacement, overhang and margins of girdle; in proportions, shape and markings of the ventral area; in shape of apical region; in size, number, and symmetry of antapical spines; in location of ventral pore; in shape of plates $1'$, $3'$, $6''$, $6'''$, 1^p, and $1''''$; in surface markings which are predominantly linear in *polygramma*, and reticulate in *spinifera*. Finally in numbers and distribution there are indications (precise information is lacking on account of confusion in literature as to the synonomy and specific limits of *G. spinifera*) that *G. spinifera* has more of a neritic distribution in colder waters and *G. polygramma* oceanic in warmer waters.

The number of characters separating species would be somewhat lessened if the comparison should, for example, be made between those of the *polygramma* series, as for example *G. turbynei* (pl. 17, fig. 44), *G. polygramma* (pl. 17, fig. 47), *G. kofoidi* (pl. 14, fig. 30), and *G. pacifica* (pl. 16, fig. 35), but even here the characters found in common in all or certain members of the series such as linear markings, antapical spines, antapical asymmetry, or apical horn, differ between several members of the series in the degree and manner of their expression in qualitative and quantitative fashion.

II. CHARACTERS OF VALUE IN DISTINGUISHING SPECIES

1. Structural Characters

Those structural characteristics which have proved to be of greatest value in the analysis of species in *Gonyaulax* fall naturally into two groups, (1) those affecting fundamental features such as number of plates, form of the body, displacement of the girdle, and form of the ventral area; and (2) superficial characters such as surface markings, and outgrowths such as spines, lists, and fins.

The *types of bodily form* may all be traced back to modifications of a sphere, a type realized almost perfectly in *G. sphaeroidea* and *G. palustris*, less so in *G. scrippsae* and *G. turbynei*. This sphericity is retained in the posterior part of the body, in the more conservative hypotheca in *G. apiculata*, *G. fragilis*, *G. digitale*, *G. scrippsae*, *G. diegensis*, *G. triacantha*, and *G. hyalina*.

Elongation of the body is apparent in the whole body in *G. apiculata* and *G. fragilis;* in the apical region only in *G. spinifera*, *G. digitale*, *G. diegensis*, and *G. ceratocoroides*, and especially in *G. mitra*. Elongation of the epitheca as a whole is seen in the large numbers of the *polygramma* group, *G. polygramma*, *G. kofoidi*, and *G. pacifica*. Elongation of the hypotheca in excess of that of the epitheca is noticeable in *G. mitra*, in *G. milneri*, and *G. ceratocoroides*. Elongation with marked accompanying attenuation of both halves is seen in the subgenus *Fusigonyaulax* in its species *birostris*, *glyptorhynchus*, and *highleii*. The polyhedral form of body is found in *G. polyedra*, *G. milneri*, and *G. ceratocoroides*. In these the sutures are somewhat salient and the plates flattened rather than convex.

The most fundamental and characteristic structure in the genus *Gonyaulax*, and for that matter in the Dinoflagellata, is the girdle, the trough in which the ribbon-like protoplasmic sheet called the transverse flagellum lies. Throughout all species of *Gonyaulax* this girdle is wound in a descending spiral about the body, the amount of descent varying from one to seven girdle widths in different species. The amount of displacement is characteristic for the species, subject however to some variation within the species. An abrupt proximal curvature is distinctive of some species, as for example of *G. pacifica* (pl. 15, fig. 35) and *G. triancantha* (pl. 11, fig. 13) and a sweeping distal one of *G. diegensis* (pl. 13, fig. 24). In *G. spinifera* (pl. 16, fig. 39) and *G. digitale* (pl. 9, fig. 3) the girdle makes more than a complete circuit of the body, the overhang of the two ends being several girdle widths.

The actual width of the girdle is fairly constant in all species, being about five microns, possibly in correlation with a constancy in the size of the flagellum or range of its field of action.

The manner in which the furrow is formed varies in different species. In one, *G. sphaeroidea* (pl. 16; fig. 41), it is not at all impressed into the body wall, in several (*G. ceratocoroides*, *G. milneri*) the surface is merely flattened, in others (*G. palustris*, *G. scrippsae*, pl. 16, fig. 38, and in the subgenus *Fusigonyaulax*) it is slightly impressed, while in the great majority of species, as in *G. spinifera* (pl. 16, fig. 39), *G. polygramma* (pl. 17, fig. 47), it is quite deeply set into the body wall.

The sides of the furrow are variously constructed. In non-impressed and shallow types the sides are formed by high membranous lists either without (*G. sphaeroidea*) or with (*G. milneri*, *G. ceratocoroides*, *G. birostris*, *G. glyptorhynchus*) ribs. In nearly all of the deeply impressed types there are no membranous lists, the edges of the furrow being formed by thick scarcely salient shelves of thecal wall, as in *G. polygramma*, *G. triacantha*, and *G. diegensis*. In a few cases, as in *G. spinifera* (all?) these edges may bear low fins with short ribs.

The form of the longitudinal furrow or ventral area also differs in different species, largely in correlation with the form of the girdle. The overhang and displacement give it a marked sigmoid curvature in *G. spinifera* (pl. 16, fig. 39), *G. digitale* (pl. 9, fig. 3), and *G. scrippsae* (pl. 16, fig. 38). In species with displaced girdle, such as *G. diegensis* (pl. 13, fig. 24), a narrow constricted region extends between the two ends of the girdle. In polyhedral forms, *G. polyedra* (pl. 17, fig. 43), *G. milneri*, and *G. ceratocoroides*, and especially in *G. catenata*, this area is a widely expanded, vertical, straight tract within which the minor skeletal elements, six in number, which compose it, can be readily determined. In all except the *polyedra* and *sphaeroidea* groups the ventral area is widened posteriorly, enormously so in *G. triacantha* (pl. 11, fig. 13) and *G. catenata*, and considerably in the *polygramma* series (pl. 17, fig. 47). In the subgenus *Steiniella* (except in *G. mitra*) the distal enlargement is considerable and rather abrupt (pl. 17, fig. 45) and in the *G. spinifera* series it is often spoon-shaped (pl. 16, fig. 39). The degree to which the armature of fins and spines is developed on the sides of this area is to a considerable extent a species character, as is also the extent of the indentation which it makes in the terminal antapical plate.

The *constituent plates of the theca* are subject to diversifications in the various species only in the apical and anterior intercalary regions, *those parts of the organism directed forward in locomotion and therefore most subject to the impact of the environment.*

The total number of plates in the apical-intercalary region is usually 3 (20 cases), occasionally 4 (6 cases), rarely 5 (2 cases), or 6 (2 cases) or even 8 (1 case). The distribution of these plates between the apical and intercalary regions varies. I arbitrarily distinguish all those plates in contact with the apex as apicals, and all others anterior to the precingulars as anterior intercalaries. The following table indicates the distribution of the several types of plating among the species of the genus.

APICAL PLATES IN SPECIES OF GONYAULAX

Species	Total plates	Number of Apicals	Number of anterior intercalaries	Position of anterior intercalaries
G. alaskensis, birostris, digitale, fragilis, glyptorhynchus, inflata, kofoidi, pacifica, polygramma, scrippsae, spinifera, turbynei	3	3	0	
G. apiculata(?), sphaeroidea	4	3	1	right ventral
G. diegensis, hyalina(?)	4	4	0	
G. triacantha	5	3	2	dorsal
G. jolliffei (=Spiraulax jolliffei)	5	4	1	right ventral
G. milneri	5	5	0	
G. polyedra	6	4	2	right ventral
G. ceratocoroides	6	6	0	
G. catenata	8	4	4	dorsal
G. highleii, mitra, palustris(?), series	?	?	?	

An inspection of the table shows at once the predominance of the $3'-0^a$ combination and also that there is no marked tendency for the deviations from this to conform to the lines which separate the subgenera and groups which I have recognized. In the discussion of the species, especially of those with the $3'$–0^a combination I have repeatedly called attention to an incipient suture in apical $3'$, which if realized would give rise to a $3'$–1^a or a $4'$–0^a arrangement. It may be noted in passing that in the individualized plates of the theca of the Dinoflagellata we come about as close to a realization of unit characters in these so-called lower and supposedly simple organisms as we do anywhere in the organic world. This exhibition in *Gonyaulax* of a tendency on the part of plate $3'$ to divide into two elements and its apparent realization in certain species (e.g. in *G. diegensis*) is strongly suggestive of a gradual rather than an abrupt transition from a three-unit to a four-unit phase in this region of the skeleton.

The differentiation in form and in position of ends of girdle and in form of ventral area modify certain plates of the thecal wall to an unusual degree. These plates are apical $1'$, anterior intercalary 1^a, precingular $6''$, the anterior plate of the ventral area, postcingular $1'''$, and the posterior intercalary 1^p. Three significant relations of these plates appear to be correlated with their relatively greater degree of diversification.

In the first place they are, with two exceptions (apical $1'$ and anterior intercalary 1^a) immediately in contact with the region of protoplasmic motion, the furrows in which the two flagella are active, during the time of thecal formation; in the second place they are all in immediate contact with the line along which the theca is parted in cell division, and thus in a region of constantly repeated liberation along one margin, from restraining contacts with other plates.

It should, however, be noted in this connection that the girdle plates *1–6* are absolutely constant in number and exhibit few modifications in the genus, and that other plates along the fission line (see text figs. A-D, p. 195) do not manifest an equal amount of diversification within the genus. In a third particular, however, the plates named, together with the whole ventral area which is quite variable, do occupy a unique relation among the elements of the theca. They all lie in the midventral region adjacent to the flagellar pore precisely in the region where the spiral movements of the two flagella bring a current of water sweeping over the surfaces of these plates. In other words they constitute a region of maximum contact with the environment. The direct action of the environment as a potent modifying agent in the process of speciation is thus strongly suggested.

The surface of the thecal wall of *Gonyaulax* exhibits nearly all of the modifications found in the whole order of Dinoflagellata ranging from the smooth almost undifferentiated spineless and finless *G. scrippsae* to the exceedingly rugose *G. milneri* and the long-spined *G. ceratocoroides*. Minute quadrangular areolations are seen in *G. triacantha* (pl. 11, fig. 13), pits which pass over into a coarse mesh work in *G. polyedra* (pl. 14, fig. 31), linear striae in the *polygramma* (pl. 17, fig. 47) group, and vermiculate in certain species of the subgenus *Steiniella* (pl. 17, fig. 46), while in many instances a reticular meshwork, usually quite characteristic of the species is found. These surface markings are peripheral characters in immediate contact with the environing medium and more than any other feature of skeletal organization exhibit variation in respect to age of the theca, but especially with reference to temperature, salinity and perhaps to more subtile chemical modifications in the water in which they are found. The proof of this statement lies in the fact that most of the individuals taken at one time in a given locality will bear a characteristic facies, expressed in *Gonyaulax* in surface markings, and this may differ in greater or less degree from the same species taken elsewhere, or at the same locality at another season.

The marked asymmetry expressed in the inequality of the two posterior horns in *Peridinium* and *Ceratium* is hinted at in the tendency toward antapical asymmetry seen in the larger members of the *polygramma* series, as for example in *G. pacifica*. It is perhaps to be correlated in all instances with the proximity of this region to the posteriorly extending flagellum with the current of water it produces sweeping backward in the immediate neighborhood of the left antapical region.

PHYSIOLOGICAL CHARACTERS

In the matter of *size* each species has its characteristic limitations, the range in size increasing with the amount and geographical distribution of the material, in which, however, the greater part of the individuals are grouped about a mean. Thus five are very small (22–40μ), *G. catenata, palustris, scrippsae, series* and *spinifera;* four are small (40–60μ), *G. polyedra, sphaeroidea, triacantha* and *turbynei;* five are of medium size (60–80μ), *G. alaskensis, apiculata, digitale, milneri* and *polygramma;* five are large (80–100μ), *G. ceratocoroides, diegensis, fragilis* and *hyalina;* four are very large (100-120μ), *G. birostris, glyptorhynchus, highleii,* and *kofoidi;* and three are giants (130–250μ), *G. inflata, mitra* and *pacifica.*

In *type of asexual reproduction* two species exhibit very distinct features which set them off from all others. In *G. catenata* Levander (1894a) has described a type of chain formation with accompanying skeletal fission, while in *G. series* I (1911a) have found chain formation with accompanying reduction in size of the terminal members of the series and what appears to be skeletal formation in entirety *de novo* after chain formation. In no other species has chain formation been noted, though normal binary fission of cell body and skeleton alike occur in a large number and possibly in all of them.

The *distribution* of the species is characteristic. Two only are known from fresh water, *G. apiculata* and *G. palustris;* one, *G. catenata,* from the brackish water of the Baltic, and one, *G. triacantha,* appears to be a northern circumpolar neritic form. By far the greater part of the species are primarily tropical or of the warm temperate zone; here belong *G. birostris, ceratocoroides, fragilis, glyptorhynchus, highleii, hyalina, inflata, kofoidi, milneri, mitra, pacifica, polygramma, sphaeroidea,* and *turbynei.* Many of these invade temperate and even far northern or far southern waters sparingly with currents from equatorial regions. The species which appear to have a predominantly temperate distribution are *G. alaskensis, diegensis, digitale, polyedra, scrippsae* and *spinifera,* though these also invade tropical and circumpolar regions to some extent. The *marked increase in speciation in waters of higher temperature is noteworthy.*

Nothing is known yet of their vertical distribution.

The relative numbers in which the species occurs is also a characteristic. In *G. polyedra* we have a species which may occur sporadically in overwhelming numbers, others, such as *G. digitale, polygramma, spinifera, pacifica, catenata, diegensis* and *triacantha* may be locally common, or have a wide distribution, while others, as in the case of most of the tropical species, have been met with in small numbers and rarely, in a few cases only, singly as yet.

Fragility of the shell is another physiological feature of *Gonyaulax* which is noticeable in the genus as a whole, but with wide divergencies among the species. It is very rarely, for example, that one finds an intact theca of *G. fragilis*, or its relatives in the subgenus *Steiniella*. Likewise *G. catenata* is excessively fragile, while *G. polyedra* and members of the *birostris* group are prone to part in the apical region. On the other hand in most species the sutures on the right shoulder of the theca and of the ventral area posterior to its anterior plate are separated with great difficulty, if at all.

The habit of ecdysis is allied to this proneness to disintegrate on the part of the thecal wall. In *G. polyedra, G. polygramma, G. spinifera* and perhaps in others members of the group to which these belong, the ecdysis is frequently seen, and it is no unusual thing to find empty thecae of many of the species with dorsal apical plates torn loose or missing, in the plankton.

F. SUMMARY

1. The genus is redefined on the basis of its skeletal morphology. The skeleton consists of three (three to six) apicals, no or one (none to four) anterior intercalaries, six precingulars, six girdle plates, six postcingulars, the posterior intercalary, one antapical and the plates of the ventral area.

2. The so-called ''longitudinal furrow'' extending to the apex is not in any morphological or functional meaning a furrow, but merely the narrow apical plate *1'*, the homologue of the rhomb plate of *Peridinium*.

3. There is always a minute closing platelet in the apex and a ventral pore (with several exceptions) on the right ventral

apical or anterior intercalary plate to the right of the mid-ventral line.

4. The ventral area or true longitudinal furrow consists of an anterior plate indenting the epitheca and bearing on its post-margin the flagellar pore; and an intermediate region of two to four small plates, and a large posterior plate.

5. The fission line in dividing thecae is described.

6. The genus is revised, twenty-five species being recognized, fourteen recorded from coasts of California, and four new ones, *G. alaskensis, G. diegensis, G. scrippsae, G. sphaeroidea* described. The synonomy, variation and distribution of each is discussed.

7. The all-pervading character of specific differences in both morphological and physiological details is described.

8. The apical region and ventral area, regions coming most in contact with the environment are most subject to diversification.

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G. BIBLIOGRAPHY

AURIVILLIUS, C. W. S.

1898. Vergleichende thiergeographische Untersuchungen über die plankton-Fauna des Skageraks in den Jahren 1893–1897. Kgl. Sv. Vet. Akad. Handl., **30**, No. 3, 427 pp., 15 figs.

BERNARD, CH.

1908. Protococcacées et Desmidiées d'eau douce, recoltées à Java et descrites par Ch. Bernard (Dept. de l'Agriculture aux Indes Néerlandaises (Batavia), 230 pp., 16 pls., 1908.

BÜTSCHLI, O.

1885a. Einige Bemerkungen über gewisse Organisationsverhältnisse der sog. Cilioflagellaten und der *Noctiluca*. Morphol. Jahrb., **10**, 529–577, pls. 26–28.

1885b. ''Dinoflagellata'' *in* Bronn's ''Kl. u. Ordn.,'' **1**; Abth. II, pp. 906–1029, pls. 51–55.

CLAPARÈDE, E., ET LACHMANN, J.

1858–1859. Études sur les Infusoires et les Rhizopodes. Mém. Inst. Genèv., **5**, mém. 3, pp. 1–260, pls. 1–13, 1858; **6**, mém. 1 (un.), pp. 261–482, pls. 14–24, 1859.

CLEVE, P. T,

1900a. Notes on some Atlantic Plankton Organisms. Kgl. Sv. Vet. Akad. Handl., **34**, no. 1, 22 pp., 8 pls.

1900b. The plankton of the North Sea, the English Channel and the Skagerak in 1899. *Ibid.*, no. 2, 77 pp.

1901a. The seasonal distribution of Atlantic plankton organisms. Göteborgs Kungl. Vet.-Vitterh. Samh. Handl., (4), **3**, Art. 3, 369 pp.

1901b. Plankton from the Indian Ocean and the Malay Archipelago. Kgl. Sv. Vet. Akad. Handl., **34**, no. 5, 58 pp., 8 pls., 2 text figs.

1902. Additional notes on the season distribution of Atlantic organisms. Göteborgs Kungl. Vet.-Vitterh. Samh. Handl., (4), **4**, Art. 1, 51 pp.

1903. Report on plankton collected by Mr. Thorild Wulff during a voyage to and from Bombay. Arkiv. Zool., **1**, 329–381, pls. 16–19.

DARWIN, CHARLES.

1871. Journal of researches into the natural history and geology of the countries visited during the voyage of H. M. S. "Beagle" round the world under the command of Capt. Fitz Roy, R. N. (New York, Appleton). x, 519 pp., figs.

DELAGE, Y. ET HÈROUARD, E.

1896. Traité de zoologie concrète. I. La cellule et les Protozoaires (Paris, Reinwald). xxx, 584 pp., 890 text figs.

DIESING, K. M.

1866. Revision der Prothelminthen, Abtheilung: Mastigophoren. Sitzber. math. nat. wiss. Cl., Akad. Wiss. Wein., **52,** Abt. 1, pp. 287–402.

EHRENBERG, C. G.

1836. Ueber das Massenverhältniss der jetzt lebenden Kiesel-Infusorien und über ein neues Infusorien-Conglomerat als Polirschiefer von Jastraba in Ungarn. Abhandl. Berlin Akad., **1836,** 111–135, 2 pls.

1838. Die Infusionsthierchen als vollkommene Organismen. Ein Blick in das tiefere organische Leben der Natur (Leipzig, Voss). xviii (4), 547 (1) pp., 44 pls.

1854. Mikrogeologie. Das Erden und Felsen schaffende Wirken des unsichtbar kleinen selbständigen Lebens auf der Erde (Leipzig, Voss). xxviii, 374, 31, 88 pp., 30 pls.

1859. Ueber das Leuchten und über neue mikroskopische Leuchtthiere des Mittelmeeres. Monatsb. d. Berlin Akad., **1859,** 727–738, 791–793.

1873. Die das Funkeln und Aufblitzen des Mittelmeeres bewirkenden unsichtbar kleinen Lebensformen. Festschrift z. Feier d. hundertjähr. Bestehens d. Ges. naturforsch. Freunde in Berlin, 1873, 1–4 pp., 1 pl.

ENTZ, G. JR.

1902. A Quarnero Peridineái. (Die Peridinieen des Quarnero). Növénytani Közlemények, **1,** 83–96, pls. 1–6.

1904. Beiträge zur Kenntniss des Planktons des Balatonsees. Result. wiss. Erforsch. d. Balatonsees. **2,** 1 Theil, Anhang, pp. 1–37, 17 (79) figs., 9 pls., 1906. Reprint dated 1904.

1905. Beiträge zur Kenntniss der Peridineen. I Die Peridineen des Quarnero und das Variieren mariner Ceratien. II Homologie des Panzers und der Teilung der Phalacromeen und Ceratien. Math. naturw. Ber. Ungarn, **20,** 96–144, figs. 1–47, 1–66.

1907. A Peridineák Szervezetéröl. Állattani Közlemények, **6,** 11–30, 49–50, pls. 2–4.

1909. Ueber die Organizationsverhältnisse einiger Peridineen. Math. naturw. Ber. Ungarn, **25,** 246–274, pls. 8–11.

Fauré-Fremiet, E.

1908. Etude descriptive des Péridiniens et des infusoires ciliés du plankton de la Baie de la Hougue. Ann. Sci. Nat. Zool., (9), **7,** 209–243, pls. 15–16, 22 figs. in text.

Gourret, P.

1883. Sur les Péridiniens du Golfe de Marseille. Ann. Mus. Marseille, **1,** no. 8, 114 pp., 4 pls.

Henckel, A.

1909. Materials of the phytoplankton of the Caspian Sea. Scripta Bot., **27,** 246 pp., 36 pls. (Russian).

Jörgensen, E.

1899. Protophyten und Protozoën im Plankton aus der norwegischen Westküste. Bergens Mus. Aarbog, **1899,** no. vi, 112, lxxxiii pp., 5 pls.

1905. The Protist plankton and the diatoms in bottom samples. Bergens Museums Skrifter, **1905,** 23–254, 21 pls., 10 text figs.

Karsten, G.

1906. Das Phytoplankton des atlantischen Oceans nach dem Material der deutschen Tiefsee-Expedition, 1898–1899. Wiss. Ergebn. d. deutsch. Tiefsee Exp., **2,** Teil 2, pp. 137–219, pls. 20–34.

1907. Das Indische Phytoplankton. *Ibid.*, pp. 220–548, pls. 35–54.

Kofoid, C. A.

1906a. Dinoflagellata of the San Diego region. 1. On *Heterodinium*, a new genus of the Peridinidae. Univ. Calif. Publ. Zool., **2,** 341–368, pls. 17–19.

1906b. On the structure of *Gonyaulax triacantha* Jörg. Zool. Anz., **30,** 102–105 pp., 3 figs.

1906c. A discussion of species characters in *Triposolenia* I. The nature of species characters. II. The adaptive significance of species characters. III. The coincident distribution of related species. Univ. Calif. Publ. Zool., 3; 117–126.

1907a. Reports on the scientific results of the Expedition to the Eastern Tropical Pacific, in charge of Alexander Agassiz, by the U. S. Fish Commission Steamer "Albatross," from October, 1904, to March, 1905, Lieut. Commander L. M. Garrett, U. S. N., commanding. IX. New Species of Dinoflagellates. Bull. Mus. Comp. Zool. Harvard College, **50,** 161–208, pls. 1–17, 1 chart.

1907b. Dinoflagellata of the San Diego region. III. Description of new species. Univ. Calif. Publ. Zool., **3**, 299–340, pls. 22–33.

1909a. Reports on the scientific results of the expedition to the Eastern Tropical Pacific, in charge of Alexander Agassiz, by the U. S. Fish Commission Steamer "Albatross," from October, 1904, to March, 1905, Lieut. Commander L. M. Garrett, U. S. N., commanding. XX. Mutations in *Ceratium*. Bull. Mus. Comp. Zool. Harvard College, **52**, 211–257, 4 pls., 5 text figs.

1909b. On *Peridinium steini* Jörgensen, with a note on the nomenclature of the skeleton of the Peridinidae. Arch. f. Prot., **16**, 25–47, pl. 2.

1910. A revision of the genus *Ceratocorys* based on skeletal morphology. Univ. Calif. Publ. Zool., **6**, 177–187.

1911a. On a peculiar form of schizogony in *Gonyaulax*. Bull. Mus. Comp. Zool. Harvard College. (In press).

1911b. On the skeletal morphology of *Gonyaulax catenata* (Levander). Univ. Calif. Publ. Zool., v. **8**, 287–294, pl. 18.

1911c. Dinoflagellata of the San Diego Region. V. On *Spiraulax*, a new genus of the Peridinidae. *Ibid.*, pp. 295–300, pl. 19.

Levander, K. M.

1894a. *Peridinium catenatum* n. sp. Eine kettenbildende Peridinee im finischen Meerbusen. Acta Soc. Faun. Fenn., **9**, no. 10, 18, 1 pp., 1 pl., 4 text figs.

1894b. Materialien zur Kenntniss der Wasserfauna in der Umgebung von Helsingfors mit besonderer Berücksichtigung der Meeresfauna. I. Protozoa. Acta Soc. Faun. Fenn., **12**, no. 2, 115 pp., 3 pls.

