A PRELIMINARY ACCOUNT OF THE MADRAS PLANKTON.

By K. SANKARA MENON, *M.A., Research Student, University Zoological Laboratory, Madras.*

(Plates IX—XV.)

INTRODUCTION.

The present paper is the outcome of two years' work devoted to the subject as a Research Student of the University of Madras. The work was started at the suggestion of Professor K. Ramunni Menon, Honorary Director of the University Zoological Laboratory, and was carried on during the first year under his direction. During the second year, the work was continued under the guidance of Professor R. Gopala Aiyar, who succeeded Professor Ramunni Menon as Honorary Director. To both of them I am indebted for many valuable suggestions and I take the opportunity here of thanking them gratefully for all the help that they have accorded me. I am also thankful to Lt.-Col. R. B. Seymour Sewell for very valuable advice on various points.

This paper has been modelled on Lebour's study of " The Microplankton of Plymouth Sound " in the Journal of the Marine Biological Association (1917). With this excellent model before me I have attempted the difficult task of putting into publishable form the rather voluminous records of two years and to give an account of the seasonal variation of the planktonic organisms of this coast. The physico-chemical conditions of the sea remain uninvestigated. In the absence of definite hydrographical data, reasons that may be given to account for the seasonal variation of the organisms must be of a very general nature only.

GENERAL.

The Madras coast is a broad strip of land lying between the low range of mountains called the Eastern Ghats and the Bay of Bengal. In the south the Cauvery, and in the north the Krishna and the Godavary, are the only big rivers which bring in large quantities of fresh water into the sea. In the neighbourhood of Madras town, however, there are no rivers worth mention, and the two small ones that are present are little more than drainage channels and are dry practically throughout the year, having connection with the sea during the monsoon period only (Mid-October to December). This fact must have considerable importance as far as life in the coastal waters is concerned, since not much of organic and inorganic food material is brought down into the sea, nor is there such a drainage of fresh water into it as to make any very great variation in the salinity, which varies from 32 in September-November to 34·5-35 in June-August (Sewell, 1929b).

The year may be divided climatically into two main periods. (1) The South-West Monsoon period, and (2) the North-East Monsoon period.

Each of these may again be subdivided into two. 1. A period from June to Mid-September when the South-West Monsoon is in full force on the west coast of the Peninsula. This period here is a hot humid one. 2. Mid-September to December is the season of the retreating monsoon, this being our rainy season. 3. January to March. This is a cool, more or less, dry period and marks the commencement of the North-East Monsoon. 4. A hot dry period extending from March to June. This last gives place to the South-West Monsoon towards the end of June.

The methods of collection were of necessity somewhat crude. A local fisherman was employed to go out to the sea every alternate day to bring in the tow-net samples. These were generally available at about 7·30 A.M. The only craft available for the work was the ordinary catamaran of the East Coast. Hauls were made beyond the six fathom line, up to a limit of about twenty fathoms. Two tow-nets were in use, one of fine mul, and the other of bolting silk. The fresh Plankton was examined as soon as it was brought in, and the organisms present noted down in sheets ruled and dated. Different signs were used to indicate the comparative abundance of organisms. Thus S. meant swarms, P. plenty, F. few, R. rare and so on. The limitations of such a method are obvious as a common standard of abundance for all the organisms cannot possibly be arrived at. The number of individuals in a swarm of Hydromedusae would naturally be much smaller than the numbers in swarms of *Coscinodiscus* or *Noctiluca*. So, excepting as a sign of abundance, a swarm of Hydromedusae is not strictly comparable to a swarm of Diatoms or Dinoflagellates. After a thorough examination of the Plankton in the fresh condition, the organisms were strained out in fine mul, and preserved as usual in 3 per cent. formalin and sea water. Later on, with a view to arrive at some exact idea of the numbers of the various forms caught, the preserved samples were examined. The samples were first stirred up well so as to ensure a uniform distribution of the organisms in the preserving fluid. One c.c. of this was then taken out with a wide mouthed, measuring pipette. The bigger forms, such as *Sagitta*, were picked out and counted. The rest of the sample was spread out and examined on a ruled slide, and the numbers of the separate organisms counted. It must be borne in mind that the counts arrived at by such a process would in no case represent the number of organisms in any known volume of sea water. For one thing it was impossible to calculate even approximately the speed of such a crude craft as the catamaran, and likewise we had no knowledge of the currents on the coast. So the amount of water draining through the nets for any given length of time remained an unknown quantity. The graphs given, based on these results, while having no value as showing the numbers of any particular form in unit volume of sea water, serve, however, to give a very good idea of the intensity of the various maxima. They fail in this, when such organisms as Dinoflagellates are concerned, which, as Lohman (1908) first pointed out, either get through the nets entirely, or are not caught by them in anything like representative numbers. Exact quantitative work must be deferred until we have a better knowledge of the currents, along with modern facilities to carry out such work. Lebour's method of quantitative estimation by means of water-samples