Lemmermann, E.

1899. Ergebnisse einer Reise nach dem Pacific. (H. Schauinsland, 1896–97). Planktonalgen. Abh. Ver. Bremen, **16**, 313–398. pls. 1–3.

1907. Brandenburgische Algen IV. *Gonyaulax palustris* Lemm., eine neue Süsswasser-Peridinee. Bot. Centralbl., **21**, Abt. 2, pp. 296–300, 5 text figs.

Linko, A. K.

1907. Investigations on the plankton of Barents Sea. Scientific-practical Murman Expedition (St. Petersburg). iv, 247 pp., 20 text figs. (Russian).

Meunier, A.

1910. Microplankton des mers de Barents et de Kara. Duc d'Orleans Campagne arctique de 1907 (Bulens, Bruxelles). xviii, 355 pp., 37 pls.

MURRAY, G. AND WHITTING, F.

1899. New Peridiniaceae from the Atlantic. Tr. Linn. Soc. London, Botany (2), 5, 321–342, 9 tables, pls. 27–33.

NISHIKAWA, T.

1901. *Gonyaulax* and the discolored water in the Bay of Agu. Annot. Zool. Japon., 4, 31–34.

OKAMURA, K.

1907. An annotated list of plankton microrganisms of the Japanese Coast. Annot. Zool. Japan, 6, 125–151, pls. 3–6.

OSTENFELD, C. H.

1899. "Plankton" *in* "Iagttagelser over Overfladevandets Temperatur, Saltholdighed og Plankton paa islandske og grönlandske Skiberouter i 1898 foretagne under Ledelse af C. T. Wandel," pp. 48–93, tables 1–8.

1900. "Plankton i 1899" *in* "Iagttagelser, etc.," pp. 44–95, tables 1–8.

1901. Phytoplankton fra det Kaspiske Hav. Vid. Medd., 1901, 129–139, 10 text figs.

1903. Phytoplankton from the sea around the Faeroes. Botany of the Faeroes, 2, 558–611, text figs. 119–144.

1906. Catalogue des espèces de plantes et d'animaux observées dans le plankton recueilli pendant les expéditions périodiques depuis le mois d'Août 1902 jusqu'au mois Mai 1906. Cons. Perm. Intern. Expl. de la Mer. Publ. de Circ., no. 33, 22 pp.

1908. The Phytoplankton of the Aral Sea and its affluents, with an enumeration of the algae observed. Wiss. Ergebn. Aralsee Exped., part 8, 123–225, pls. 5–7, 1 folded table, 3 text figs.

1909. Catalogue des espèces de plantes et d'animaux observées dans le plankton recueilli pendant les expéditions périodiques depuis le mois d'Août jusqu'au mois de Mai 1908. Cons., Perm. Intern. Expl. de la Mer. Publ. de Circ., no. 48, 151 pp.

OSTENFELD, C. H., OG PAULSEN, O.

1904. Planktonpröver fra Nord-Atlanterhavet (c. 58°–60° N Br.), samlede i 1899 af Dr. K. J. V. Steenstrup. Medd. om Grönland, 26, 143–210.

OSTENFELD, C. H., OG SCHMIDT, J.

1901b. Plankton fra det Röde Hav og Adenbugten. Vid. Medd., 1901, 141–182, 30 text figs.

Paulsen, O.

1903. Plankton tables for Denmark, August and November, 1903. Bull. Rés. Courses Périod. Cons. Perm. Intern. Expl. de la Mer, Année 1903–1904. Part D, pp. 88–92.

1904. Plankton investigations in the waters round Iceland in 1903. Medd. Komm. Havundersög. Serie: Plankton, **1**, no. 1, 39, 2 pp., 2 maps.

1907. The Peridiniales of the Danish waters. *Ibid.*, no. 5, 26 pp., 33 text figs.

1908. ''Peridiniales'' *in* Brandt und Apstein ''Nordisches Plankton'' (Kiel und Leipzig, Lipsius und Tischer). No. 18, 124 pp., 155 text figs.

Pavillard, J.

1905. Recherches sur la flore pélagique (phytoplankton) de l'étang de Thau. Travail de l'Institut Bot. de l'Universite de Montpellier, Série Mixte. Mem. no. 2, 116 pp., 1 carte, 3 pls.

1909. Sur les Péridiniens du Golfe du Lion. Bull. Soc. Bot. de France, (4) **9**, 277–284, 5 text figs.

Penard, E.

1891. Les Péridiniacées du Léman. Bull. Trav. Soc. Bot. Genève, **6**. Reprint, 63 pp., 5 pls.

Pouchet, G.

1883. Contribution à l'histoire des cilio-flagellés. J. Anat. Physiol., **19**, 399–455, pls. 18–21, 50 text figs.

Schmidt, Johs.

1901. Preliminary report on the botanical results of the Danish Expedition to Siam (1899–1900). Flora of Koh Chang. Contributions to the knowledge of the vegetation in the Gulf of Siam. Part IV. Peridiniales. Bot. Tidsskrift, **24**, 129–138, 8 text figs.

1905. The pelagic and post-larval stages of the Atlantic species of *Gadus.* Part I. Medd. Komm. Havundersög. Serie: Fiskeri, **1**, no. 4, 77 pp., 3 pls., 16 text figs.

1906. *Idem.*, Part II. *Ibid.*, 20 pp., 1 pl.

Schröder, Br.

1900. Das Phytoplankton des Golfes von Neapel nebst vergleichenden Ausblicken auf das atlantischen Oceans. Mitt. Zool. Sta. Neapel, **14**, 1–38, pl. 1.

1906. Beiträge zur Kenntniss des Phytoplankton warmer Meere. Vierteljahrschr. Nat. Ges. Zurich, **51**, 319–377, 46 text figs.

SCHÜTT, F.

1887. Ueber die Sporenbildung mariner Peridineen. Ber. deutsch. bot. Ges., 5, 364–374, pl. 18.

1895. Die Peridineen der Plankton-Expedition. Ergebnisse Plankton-Expedition der Humboldt-Stiftung, 4, M. a. A., 170 pp., 27 pls.

1896. "Peridiniales" *in* Engler. u. Prantl. "Nat. Pflanzenfamilien" (Leipzig, Englemann), 1 Teil, 1 Abt., 30 pp., 43 text figs.

STEIN, F.

1883. Der Organismus der Infusionsthiere. III. Abt., 2 Hälfte. Die Naturgeschichte der Arthrodelen Flagellaten. 30 pp., 25 pls.

STÜWE, W.

1909. Phytoplankton aus dem Nord-Atlantik im Jahr 1898 u. 1899. Botan. Jahrb. f. Syst., Pflanzengesch. u. Planzengeogr., 43, 225–302, pls. 1, 2. Also as Inaug. Diss. Greifswald.

STREETS, T. H.

1878. The discolored waters of the Gulf of California. Am. Nat., **12**, 85–92.

TORREY, H. B.

1902. An unusual occurrence of Dinoflagellata on the California coast. Am. Nat., **36**, 187–192, 3 text figs.

WHITELEGGE, T.

1891. On the recent discoloration of the waters of Port Jackson. Rec. Australian Mus., **1**, 179–192, pl. 28.

VAN BREEMEN, P. J.

1905. Plankton van Noordzee en Zuiderzee. Tijdschr. Nederland. Dierk. Vereen., (2) **9**, 145–324, pls. 6–7, 21 text figs.

VAN HÖFFEN, E.

1897. Die Fauna und Flora Grönlands, Grönland Exped. d. Ges. f. Erdkünde zu Berlin, 1891–1893, **2**, 249–253, pl. 5.

WRIGHT, R. R.

1907. The plankton of eastern Nova Scotia waters. An account of floating organisms upon which young food fishes mainly subsist. Further contributions to Canadian biology, being studies from the Marine Biological Station of Canada, 1902–1905. Ann. Rept. of the Dept. of Marine and Fisheries, Fisheries Branch, Ottawa, **39**, 1–18, pls. 1–7.

ZACHARIAS, O.

1906. Ueber Periodizität, Variation und Verbreitung verschiedener Planktonwesen in südlichen Meeren. Arch. Hydrobiol. u. Planktonkunde, **1**, 498–575, 23 text figs.

EXPLANATION OF PLATES

PLATE 9

Gonyaulax digitale (Pouchet) Kofoid

Fig. 1. Ventral view of theca showing plates. Specimen from Loring, Alaska, September 15, 1905. × 1000.

Fig. 2. Ventral view of heavy theca possibly approaching fission. From 0–5 m., August, 1907, Faeroes Channel. × 1000.

Fig. 3. Ventral view, showing surface markings, from same collection as specimen in figure 2. × 1000.

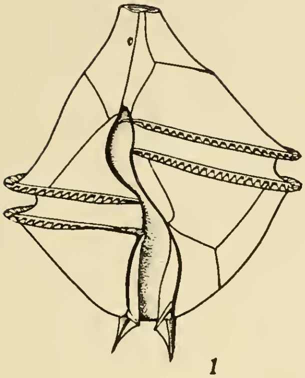
Fig. 4. Ventral view of heavily finned type. Loring, Alaska, September 15, 1905. × 1000.

Fig. 5. Ventral view of very rugose form with reticulations replacing spines in antapical fins. Surface reticulations shown only on plates *6″*, *1p*, and *1⁗*. From same collection as specimen shown in figure 2. × 1000.

ABBREVIATIONS

1–6—girdle plates.
1′–3′—apical plate.
1″–6″—precingular plates.
1‴–6‴—postcingular plates.
1p—posterior intercalary.
1⁗—antapical plate.
ant. pl.—anterior plate of ventral area.
ant. sp.—antapical spine.
cl. pl.—closing platelet.
f.—fin of ventral area.
fl. po.—flagellar pore.
int. pl.—intermediate plates of ventral area.
post. pl.—posterior plate of ventral area.
v. po.—ventral pore.

Figures 1, 2, 4, 5, drawn by Mrs. Josephine Rigden Michener, figure 3 by Miss Ethel Abeel.



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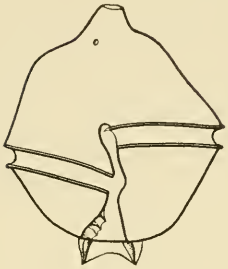

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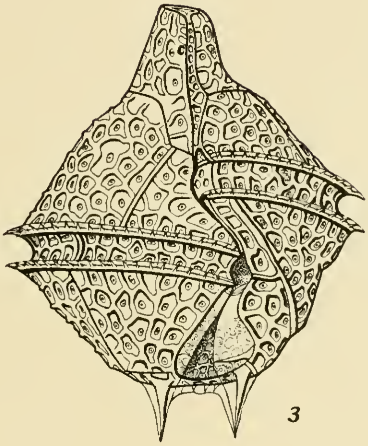

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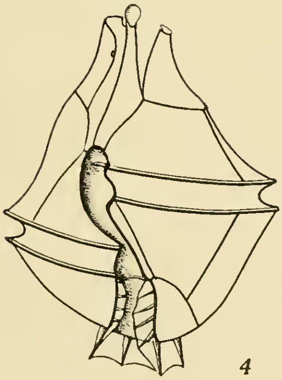

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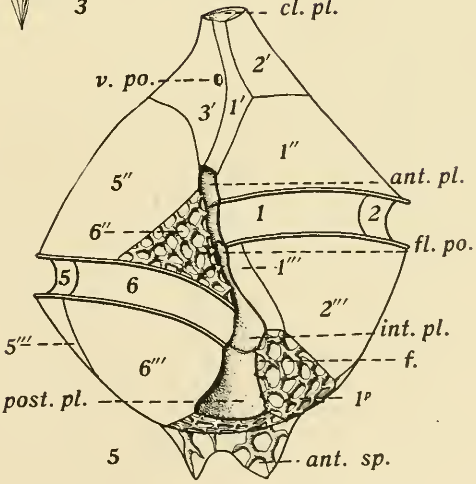

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PLATE 10

Fig. 6. Dorsal view of theca of *Gonyaulax polygramma* Stein, showing plates. San Diego, December 12, 1904. × 1000.

Fig. 7. Ventral view of same. The specimen figured shows an unusual number of antapical spines. × 1000.

Fig. 8. Ventral view of theca of *Gonyaulax spinifera* (Clap. et Lach.) Diesing *sensu stricta*. San Pedro Harbor, May 31, 1901.

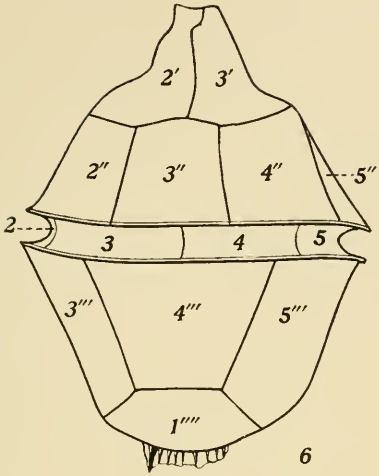
Fig. 9. Dorsal view of another individual from same collection, showing theca after recent fission. The newer moiety is smooth, the older reticulate. × 1000.

Fig. 10. Ventral view of same. × 1000.

ABBREVIATIONS

1–6—girdle series of plates.
1′–3′—apical series.
1″–6″—precingular series.
1‴–6‴—postcingular series.
1^p—posterior intercalary plate.
1⁗—antapical plate.
ant. pl.—anterior plate of ventral area.
ant. sp.—antapical spine.
cl. pl.—closing platelet of apical region.
f. l.—fission line.
fl. po.—flagellar pore.
int. pl.—intermediate plates of ventral area.
post. pl.—posterior plate of same.
v. po.—ventral pore.

Figures 6–8 drawn by Mrs. Josephine Rigden Michener; figures 9 and 10 by C. A. Kofoid and Mr. R. W. Harvey.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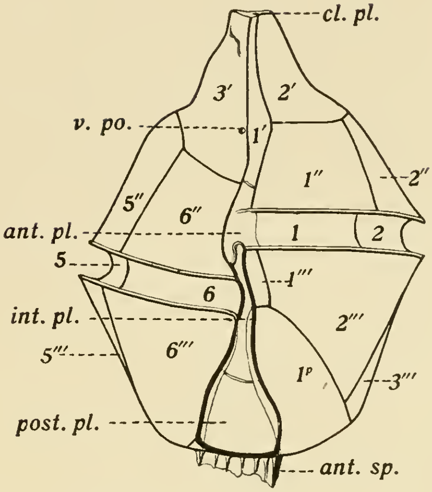
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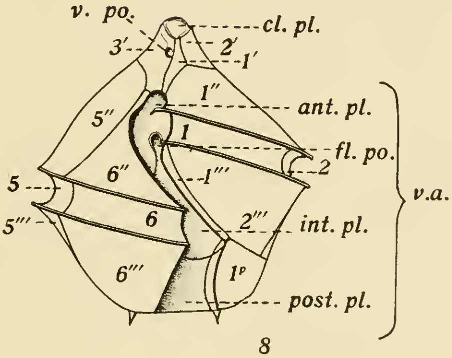
7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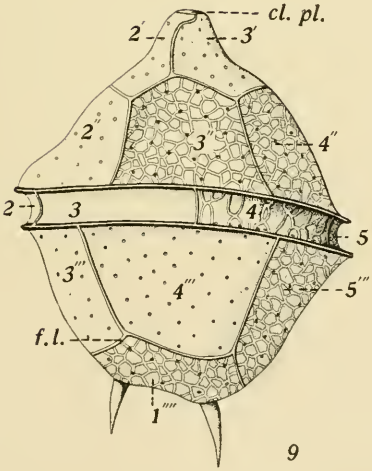
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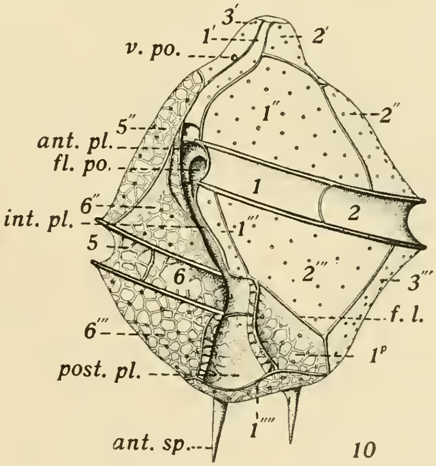
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ant. sp.
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10

PLATE 11

Gonyaulax triacantha Jörg.

All from specimens from Loring, Alaska, September 15, 1905.

Fig. 11. Antapical view of hypotheca. × 1000.

Fig. 12. Diagram of apical view of epitheca. × 1000.

Fig. 13. Ventral view of theca, with plates and surface markings. From an empty theca. × 1000.

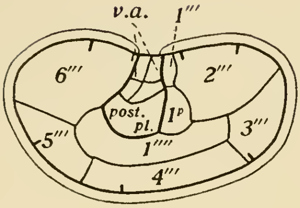
Fig. 14. Lateral view of same. × 1000.

Fig. 15. Dorsal view of same, showing plates and thickness of wall. Note solid antapical spines. × 1000.

ABBREVIATIONS

1–6—girdle plates.
1′–4′—apical plates.
1^a–2^a—anterior dorsal intercalaries.
1″–6″—precingulars.
1‴–6‴—postcingulars.
1^p—posterior intercalary.
1⁗—antapical.
a. sp.—antapical spines.
ant. pl.—anterior plates of ventral area.
cl. pl.—closing platelet.
f.—fin on margin of ventral area.
fl. po.—flagellar pore.
int. pl.—intermediate plates of ventral area.
l.—list of ventral area.
post. pl.—posterior plate of ventral area.
v. a.—ventral area.
v. po.—ventral pore.

Figures drawn by C. A. Kofoid, R. W. Harvey and Mrs. Josephine Rigden Michener.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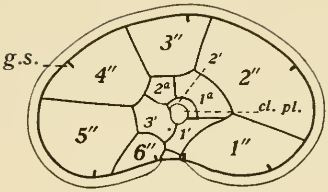
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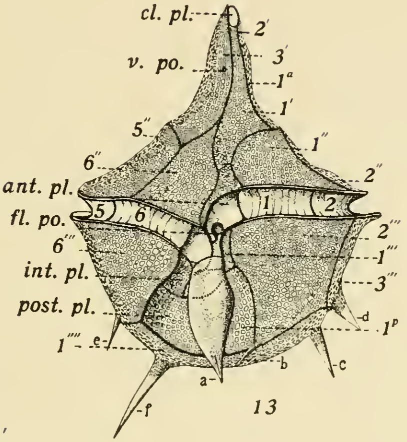
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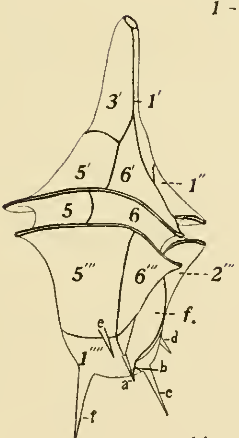
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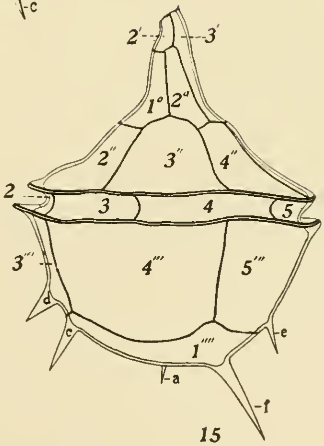
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15

PLATE 12

Gonyaulax polyedra Stein

All specimens from San Diego, June, 1904.

Fig. 16. Dorsal view of theca showing plates. × 1000.

Fig. 17. Ventral view of same. × 1000.

Fig. 18. Ventral view of recently divided theca, showing unmarked anterior moiety and porulate posterior one and the fission line (*f. l.*) × 1000.

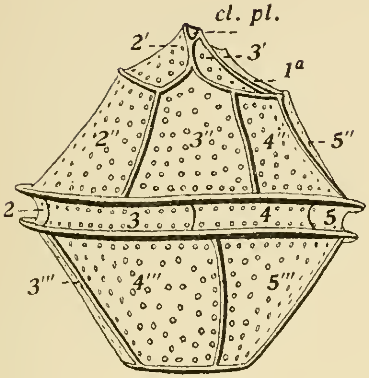
Fig. 19. Antapical view of hypotheca. ×1000.

Fig. 20. Apical view of epitheca with normal type of apical plates. × 1000.

ABBREVIATIONS

1–6—girdle series of plates.
1′–4′—apical series.
1^a–2^a—anterior intercalary plates.
1″–6″—precingular series.
1‴–6‴—postcingular series.
1^p—posterior intercalary plate.
1⁗—antapical plate.
ant. pl.—anterior plate of ventral area.
cl. pl.—closing platelet of apex.
f. l.—fission line.
fl. po.—flagellar pore.
int. pl.—intermediate plate of ventral area.
post. pl.—posterior plate of same.
v. po.—ventral pore.

Figures 16, 17, 19, and 20 drawn by Mr. D. B. Billinghurst, figure 18 by Mrs. Josephine Rigden Michener.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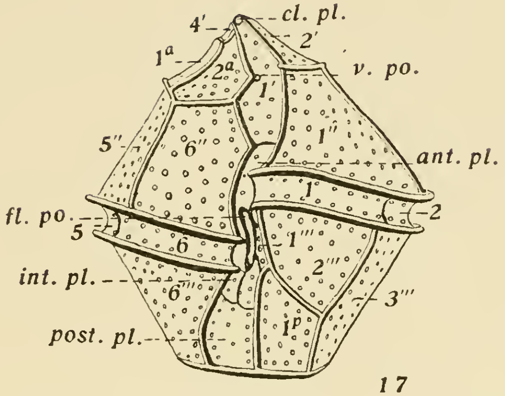
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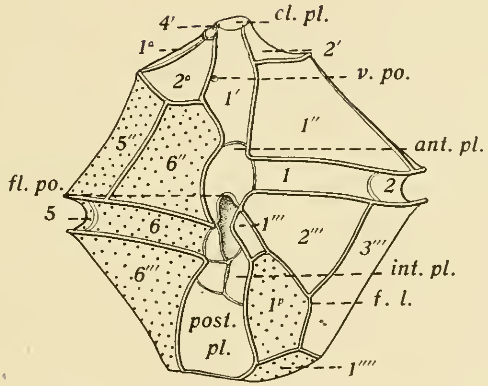
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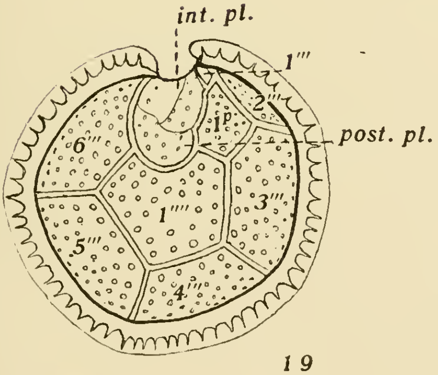
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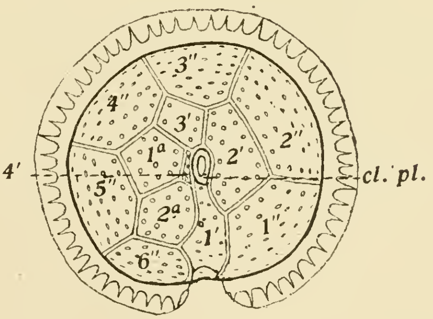
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PLATE 13

Fig. 21. Diagram of plates of hypotheca of *Gonyaulax diegensis* sp. nov. in antapical view. × 500.

Fig. 22. Surface view of apical closing platelet of same. × 1000.

Fig. 23. Diagram of plates of epitheca of same in apical view. × 500.

Fig. 24. Ventral view of theca of rugose specimen with wide intercalary bands. Figures 21–24 all from specimens taken June 21, 1904, on the "New Cod Ground," off San Diego, California.

Fig. 25. A precingular plate of *Gonyaulax* (*Steiniella*) *fragilis* (Schütt) showing surface markings. Note nodal pores and partial submergence of linear markings. San Pedro Harbor, California, May 31, 1901. × 1000.

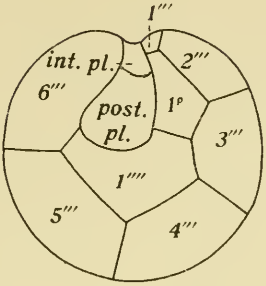
Fig. 26. Antero-dorsal view of theca of *Gonyaulax scrippsae* sp. nov. Channel, San Pedro Harbor, California, May 29, 1901. × 1000.

Fig. 27. Ventral view of theca of same. × 1000.

ABBREVIATIONS

1′–4′—apical series of plates.
1″–6″—precingular series.
1‴–6‴—postcingular series.
1p—posterior intercalary plate.
1⁗—antapical plate.
ant. pl.—anterior plate of ventral area.
cl. pl.—closing platelet of apex.
fl. po.—flagellar pore.
int. pl.—intermediate plates of ventral area.
post. pl.—posterior plate of same.
v. po.—ventral pore.