might also be tried, but this would fail with the Macroplankton, and lead to inconclusive results.

While a few forms such as *Sagitta* and *Pleurobrachia* do not show much variation in numbers throughout the year, and do not have a definite maximal period, most of the organisms exhibit a regular seasonal abundance, and corresponding periods of maxima and minima. This variation, however, is not so clear cut as in more northern latitudes, as the records of Herdman (1907-1921) and other European workers show- Many of the Copepods for example, while having a definite maximal period, are hardly ever completely absent from the Plankton. This is probably because the weather conditions and the resulting changes in the constitution of the sea-water do not vary so much here as in the colder seas. A comparison of the Madras Plankton with the Plankton of the West Coast of India (Hornell and Ramaswami Naidu, 1923) is interesting and reveals certain important differences between the two regions. The seasonal variation of the Phytoplankton is probably the most important of these differences. The West Coast Plankton shows great Diatom scarcity in December, which is the end of a gradual decrease starting in September. In January and February there is a secondary maximum. This is followed by the great maximal period of May after a distinct fall in March. With us, on the other hand, October to December is a period of gradual Diatom increase after the barren months of August and September. This is probably due to the fact, that an enormous Dinoflagellate maximum, which takes place on the West Coast at about this time, uses up the inorganic food material that is so necessary for the Diatoms. Johnstone, Chadwick and Scott (1924) mention this as a probable reason for the secondary Diatom maximum being smaller than the main one in European waters. The advancing South-West Monsoon which brings torrential rains to the West Coast of India does not penetrate through the Ghats to influence the Madras coast. So, when on the West Coast there are heavy rains (June-September), the East Coast enjoys only very occasional showers. Consequent on these heavy rains there is a lowering of the salinity of the coastal waters, and to this fact the West Coast workers attribute their Phytoplankton maximum. This Phytoplankton maximum, however, takes place at practically the same time of the year in Madras as in European waters: this would seem to afford strong support to the conclusion that Allen and Nelson (1910) came to in their work on the artificial culture of Marine organisms, that variation in salinity within natural limits affects life in the sea only very little, and that salinity may be varied to a greater extent than natural variation in the sea without much effect on the rate of reproduction of the Diatoms. It is, therefore, likely that the coincidence of the Phytoplankton maximum with the onset of the monsoon in the West Coast is due more to the river floods that bring in vast quantities of organic and inorganic food-matter into the sea than to the lowering of salinity. In Madras, September, which may be taken as the commencement of the biological year, starts with a great scarcity of Diatoms. By the end of the month, however, various Diatoms have begun to appear, the most important among them being *Coscinodiscus* spp. From November to January inclusive we have what may be termed a secondary maximum. If we define the maximum of such a

large group as the Phytoplankton as the period when the greatest number of forms occur in the largest numbers, we cannot strictly call the November to January period a maximum period, since it is made up mainly of *Coscinodiscus* spp. From March the true Phytoplankton maximum commences and reaches its greatest intensity in May. In the beginning of June the Diatoms get fewer in numbers, but towards the end of the month and the beginning of July they reappear again in large numbers. They then disappear very rapidly and the Diatom scarcity may be said to start from the second week of July and last till the second week of September.