Figures 21–25 drawn by Mrs. Josephine Rigden Michener; figures 26, 27 by Mr. R. W. Harvey.



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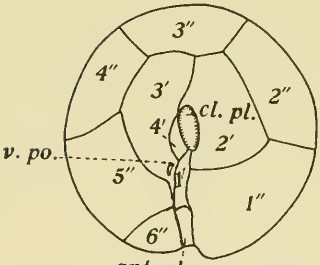

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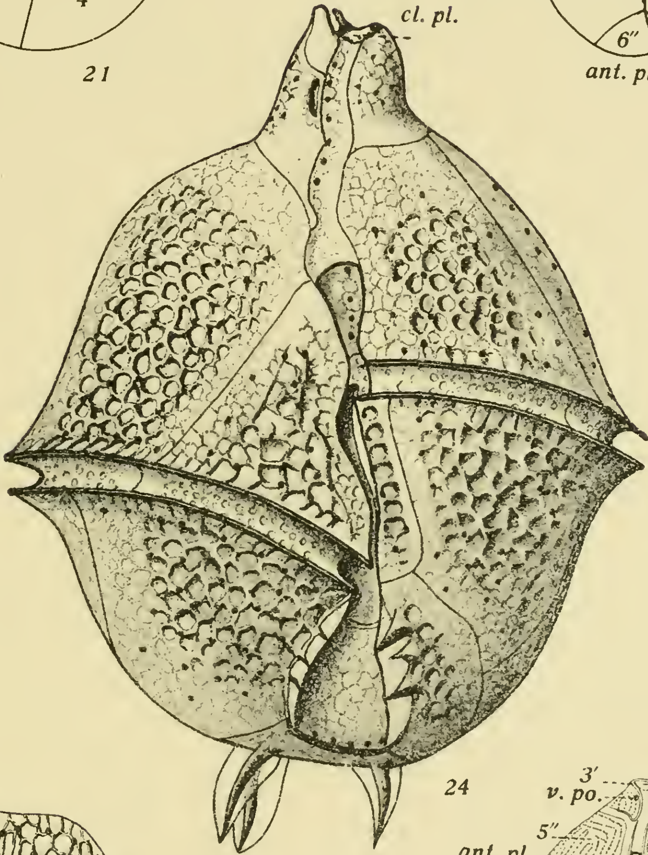

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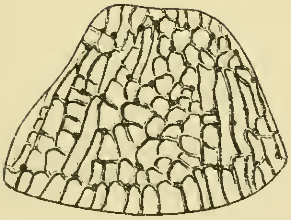

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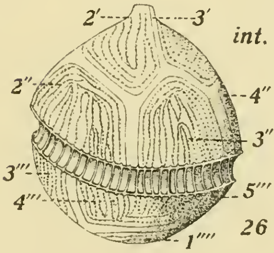

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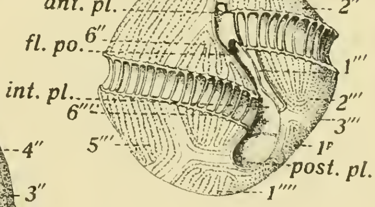

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PLATE 14

Fig. 28. Diagram of plates of epitheca of *Gonyaulax polyedra* Stein in apical view, showing an extra anterior dorsal intercalary. San Diego, California, July, 1904. × 1000.

Fig. 29. Same of another and much larger individual, showing contact of anterior intercalary 2^a with the apical region (*cl. pl.*). San Diego, California, July, 1904. × 1000.

Fig. 30. Ventral view of theca of *Gonyaulax kofoidi* Pavillard, showing parted apex, and surface markings. Seven miles WNW Point Loma, California, November 12, 1904. × 1000.

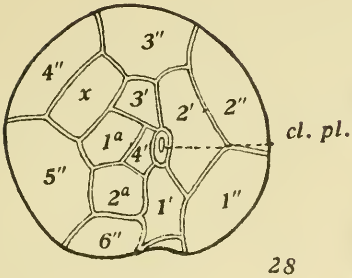
Fig. 31. Midventral region of theca of *Gonyaulax polyedra* Stein, showing markings, pores, and plates of ventral area. San Diego, July, 1904. × 1000.

Fig. 32. Apical view of epitheca of *Gonyaulax* (*Steiniella*) *alaskensis* sp. nov., showing plates. Loring, Alaska, September 15, 1904. × 1000.

ABBREVIATIONS

$1'$–$4'$—apical series of plates.
1^a–2^a—intercalary plates.
$1''$–$6''$—precingular series.
ant. pl.—anterior plate of ventral area.
cl. pl.—closing platelet of apex.
fl. po.—flagellar pore.
g. s.—girdle suture.
int. pls.—intermediate plates of ventral area.
post. pl.—posterior plate of same.
v. po.—ventral pore.
x.—extra anterior intercalary plate.

Figures 28, 29, and 31 drawn by Mr. B. D. Billinghurst; figures 30 and 32 by Mrs. Josephine Rigden Michener.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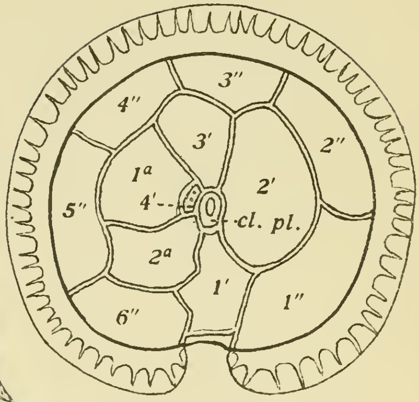
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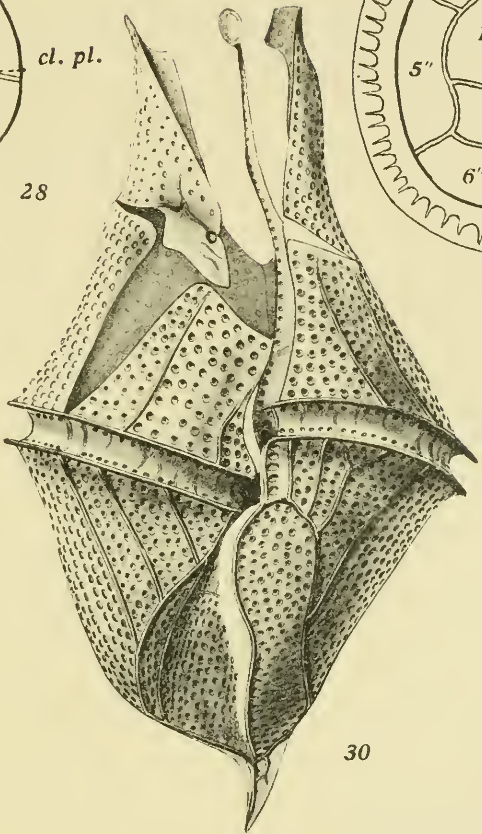

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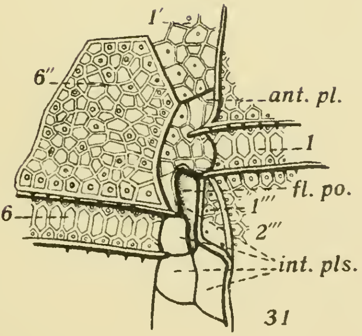
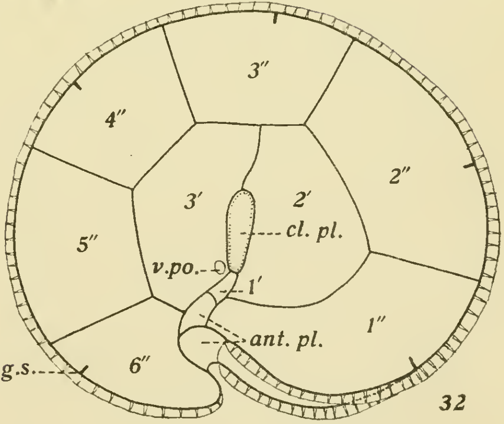

1′
6″
ant. pl.
1
fl. po.
1‴
6
2‴
int. pls.

31


3″
4″
2″
3′
2′
cl. pl.
5″
v.po.
1′
1″
ant. pl.
g.s.
6″

32

PLATE 15

Fig. 33. Antapical view of hypotheca of *Gonyaulax* (*Steiniella*) *fragilis* (Schütt), showing plates. San Pedro Harbor, California, May 31, 1901. × ca. 500.

Fig. 34. Apical view of epitheca of same, showing plates, girdle, and ventral area. Anterior plate, and plate *1′* stippled. × ca. 500.

Fig. 35. Oblique ventral view of *Gonyaulax pacifica* Kofoid with apicals parted. Seven miles WNW Point Loma, California, November 12, 1904. × 1000.

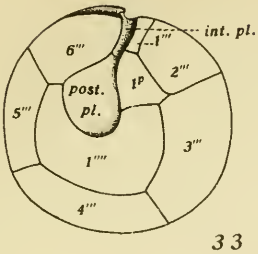
Fig. 36. Dorsal view of theca of *Gonyaulax fragilis* Schütt, showing plates. Same individual as figure 33. × ca. 500.

Fig. 37. Ventral view of same, showing plates, except subdivisions of intermediate region of ventral area. Girdle and ventral area stippled. × ca. 500.

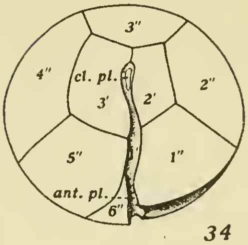
ABBREVIATIONS

1–6—girdle series of plates.
1′–3′—apical series.
1″–6″—precingular series.
1‴–6‴—postcingular series.
1^p—posterior intercalary plate.
ant. pl.—anterior plate of ventral area.
1⁗—antapical plate.
cl. pl.—closing platelet of apex.
fl. po.—flagellar pore.
int. pl.—intermediate plates of ventral area.
post. pl.—posterior plate of same.

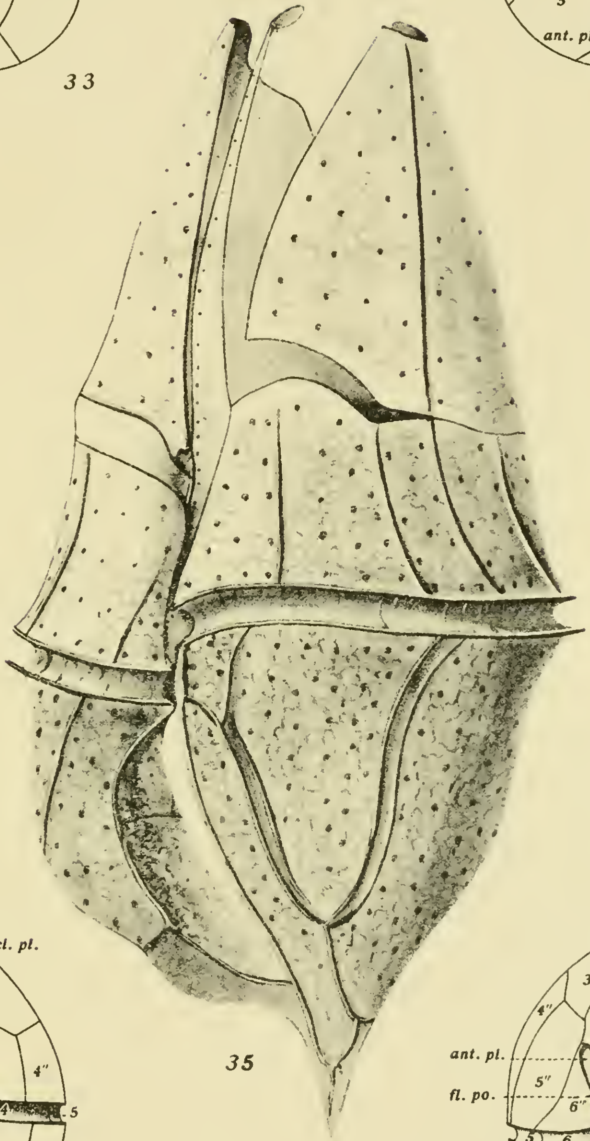
Figures drawn by Mrs. Josephine Rigden Michener.


int. pl.
6'''
1'''
post. pl.
1p
2'''
5'''
3'''
1''''
4'''

33


3''
4''
cl. pl.
3'
2'
2''
5''
1''
ant. pl.
6''

34



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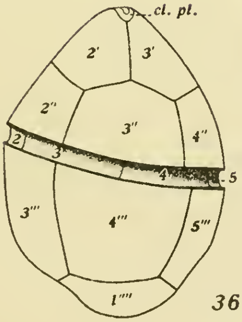
cl. pl.
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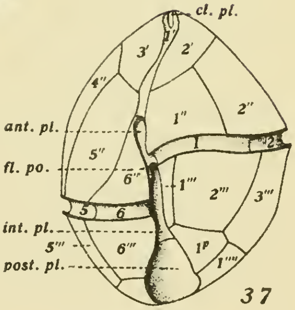
3'
2''
3''
4''
2
3
4
5
3'''
4'''
5'''
1''''

36


cl. pl.
1'
3'
2'
4''
1''
2''
ant. pl.
5''
1
2
fl. po.
6''
1'''
2'''
3'''
5
6
int. pl.
5'''
6'''
1p
post. pl.
1''''

37

PLATE 16

Fig. 38. Ventral view of *Gonyaulax scrippsae* sp. nov., showing surface markings. Channel, San Pedro Harbor, California, May 29, 1901. × 1000.

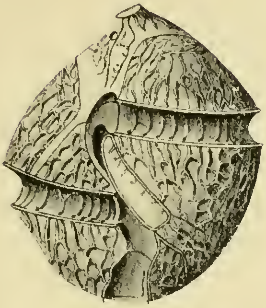
Fig. 39. Ventral view of *Gonyaulax spinifera* (Clap. et Lach.) Diesing *sensu strictu*. Loring, Alaska, September 15, 1904. × 1000.

Fig. 40. Ventral view of lightly reticulated individual of *Gonyaulax diegensis* sp. nov. with wide intercalary bands. New Cod Grounds, San Diego, California, June 23, 1904. × 1000.

Fig. 41. Postero-dorsal view of theca of *Gonyaulax sphaeroidea* sp. nov., showing surface structure. Nine miles WSW Point Loma, California, surface, November 26, 1904. × 1000.

Fig. 42. Ventral view of same.

Figure 38 drawn by Miss Ethel Abeel, figures 39–42 by Mrs. Josephine Michener.



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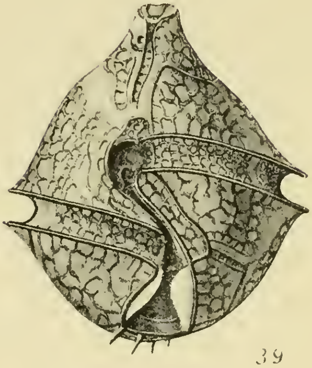

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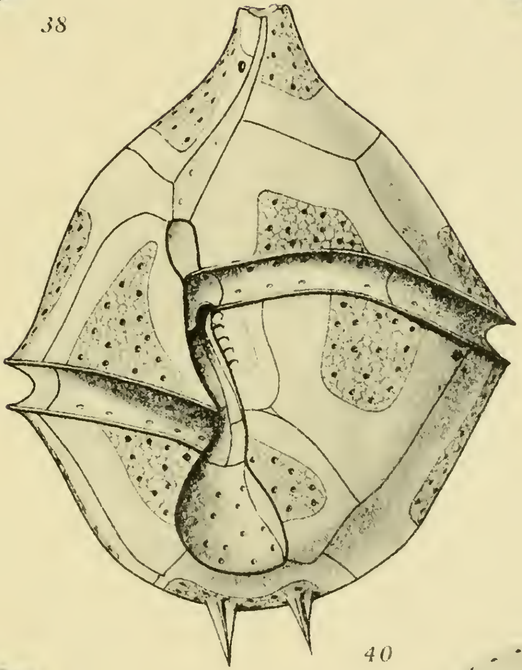

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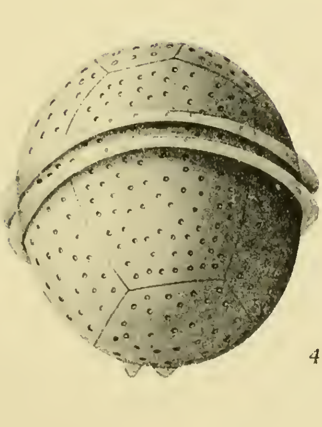

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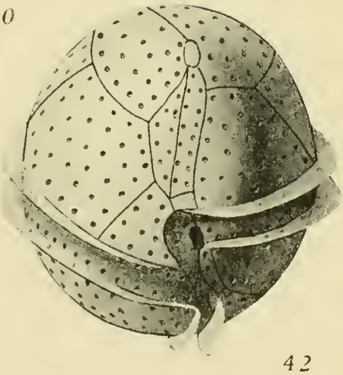


42

PLATE 17

Fig. 43. Ventral view of theca of *Gonyaulax polyedra* Stein, showing surface structure and plates. San Diego, California, June 23, 1904. × 1000.

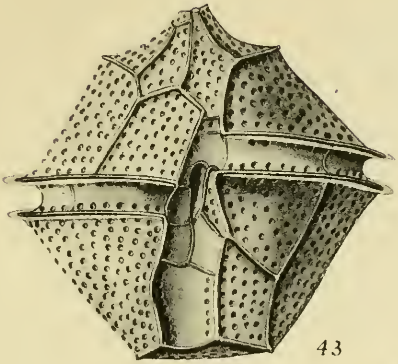
Fig. 44. Ventral view of *Gonyaulax turbynei* Murray and Whitting, showing surface structure. San Diego, California, July 12, 1904. × 1000.

Fig. 45. Ventral view of theca of *Gonyaulax* (*Steiniella*) *alaskensis* sp. nov., showing plates and surface structure. Loring, Alaska, September 15, 1904. × 1000.

Fig. 46. Dorsal view of same. × 1000.

Fig. 47. Ventral view of theca of *Gonyaulax polygramma* Stein, showing surface structure. San Diego, California, November 12, 1904. × 1000.

Figures 43, 44, 46, 47 drawn by Mrs. Josephine Rigden Michener. figure 45 by Miss Ethel Abeel.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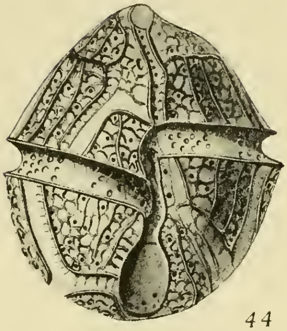
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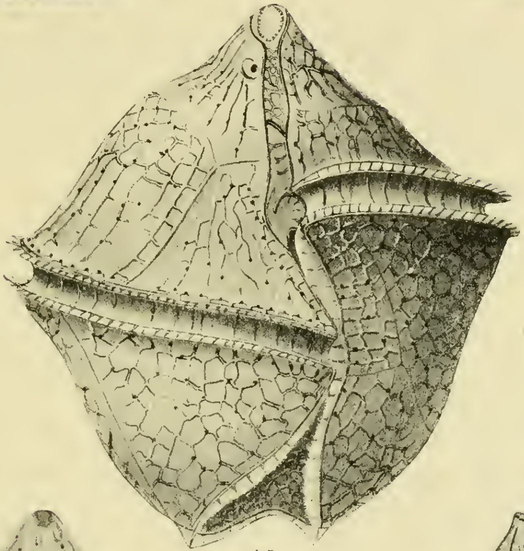
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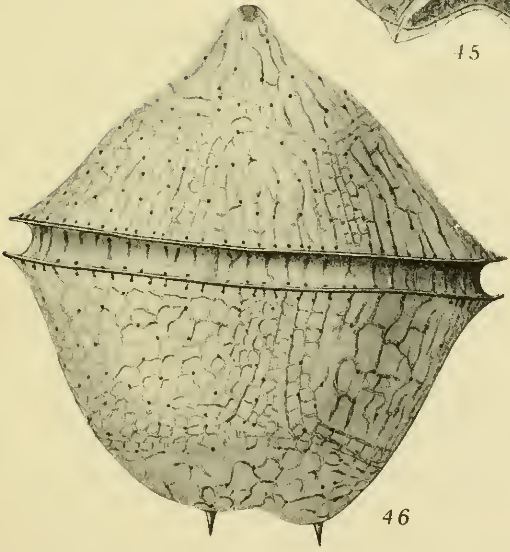
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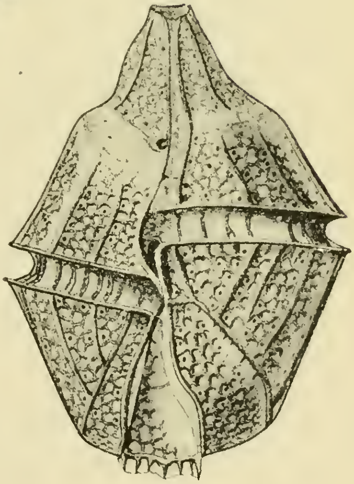
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UNIVERSITY OF CALIFORNIA PUBLICATIONS
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ZOOLOGY
Vol. 8, No. 5, pp. 287-294, pl. 18 September 14, 1911

ON THE SKELETAL MORPHOLOGY OF *GONYAULAX CATENATA* (LEVANDER)

BY

CHARLES ATWOOD KOFOID

Through the kindness of Dr. K. M. Levander of the University of Helsingfors, Finland, I have been enabled to make an examination of abundant material of his *Peridinium catenatum* (see Levander, 1894a), and to compare its skeletal structure with that of *Gonyaulax* described in the preceding paper (*Univ. Calif. Publ. Zool.*, vol. 8, no. 4). The material placed at my disposal is a collection made in the Gulf of Finland, May 26, 1900, from 20 meters to the surface. It abounds in isolated individuals and in chains of 2, 4, 6, or even 10 individuals. With this abundant material, apparently in a similar phase of thecal condition, I have been enabled to analyze the plates and thus to clear up some uncertainties regarding the skeletal structure of the organism and to demonstrate its close relationship to the genus *Gonyaulax*, so close indeed that it seems best to include it herein. My most cordial thanks are extended to Dr. Levander for his courtesy and to Mrs. Josephine Rigden Michener for the carefully made drawings which illustrate this paper.

In Levander's (1894a) account of the species he relates his analysis of the plates and concludes that the organism on that basis is most nearly related to *Peridinium*. In reaching this conclusion he was evidently influenced by the presence of a narrow midventral plate in the epitheca, apical *1′* of my nomenclature (pl. 18, fig. 2) and *r* of his (pl. 18, fig. 6), the homologue of the rhomb plate of *Peridinium*, and by the fact that the total number of plates in both his form and in *Peridinium* was apparently the same. Although he explicitly notes the general resemblance of the hypotheca to that of *Gonyaulax* he still concludes that "sowohl nach der Gestalt der Schale wie auch der *Zusammensetzung* derselben aus Tafeln schliesst unsere Art am meisten an die Gattung *Peridinium* an, in welche ich sie auch deshalb angereiht habe."

The diagrams of the plates of his *Peridinium catenatum* in an apical view of the epitheca and a view of the hypotheca from above looking toward the antapex are reproduced in plate 18, figures 6 and 7. The results of my analysis are shown in figures 1 and 2. The numbers and general relations of the plates in the epitheca are essentially similar in his diagram and my own, the differences being mainly in the relative dimensions of the plates and directions of the bounding sutures portrayed in the two diagrams.

In the analysis of the hypotheca, however, there are two differences between the two diagrams (figs. 2 and 7) which have an important bearing on the relationships of the species in question. Levander figures the hypotheca as composed of six postcingular plates (his "post-äquatorialen Felder" I, I′–V′), a midventral furrow plate, and a pentagonal antapical plate which in his figure is deeply invaded by an elliptical area (unlabeled) bearing the posterior point of connection with the adjacent member of the chain. As determined by me the hypotheca (pl. 18, fig. 1) consists of six postcingular *1‴–6‴* one posterior intercalary *1^p* one antapical *1⁗*, and the ventral area composed of several intermediate plates (*int. pl.*) and a widely expanded posterior plate (*post. pl.*) bearing the posterior attachment pore (*post. att. po.*). This plate is not deeply indented into the antapical. The hypotheca as thus analysed corresponds plate for plate with that of *Gonyaulax*, not of *Peridinium*.

Levander seems to have represented the relations of the antapical and posterior furrow plate in different fashion from that portrayed in my figure.

The plate formula for *Peridinium steini* as determined by me (1909) and that of *Gonyaulax spinifera* and *G. polyedra* and of Levander's *Peridinium catenatum* are given below.

TABLE OF PLATE FORMULAS

	Apicals	Anterior intercalaries	Precingulars	Girdle	Postcingulars	Posterior intercalary	Antapicals
Peridinium steini	$4'$	3^a	$7''$	3	$5'''$	0^p	$2''''$
P. catenatum	$4'$	4^a	$6''$	6	$6'''$	1^p	$1''''$
Gonyaulax spinifera	$3'$	0^a	$6''$	6	$6'''$	1^p	$1''''$
G. polyedra	$4'$	2^a	$6''$	6	$6'''$	1^p	$1''''$

The essential likeness of *P. catenatum* to *Gonyaulax* and its dissimilarity to *Peridinium* is at once apparent in the table. A detailed examination only serves to emphasize these conclusions, as follows:

The apical plates of *Peridinium* show marked uniformity and bilateral symmetry (See Stein, 1883, pls. 9–11, and Kofoid, 1909, pl. 2, fig. 1) while those of *Gonyaulax* (see preceding paper, pls. 9–17) usually show marked irregularities in size and position and also decided bilateral asymmetry which is usually more marked in the dorsal region and left face. This is also true of Levander's species. Apical $1'$ is not a subsymmetrical rhomb plate as in *Peridinium* but an asymmetrical narrow plate strikingly like that in *Gonyaulax*, running from the anterior margin of the anterior plate of the ventral area to the apex where it is connected with a small closing platelet (*cl. pl.*, pl. 18, fig. 2) just as in *Gonyaulax*. Again in *Peridinium* the anterior intercalaries are symmetrically placed mid-dorsal plates two or three in number, and of approximately equal size, or placed in nearly a bilaterally balanced relation. In Levander's species they (1^a–4^a) are irregular in size and lie somewhat upon the right dorsal shoulder, again just as in *Gonyaulax*, especially *G. polyedra* (see preceding paper, pl. 12, fig. 20.).

There are six precingulars ($1''$–$6''$) in Levander's species and in all species of *Gonyaulax*, and seven in *Peridinium*. Moreover in the latter genus plate *1''* is triangular or pentagonal and usually small. In *Gonyaulax* and in Levander's species *1''* is quadrangular and large.

The girdle plates (*1–6*) in *Gonyaulax* and in Levander's species are six in number with sutures approximately those of the two adjacent series in location. In *Peridinium* there are three with no dorsal sutures.

There are six postcingulars (*1'''–6'''*) in *Gonyaulax* and in Levander's species, and but five in *Peridinium*. Postcingular *1'''* in *Gonyaulax* is a very small plate, in *Peridinium* it is relatively much larger. In Levander's species it is relatively smaller than in any species of *Peridinium*, though still unusually large for *Gonyaulax*.

In Levander's species and in *Gonyaulax* there is always present a posterior intercalary plate, 1^p. This is absent in *Peridinium*, though possibly represented by the left antapical.

In *Peridinium* there are two nearly symmetrically placed antapical plates, in *Gonyaulax* and in Levander's species there is but a single median one *1''''*.

The *ventral area* of both *Peridinium* and *Gonyaulax* consists of an anterior and posterior plate, with several intermediate plates between. These plates in Levander's species much resemble those in those species of *Gonyaulax* in which the ventral area is wide and nearly straight as in *G. polyedra* and *G. triacantha*. The anterior plate is deeply notched by the flagellar pore (pl. 18, fig. 5) and the ventral area widens into the posterior plate as in *G. triacantha*. This plate is, however, relatively much wider in Levander's species than in any other species of *Gonyaulax*. *Peridinium* usually has a ventral notch at the apex while this is not found in any species of *Gonyaulax* nor in Levander's species. The ventral pore so generally present in *Gonyaulax* is not found in *Peridinium* and appears to be lacking in Levander's species, in which, however, the general porulation is greatly reduced.

From the facts detailed above I conclude that this interesting species of Levander's belongs in the genus *Gonyaulax* rather than in *Peridinium*. A brief description is here appended.

Gonyaulax catenata (Levander) Kofoid

Pl. 18, figs. 1–7.

Glenodinium cinctum, Pouchet (1883), p. 441, pl. 20/21, fig. 36, *fide* Cleve (1901a), p. 256.
Peridinium catenatum Levander (1894), pp. 1–19, pl. —, figs. 1–10.
P. catenatum, Van Höffen (1897), p. 267, pl. 5, fig. 5.
Amylax catenata, Meunier (1910), p. 52, pl. 1bis, figs. 46, 47; pl. 3, figs. 28–34.

DIAGNOSIS: A minute species with the general form of a *Peridinium* but the plates of *Gonyaulax*. Plate formula $1'$, 4^a, $6''$, 6, $6'''$, 1^p, $1''''$. Posterior plate of ventral area exceeding 0.5 transdiameter in width. Several antapical spines present. Ring shaped starch grains. Fission with chain formation.

DESCRIPTION: *Body* rounded, flattened dorso-ventrally, length 0.85–0.95 transdiameter, dorso-ventral diameter (between levels of extremes) 0.75 transdiameter, in middorsal line about 0.5 transdiameter. Cross-section at girdle reinform. *Epitheca* slightly exceeds hypotheca, its right shoulder convex, its left slightly concave, its altitude 0.47 transdiameter, contracted distally to a low apical horn scarcely differentiated, with apex attaining a girdle with across and guarded laterally by two spine-like extensions of the apical plates (pl. 18, fig. 4). *Hypotheca* low and wide with concave postmargin 0.6 transdiameter across, its altitude 0.4 transdiameter, deeply excavated ventrally.

Girdle equatorial, descending, displaced distally 1 girdle width, without overhang, often constricted middorsally (pl. 18, fig. 4) near the fission line (between girdle plates *3* and *4*). The furrow is deeply impressed, with scarcely salient ridges, and no fins. The *ventral area* is exceptionally open, very slightly indenting the epitheca and expanding posteriorly to a width of 0.6 transdiameter and reaching the postmargin. Its width at the distal posterior girdle ridge equals or exceeds that of the girdle.

The *plate formula* is $1'$, 4^a, $6''$, 6, $6'''$, 1^p, $1''''$ (pl. 18, figs. 1, 2). *Apical* $1'$ is very slender, about 0.3 girdle width across, $2'$ and $4'$ are elongated in the longitudinal and $3'$ in the transverse direction. The *anterior intercalaries* 1^a–4^a are very uneven in size, 1^a and 4^a on the left and right shoulders, and 2^a superposed (anteriorly) upon 3^a near the middorsal line. *Precingular* $6''$ is quadrangular and *postcingular* $1'''$ nearly square, 1 girdle width across and 1.5 long. *Posterior intercalary* 1^p is much wider than long. The anterior plate of the ventral area (pl. 18, fig. 5), is deeply notched on its posterior margin by the flagellar pore and a small extension meets apical $1'$. Two intermediate plates (*int. pl.*, pl. 18, fig. 1) of nearly equal size are plainly discernible and the wide posterior plate (*post. pl.*) reaches the postmargin and extends from the left antapical spine to the right face somewhat above the right spine.

The *surface* is marked by faint salient lines and a delicate tracery which rarely attains the condition of a meshwork. Several prominent pores are found along the girdle and several on the apical plates. No ventral pore could be with certainty distinguished. A delicate fin guards the left margin of the ventral area and two tapering antapical spines rise nearly 0.5 transdiameter apart from the antapical plate. They are 0.5 to 0.75 girdle width in length. The left one is sometimes double (fig. 5). Two or three accessory antapicals arise from the margins of the ventral area. Fins are scarcely developed upon any of the spines.

The individuals both isolated and in chain exhibit very clearly the attachment pores through which the protoplasmic continuity of sister cells in chain is maintained. The anterior pore (*ant. att. po.*, pl. 18, fig. 2) lies just dorsal to the apex in the upper edge of apical *3'*, not in the apex itself. The posterior pore (*post. att. po.*, pl. 18, fig. 1) is on the right side of the posterior plate of the ventral area. The apex and anterior attachment pore of *Ceratium* (see Kofoid, 1909) coincide. This fact raises the question as to the homology of the apex of *Ceratium* and that of *Gonyaulax*.

The plasma in the two individuals in chain (pl. 18, fig. 3) contained constricted nuclei (pl. 18, fig. 3); and all in the collection were crowded with globular, ring-shaped and occasional comma-shaped starch granules.

Chain formation was exceedingly common and chains of even ten individuals were noted.

DIMENSIONS: Length, 30μ; transdiameter, 33μ; dorso-ventral diameter, 16–22μ; width of girdle, 3–5μ; length of antapical spine, 2–4μ.

SYNONOMY: Cleve (1901a) is probably correct in regarding *Glenodinium cinctum* of Pouchet (1883) as Levander's (1894) *Peridinium catenatum*. Meunier (1910) includes this species in his new genus *Amylax*, a genus based on the presence of starch grains. On the basis of skeletal morphology this species is, however, a *Gonyaulax*, and I therefore reject his assignment. He has not analyzed the skeletal morphology of any species of his newly created genus.

COMPARISONS: Resembles *G. series* Kofoid in the fact that it forms chains but not in the method of their formation. In the presence of numerous antapical spines, wide ventral area, and especially wide posterior plate, this species is nearest *Gonyaulax triacantha*. It also approaches this species in having four anterior intercalaries in the right dorsal region. *G. triacantha* has two, while none, or but one, in the right ventral region is the usual arrangement. This species is perhaps worthy of subgeneric distinction.

Distribution: Known from the Baltic, and North Sea, the North Atlantic and waters about Greenland.

Described by Levander (1894a, b) from the winter and spring plankton of the Gulf of Finland with maximum in May; reported from the Baltic by Cleve (1897), Apstein (1908), Driver (1908), Kraefft (1900), and Lohmann (1908), and by various observers of the International Commission for the Investigation of the Sea (see Ostenfeld, 1906, 1909); from the coastal waters of Greenland by Van Höffen (1897); as rare in the North Atlantic, 66° to 69° N, 53° to 55° W, by Ostenfeld (1899) and by Ostenfeld and Paulsen (1904) as *Peridinium* sp., aff. *P. catenatum* as rare at ten stations in the North Atlantic, 59° to 60° N, 13° to 49° W.

It is plainly a boreal species with preference for neritic, brackish, waters, but occasionally oceanic.

For papers cited see bibliography of preceding paper.

Zoological Laboratory, University of California.
Transmitted June 13, 1911.

EXPLANATION OF PLATE 18

Gonyaulax catenata (Levander) Kofoid

All figures magnified 1400 diameters

Fig. 1. Antapical view of hypotheca, showing plates.

Fig. 2. Apical view of epitheca, showing plates.

Fig. 3. Two individuals in chain, showing cell contents, nucleus and starch grains.

Fig. 4. Dorsal view of theca, showing surface structure.

Fig. 5. Ventral view of same.

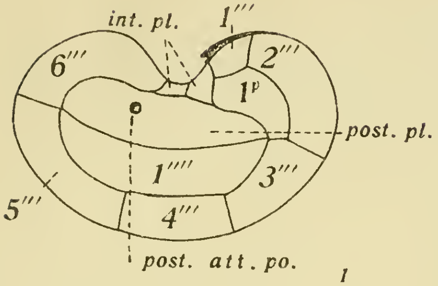
Fig. 6. Diagram of epitheca in apical view, with Levander's (1894) nomenclature. After Levander (1894) text figure 3.

Fig. 7. Same of hypotheca from above. After Levander (1894) text figure 4.

ABBREVIATIONS

1′–4′—apical series of plates.
1^a–4^a—anterior intercalary plates.
1″–6″—precingular series.
1‴–6‴—postcingular series.
1^p—posterior intercalary plate.
1⁗—antapical plate.
ant. att. po.—anterior attachment pore.
ant. pl.—anterior plate of ventral area.
cl. pl.—closing platelet of apex.
int. pls.—intermediate plates of ventral area.
post. att. po.—posterior attachment pore.
post. pl.—posterior plate of ventral area.

Figures drawn by Mrs. Josephine Rigden Michener.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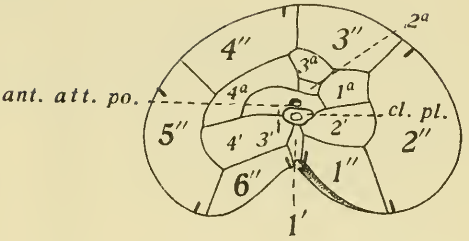
post. pl.
1''''
3'''
5'''
4'''
post. att. po.

1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3^a
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1^a
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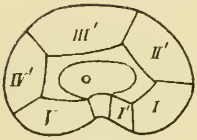
3'
2'
2''
6''
1''
1'

2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II'
IV'
V'
I'
I

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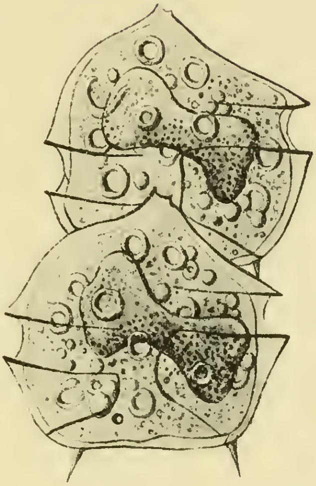

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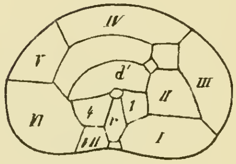
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IN
ZOOLOGY
Vol. 8, No. 6, pp. 295-300, pl. 19 September 14, 1911

DINOFLAGELLATA OF THE SAN DIEGO REGION, V. ON *SPIRAULAX*, A NEW GENUS OF THE PERIDINIDA

BY

CHARLES ATWOOD KOFOID

Among the species which have been erroneously assigned to the genus *Gonyaulax* is *G. jolliffei* Murray and Whitting, a common form in tropical seas and a regularly recurring constituent of the winter plankton at San Diego. A careful analysis of its plates has made its removal from the genus *Gonyaulax* necessary.

Spiraulax gen. nov.

Characterized by the anterior plate of the ventral area not meeting apical *1′*, or in other words, by the absence of the so-called extension of the longitudinal furrow to the apex. Ventral notch in the apex of apical *1′*. Ventral pore absent. Form biconical, apices pointed, widely spreading at girdle, which is much displaced but without marked overhang. Plate formula *4′*, 1^a, *6″*, *6*, *6‴*, 1^p, *1⁗*. Precingular *6″* and posterior intercalary 1^p very wide. The slender apical *1′*, the so-called anterior extension of the ventral furrow upon the epitheca to the apex of *Gonyaulax* is absent in this genus. Either the homologue of this plate in *Gonyaulax* has dropped out entirely here, or has withdrawn anteriorly from the girdle and become greatly expanded into the wide apical $1'$ of *Spiraulax*. I incline to the latter alternative, for a widening of this nature may be seen in apical $1'$ of *Gonyaulax triacantha*. Fission line as in *Gonyaulax*. Surface heavily pitted. The type species is *G. jolliffei* (Murray and Whitting) Kofoid.

Spiraulax jolliffei (Murray and Whitting) Kofoid

Pl. 19, figs. 1–5.

Gonyaulax jolliffei Murray and Whitting (1899), p. 324, pl. 28, figs. 1a, b.
G. jollifei, Schröder (1900), p. 17.
G. joliffei, Karsten (1907), pp. 255, 257, 473.

Diagnosis: A stout species, body very broadly and somewhat irregularly fusiform, of medium size, epitheca and hypotheca subequal, subconical, apex truncated, distal end of girdle displaced thrice its width, plates $1'$, 1^a, $6''$, 6, $6'''$, 1^p, $1''''$, girdle lists low, surface coarsely pitted, antapex terminating in a symmetrically located, stout, acute, solid, horn.

Description: The *body* is very broadly fusiform, its length a little less (1.8) than two transdiameters. Apical horn 0.5 transdiameter in altitude. Apex quite pointed. *Epitheca* middorsally almost equal in altitude to hypotheca, both subconical, usually less rotund than figured by Murray and Whitting (1899), the sides somewhat deeply concaved, especially the left anterior and right posterior, and slightly swollen in the right anterior and left posterior faces. Murray and Whitting figure an unusually rotund specimen. Girdle section nearly circular.

The *girdle* is median, descending, displaced distally thrice its own width, not overlapping, very deeply impressed (0.8 of its width) with heavy overhanging ridges of thecal wall or with low lists with close-set ribs. The *ventral area* (pl. 19, fig. 5) is very slightly sigmoid, laterally compressed to a narrow slit between the ends of the girdle. It expands posteriorly into an elongated elliptical area 2 furrow widths across and 3 to 4 in length, depending upon the elongation of the antapex.

The *theca* (pl. 19, figs. 1–3) consists of the following plates: $4'$, 1^a, $6''$, 6, $6'''$, 1^p, $1''''$. Of the four apicals three are large ones, $1'$, $2'$, and $3'$ and one, $4'$, a small triangular one above the right intercalary. Murray and Whitting find but three plates. The scarcely truncated apex appears to belong to plate $1'$ and to be closed by a minute translucent closing platelet (*cl. pl.*) attached at the tip of the plate to the membrane closing the notch. Apical $1'$ bears on its ventral face at the edge of the apex in the midventral line a rounded notch (*n.*, pl. 19, fig. 3) which is a thin, rather than open region in the wall and recalls the similar region in certain species of *Peridinium*. I have not found it in the genus *Gonyau-*

lax. Apical *1′* does not in this species extend posteriorly between precingulars *1″* and *6″* as in species of the genus *Gonyaulax,* but terminates obscurely some distance above the indenting ventral area. The right intercalary 1^a is not found in the subgenus *Fusigonyaulax,* which contains the species of *Gonyaulax* most resembling *S. jolliffei.* This is, in *Spiraulax,* a large well-developed plate. It was overlooked by Murray and Whitting (1899) but appears in Entz's (1905) figure. There are six precingulars, of which *1″* is the longest, *3″* and *4″* (middorsals) are smallest, and *6″* is quadrilateral and relatively very large, its size and that of *1″* being correlated with the spreading equatorial region. Of the six postcingulars *1‴* is very small and narrow, with a reticulate lip overhanging the left margin of the ventral area. By reason of the pressure of the left intercalary 1^p, the adjacent postcingular *2‴* is much shorter than the other members of this series. The single antapical *1⁗*, is conical in contour with a slight constriction midway of its length. It bears on its distal end a short (1.5 girdle widths) stout, semi-hyaline, solid, median spine. The girdle plates are six in number with sutures (*g. s.*) as shown in the diagrams (pl. 19, figs. 1, 2).

The ventral area (pl. 19, fig. 5) has a small anterior plate, and an elongated posterior one (*post. pl.*). The intermediate plates are hidden in the narrow furrow.

The *surface* of the theca is variously marked. In thick-walled individuals the surface is deeply and regularly pitted with crowded, coarse, circular pits with minute pores at the bottom and the girdle lists are heavily and regularly ribbed. In thin-walled individuals both inner and outer surfaces are faintly reticulate with subregular rounded polygons, each with a minute pore in the center and the girdle lists are not ribbed. In some cases the pits and reticulations are less regular and not all of the pits bear pores. The single large pore of the ventral apical region so conspicuous in species of the genus *Gonyaulax* is not found in *S. jolliffei.* A peculiar round opening (*op.*) in the margin of the suture at the lower median corner of apical plate *1′* is visible on parting the plates. Low, sparsely ribbed, hyaline lists which increase in height distally guard either side of the ventral area, except in the distal region. The antapical spine is a thickened symmetrical terminal extension of the antapical plate, whose whole surface may be faintly areolated, but in some cases is structureless and hyaline. Intercalary bands along the otherwise unornamented sutures are sometimes to be seen.

Cell contents dense, chromatophores dark yellow. Contents frequently escape through the parted apicals. Empty thecae often abundant in the plankton.

DIMENSIONS: Length, 132μ; transdiameter, 92μ; dorso-ventral, 75μ; width of furrow, 5μ.

VARIATION: San Diego material is more angular and much less rotund than the specimen figured by Murray and Whitting. The surface varies greatly in thickness of the reticulations and general rugosity. These is much variation also in length of apical and antapical horns.

Comparisons: This species is readily distinguished from all those in the subgenus *Fusigonyaulax* (see *Univ. Calif. Publ. Zool.*, vol. 8, no. 4, p. 246) by its stout apical and antapical horns and by the presence of four instead of three apicals, and by its anterior intercalary plate. As yet there is but the one species in the genus.

Distribution: Described by Murray and Whitting (1899) from the tropical Atlantic between 42° N and 26° S, from the Caribbean and the Azores; and later recorded by Cleve (1902) from the tropical Atlantic between 28° N and 32° S. Also reported by Schröder (1900) from Naples, by Entz (1902, 1905) from Quarnero, and by Pavillard (1907) from the Gulf of Lyons. Cleve (1903) reports it from the Mediterranean, Red and Arabian Seas, and Karsten (1907) in two localities near the equator in the Indian Ocean.

Taken at surface ten miles off Point Loma, November 12, 1904, and occasionally elsewhere in San Diego region in October-December in oceanic plankton of subtropical facies in association with *Ceratocorys horrida, Ceratium reticulatum* and *C. trichoceros.*

For papers cited see bibliography of Article 4 in this volume.

Zoological Laboratory, University of California.
Transmitted June 13, 1191.

EXPLANATION OF PLATE 19

Spiraulax jolliffei (Murray and Whitting) Kofoid

All figures magnified 500 diameters.

Fig. 1. Diagram of antapical view of hypotheca, showing plates and fission line (*f. l.*)

Fig. 2. Diagram of apical view of epitheca showing same.

Fig. 3. View of right side of theca, showing plates. Apical plates parted. Seven miles WNW Point Loma, California, November 12, 1904.

Fig. 4. Dorsal view of same, showing surface structure.

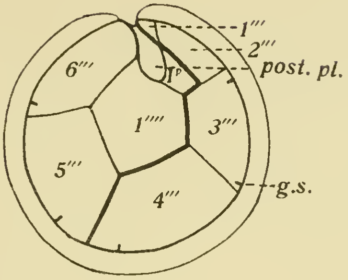
Fig. 5. Ventral view of same.

ABBREVIATIONS

4–6—girdle series of plates.
1′–4′—apical series.
1^{a}—anterior intercalary plate.
1″–6″—precingular series.
1‴–6‴—postcingular series.
1^{p}—posterior intercalary plate.
1⁗—antapical plate.

cl. pl.—closing platelet of apex.
f. l.—fission line.
g. s.—girdle suture.
n.—ventral apical notch.
post. pl.—posterior plate of ventral area.

Figures drawn by Mrs. Josephine Rigden Michener.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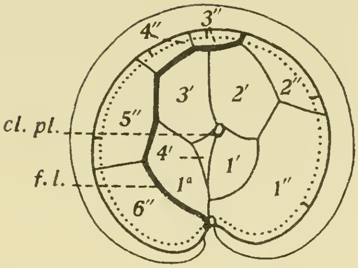
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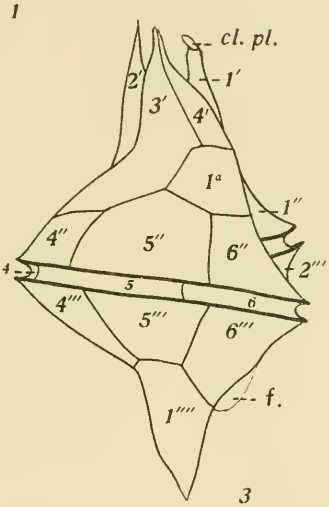
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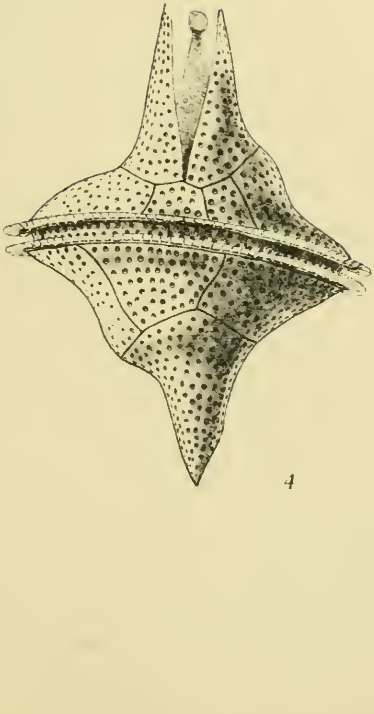

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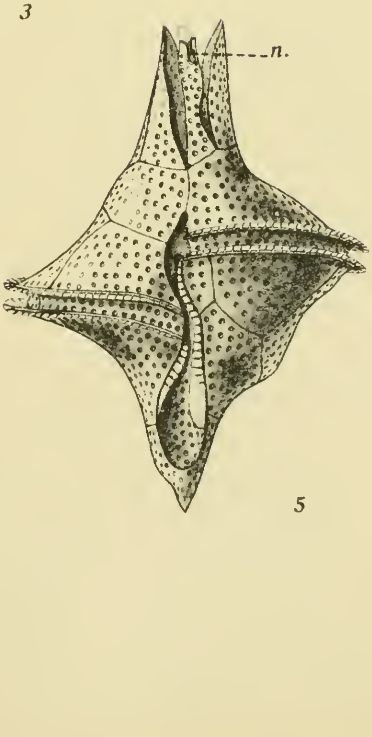
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BY

S. S. BERRY

The following notes have to do with certain squids and devilfishes preserved in the collections of the Department of Zoology at the University of California. Only those from Californian and Alaskan waters are included. The chief sources of material have been the various expeditions and summer seaside laboratories conducted by the University in the southern part of the state and from the Marine Biological Station at La Jolla. While no especial search was maintained for cephalopods and no new species have come to light, nevertheless, from a standpoint of distribution and variation, the collection contains considerable material of interest. Most of the localities represented are southern. Monterey Bay, however, has contributed the interesting specimen of *Dosidicus.* The thirty-one specimens recorded are referable to but four species, three of which belong to the genus *Polypus.*

My thanks are due to Professor Charles Atwood Kofoid, of the University of California, for placing the material at my disposal, as well as kindly affording the facilities for its examination.