Both Lebour (1917) and Herdman (1922) are in agreement as to the succession in definite order of the maxima of the three main constituent groups of the Plankton, namely the Diatoms, the Dinoflagellates, and the Copepods. They record a spring and early summer maximum for Diatoms, a summer maximum for the Dinoflagellates, and an autumn and early winter maximum for Copepods. Here we do not have a separate Dinoflagellate maximum : it coincides with the Diatom maximum of April and May. The Copepod maximum occurs later than the Liverpool and Plymouth records show. The maximum period is from November to February inclusive. Thus December, which is the month when the Plankton is extremely poor in the European and the Temperate seas, is included in our Zooplanktonic maximum period. The absence of such a scarcity in December is only to be expected, considering the absence of any such inhibiting factor as the intense cold of the northern winter.

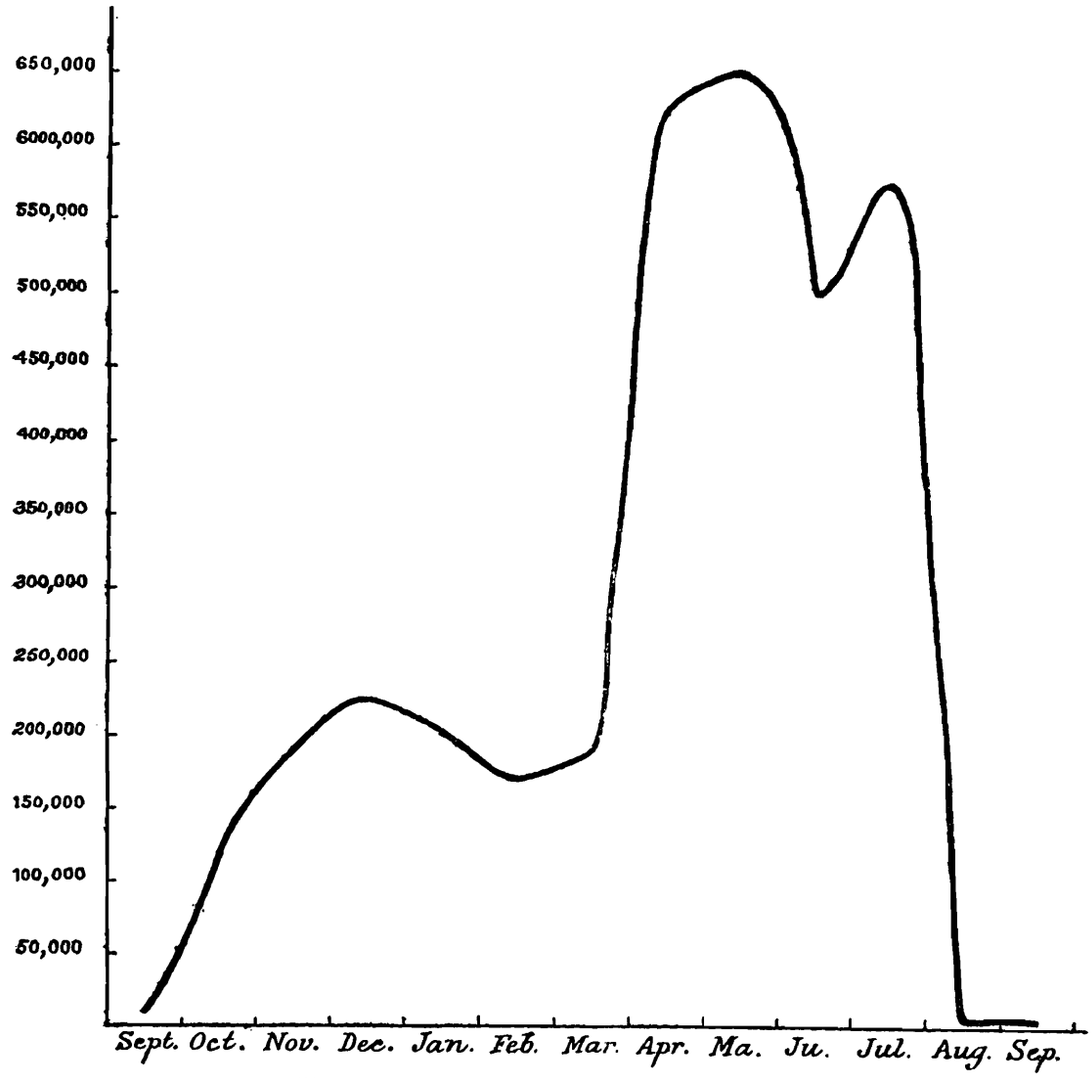
If we examine Herdman's conclusions in the light of our material, we find ourselves in accordance with most of his generalisations, excepting that the various maxima have been shifted either forward or back, as the case may be. We also find in our catches the numbers of any particular form varying greatly from day to day, occurring in great abundance one day, being scarce the next, and then again becoming plentiful, so that Herdman's conclusion that many animals such as Copepods and the larval forms are present in swarms or patches would seem to be correct.