Polypus bimaculatus (Verrill)

Octopus bimaculatus Verrill (1883), p. 121, pl. 5, figs. 1-1*a*, pl. 6.

This species is well represented in the collection, although the greater part of the specimens are clearly immature. It is apparently very abundant on the coast of Southern California, replacing *P. hongkongensis* (*Octopus punctatus* Gabb [1862], not of Blainville [1826]) of the northern coast as the common devilfish of the region. The latter species also occurs on the southern coast though not in such numbers as farther north. *P. bimaculatus* is readily recognized by the exceeding smallness of that portion of the third right arm in the male which undergoes hectocotylization, and more prominently by the large pigmented spot on the base of the second arm just in front of and below the eye on each side. An interesting feature revealed by the present material is that these spots are not unicolored throughout, as has been stated, but show a narrow, well-defined, bluish ring enclosing a blackish center and surrounded by a wider outer border of similar hue.

The following specimens were examined:

No.	Locality	Data	Sex	Author's Register
3	White's Point, Calif.	Univ. Calif. Mar. Lab., 1902	1♂, 2 juv.	[80]
1	San Pedro, Calif.	July, 1895	♂	[74]
1	San Pedro, Calif.	Dec., 1905	juv.	[86]
1	no locality		♀	[70]
5	no locality	various lots	juv.	[75]
1	no locality	San Diego Mar. Biol. Ass.	juv.	[78]
1	off San Diego, Calif.	Univ. Calif. Sta. LXXX, haul 3, 59-135 fms.	juv.	[85]

Polypus hongkongensis Hoyle

Octopus punctatus Gabb (1862), p. 170 [not *O. punctatus* Blainville (1826), p. 195, *teste* d'Orbigny (1845), p. 224.]
Octopus hongkongensis Hoyle (1885), p. 224.
Octopus punctatus Hoyle (1886), pp. 11, 100, pl. 5.

This *Polypus*, if Hoyle correctly identified his specimens with those described by Gabb, is the commonest species of the region, ranging along the entire coast from Lower California to Alaska and thence around the Aleutians to Kamchatka, Japan, and China. It is the *Octopus punctatus* of Gabb and authors generally, but as Gabb's name is unfortunately preoccupied, we can no longer be consistent in its use and the next oldest name appears to be that of Hoyle, although it is not without some doubt that I follow the prevailing opinion that the two are the same.

The most noteworthy specimen of this species in the collection comprises only the buccal mass and two suckers of an animal taken on the Harriman Alaska Expedition by Dr. William E. Ritter in the Shumagin Islands, Alaska, but these are well preserved and of such size that it seems well to place them on record:

Diameter of larger sucker	49 mm.
Diameter of smaller sucker	45 mm.
Diameter of mandible (transverse) about	40 mm.

The remainder of the material is mainly juvenile. Specimens examined as follows:

No.	Locality	Data	Depth in fathoms	Sex	Author's Register
1	Humboldt Bay, Popoff Id., Alaska	W. E. Ritter, July 10, 1899	....	♀	[169]
1	San Francisco Lightship, Calif.	Mr. Turkington, Dec. 15, 1910	....	♂	[168]
1	Oakland Wharf, Oakland, Calif.	J. W. Wood	....	♂	[170]
1	?	"Presented by Mr. Voy."	....	♂	[167]
1	Isthmus Cove, Santa Catalina Id., Calif.	Univ. Calif. Sta. XXVIII haul a	....	juv.	[77]
1	near Avalon, Calif.	Univ. Calif. Sta. XXIII haul 2	46	juv.	[82]
2	off San Diego, Calif.	Univ. Calif. Sta. LXVII haul 1	30.5	juv.	[87]
1	off San Diego, Calif.	Univ. Calif. Sta. LXVII haul 1	30.5	juv.	[83]
2	near Los Coronados Is., Lower Calif.	Univ. Calif. Sta. LXII haul 1	16.5-18.5	juv.	[84]
1	near Los Coronados Is., Lower Calif.	Univ. Calif. Sta. LVII haul 1	18-24	juv.	[76]
3	near Los Coronados Is., Lower Calif.	Univ. Calif. Sta. LVIII haul 1	15-18	♂♀ juv.	[81]

Polypus (sp.) young

There is a small specimen in the collection which does not seem to be referable to either of the above species. It is too immature to be given a new name with safety, but its characters are in brief as follows:

Body smooth, rather elongate, somewhat pointed behind, very delicate, semigelatinous, and iridescent, especially about the eyes and the base of the arms. Funnel long, extending past the rounded, prominent eyes. Arms delicate, slender, attenuate, connected at the base by a tenuous umbrella of about equal extent all around; order of length 1, 2, 3, 4. Suckers small but elevated, clearly in two rows except at the base where they show a tendency to remain in the median line.

Chromatophores small, distinct and numerous, with two rows of larger irregular ones along the outer surfaces of the arms.

From Univ. Calif. Sta. XXXVa, off Catalina Harbor, Santa Catalina Island, California. (No. 76 of the author's register.)

Dosidicus gigas (d'Orbigny) Pfeffer

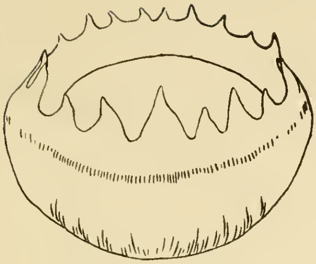
Plate 20

Ommastrephes gigas d'Orbigny (1835), p. 50, pl. IV.
Dosidicus gigas Pfeffer (1900), p. 180.

This great squid has frequently been reported from Monterey Bay, the Santa Barbara Islands, and other points on the coast, but never in such a fashion as to establish its identity satisfactorily beyond reasonable doubt. It is therefore noteworthy that the University possesses a beautifully preserved, undoubted, adult individual from Monterey Bay, thus assuring this interesting species an established place in our fauna.

The species is very readily recognized by its size; the attenuate arms having the very numerous strongly-toothed suckers much reduced on the distal part; and the characteristic trabeculae, which appear as stout outgrowths extending past even the broad swimming web of the third arms except for a space on the ventral margin (pl. 21, fig. 3) of the latter.

The more proximal suckers on the sessile arms (pl. 21, fig. 5) are very large, oblique, hood-shaped, with short, robust pedicels and very conspicuous horny rings, armed with about 19-20 sharp, curved, conical teeth, the upper median and two lateral teeth notably the largest (text fig. 1). Coincident with the extreme attenuation undergone by the distal half of the arms, their suckers suffer a striking modification, suddenly becoming greatly reduced in size, as well as deeper, their bases more elevated, and pedicels more elongate and slender (pl. 21, figs. 4, 6).



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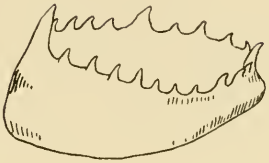

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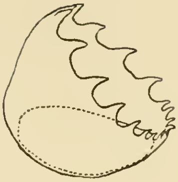

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Fig. 1.—*Dosidicus gigas* (d'Orbigny) Pfeffer. Horny ring from large sucker near base of second arm (× 4).

Fig. 2.—Horny ring from a median sucker of the tentacle club (× 5).

Fig. 3.—Horny ring from a lateral sucker of the tentacle club (× 7).

On the clubs of the tentacles there are four rows of suckers (pl. 21, fig. 2), those of the two median series attaining a size almost commensurate with that of those of the proximal portions of the sessile arms, but more flattened, and with their horny rings equipped with one or two more teeth, one tooth in each quadrant being considerably enlarged (text fig. 2). The lateral suckers are much smaller and their horny rings extraordinarily deep on the upper side, besides possessing but 16-17 teeth (text fig. 3). The so-called "fixing apparatus" comprises a single well-developed series of four rounded, fleshy, elevated tubercles or knobs occurring in alternation with three small smooth-ringed suckers along the dorsal margin in the carpal region of the club (pl. 21, fig. 2).

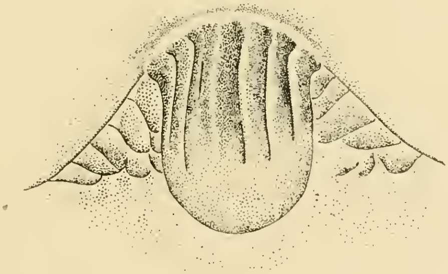

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Fig. 4.—Foveola of *Dosidicus gigas.*

These features are not shared by any other species, the nearest being the widely distributed *Sthenoteuthis bartramii* (Lesueur), which has, however, not yet been reported from the coast of California. The latter species differs in many details, but most notably in its much smaller size, the normal structure of its arm tips, the shallower and somewhat more simple foveola ornamenting the apex of the funnel groove (cf. fig. 5), and the great development of the web bordering the arms which there is nowhere exceeded by tentacle-like trabeculae.

The measurements in millimeters of the present specimen are as follows

Total length including tentacles	1245
Length excluding tentacles	1180
Length of mantle (dorsal)	635
Width of mantle	162
Length of fins (total)	330
Length of fins at plane of attachment	300
Width across fins	515
Width of head	160
Length of dorsal arm	425
Length of dorso-lateral arm	446
Length of ventro-lateral arm	450
Length of ventral arm	375
Length of tentacle	495
Length of tentacle club	215
Diameter of large sucker from second arm	13
Diameter of large sucker from tentacle	11

(No. 72 of the author's register.)

Thanks are due to the United States Bureau of Fisheries for permission to use the accompanying drawings.

LITERATURE CITED

BLAINVILLE, H. DE

1826. "Poulpe," *in* Dict. Sci. Nat., **43**, 170-214.

GABB, W. M.

1862. Description of Two New Species of Cephalopodes in the Museum of the California Academy of Natural Sciences. Proc. Cal. Acad. Nat. Sci., **2**, 170-172.

HOYLE, W. E.

1885. Diagnoses of New Species of Cephalopoda collected by H.M.S. 'Challenger.' Part I. The Octopoda. Ann. Mag. Nat. Hist. (5), **15**, 222-236.

1886. Report on the Cephalopoda collected by H.M.S. "Challenger" during the years 1873-76. Voy. Challenger, **16**, I, 1-245, pls. 1-23.

D'ORBIGNY, A. D.

1835. Mollusques *in* "Voyage dans l'Amérique méridionale exécuté pendant les anneés 1826-1827, 1828, 1829, 1830, 1831, 1832, et 1833. (Paris et Strasbourg, 1835-1843), **5**, pt. 3, pp. 1-64, pls. 1-4.

1845. Mollusques vivants et fossiles ou description de toutes les espèces de coquilles et des Mollusques classées suivant leur distribution géologique et géographique. (Paris, Gide & Co.) 605 pp., atlas with 30 pls.

PFEFFER, G.

1900. Synopsis der oegopsiden Cephalopoden. Mitteil. Naturhist. Mus., Hamburg, **18**, 147-198.

VERRILL, A. E.

1883. Descriptions of Two Species of *Octopus* from California. Bull. Mus. Comp. Zool., Harvard College, **11**, 117-124, pls. 4-6.

PLATE 20

Fig. 1. Ventral view of *Dosidicus gigas* (d'Orbigny) Pfeffer. × ⅙.

PLATE 21

Dosidicus gigas (d'Orbigny) Pfeffer

Fig. 2. Inner aspect of carpal portion of right tentacle. Natural size.

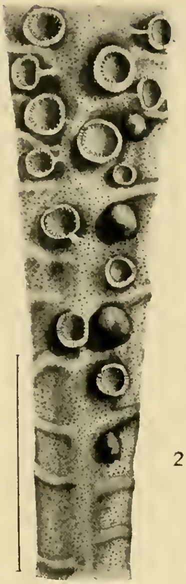
Fig. 3. Inner aspect of portion of left third arm near base of the wide web. (× ⅔.)

Fig. 4. Inner aspect of portion of right third arm near the tip. Greatly enlarged.

Fig. 5. Lateral aspect of sucker from basal portion of right second arm. Greatly enlarged.

Fig. 6. Lateral aspect of small sucker from extreme distal portion of second arm. Greatly enlarged.

All of the figures are from drawings by Miss Lora Woodhead, of Stanford University.



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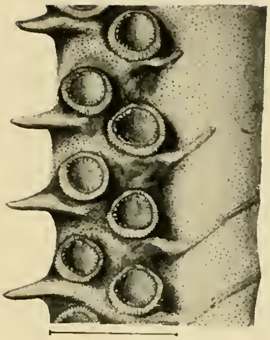

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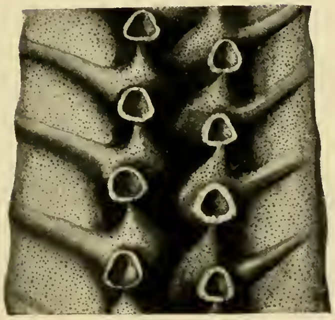

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ON A SELF-CLOSING PLANKTON NET FOR HORIZONTAL TOWING

BY

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(Contribution from the Laboratory of the Marine Biological Association of San Diego)

A prime desideratum for marine exploration has long been a self-closing plankton net for horizontal towing. This type of apparatus is especially needed for the investigation of the vertical distribution of pelagic organisms, is indispensable for the detection and analysis of their vertical migrations, and is a necessity for the study of distribution and of migrations in stratified waters where abrupt changes in temperature, salinity, and plankton content may occur within a short vertical distance.

The evidence of such stratification brought to light by the investigations of the Biological Station at La Jolla (see McEwen, 1910) and the plan of this enterprise to conduct a systematic régime of work upon the plankton (see Ritter, 1905) have made necessary a survey of existing models of self-closing plankton nets, with the result that it seemed necessary that a net for horizontal towing would have to be devised especially for this work. A brief historical resumé will outline the development of this line of apparatus and also serve to indicate the limitations and defects which have been, or may be, attributed to the various patterns hitherto employed for submarine investigations of the plankton.

HISTORICAL DISCUSSION

The Sigsbee (1880) gravitating trap appears to be the first self-closing instrument devised for plankton collecting in deep water. It is a small sieve operating vertically, clamped upon the cable and lowered closed; released by messenger at the desired level, it slides down the cable to a buffer which stops and again closes it. It is held closed by its own weight. This apparatus can be used only in a vertical direction, is small, and any increase in size involves difficulties in its clamping to, and release from the cable. As constructed there is a possibility, readily obviated by a spring catch, of the surge of the vessel, or irregularities in heaving in the cable, temporarily opening the bottom of the trap. This apparatus was used by Agassiz (1888a) on the "Blake," but has not been generally adopted or developed. The recently devised vertical net of Buchanan-Wollaston (1911) is the nearest approach to it in working principle.

The protozoan trap of Cattaneo (1882), devised for collecting the bottom fauna of Lake Como, functions only upon striking a substratum. It is really a water-trap some of whose principles are developed in later patterns of water-buckets (see Kofoid, 1906).

The first plankton net for horizontal towing seems to have been devised by Pavesi (1883) for use in Italian lakes. It is lowered while open, and its lateral semicircular jaws are closed by a spring released by a messenger. This net is of frail construction, not adapted for deep-sea work. There is nothing to prevent its functioning as a filter, partially at least, during descent, and the closure is neither exact nor certain.

The closing-net devised in 1882 by Captain Palumbo of the "Vettor Pisani" Expedition described by Chierchia (1884, 1885, see also Richard, 1908) was so constructed that the pressure against the water during descent was expected to keep the net closed and that it would open upon ceasing to descend. The propeller mechanism of a Miller-Casella reversing thermometer was employed to close the net. This was placed above the net and released a weight whose pressure was expected to hold the net closed. Chierchia (1885) regards the closure as inadequate, and Chun's trials of a net of the Palumbo pattern led him to reject it as unsatisfactory. Agassiz (1892) has criticized it on the ground of incomplete closure and possibility of reopening during descent. The net of Imhof (1885) was never adequately described, while that of Turbyne (1885) was adapted to vertical or oblique towing in shallow waters only, and was opened and closed (by constriction) with a special rope for the purpose. The two lines would inevitably become entangled in use at any considerable depth, and perfect closure would be difficult to secure and maintain.

Pouchet and Chabry (1887) describe a net, used (?) at Concarneau after experiments on the "Hirondelle" with the Chun net, which is an adaptation of the Pavesi model. Two heavy semicircular jaws turning on a vertical axis which traverses the mouth of the net are slipped down this axis by the action of messengers, a curved slot in the surface of the axis guiding each jaw through an opening and closing movement of 90°. Details as to messengers, trips, and control of the movement of the arms are wholly lacking in both the description and figures, and the further development of the model seems to have been abandoned.

Later the Prince of Monaco (1887) describes an improved form of closing-net made by Dumaige, the original of which he ascribes to de Guerne. Both the original de Guerne net and the improved form differ from the Pavesi net, upon which they also are modeled, in having a vertical axis bearing the coiled spring which traverses the opening of the net, and in being both opened and closed by messenger. The axis is an obstacle to some forms of organisms entering the net and it is evident that the closure cannot be complete in the nets as figured. No further use or improvements in this net seem to have been made in the later campaigns of the "Hirondelle" and her successors, and the author later (1889a) describes the closing action of the half-ring as inconstant and the closure as sometimes delayed till the net is removed from the water.

In the same paper (1887) a modified form of the Chun-Petersen net then in use by Professor Chun at the Naples Station is also described and figured. The modifications pertain to minor matters of the form of the spiral thread on the axle, the propeller, and the attachment of the net. The principles of operation by propeller and of vertical action remain unchanged.

The Chun-Petersen net described by Chun (1888, 1903) is a vertical net which is lowered closed, opened by the action of a propeller, and, after a period of towing, is later closed by continued action of the propeller and the release of one set of connections between the net and the cable, and the transfer of its weight to another set, which closes the jaws. This net has been criticized by the Prince of Monaco (1889a), who regarded the action of the propeller as so uncertain that the depth at which the net functioned could not be established, since the surge of the ship, irregularities in heaving out and hauling in the cable, and entanglement of siphonophores and medusae upon the propeller would all tend to modify, or impede the releasing action of the propeller, and render uncertain the time and levels in which the net was in operation. He also regarded the closure as incomplete, a defect noted by Chun (1889) himself, which has, however, been remedied in later models of the net. Later Agassiz (1888b, 1892) criticizes the net on the grounds of its imperfect closure, and Hensen (1895) regards even the improved form as still defective. In any event some uncertainty as to the time and level at which any closing-net, which is actuated by a propeller, is really in operation, must always remain.

Hoyle's (1889) deep-sea towing net is built on a unique pattern for operation while towing with the cable in oblique position. The net is operated by messengers which release ropes attached to the hinged semicircles which constitute the rim of the net. The strain of towing is relied upon to keep the net closed both in descent, and, after closing, during ascent. It is obvious that irregularities in the tension upon the towing cable due to surge of the ship or changes in speed of reeling engine or ship will endanger the continuity and certainty of closure of the jaws of the net both during descent and ascent. This net does not seem to have been adopted elsewhere.

The next considerable step in advance was made by the Prince of Monaco's (1889a, 1889b, see also Marenzeller, 1891, and Richard, 1902, 1910) curtain net. This is built upon an entirely new principle and was adopted after partial tests at sea of the net of the Pavesi (1883) type as modified by de Guerne and later by Dumaige (see Monaco, 1887), and after tests of a net of the Chun-Petersen type. The net is devised for horizontal towing, at the end of a vertical cable. The cable with terminal weights is first lowered to the desired level and then the net is slid down on the cable and the curtain across its square opening is withdrawn and rolled up as the net strikes the terminal weight. After towing, the net is closed by a messenger whose impact unrolls the curtain again across the opening. The amount of weight at the end of the cable can be readily increased for increased depths or greater speed in towing, so as to maintain a horizontal position of the net. The bag of the net itself is very short so as not to become entangled during descent with the closing apparatus or weights. This net in its operation on the "Hirondelle" and her successors has, according to all reports, functioned with accuracy and certainty. It was used also upon the "Pola" Expedition (see Mörth, 1892), but not with entire satisfaction. The rather complicated structure of this net and the great cost, over fifteen hundred francs, appear to have interfered with its general adoption. It may also be noted that in hauling in the net some pressure will be exerted through the upper side of the bag against the flexible curtain whose free lateral edges might be pushed outward with resulting loss of contents. Furthermore, there appears to be no device in the net, as constructed, for insuring positively that it is at the bottom and has been opened when the messenger strikes it and brings about a condition indicating closure. The net has also a minor disadvantage in having two vertical bars crossing the opening.

It is unfortunate that the closing net in process of perfection by Fol (1890) was never described.

An ingenious device for a closing-net to be opened and closed at any desired depth by the pressure of the sea-water is described by Viguer (1890) of the Algerian biological station. This net would be opened upon reaching the depth to which the pressure apparatus was adjusted and closed again upon leaving it. It does not appear that it was ever actually successfully constructed. It is obvious that it would be expensive to build and difficult to maintain in efficient working order.

A modification of the curtain net of the Prince of Monaco was used by Professor Th. Barrois (1892) in his exploration of Syrian lakes. He substituted for the silk curtain which closed the net a sliding sheet of copper. The chains which controlled the movement of the curtain were also dispensed with. The net was otherwise opened and closed as in the original model, and is reported to have worked with certainty and to have given satisfactory results.

The Tanner self-closing net, first described by Agassiz (1892), and later, also in an improved form, by Tanner (1893, 1894), is designed for "intermediate towing," which in action is practically horizontal, since, by "veering and heaving in on the tow line" the desired depth may be maintained. The depth at which the net is operating is ascertained by the dredging quadrant. The net is lowered vertically while open and is then towed at the desired depth and closed by messenger after return of cable to the vertical position. The closure is by weights which draw a puckering string about the middle of the bag. The lower end will thus contain the catch made before closure. In the earlier model the closing weights worked on guy ropes running from the net ring to the terminal weight. In the later model two lateral brass pipes were substituted for the ropes and the weights slide down these. At the lower ends the pipes are attached to an apron or vane which is supposed to prevent the whirling of the net.

In the hands of Mr. Agassiz and Captain Tanner this net has given satisfactory results. The objections which may be urged against it are that (1) the successful operation in intermediate levels, i.e., while functioning as a horizontal net, requires considerable speed and introduces some uncertainty as to the level of its operation, (2) the net is open in descent and the vortex about its rim may introduce some animals into the net, (3) the open upper part of the bag of the net brings, during ascent, considerable pressure to bear upon the region of closure, tending to force the catch of the upper part of the bag into the lower. Another objection, applicable especially to the first model, is that the heavy weight attached to the tail of the net to keep the guy ropes supporting the closing weights in place, would tend to interfere with the mouth of the net taking a position of maximum exposure to the water entering the net, i.e., to keep it vertical, instead of oblique, during the horizontal towing, and thus to reduce the relative amount of the catch as compared with that taken during the ascent of the net. This objection is less applicable to the improved models in which the only weight to the rear is that in the light pipe-frame for the closing weights.

The small horizontal closing-net of Frič and Vavra (1893) is of a simple type with two ropes, one for towing and a second for closure by constriction, obviously ill-adapted for work in deep water.

The idea of using the pressure of the water to open and close the net is embodied in the description given by De Livron (1893), Lieutenant of Marine in the Russian Navy, of an apparatus with a piston, set to begin movement under the desired pressure, that is, at the desired depth. The lids are connected with the piston and its first movement opens the net. It is closed again by the piston when it moves because of the increase or decrease of the pressure. No figures of the apparatus are given and there is no evidence that it was ever actually successfully operated.

The Giesbrecht (1893) self-closing net is devised for horizontal towing and is sent down closed, is opened by resistance of the water upon the two spreading wings, when towed horizontally, which releases the closing lever. It is closed by messenger. The four hinged sides of the square opening of the net spread open by their own weight upon release and closure is accomplished by their folding together again. In its original form the bag of the net is rather complicated and not readily cleaned and the system of opening not sufficiently under control. In operation at sea in rough weather or in deep water it would be impossible to determine with any certainty when the net really opened or to be positive that the closure was complete and continuous, since the net is held closed merely by its own weight. Furthermore, the vertical bar across the opening interferes with the capture of certain pelagic organisms. In a modified form (Richard, 1896) the net has been used somewhat extensively in connection with the explorations of the Prince of Monaco, apparently with satisfactory results.

Heincke (1894) describes a ''Brut-netz'' used at the Helgoland Station for taking fish-eggs and fry. It is anchored in a current to a float, being lowered open, till it floats out at the desired level. While in operation it is suspended by a line to the crowfoot running to the usual marginal ring. When withdrawn it is hauled in by a second line running to a second ring about one-third of the length of the net from its mouth. The terminal ring, as it falls, carries the upper part of the bag across the opening of the second ring and thus closes the net during descent, a principle later employed in the Marsh and Nansen closing-nets.

The Birge (1895) closing-net devised for limnological exploration is adapted only for vertical hauling. It is opened and closed by weights released by messenger. The lid is slid off horizontally from the top of the net in opening and returned in closing. As constructed, the net is cumbersome and ill-adapted to work at sea because of the numerous lines and dangling weights.

Hensen (1895) mentions a photograph of a Norwegian closing-net drawn by three cables and operated by propellers and clockwork, devised for exploration of currents, and evidently for horizontal towing. He unfortunately gives no clue to its origin and I have found no other reference to it in literature. It seems to have joined the procession of failures. Professor Gran writes me that he does not know the history of this net.

The Townsend (1896) closing-net is adapted to vertical hauling or to towing at the end of an oblique cable (intermediate towing). It is lowered open and closed by messenger. Closure is effected by release by messenger of a lever which shifts the weight of the net upon tow lines which close the semicircular jaws. A sliding weight upon the original tow lines tends to hold the jaws closed. The trip requires very careful adjustment of a bent spring to insure control of its operation and is liable to get out of order. Furthermore, the net open in descent is objectionable, and the system of closing is open to the criticism of uncertainty as to its continuity. The net has not been generally adopted for deep-sea work.

A folding-ring net for opening and closing by messenger which "worked satisfactorily" in the experimental model but was not perfected for work at sea was also devised by Townsend. The trips of this net are of a better type than in the net just noted, but the means of maintenance of closure during descent and ascent are subject to criticism since closure depends upon the weight of the net upon the tow lines. Currents and irregularities in movement due to surge of the ship or irregularities in hoisting might lead to release of tension and gaping of the jaws.

A modified form of the Giesbrecht net has been devised by Richard (1896), who abandoned the horizontal pressure upon the wings as a means of opening the net and substituted the method employed in the curtain net of the Prince of Monaco, to wit, sliding the net down the cable and opening it by impact on the terminal weight. He also modified the trip for closing and hinged the horizontal vanes designed to keep the apparatus from whirling. Richard (1896) speaks well of the original model, but prefers the improved one because of certainty of closure. "C'est un instrument robuste, qui mérite, modifié, ou non, d'être employé de préférence à ceux qui ont été décrits jusqu' ici pour remplir le même but." See also Monaco (1902) and Richard (1900, 1902, 1910).

The closing-net of Lakowitz (1896) is designed for horizontal towing and is opened and closed by accessory lines which operate two hinged lids on the square opening of the net. The lids when closed are latched by spring catches. The closure is thus exact and continuous, but the accessory lines could not be adapted to work in deep water.

The closing-net designed by Cori (1897) operates in a horizontal position and is opened and closed by messenger. The opening of the net is rectangular with a rim of six straight pieces, long top and bottom pieces and jointed sides of two pieces each. The vertical sides are jointed in their centers and bend inward when the net is closed. The net is lowered closed with the lower horizontal margin raised against the upper one and the sides collapsed inward. The first messenger drops the lower bar and thus opens the mouth of the net, while the second drops the upper bar down upon the lower, folding the sides inward again and thus closes the net. This net is simple, with an opening free from impeding bars, and the plan seems to be capable of adaptation to deep-sea work, by the addition of an automatic lock to hold the net firmly in place when closed and by the necessary strengthening of the frame to carry the weights needed below the mouth of the net. It would also need some adjustment of parts at the rim to make the closure absolutely complete and a supporting rod for the bag of the net to keep it from wrapping itself about trips and cable during descent. The general design is one meriting perfection and wider adoption.

In his investigations upon the plankton of Bodensee, Hofer (1896) used the horizontal net of the Cori (1897) model, which he states functioned with extraordinary certainty, the opening and closing of the net being distinctly noticeable on the cable, even when the net was at the depth of one hundred meters. He also adopted a net of the strangulation type towed by two ropes, the tow-line passing obliquely to the net and a second closing line vertically from the net to a life-preserver towed sixty meters behind the boat. This method is criticized by him as cumbersome.

Marsh's (1897) vertical closing-net is lowered open, closed by a messenger which releases the line which goes from the head of the crowfoot to the trip, and transfers the weight of the net to a constricting line about the middle of the bag. The upper part falls down and effectively prevents the entrance of any material during ascent after closure. The objections to this and all other nets of its pattern are (1) that it is lowered open and critical results are not obtainable since contamination is possible, as a result of the swirl about the open mouth during descent; and (2) the contents of the upper part of the bag where filtration is greatest may be lost in closing, a difficulty partially obviated in the Nansen net by an elongated non-filtering area at the head of the bag.

The Petersen (1898) closing-net is a modification of the Hensen plankton net, the only change being the addition of two hinged semicircular lids which are released by messenger and fall into closing position by their own weight. The net is lowered open and the lids are not locked after closing. Since the filtering area of the silk bag normally exceeds the area of the orifice of the net and the upper cone of the net is of impervious canvas, there is no certainty that the irregularities in movement of the net after closure will not open the lids, spill out part of the catch, or even admit other organisms. This type of closing-net seems to have been first figured by Apstein (1906).

Fowler's (1898) "mid-water" tow-net is devised for vertical work, is sent down closed, and is opened and closed again by messengers. The net is suspended by two sets of chains to the "locking gear" or tripping apparatus at the end of the cable. The mouth of the net is rectangular with hinged jaws working on a central axis. When suspended by the closing chains the two jaws are held together by weight of the net, when suspended by the towing chains the jaws fall open by their own weight and the tension upon the net. This net was used extensively by Fowler in his investigations in the Faeroe Channel and Bay of Biscay and worked satisfactorily. It was also used on the "Valdivia" and "Siboga" expeditions (see Fowler, 1898, and Weber, 1902). The criticisms which might be passed upon it are perhaps more of a theoretical than of a practical nature. The large tripping apparatus and the bar and chains across the opening are undesirable as impeding the entrance of active or filamentous organisms. It also seems to the writer that the light weight of the net, upon which the certainty and continuity of closure wholly rest, is its weak point. The frame weighs, according to Fowler, only sixteen and one-half pounds and this would be reduced in sea-water to about fourteen pounds. The locking gear and chains weigh thirty-three pounds and have less area of resistance than the net and bag. It would seem possible that the surge of the ship and irregularities in heaving in the cable might lead to an intermittent gaping of the jaws of the net before opening or after closing, since the heavier locking gear would tend to respond more readily than the lighter net and bag to oscillations of the cable. With an even tension on the towing chains there is no chance for the resistance of filtration to spread the jaws, but the instant the chains are slackened their weight at the ends of the closing levers would tend to open the net and permit the spreading effect of the resistance of the filtering surface. It is probable that the chances of such an intermittent gaping under normal operation of the net are remote, but one would be more certain of the accuracy of the results if this remote possibility were removed.

The Cori net is criticized by Burckhardt (1900), who used a model constructed by Hofer (1896), double the size of the original Cori pattern, on the ground that the closure is not complete on account of the lack of attachment of the bag at the six hinges and the insufficiency of the vertical closing plate across the closed mouth of the net. He also found the net failing to function because the net or the wire became entangled in the trips, possibly due to lack of experience in handling the apparatus. He also expresses uncertainty as to the control of the opening of the net and of the level at which it operates, and finally calls attention to the practical difficulty of determining the distance traversed by the net. Burckhardt is a proponent of the vertical net and has quite fully stated the difficulties of the horizontal net. They can, however, be obviated in the main: the closure perfected by slight changes in construction, the net bag controlled by a supporting arm, the messengers adjusted in weight to give certain action on the trips, and the horizontal course of the net improved by increase in weight of the frame and adjustment of the speed of towing. The determination of the length of the haul presents the greatest practical difficulty of the defects he enumerates.

The Burckhardt (1900) vertical closing-net has a contracted conical head after the Hensen model with circular lid hinged at one side, opened and closed by weights released by a trip of the Cori pattern. The trip is operated by messengers. Burckhardt experimented with the net, sinking it open, immediately closing it before raising it, and found that the net "ganz leer blieb." He therefore rearranged the connections of the net and trips so that the first trip closed the net and the second released the head of the net so that it fell to one side as in the Nansen net. This decreased the resistance in hauling in and hastened the operation of collecting. The objections to a net of this pattern, for work at sea, are the dangling weights, and the resistance of the impervious head of the net in hauling in. Burckhardt's experimental proof that the net remains empty when lowered open may be valid in quiet waters, but would be less probable in a net subject to the surge of a ship. In any event, with the net open in descent, a certain element of uncertainty is always present which is entirely eliminated in the net closed in descent.

The Voigt (1902) horizontal closing-net is sent down closed, and opened and closed again by concentric messengers. The first releases the oblique door which falls to a horizontal position by its own weight. The second releases the square frame or rim of the net, which also falls into a horizontal position upon the door and thus closes the mouth of the net again. The weight of the frame alone is depended upon to keep the net closed. The net is simple and apparently effective. For marine work the no less than five vertical bars of the frame, as well as the considerable horizontal parts, offer an impediment to entering plankton of the larger sorts. A self-locking device on both the door and rim would be necessary for use at sea to keep these parts in place. The model is one deserving further elaboration.

In the explorations of the "Puritan" off Capri, Lo Bianco (1903) used a closing-net of very large size, planned and built in the Krupp works at Essen. The net is now at the Naples Station. It is constructed in the main after the pattern of the Chun-Petersen net, for vertical work, with hinged semicircular jaws, opened by and closed by messengers. Its operation was satisfactory.

The Garstang closing-net operated at the Plymouth Station since 1903 is planned for horizontal towing, with diagonally suspended quadrilateral rim as in the Giesbrecht net. It is opened and closed by messengers. It is very compact, all of the parts being included in the large, cylindrical, vertical axis, and the hinged frame sliding upon it. It is rather light for work at sea with a vertical cable, and the trips are not always successfully discharged by the messengers. I have not found a description of this net.

The "Scotia" closing-net devised by Bruce (1904) is essentially like the "Nansen" net, being available only for vertical work and having a messenger which cuts loose the tow line and transfers the weight to a puckering line which closes the net some distance below the opening. The trip is that of the Scottish reversing thermometer frame. The objections to the net are practically the same as those to the Nansen net, with the addition that the trip does not appear to be sufficiently guarded against miscarriage.

The Nansen net has been in use for a number of years by the various bureaus of the International Commission for the Investigation of the Sea, but seems not to have been described in detail by any one. Figures and an account of its operation will be found in the papers of Gran (1905) and Herdman (1908). It is a vertical net, lowered open, drawn up for the desired interval and closed by messenger which releases the crowfoot above the bag transfering the weight to a strangulation cord. The net is simple, easily operated, and effective. It has the defect of being lowered open, and thus admits the possibility of contamination. For mass work it is to be highly commended, but its results are not critical.

The Buchanan-Wollaston (1911) vertical net functions mouth downward during descent only, and closes by a puckering string tightened by a weight sliding on the standards which form the frame. This net has the unique advantage, among vertical nets, that the column of water which it filters is undisturbed by cable, lines, or bars of any sort as it enters the net. The addition of a double trip and some method of sending down the net closed to any desired level, before opening it by messenger, would convert this into a very valuable type of vertical self-closing net.

A NEW TYPE OF HORIZONTAL CLOSING-NET

The desiderata to be sought in a net for this kind of towing are (1) a net closed during descent, (2) a method of opening and closing entirely under control of the operator and wholly free from interference by external conditions, such as irregularities in unreeling or reeling in the cable, or by oscillations due to surge of the ship, thus insuring continuity of closure both prior to opening and subsequent to closing, (3) perfect closure in all respects so that no plankton can enter while the net is closed, a feature obviously requiring finer adjustment in nets using the finest (no. 20) silks than in those with bags of coarser mesh, (4) sufficient weight to insure a measurable control of level of operation in towing, and (5) an orifice free from impeding structures. These desiderata have been secured in the net here described (pls. 22 to 25) which is the result of many tentative designs and is an improved form of the model first constructed.

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The general type of net adopted is one suggested to me in correspondence by my friend, Dr. G. Herbert Fowler, of Aspley Guise, Bedfordshire, England, of the "Research" Expedition. I am greatly indebted to the San Diego Marine Biological Association, and its scientific director, Professor W. E. Ritter, for their continued interest in the project, and for the aid which carried it through the expensive experimental stage. In the original designing of the net I have had the valuable aid of Mr. Val Arntzen, expert mechanician at the University of California, and in the final designing, pattern-making, and solution of mechanical difficulties of construction, I have had the invaluable assistance of Mr. Robert Baker of the Baker Machine Company of San Diego. I am also indebted to Mr. E. L. Michael of the Biological Station at La Jolla, who has had considerable experience in the use of the first model of the net, for suggestions and criticisms.

The net here described was first built in 1908. In 1909–10 a second and improved model was constructed for the Prince of Monaco for the exhibit of oceanographic instruments in the Musée Océanographique at Monaco, Princepauté de Monaco. The description which follows pertains, in the main, to this net.

GENERAL DESCRIPTION

The net in general plan is a jointed-ring net with circular opening, operated by messengers which release the semicircular laterally hinged jaws actuated by springs. The frame is very heavy and its weight may be increased by the addition of special weights below. The trips are held in place by springs. The bag is supported in a horizontal position and the net itself is easily removed from the frame for emptying the catches.

The bag of the net (pls. 22 and 23) is a simple cone of silk bolting cloth held in a horizontal position, with detachable bucket of brass at the truncated tip and head-piece of heavy linen. The jaws which form the rim about the opening of the net stand in a vertical plane when open. The two jaws (*up. j.* and *l. j.*, pl. 24, fig. 5) are of semicircular form and are bevelled so as to close tightly on the bevelled surfaces (*bev.*) and rotate on a horizontal axle (*ax.*) which is enclosed in each of the hubs in the frame.

THE NET FRAME

The frame (pls. 22 and 23) is a massive casting of phosphor-bronze, of circular form with enlargements at the horizontal axis for the reception of the hubs of the jaws of the net. It widens on the lower edge to a square foot which bears a recessed groove for the reception of the accessory weight. The upper end of the frame is expanded into a round head-piece or pedestal from which project the pins of the trips and within which their mechanism is protected. Its rear face (pl. 23, fig. 4) bears a slotted lug (*lug*, pl. 25, fig. 15) in which the rods supporting the net (*n. sup.*) and accumulator support (*acc. sup.*) are hinged. Between the four projections upon the frame its outer surface bears a low rib, so that in cross-section it is low T-shaped, to insure rigidity when heavy weights are attached below. The front of each recessed chamber which receives the hub is closed by a hinged door (*d.*, pl. 24, fig. 6, compare also figs. 3 and 4) locked in place by hinged thumb-bolt (*th. b.*) which binds the bearing (*bear.*) on the inner concave face of the door against the machined outer surface of the cylindrical hub (*hub*) of the jaw of the net, and thus holds it rigidly in place, but allows freedom of rotation.

The steel dredging cable (*c.*, pl. 25, fig. 15), a ⅜ inch plow-steel cable on the "Alexander Agassiz," with terminal eye adapted to all types of deep-sea apparatus, emerges from the vertical axis of the net. The perfect balance of the net in a vertical position is regulated in part by the lower flatiron-shaped weight which can be slipped to any desired position in front-to-rear direction and secured there by the set-screw above it (pl. 23, fig. 4.). The parts in the right-to-left plane are structurally balanced in the main. The cable is passed into the position in the axis of the head-piece through a narrow cable slot (*c. sl.*, pl. 25, fig. 15) which is closed again by a close-fitting wedge or slot filler (*sl. fil.*) held securely in place by a pinto set screw (*s. scr.*) whose head projects laterally slightly beyond the margin of the pedestal (pl. 23, fig. 3). A stout steel cable bolt (*c. b.*), 2.5 by 24 cm., is passed from the side of the pedestal through the eye of the cable and secured in place by a winged thumb-bolt (*th. b.*^{1}). The end of the cable bolt bears a circular opening (*op.*) for withdrawing it, when the thumb-bolt is released. When the bolt is free of the cable the thumb-bolt falls in the second position (*th. b.*^{2}) after the fashion of a door bolt, and the cable bolt cannot be entirely withdrawn.

THE CLOSING MECHANISM

The closing mechanism consists of the two hinged jaws at the mouth of the net which swing forwards and downwards, the tripping apparatus in the head-piece, and the two messengers which open and close the net. The two hinged jaws (pl. 24, fig. 5) are semicircular phosphor-bronze castings which together complete a circle 37 cm. in inside diameter. Upon either side, each passes into a cylindrical hub (*hub.*, pl. 24, fig. 6, see also figures 5 and 10) 82 mm. long and 82 mm. in diameter. Each hub consists of three main regions, two of which (2 and 3) are structurally parts of the jaws; (1) the central axle (*ax.*, pl. 24, fig. 5), (2) the inner cylinder (*in. cyl.*), and (3) the outer cylinder (*out. cyl.*).

The central axis consists of a shaft 82 mm. long and 25 mm. in diameter whose inner end is bored and threaded for the screw (*sc.*) which holds the fixed pulley (*pul.*) against the inner face of the jaws and holds the axle (*ax.*) within the inner cylinder (*in. cyl.*). The outer end of the axle is a cylindrical head (*hd.*) 27 mm. long and 50 mm. in diameter with a cubical socket (*sock.*, pl. 24, figs. 5, 6 and 9) in the axis, 17 mm. square and 8 mm.

deep, for insertion of the key used in setting the coiled spring. The side of the cylindrical head is bored with twelve equidistant holes, 7 mm. in diameter, for the set screw (pl. 23, fig. 4; *s. scr.*, pl. 25, fig. 6) which holds the axis (*ax.*) in place when the spring is set. Wound around the shaft is a coiled spring (*r. coil sp.* and *l. coil sp.*) of heavy steel wire which makes about twelve turns around the shaft and has its inner and outer ends fixed respectively in the end of the jaw and in the head of the axis. Surrounding the shaft is a narrow chamber (*sp. ch.*), 8 mm. wide, in which the coiled spring, whose wire is 4 mm. in diameter, has some room in which to come and go, as the tension is changed. The outer wall of this chamber is formed by the inner cylinder (*in. cyl.*). Between the head (*hd.*) of the axis and this chamber for the spring and resting against the outer ends of the inner and outer cylinders, is a circular washer (*w.*) 82 mm. in diameter, 2 mm. thick, with central orifice 25 mm. in diameter.

The inner cylinder is 60 mm. in outside diameter, 82 mm. in length, has a wall 10 mm. thick, and central opening 39 mm. in diameter. The cylinder is continuous on the right side (of the figure) with the lower jaw and on the left side with the upper, that is, each inner cylinder is a part of a different jaw. From this method of construction it follows that the lower jaw is actuated by the spring of the right side (of figure) and the upper one by that of the left.

The outer cylinder (*out. cyl.*) is 82 mm. long and 82 mm. in diameter, with wall 10 mm. thick, and central opening 60 mm. in diameter. This cylinder is structurally continuous upon the right side (of figure) with the upper jaw, and on the left with the lower. The relations of the inner (*in. cyl.*) and outer (*out. cyl.*) cylinders respectively to the lower (*l. j.*) and upper (*up. j.*) jaws respectively are clearly shown in the views looking from the center of the opening of the net toward the hub, with the pulleys (*pul.*, pl. 24, figs. 7, 8) removed. With this method of construction it will be seen that the outer cylinder is perfectly free to turn around the inner cylinder between the outer washer (*w.*) which is held by the outer terminal of the coiled spring to the head (*hd.*) of the axis (*ax.*), and the inner pulley (*pul.*)

which is fastened by two small screws (*s.′*) to the flat inner end of the hub. The impelling force, however, for the movement of the outer cylinder comes in either jaw from the coiled spring in the hub opposite to the cylinder in question.

The pulley (*pul.*, pl. 24, fig. 5) is 77 mm. in diameter and 14 mm. thick with an asymmetrical groove 13 mm. deep. It serves to carry the elastic string which binds the adjacent margin of the net to the hub (*el.*, pl. 24, fig. 5; pl. 23, fig. 4). It is obvious from a comparison of figures 1 to 4 (pls. 22 and 23) that the margin of the net adjacent to the hinge, when the net is closed, encircles nearly the whole of the pulley, except only the part included in the width of the closed jaws, while in the open net (pl. 23, fig. 4) it is compressed to less than one-half of the circumference. The elastic tie-string (*el.*) passes around in the groove of the pulley and through a fold in the margin of the cloth head-piece of the net of a length sufficient to stretch over the necessary part of the pulley when the net is closed. This insures a plankton-tight junction of the net and its rim in this critical part of the apparatus.

The jaws proper are semicircular, flattening to rectilinear as they approach the hub. They (pl. 25, figs. 12, 13) are 40 mm. wide, 14 mm. thick at the base (*b.*), and 5 mm. on the square lip (*l.*). For a distance of 30 mm. back from the lip the surface of each is beveled (*bev.*) so that when the jaws are closed the two beveled surfaces are in immediate contact to the shoulders (*sh.*), thus insuring plankton-tight closure.

The structure of the trips (*tr.*[1] and *tr.*[2], pl. 24, fig. 9 and pl. 25. fig. 15) is simple. There are two, the one nearer the axis (*tr.*[1]) being operated by the first messenger and the outer one (*tr.*[2]) by the second. Each is located in a separate vertical trip chamber (*tr. ch.*) in the head-piece of the frame and consists of a shaft (*shaft*) about which is a coiled spring (*c. sp.*) which draws the clutch (*cl.*[1] or *cl.*[2]) on the lower end of the shaft firmly up against the projecting hook of the rim of the jaw of the net (*hk.*[1] or *hk.*[2], pl. 24, fig. 9). These lugs are hooked and hold the jaws firmly in place. Each messenger strikes not only the trip but a second pin (*buf.*[1], *buf.*[2]) on the opposite side of the cable from the trip. This stop is adjustable and absorbs the shock of the messenger as soon as the trip is driven down sufficiently to release the jaw of the net.

The messengers are of two distinct types. The first messenger (pl. 22, fig. 1) is cylindrical, about 9 by 11.5 cm. and weighs about 4 kilos. Its diameter is just sufficient to strike the pin of the trip which releases the lower jaw and thus opens the net (pl. 22, fig. 2). The second messenger is provided with four spreading arched arms which carry a distal ring which drops over the first messenger and strikes the trip which releases the upper jaw and closes the net (pl. 23, fig. 3). Its total length is 30 cm. and greatest diameter 15 cm. and its weight about 8 kilos. Both messengers are made in halves which may be lashed together about the cable. The first messenger requires but a single lashing, the second two, one in each of the groves at each end (pl. 23, fig. 3). The greater length of the second messenger not only provides for overriding the first but it also tends to obviate anything but a square blow upon the tripping pins. The messengers may be lined with Babbitt metal to take up wear, as in the Arntzen detachable messengers used on my (1906) self-closing water-bucket, if desired.

THE NET AND PLANKTON BUCKET

The net proper is a simple conical bag of any desired stuff, preferably of silk bolting-cloth, with head-piece and bucket band of butcher's linen. The bag is fastened to the jaws by brass strips or closing bands (*cl. bd.*, pl. 25, fig. 13) held in place by numerous screws set into the inner face of the jaws. In the case of the finer silks, such as nos. 12 to 20, it is important to make the bag as long as possible, up to 2 meters.

To keep the bag from becoming entangled in the tripping device or about the cable, a supporting rod (*n. sup.*, pl. 25, fig. 15) 1.5 to 2 meters long, made in three sections, with distal end curved downwards (pl. 23, fig. 4) is attached to the rear of the head-piece of the frame. It carries a coiled spring at its outer end which connects it with the bucket which in turn is supported by a wire hook to the rod above it. The proximal end of this supporting rod works on an axle suported in a slotted lug (*lug*, pl. 25, fig. 15) on the rear face of the head-piece of the frame (pl. 23, fig. 4) and can thus be bent downward during ascent of the net and upward during descent. This makes possible a more rapid heaving out or in of the net by reducing the area of exposure of the bag and tends to protect the catch during the handling of the net. As shown (pl. 23, fig. 4) the basal casting into which this rod is seated also carries a short rod (*acc. sup.*) curved upward, with two accumulator springs. During descent the basal casting in the slotted lug rests firmly against a shoulder or cushion (*cush.*, pl. 25, fig. 15).