Taking these various facts into consideration, the wonder is not that the various Plankton records differ so much, but that there is so much of general agreement between them. In spite of the great climatic differences between the European waters, accustomed to sharp variations of temperature, and our warm topical seas, where the difference between maximum and minimum temperatures is only slight, the general features of the seasonal variation of the Plankton remain the same. A difference in the fauna between tropical and temperate regions is only to be expected and is present, but there is no essential difference in the organic cycle and the features of variation.

In talking of the Phytoplankton maxima, the Zooplankton maxima, etc., it must always be remembered that there are very many exceptional days during both maximal periods when the character of the Plankton is different from what has been the rule at that time. For example on 4th June, 1930 swarms of *Sagitta* and various Copepods were present in the water. It is only when we consider the dominant organisms for any particular period as a whole that we can talk of any maxima.

DIATOMS.

General.—Compared with the Diatom lists of Herdman, Lebour, Gran and others, the number of our Diatoms seems to be few. This may be attributed to three causes ; firstly, the general Diatom scarcity of the tropical seas which seems to have impressed most workers ; secondly, Lebour's explanation that many Diatoms such as *Skeletonema costatum* and *Nitzchia* spp. are not caught by the nets, at least in representative numbers ; and thirdly, the fact that our collections are entirely surface collections. Johnstone, Chadwick and Scott (1924) view with favour Brandt's hypothesis, that one of the reasons of the Diatom scarcity of tropical seas is the activity of denitrifying bacteria, which break down the essential inorganic nitrogen compounds into elementary nitrogen at a more rapid rate in warmer temperatures than cold, thus depriving the Diatoms of their food-material. Whether this is a fact which operates on our coasts with regard to the Diatoms it is difficult to determine without actual experimental proof, but it certainly is a theory which offers a reasonable explanation.



TEXT-FIG 1.—The total Diatom curve.

Though our Diatom flora resembles that of European seas in having a general maximum in April and May, one essential difference must be mentioned. It is, that excepting for a false secondary maximum from