The bucket is attached at the end of the net support (pl. 23, fig. 4) whose distal end is bent downward to the level of the bucket. Between the bucket and the tip of the carrier is a coiled spring which affords play to the net in the horizontal direction as the jaws open and close. The bucket bears two rings on one side for attachment by wire hooks (but one in figure) to the supporting rod above.

The bucket (pl. 25, fig. 16) is made from spring brass tubing 10 cm. in diameter. Its total length is 12.5 cm. It consists of a head-piece (*hd. p.*) which is encircled by a net clamp (*n. cl.*) which binds the linen bucket bands at the lower end of the bag to the top of the bucket. The clamp is a narrow band of spring brass bearing two flanges (*fl.*) drawn together by a small bolt. The head-piece is threaded on its inner face and the remainder of the bucket may be unscrewed from it for removal of the catch, without releasing the net from the clamp. The detachable part is a plain cylinder with dished bottom formed of a casting sweated into place with central outlet terminating in a drip-point (*dr. pt.*) below. The outlet is closed by a removable plug (*pl.*) of brass, ground in emery to fit closely and terminating above in a shaft with a ring above the level of the top of the bucket. This can easily be found and the plug removed or replaced through the silk bag without opening the net if desired, and the contents of the bag removed without detaching the bucket.

On one side of the bucket there is a circular window 4 cm. in diameter and 1 cm. in height at lowest elevation with wire at its lip. Over this wire a silk window (*s. w.*) is stretched tightly and tied in place by a string (*str.*) behind the wire. This window affords sufficient filtration surface to reduce an ordinary catch to a volume readily contained by the detachable part of the bucket, and, when worn, the silk is readily replaced.

The weight (pl. 23, figs. 3 and 4) is flatiron-shaped, with pointed end anterior, to reduce resistance in towing. It serves as a foot for the net in landing on shipboard and may be removed easily if not needed, as in shallow waters. Its weight is 40 kilos, and it is made of cast iron. The spreading flange on its upper surface fits into the recessed groove on the under surface of the foot of the frame. It may be similarly grooved for a second weight on its under face if desired.

The total weight of the first model constructed, which differed from the one here described principally in certain minor details of construction and in the form of the frame and its weight, was over 125 kilos. The present model without weight or messengers weighs 70 kilos, with messengers 82 kilos. The cost of the improved model, which necessarily included some experimental work, and new patterns in large part, was three hundred and twenty dollars, complete with messengers, silk net and bucket. The apparatus was made by the Baker Machine Company of San Diego, California.

METHOD OF OPERATION

The setting up of the net for use is accomplished by fastening the silk bag in place with the inner brass bands and tying the closing strings around the pulleys. The supporting rod is adjusted to the bucket and the weight slipped into the foot. The springs are then adjusted to the proper degree of tension to insure closure on release by the trips. The adjustment is made by a square headed key which is inserted in the aperture at the end of the hub and fitted into the recess (*sock.*, pl. 24, fig. 9) at the end of this axis (*ax.*, pl. 24, fig. 5). The set screw at the rear of the hub (*s. scr.*, pl. 24, fig. 6; pl. 23, fig. 4) being released, the spring is wound up and the axis secured in the desired place by screwing in the set screws. It has been found empirically that the springs, when set for satisfactory action in the air or surface waters, may not function as desired in one hundred fathoms or more. A number of variables enter into the problem of adjustment, such as resistance of the water, temperature, pressure, the mesh and tension of the net, and the depth. It is possible, however, with a given set of springs to adjust each coil so that the jaw which it controls will certainly function at any desired depth. This capacity for adjustment renders the net adaptable to messengers of different weights and to operation in different depths. In practice it has been found advisable in determining the proper tension to set the springs for operation in the air and then to slightly increase the tension little by little till the trips are properly released in the desired depth. The number of turns of the key for the tension demanded can then be made a matter of record and the given tension may thereafter be employed whenever the net is sent down to that depth.

The cable is then inserted in the head of the net, the cable slot closed, the net hoisted on the cable, and the weight upon the foot locked in place by the set screw so that the net is well balanced, the jaws are both raised in the upper position (pl. 22, fig. 1) and grasped by the clutches of the trips. The net is then ready for descent.

When it has been lowered to the desired level the first messenger is sent down, care being taken that the cable is in a vertical position. This drops the lower jaw to the lower position (pl. 22, fig. 2, and pl. 23, fig. 4) against the ledge in the lower arc of the frame (pl. 22, fig. 1) and opens the net. The vessel is then put in motion along the desired course and the net is in operation in a horizontal position at approximately the depth to which it was sent down.

I know of no satisfactory way of determining absolutely the precise depth at which this or any other piece of towed deep-sea apparatus functions. This depth is a resultant of a number of variables such as the speed of the vessel, force and direction of currents, resistance of the net and cable, the weight of the apparatus, the mesh in the bag, the quantity of the catch which may increase resistance by clogging, etc., etc. The determination of the depth of the apparatus by use of the dredging quadrant (see Tanner, 1894) seems to be subject to increasing error as the depth is increased. Repeated instances occur in practice (see Fowler, 1898) in which bottom has been struck by apparatus when the dredging quadrant indicated that it should be some distance above the bottom. Giesbrecht (1893), as a result of experiments in aquaria with miniature apparatus, has arrived at the conclusion that much of the curvature, at least under certain conditions of strain, may occur in the upper part of the cable and the lower end be more and more approximated to the perpendicular.

In any event it is possible with the net here described, suspended by a ⅜-inch plow-steel cable, to a depth of 550 fathoms, to tow slowly with the visible part of the cable in an almost vertical position. Even with greater speed and some obliquity of the cable it is possible to reduce the vertical component of the path of the net far below that which is unavoidable in all vertical closing nets and perhaps, because of its greater weight, to reduce that hitherto obtainable in other types of horizontal nets.

When the towing is completed and the cable is again perpendicular the second messenger is sent down and releases the upper jaw which falls to the lower position, is held firmly against the lower jaw by the spring, and thus closes the net (pl. 23, fig. 3). In the original design spring-catches were used to hold the jaws firmly shut after closure. It has been found in practice that the closing secured by springs is adequate and constant. The cable is then reeled in, the spring in the supporting apparatus permitting the bucket to drop downward and thus tending to concentrate the catch towards the lower end of the net during ascent. Upon arrival on deck the rim of the net is released by unscrewing the thumb-nuts on the doors to chambers containing the hubs and dropping the doors downward (pl. 23, fig. 3). The set screws at the rear of the hubs are released and the net is lifted from the frame, its sides rinsed down to concentrate all the catch in the bucket, which is then removed. The net may be quickly returned to position for a second descent, by replacing the hubs, closing the gates, suspending the bucket and setting the spring.

This net has been used extensively in the form of the older model since the summer of 1908 (see Esterly, 1911a, b, and

Michael, 1911) with very satisfactory results in depths of 5 to 550 fathoms in explorations at sea in the Pacific off San Diego in the "Alexander Agassiz," a vessel of twenty tons, seventy feet in length.

The main objection to the net has been its great weight, a difficulty partly removed in the somewhat lighter model here described. The determination of the tension of the springs for closure at given depths has taken some time, but when once determined empirically for certain intervals the tensions for intermediate depths may be approximated without trial.

The net, especially with the finer grades of silk in the bag, is not devised for rapid towing, nor for large, actively moving animals such as the larger fishes and cephalopods. It does, however, take the very alert and actively moving *Sagitta* in large numbers and its catches in general exhibit a wide range of plankton forms from *Salpa*, Schizopoda and other plankton crustaceans, to the smaller forms. It should be possible to construct a net on this plan with large orifice with a bag of coarse mesh for the larger and more active forms. Such a net would have the advantage of an entire absence of all disturbing bars, ropes, cables, etc., in front of the opening.

The advantages which the net here described possesses over other models devised for deep-sea work are as follows:

1. A method of opening the net and closing it again at any desired level in the sea under complete control of the operator and free from interference by outside conditions.
2. Perfect and continuous closure of the net during descent and ascent of the apparatus, completely preventing the entrance of organisms except when the net is opened by the operator and preventing their escape after the net is closed.
3. The possibility of horizontal towing which makes feasible the more precise exploration of stratified waters, and the vertical migrations of pelagic organisms.
4. An opening free from interfering structures which tend to ward off the more active pelagic animals.

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BIBLIOGRAPHY

Agassiz, A.

1888a. Three cruises of the United States Coast and Geodetic Survey steamer "Blake" in the Gulf of Mexico, in the Caribbean Sea, and along the Atlantic Coast of the United States, from 1877 to 1880, Vol. I. Bull. Mus. Comp. Zool. Harvard College, **14**, xxii + 314 pp., 194 figs. in text.

1888b. Review of Chun (1888). Am. Journ. Sci., (3), **35**, 429–424.

1892. Reports on the dredging operations off the west coast of Central America to the Galapagos, to the west coast of Mexico, and in the Gulf of California, in charge of Alexander Agassiz, carried on by the U. S. Fish Commission steamer "Albatross," Lieut.-Commander Z. L. Tanner, U. S. N., commanding. II. General sketch of the expedition of the "Albatross," from February to May, 1891. Bull. Mus. Comp. Zool. Harvard College, **23**, 1–89, 22 pls.

Apstein, C.

1906. Plankton in Nord und Ostee auf den deutschen Terminfahrten. I Teil. (Volumina 1903). Wiss. Meeresunters. Abth. Kiel, N. F., **9**, 1–27, 14 figs. in text and 10 tables.

Barrois, Th.

1892. Description d'un appareil destiné à la recherche des organismes pélagiques par des profondeurs déterminées. Rev. Biol. Nord France, **4**, 192–197, 9 figs. in text.

Birge, E. A.

1895. Plankton studies on Lake Mendota. I. The vertical distribution of the pelagic Crustacea during July, 1894. Trans. Wisc. Acad. Sci. Arts and Letters, **10**, 421–484, pls. 7–10.

Bruce. R.

1904. The "Scotia" closing plankton net. Proc. Roy. Phys. Soc. Edinburgh, **15**, 141, 1 fig. in text.

Buchanan-Wollaston, N. J.

1911. On a new form of plankton net, designed to make truly vertical hauls in any weather. Cons. Perm. Inter. Expl. de la Mer, Publ. de Circ., **58–59**, 9–13, figs. 2–4 in text.

Burckhardt, G.

1900. Quantitative Studien über das Zooplankton des Vierwaldstättersees. Mitth. Naturf. Ges. Luzern, **3**, (129) 131–437, 1 fig. in text.

Cattaneo, G.

1882. Sui protisti del lago di Como. Boll. Scient., **3**, 111–121, 3 figs. in text.

CHIERCHIA, G.

1884. The Voyage of the "Vettor Pisani." Nature, **30**, 365–366.

1885. Collezioni per studi di scienze naturali fatte nel viaggio intorno al mondo dalla R. Corvetta "Vettor Pisani" (Commandante G. Palumbo) Anni 1882–83–84–85. Revista maritima, **18**, fasc. 9, pp. 239–274, pls. 1–6; fasc. 10, pp. 5–42, pls. 7, 8; fasc. 11, pp. 195–238, pls. 9–12.

CHUN, C.

1888. Die pelagische Thierwelt in grössen Meerestiefen und ihr Beziehungen zu der Oberlächenfauna. Zoologica, **1**, Heft 1, 72 pp., 5 pls.

1889. Untersuchungen über die pelagische Fauna der Canarischen Inseln. Sitzb. preuss. Akad. Wiss. Berlin, **1889**, 519–553, pl. 3.

1903. Aus dem Tiefen des Weltmeeres Schilderungen von der Deutschen Tiefsee-Expedition. (Fischer, Jena) Ed. 2, 592 pp., 46 pls., 3 charts, 482 figs. in text.

CORI, K. I.

1897. Ein horizontal fischendes Schliessnetz. Zeitschr. f. wiss. Mikr., **14**, 178–184, 3 figs. in text.

ESTERLY, C. O.

1911a. Diurnal Migrations of *Calanus finmarchicus* in the San Diego Region in 1909. Intern. Revue Hydrob. u. Hydrog., **3**, 140–151.

1911b. The vertical distribution of *Eucalanus elongatus* in the San Diego Region in 1909. Univ. Calif. Publ. Zool., **8**, 1–7.

FOL, H.

1890. Le tour de la Corse par mer. Rev. Sci., (3) **19**, 144–146.

FOWLER, G. H.

1898. Contributions to our knowledge of the plankton of the Faeroe Channel. No. VI. Description of a new mid-water tow-net. Proc. Zool. Soc. London, **1898**, 567–580, 6 figs. in text.

FRIC, A. UND VÁVRA, V.

1893. Untersuchungen über die Gewässer Böhmens. IV. Die Thierwelt des Unterpocernitzer und Gatterschlager Teiches als Resultat der Arbeiten an der übertragbaren zoologischen Station. Arch. naturw. Landesdurchforsch. von Böhmen, **9**, no. 2, 124 pp., 80 figs. in text.

GIESBRECHT, W.

1893. Ein neues Schliessnetz. Mitth. zool. Station Neapel, **11**, 306–324, pl. 13.

GRAN, H. H.

1905. "Nordhavets fritsvaevende plante- og dyreliv (plankton)" *in* Hjort "Norges fiskerier," **1**, 21–53, figs. 6–26 in text.

HEINCKE, F.
1894. Die Arbeiten der biologischen Anstalt auf Helgoland. Wiss. Meeresunters. Abth. Helgoland, **1,** 1–33, 7 figs. in text.

HENSEN, V.
1895. Methodik der Untersuchungen. Ergbn. Plankton Exped., **1,** b, 1–200, pls. 1–11, 14 figs. in text and 1 map.

HERDMAN, W. A.
1908. The marine biological station at Port Erin, being the twenty-first annual report of the Liverpool Marine Biology Committee. Proc. Liverpool Biol. Soc., **22,** 33–92, 13 figs. in text.

HOFER, BR.
1896. Die Verbreitung der Tierwelt im Bodensee nebst vergleichende Untersuchungen in einigen anderen Süsswasserbecken. Schr. Ver. Geschichte Bodensees. Heft 25, 64 pp., 2 pls., (2) figs. in text. Issued with Heft 28.

HOYLE, W. E.
1899. On a deep sea tow-net for opening and shutting under water. Proc. Liverpool Biol. Soc., **3,** 100–112, pl. 3.

IMHOF, O.
1885. Ueber die pelagische und Tiefsee-Fauna. Tageblatt d. 58 Vers. d. Naturf. u. Aerzte in Strassburg, 1885, p. 403.

KOFOID, C. A.
1906. A self-closing water-bucket for plankton investigations. Cons. Perm. Expl. de la Mer, Publ. de Circ., **32,** 1–10, 4 figs. in text.

LAKOWITZ.
1896. Ein neues Horizontal-Schliessnetz. Schr. naturf. Ges. Danzig, **9,** 275–279, pl. 2.

LIVRON DE.
1893. Drague pour pêcher de petits animaux à une profondeur donnée. Compt. Rend. Congr. Intern. Zool. Deuxième Session, à Moscou, **2,** 259–261.

LO BIANCO, S.
1903. La pesche abissali eseguite da F. A. Krupp col Yacht ''Puritan'' nele adiacenze di Capri ed in altre località del Mediterraneo. Mitth. zool. Sta. Neapel, **16,** 109–280, pls. 7–9.

McEWEN, G. F.
1910. Preliminary report on the hydrographic work carried on by the Marine Biological Station of San Diego. Univ. Calif. Publ. Zool., **6,** 189–204, 1 fig. in text and 1 map.

MARENZELLER, E. von.
1890. Ueber den modernen Apparat zur Erforschung der Meerestiefen. Verh. k.k. zool.-bot. Gesellsch. Wien, Quart. Abh., **40,** 207–226, 10 figs. in text.
1891. Zur Erforschung der Meere und ihrer Bewohner, gesammelte Schriften des Fürsten Albert I von Monaco. (Holder, Wien) xvi + 207 pp., 39 figs. in text.

MARSH, C. D.

1897. On the limnetic Crustacea of Green Lake. Trans. Wisc. Acad. Sci. Arts and Letters, **11**, 179–224, pls. 5–14.

MICHAEL, E. L.

1911. Classification and vertical distribution of the Chaetognatha of the San Diego Region, including descriptions of some doubtful species of the group. Univ. Calif. Publ. Zool., **8**, 20–186, pls. 1–8.

MÖRTH, W.

1892. Die Ausrüstung S. M. Schiffes "Pola" für Tiefsee-Untersuchung *in* Ber. d. Comm. Erforschung d. Ost. Mittlemeeres. Denk. k. Akad. Wiss. Wien, **59**, 1–16, 9 pls.

MONACO, ALBERT I., PRINCE DE.

1887. Sur les filets fins de profondeur employés a bord de l'Hirondelle. Compt. Rend. Soc. Biol. Paris, **39**, 661–664, 4 figs. in text.

1889a. Recherche des animaux marins, Progrès réalisés sur l' Hirondelle dans l'outillage special. Compt. Rend. Congr. Intern. Zool., **1**, 133–159, pl. 1, 15 figs. in text.

1889b. Sur un appareil nouveau pour les recherches zoologiques et biologiques dans des profondeurs determinées de la mer. Compt. Rend. Acad. Sci. Paris, **109**, 17–20, 2 figs. in text.

1902. Sur la troisième campagne de la Princesse Alice II. *Ibid.*, **134**, 961–965.

PAVESI, P.

1883. Altra serie, di recherche e studi sulla fauna pelagica di laghi italiani. Atti Soc. Venet.-Trent. Sci. Nat., **8**, 340–403, pls. 8–15.

PETERSON, C. G. J.

1898. Plankton of the Limfjord. Rep. Danish Biol. Station, **7**, 23 pp., (1) fig. in text and 4 tables.

POUCHET, G. ET CHABRY, L.

1887. Sur un filet fin de profondeur. Compt. Rend. Soc. Biol. Paris, **39**, 602–604, 1 fig. in text.

RICHARD, J.

1896. Modification du filet bathypélagique de Giesbricht. Bull. Zool. Soc. France, **21**, 214–218, 5 figs. in text.

1900. Les campagnes scientifiques di S. A. S. le Prince Albert I^{er} de Monaco. Expos. Univ. de 1900 [Paris]. (Imprimerie de Monaco, Monaco). 140 pp., 10 pls., 60 figs. in text.

1902. Campagne scientifique de la "Princesse Alice" en 1901. Bull. Soc. Zool. France, **27**, 81-104.

1908. L'oceanographie. Paris (Vinbert and Nony), vi + 398 pp., 339 figs. in text.

RICHARD, J.

1910. Les campagnes scientifiques de S. A. S. le Prince Albert I^{er} de Monaco. Bull. Inst. Océanographique Monaco, **162**, 159 + xxix pp., 116 figs. in text.

RITTER, W. E.

1905. A general statement of the ideas and the present aims and status of the Marine Biological Association of San Diego. Univ. Calif. Publ. Zool., **2**, i-xiv, 2 maps.

SIGSBEE, C. D.

1880. Reports on the results of dredging, under the supervision of Alexander Agassiz, on the east coast of the United States, by the U. S. Coast Survey steamer "Blake," Commander J. R. Bartlett, U. S. N. VII. Description of a gravitating trap for obtaining specimens of animal life from intermedial ocean-depths. Bull. Mus. Comp. Zool. Harvard College, **6**, 155–158, 1 pl.

TANNER, Z. L.

1893. Report upon the investigations of the U. S. Fish Commission steamer "Albatross" from July 1, 1889, to June 30, 1891. Rep. U. S. Comm. Fish and Fisheries, **17**, 207–342, pl. 1.

1894. On the appliances for collecting pelagic organisms, with special reference to those employed by the United States Fish Commission. Bull. U. S. Comm. Fish and Fisheries, **14**, 143–151, pls. 9–12.

TOWNSEND, C. H.

1896. Description of a closing tow-net for submarine use at all depths. Rep. U. S. Comm. Fish and Fisheries, **1894**, pp. 279–282, pls. 9, 10.

TURBYNE, A.

1885. The Scottish Marine Station for research; its work and prospects. Edinburgh.

VIGUER, L.

1890. Nouveau filet pélagique à functionnement automatique. La Nature, **18**, II, 42-44, 1 fig. in text.

VOIGT, M.

1902. Beiträge zur Methodik der Planktonfischerei. I. Ein horizontal fischendes Schliessnetz. Forschungsber. Biol. Sta. Plön, **9**, 87–86, 8 figs. in text.

WEBER, M.

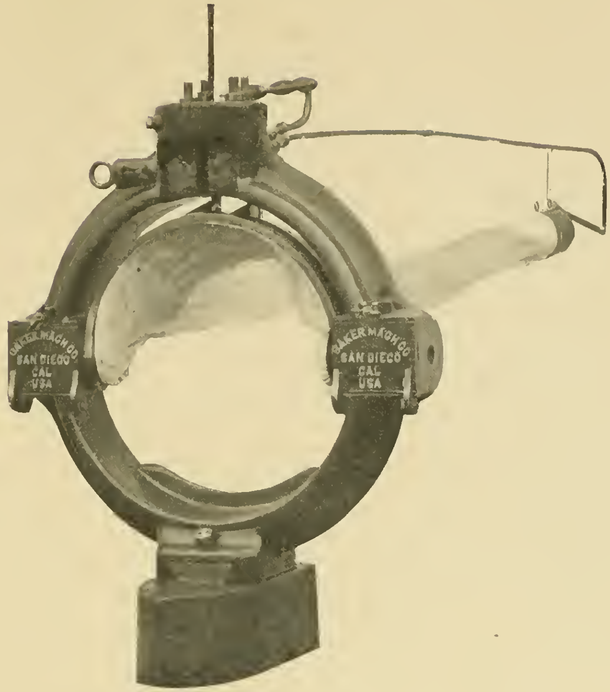
1902. Introduction et description de la expedition. Siboga Exped., **1**, 159 pp., [92] figs. in text.

EXPLANATION OF PLATES

PLATE 22

Fig. 1. Front view of self-closing horizontal towing net. The net is set for descent, with both jaws in the upper position.

Fig. 2. Same view with net open, ready for towing. The first messenger rests upon the inner trip which has released the lower jaw and allowed it to fall to the lower position.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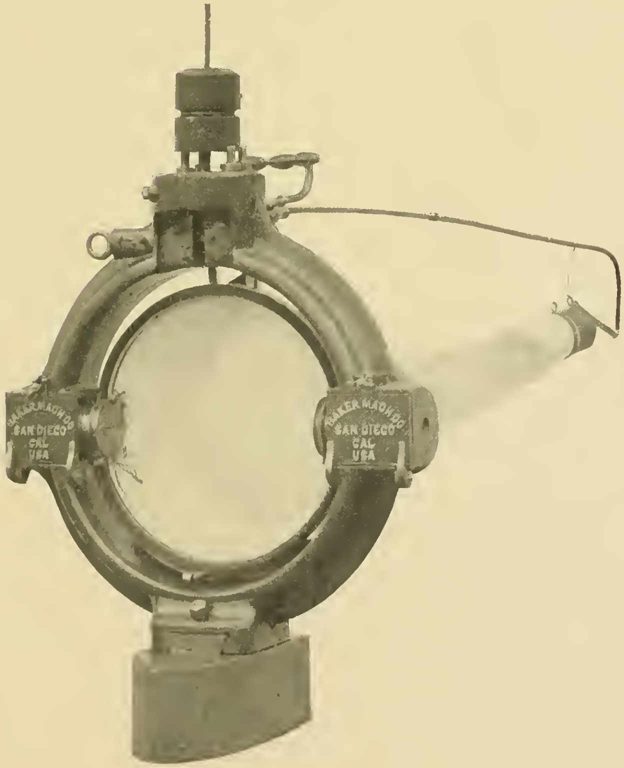
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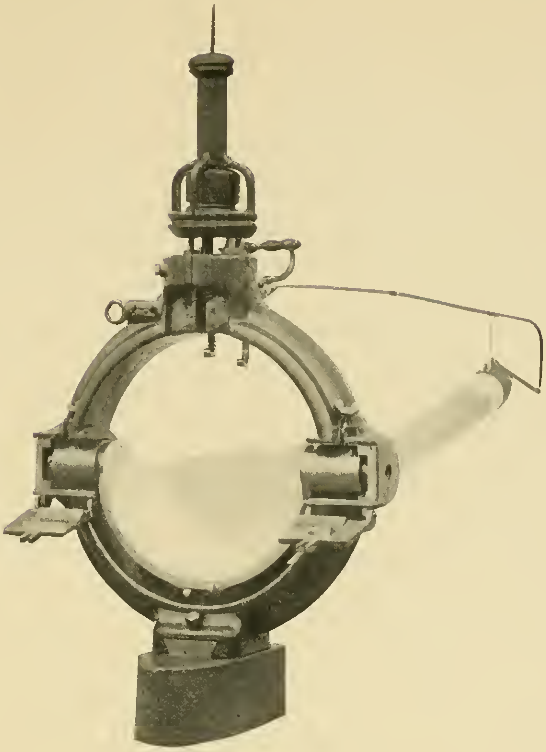
PLATE 23

Fig. 3. Front view of net after closure. The second messenger rests upon the outer trip which released the upper jaw and allowed it to fall down against the lower one, thus closing the net. The thumb-nuts to the doors of the chambers containing the hubs have been released and the doors dropped down, exposing the hubs. The clutches of the trips project downward from the upper arc of the frame.

Fig. 4. Side view of net opened for towing. Note the set screw at rear of horizontal axis for holding spring in tension, and double acting accumulator springs at the rear of the head of the frame.



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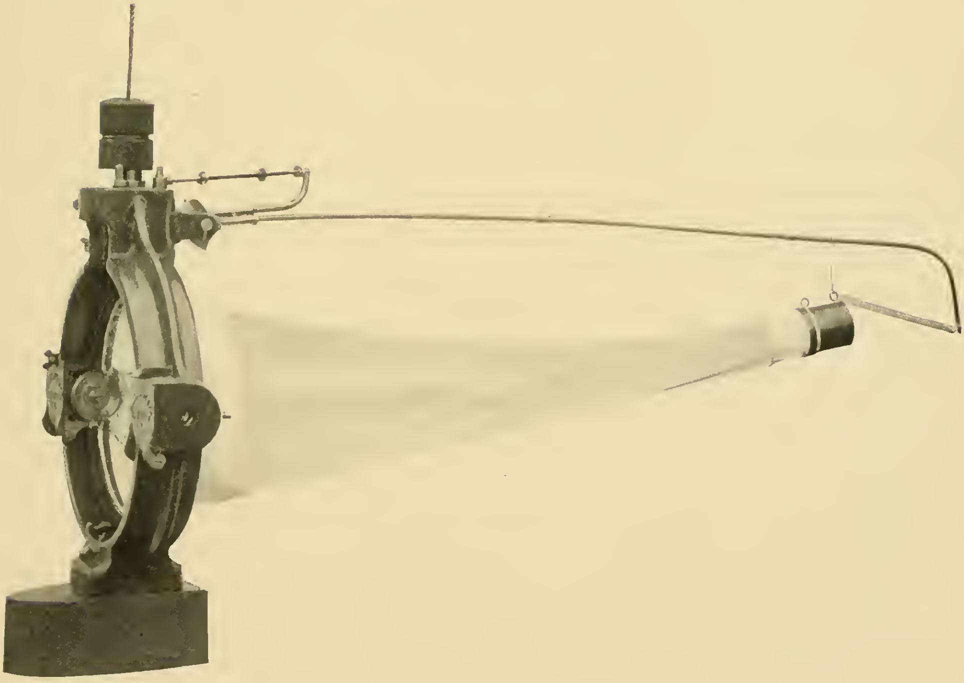

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PLATE 24

Fig. 5. Metal rim of net with jaws open, showing the hubs, at the side and the axle upon which they turn, in section. × ½.

Fig. 6. Section through lateral box at end of the hub showing relations of axle (*ax.*), hub, door (*d.*), and set screw (*s. sc.*). × ½.

Fig. 7. Face view of inner end of left hub showing relations of jaws and cylinders after removal of the pulley. × ½.

Fig. 8. The same of right hub. × ½.

Fig. 9. Section through head of the frame showing trips in place and both jaws locked as in the net when closed ready for descent. The position of the first (inner) trip is indicated by dotted lines. Rear lug for net carrier not shown. × ¼.

Fig. 10. Surface view of right hub. × ½.

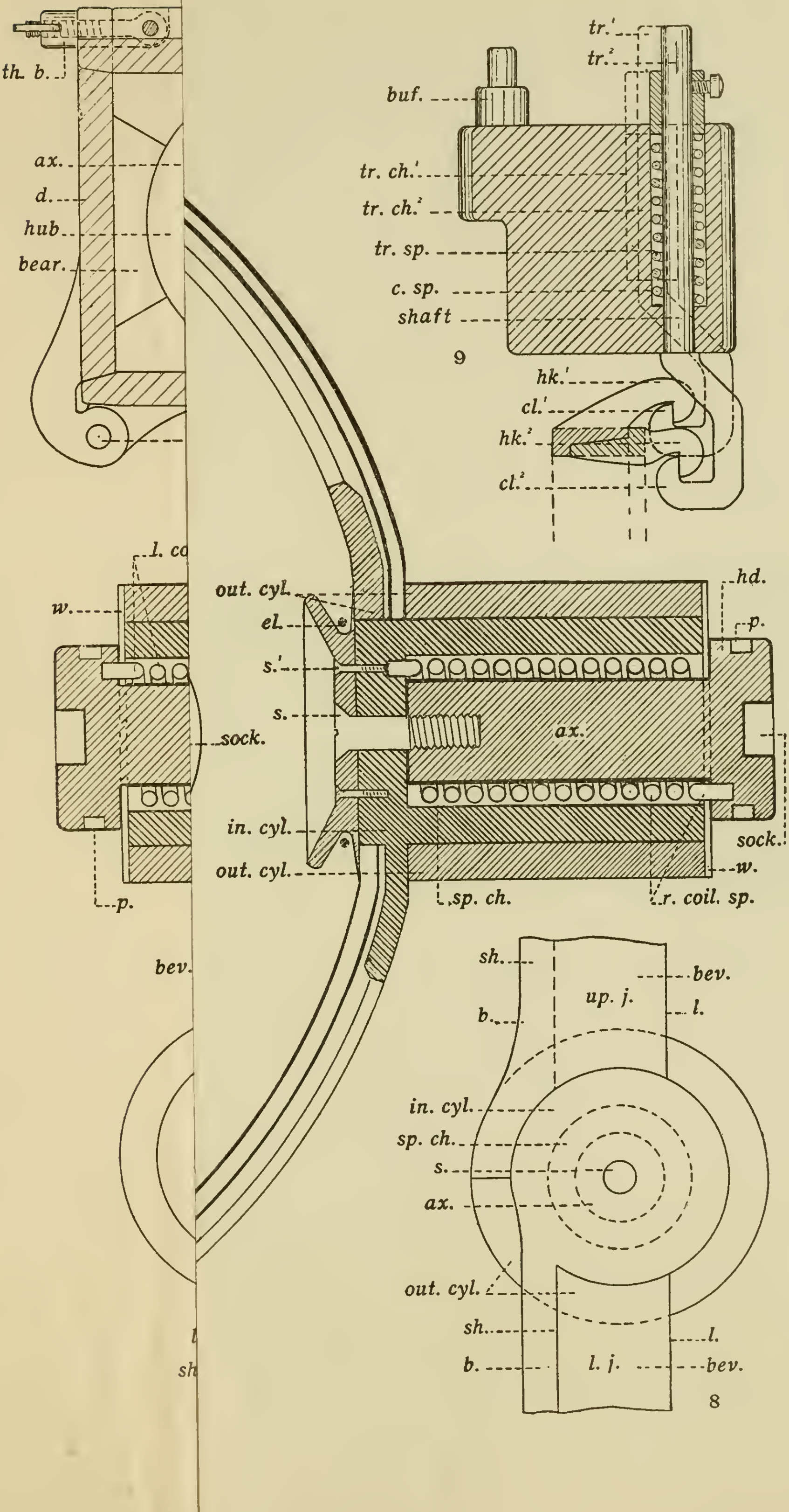
Fig. 11. View of outer end of hub. × ½.

Fig. 12. Radial section of upper jaw, showing method of attaching net. × ½.

Fig. 13. Same of lower jaw. × ½.

ABBREVIATIONS

ax.—axle.
b.—base of jaw.
bear.—bearing of hub.
bev.—bevel on face of jaw.
buf.—buffer.
c. sp.—coiled spring of trips.
cl.^{1} *cl.*^{2}—clutches of first and second trips.
cl. bd.—clamping band for net.
d.—door to hub chamber.
el.—elastic band for net at hinge.
h.—hinge of door.
hd.—head of axle.
hk.^{1}, *hk.*^{2}—hooks of lower and upper jaws.
hub—hub of net.
in. cyl.—inner cylinder of net.
l.—lip of jaw.
l. coil. sp.—left coiled spring.
l. j.—lower jaw.
marg. cd.—marginal cord of net.
n.—net.
out. cyl.—outer cylinder of hub.
p.—pit for set screw.
pul.—pulley for elastic at hinge.
r. coil. sp.—right coiled spring.
s.—screw into axle.
s.′—screws for pulley.
s. scr.—set screw.
sh.—shoulder of jaw.
shaft—shaft of trip.
sock.—socket for wrench.
th. b.—thumb-bolt.
tr.^{1}, *tr.*^{2}—first and second trips.
tr. ch.—trip chamber in head of frame.
tr. sp.—trip spring.
up. j.—upper jaw.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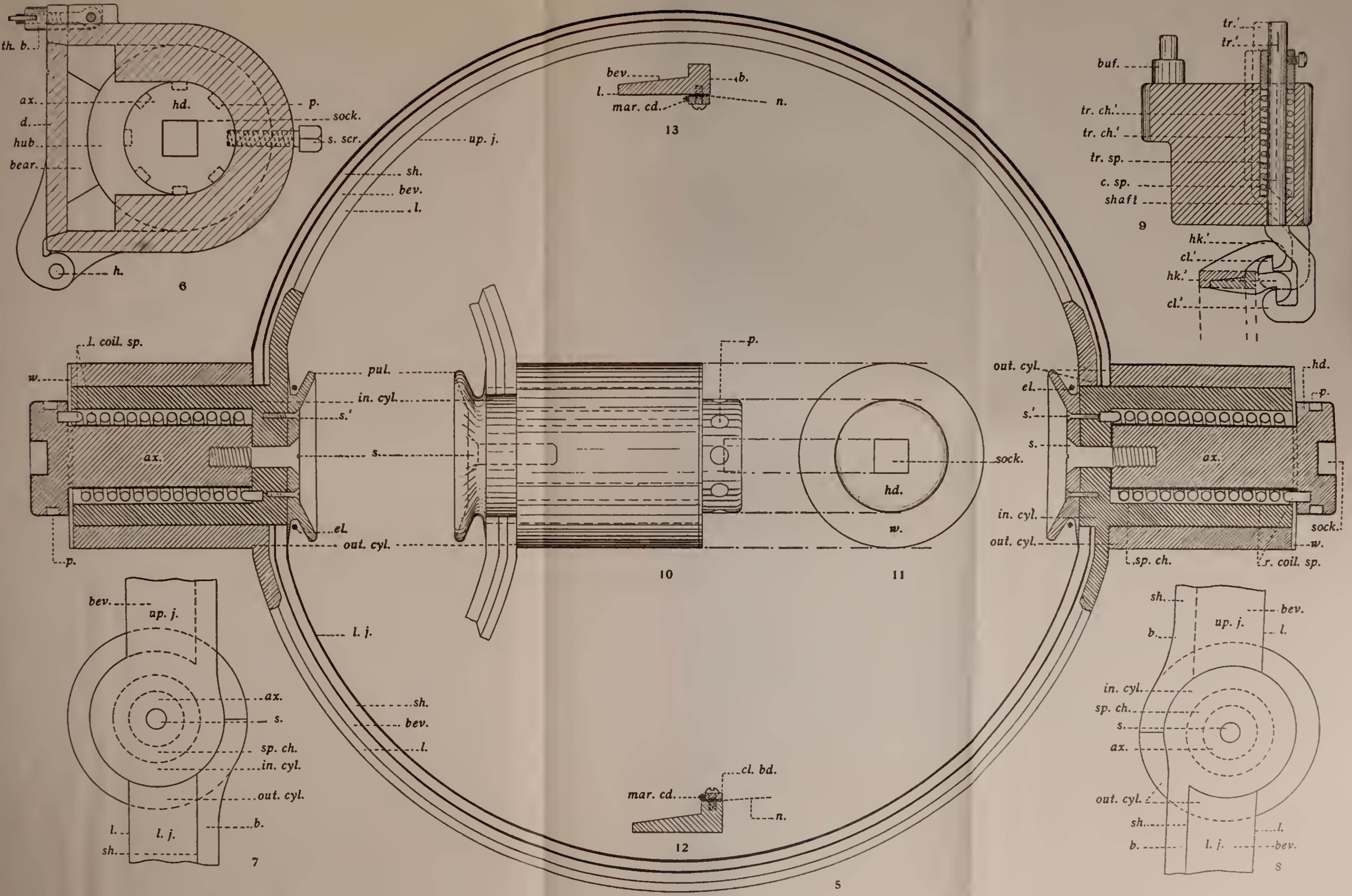
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PLATE 25

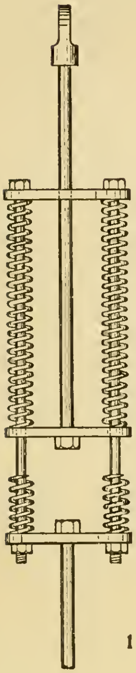
Fig. 14. Accumulator springs on the supporting arm for the net. × about ⅜.

Fig. 15. Diagram of top of head piece of net showing cable slot (*c. sl.*), cable bolt (*c. b.*), trips (*tr*^{1}, *tr*^{2}), buffers (*buf.*^{1}, *buf.*^{2}), thumb-bolt (*th. b.*^{1}) for releasing and setting cable bolt, set screw (*s. scr.*) for the slot filler (*sl. fil.*) and the rear lug (*lug*) for the net support (*n. sup.*) and accumulator carrier (*acc. sup.*). × ¼.

Fig. 16. Longitudinal section through plankton bucket showing head-piece (*hd. p.*), net clamp (*n. cl.*), silk window (*s. w.*) and closing plug (*pl.*). × ½.

ABBREVIATIONS

acc. sup.—accumulator supporter.
buf.^{1}, *buf.*^{2}—first and second buffers.
c.—cable.
c. b.—cable bolt.
c. sl.—cable slot.
cush.—cushion for accumulator.
dr. pt.—drip point of bucket.
fl.—flange of net clamp.
hd. p.—head-piece of net.
lug—lug for net support.
n. cl.—net clamp.
n. sup.—net supporter.
op.—opening in end of cable bolt.
pl.—plug of bucket.
r.—supporting rings of bucket.
s. scr.—set screw.
sh.—shoulder of supporter casting.
sl. fil.—slot filler.
sp. ch.—spring chamber.
str.—tie string for silk window.
s. w.—silk window.
th. b.^{1}, *th. b.*^{2}—two positions of thumb-bolt.
tr.^{1}, *tr.*^{2}—first and second trips.
w.—window in side of bucket.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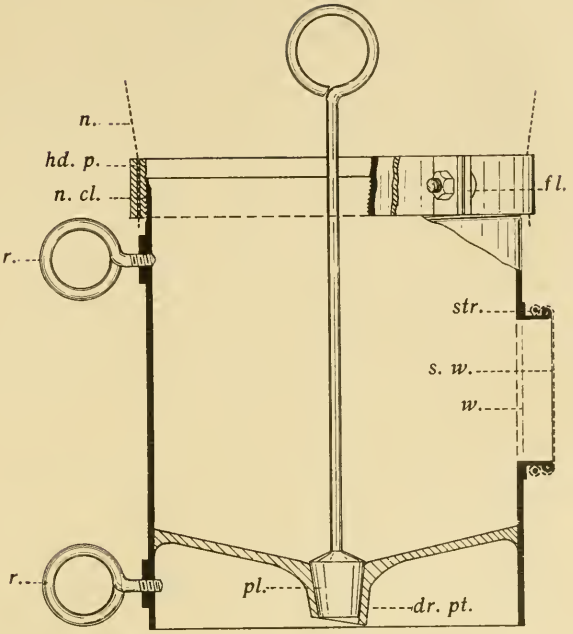
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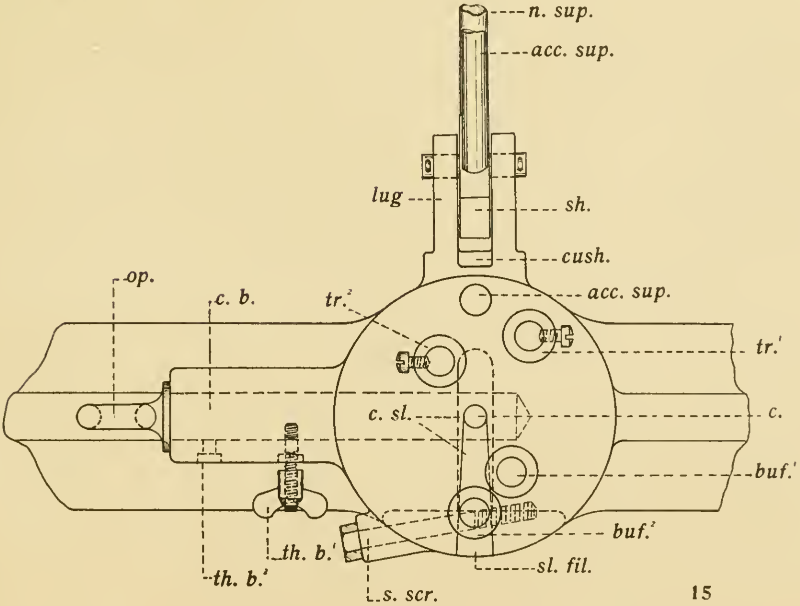
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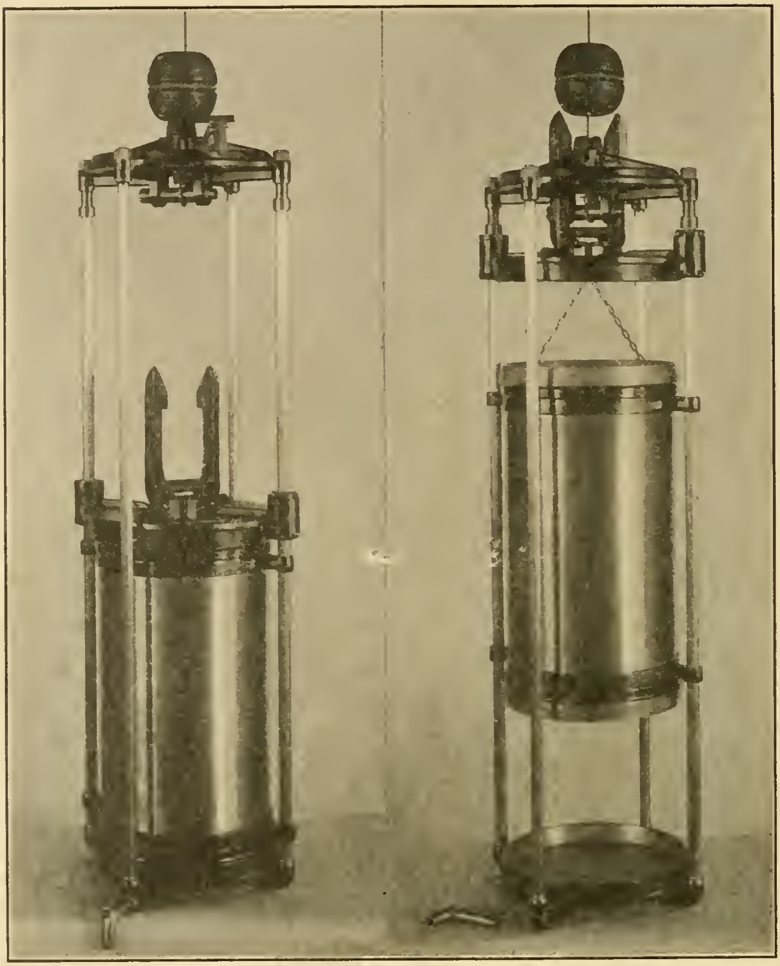
ON AN IMPROVED FORM OF SELF-CLOSING WATER-BUCKET FOR PLANKTON INVESTIGATIONS

BY
CHARLES ATWOOD KOFOID

(Contribution from the Laboratory of the Marine Biological Association of San Diego)

An account of the water-bucket used in plankton investigations at the Biological Station at La Jolla, near San Diego, was published by me (1905) several years ago. This bucket has been used repeatedly in connection with various investigations (see McEwen, 1909) in progress at the station, and has worked very satisfactorily. Continued use and the accidents inevitable on shipboard have developed certain defects in construction which have been eliminated in a new model constructed for me by Mr. V. Arntzen, expert mechanician of the University of California, and placed in the exhibit of instruments for oceanographic research in the Musée Océanographique at Monaco, Principauté de Monaco, founded by S. A. S. Albert I, Prince of Monaco (see Kofoid, 1910). It is the purpose of this note to record these improvements.

In the first model the four standards (figs. A, B) connecting the brass castings which form the head and base, were made of heavy brass tubing 16 mm. in diameter. These proved too weak to stand the usage in handling the heavy load of water, and also gave trouble by slight dents which they received and which interfered with the smooth working of the sleeves upon the cylinder and lid that guide these parts to their seats in closure. Accordingly in the new model solid rods of hard brass were substituted.



B A

Fig. A. Self-closing water-bucket set for lowering, with lid and cylinder suspended by two clutches held in place by springs to the headpiece. Detachable messenger in descent just above the clutches. Key-faucet removed from outlet. × $\frac{1}{10}$.

Fig. B. The bucket after closure, lid and cylinder held in place by snap locks in standards. Messenger resting on rubber buffer. The hinged arm with turn-button below (above in figure), which closes the slot through which the cable is passed to the axis of the apparatus, is withdrawn and thrown outward. The cable eye is shown on the steel bolt which carries the weight of the apparatus. Key-faucet in place for emptying the contents. × $\frac{1}{10}$.

The bucket is lowered on the end of the cable to the desired depth with the cylinder and lid in the position shown in figure A. Then the spherical cast-iron weight which parts in two halves is tied about the cable and dropped upon the head of the bucket, releasing the two hooked clutches which suspend the lid, with the attached cylinder, to the head, and dropping them to the position shown in figure B. The lid is locked in place by spring catches in the standards, and twenty liters of water from any desired depth are thus secured.

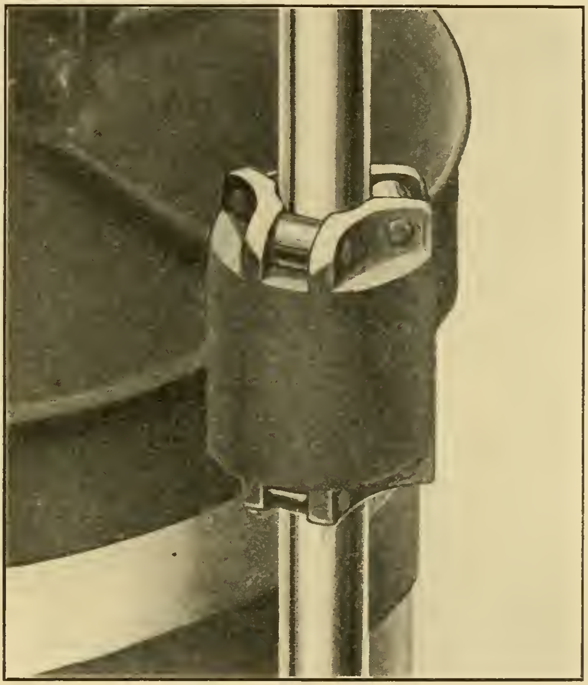


Fig. C. Sleeve of headpiece on standard, with steel rollers above and below. × ½.

In practice we found that slight unevenesses on the standards, or slight obliquities in the positions of lid and cylinder, led to one or both failing to close when released, because of this binding of the sleeves upon the standards. In the new model this defect has been obviated entirely by reconstructing the sleeves of the lid. In place of the simple hub bored as a sleeve in the old model, the new model has a larger hub (fig. C), 40 mm. in diameter, with a bore rather greater than the standard in diameter and carrying between flanges on both the upper and lower surfaces of the hub three equidistant steel rollers 8 mm. in length and the same in diameter. These stand with their axis of revolution in the horizontal plane and in such a position that the least tilting of the lid in any direction brings one or more of them in contact with the standard, and their rolling motion facilitates the immediate descent of the lid.

The key-faucet and its revolving seat which closes the outlet, have both been constructed of bronze, which is more durable than the brass used in the first model, and the diameter of the outlet has been increased to hasten the emptying of the catch and thus to make possible more rapid repetition of catches at sea.

Zoological Laboratory, University of California.
Transmitted August 17, 1911.

LITERATURE CITED

Kofoid, C. A.

1905. A self-closing water-bucket for plankton investigations. Cons. Perm. Intern. Expl. de la Mer. Publ. de Circonstance, no. 32, 10 pp., 4 figs. in text.

1910. The biological stations of Europe. Bull. U. S. Bureau of Education, **1910**, no. 4, xiv, 360 pp., 55 pls., 48 figs in text.

McEwen, G. F.

1910. A preliminary report on the hydrographic work carried on by the Marine Biological Station of San Diego. Univ. Calif. Publ. Zool., **6**, 189–204, 1 fig. in text and 1 map.

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