November to January inclusive, made up entirely of *Coscinodiscus* spp., this general maximum is, as has already been stated, the culmination of a regular and constant Diatom increase beginning in September, while in European waters it is the culmination of a sudden rise beginning in March. A suggestion may be made to explain this apparently great difference. In European waters, as here, immediately after the Phytoplankton maximum of May, there is an almost complete absence of Diatoms from the Plankton. In September the Diatoms begin to increase here as there, and in European waters there is a secondary maximum somewhere about this time. But now a climatic factor of great importance, as far as their growth and reproduction are concerned, intervenes. The rigorous northern winter with its short days sets in and in spite of the fact that there are large quantities of food material available in the sea at this time, as is shown by Atkins (1930), the lack of sunlight, which is an important factor as far as plant life is concerned, combined with low temperatures, does not allow the Diatoms to reproduce freely. In the absence of such an inhibiting factor as a severe winter, the comparatively slight changes in temperature or in the total amount of sunlight, do not affect the Diatoms in our seas, which grow and reproduce and have a final maximum at practically the same time as in those northern latitudes. It has been suggested to me by Lt.-Col. Seymour Sewell that the period of Diatom increase that commences in September corresponds to the period in which the surface-currents set from the head of the Bay of Bengal to the south along the Madras Coast, bringing with them water rich in silicates and other salts brought down by the Ganges and the Brahmaputra. He has also pointed out the correlation between the comparative paucity of the Diatoms during the November to February period with the period of maximum incidence of the Copepods, which for the most part feed entirely on the Diatoms.

Several theories have been advanced to explain the Diatom increase of April and May in European waters. The most important of these briefly are Sir John Murray's theory of the Diatom increase being due to the increase of sunlight in spring, which is the most widely accepted ; Prof. Benjamin Moore's of the increase coinciding with the variation of alkalinity of the sea water, which, it must be remembered, is due to the amount of CO_2 held in solution ; and, lastly, Brandt's hypothesis that it depends on the amount of nitrates held in solution. Of these the first seems to be a reasonable and very tenable theory seeing that the Diatoms partake of plant life. As far as the second theory is concerned, though it is true that the amount of CO_2 varies with the variation of the Diatoms, being great in the absence of Diatoms and *vice versâ*, this is hardly so much the cause as the result. A large amount of CO_2 is present in the water during the winter months, when Diatoms are scarce, probably because in the absence of sunlight the Diatoms are not able to make use of it. As for the third theory, Atkins (1930) and others have shown that there is a sufficiency of food-material in the sea in winter. Of late Atkins (1925, 1926a, 1926b, 1928, 1930), Marshall and Orr (1927) and others have shown that the Diatom increase can also be correlated with a rise in the O_2 saturation, and pH value, and a fall in the amount of dissolved phosphate and silicate. Though undoubtedly these same factors must be controlling the seasonal distribution of Diatoms in our

waters, their actual mode of action must be left a subject for future investigation.

As in other places, our chief Diatoms belong to the four genera *Rhizosolenia*, *Chaetoceras*, *Coscinodiscus* and *Biddulphia*. The others fall conveniently into two groups, those that have a definite maximum period, and those that occur throughout the year without showing much variation in numbers. All the four chief genera occur throughout the year. *Chaetoceras* spp. and *Rhizosolenia* spp. form the main constituents of the chief Phytoplankton maximum. *Coscinodiscus* spp. appears in swarms from October to February. *Biddulphia*, on the other hand, does not appear to have any fixed maximum period. It suddenly appears in large quantities in the Plankton and as suddenly disappears.

Genus **Coscinodiscus** Ehr.

All the species of *Coscinodiscus* in the Madras Plankton agree in having one maximum from October to January. They are, however, never completely absent from the Plankton. During their maximum period they occur in very large numbers. It is not known to what extent species of *Coscinodiscus* are used as food by other Planktonic organisms. At least one Terebellid larva, a Glycerid, and one or two Copepods have been observed with *Coscinodiscus* inside them. Under the microscope a swarm of *Coscinodiscus* has a slightly greenish tint which remains for sometime even after preservation. A few forms have been found harbouring bacteria.

1. *Concinodiscus concinnus* W Smith. (Gran, 1905, pp. 33 and 34). Common from October to April.

2. *Concinodiscus excentricus* Ehr. (Gran, 1905, p. 29). Time of occurrence same as that of the preceding.

3. *Coscinodiscus radiatus* Ehr. (Gran, 1905, pp. 31-32). Not as common as the preceding forms. Period of abundance the same.

4. *Conscinodiscus lineatus* Ehr. (Gran, 1905, p. 30). The rarest of the *Coscinodisci*. Occurs along with the other species of *Coscinodiscus*.

5. *Planktoniella sol* Schutt. (Gran, 1905, p. 44). This is a form which, for the sake of convenience, may be put here. In our collections it begins to appear in September in very small numbers, continues through October and November without any appreciable increase, is more abundant in December, and has a maximum at the end of January and the beginning of February. Never present in very large numbers.

Genus **Biddulphia** Gray.

The numbers in which the *Biddulphia* species appear are much less than those of the other three genera. This genus is represented here by the five species mentioned below. Of these *B. mobiliensis*, *B. regia*, and *B. sinensis* have been the subject of much discussion. Ostenfeld showed that *B. sinensis* was a species foreign to European waters, which appeared suddenly at the mouth of the Elbe, and he predicated accurately that it would appear in the English Channel in 1908. Herdman (1913) suggests, on the ground that some of his *sinensis* specimens, while normal in structure at one end, at the other end showed a decided approach to the

regia form, that *B. sinensis* is only a mutant form of *B. regia*. Herdman also treats *B. regia* as identical with *B. mobiliensis*. But the fact, also quoted by Lebour (1917), that Allen and Nelson (1910) in their work on Diatom cultures found all the three forms breeding true to type is certainly strong evidence in favour of their being separate species. Ostenfeld, after Herdman's results were published, examined the plates and samples thoroughly and wrote to Herdman affirming his belief in the verity of the species. In our samples all the three forms are present quite commonly, and all three seem to be perfectly distinct. It is more common to find the *Biddulphia* cells in an isolated condition than in chains.

6. *Biddulphia mobiliensis* (Bail.) Grun. (Gran, 1905, p. 106). Occurs throughout the year with short intervals of absence.

7. *Biddulphia regia* Schulze. (Johnstone, Chadwick and Scott, 1924, p. 16). The commonest form of *Biddulphia* in the Madras Plankton. Confined in the main to February, March and April; but occurs in small numbers also during other periods of the year.

8. *Biddulphia sinensis* Grev. (Gran, 1905, p. 107). Rarer than the two preceding forms. In common with *B. regia* it is probably slightly more abundant during February, March and April than in other months.

9. *Biddulphia granulata* Roper. (Gran, 1905, pp. 107-108). Much rarer than the preceding forms. Occurs in very scanty numbers at intervals. Was observed to be present in chains once during July, 1930.

10. *Biddulphia rhombus* (Ehr.) W. Smith. (Gran, 1905, p. 108). Very rare. Found on a few occasions in the year.

Genus **Rhizosolenia** (Ehr.) Brightwell.

Rhizosolenia, though having a very large maximum in May, is present in the Plankton at other times also. The Spring-Summer maximum of *Rhizosolenia* is made up mainly by the three species *R. semispina*, *R. shrubsolei* and *R. stolterfothii*. Of these, the last has a distinct short maximum at the end of April and the beginning of May. During the two or more weeks when they are present, they occur almost to the exclusion of every other Diatom. They appear in long spirals. The forms *R. shrubsolei* and *R. semispina* occur in very large quantities in May and often occur in chains of three or four cells each. The other forms hardly ever occur in as large numbers.

11. *Rhizosolenia shrubsolei* Cleve. (Gran, 1905, p. 52). Begins to appear in large numbers in March. Present in swarms in April and May. Occasionally numbers of them are met with in the Plankton during other months also.

12. *Rhizosolenia semispina* Hensen. (Johnston, Chadwick and Scott, 1924, p. 20). Occurs with *R. shrubsolei* and has the same period of maximum intensity.

13. *Rhizosolenia stolterfothii* H. Perag. (Gran, 1905, p. 49). Has a very limited maximum period of about two weeks at the end of March and the beginning of April. Begins to appear as stragglers in February. Its disappearance is very abrupt. It is rarely, if ever, found in the tow-nettings from April to February.

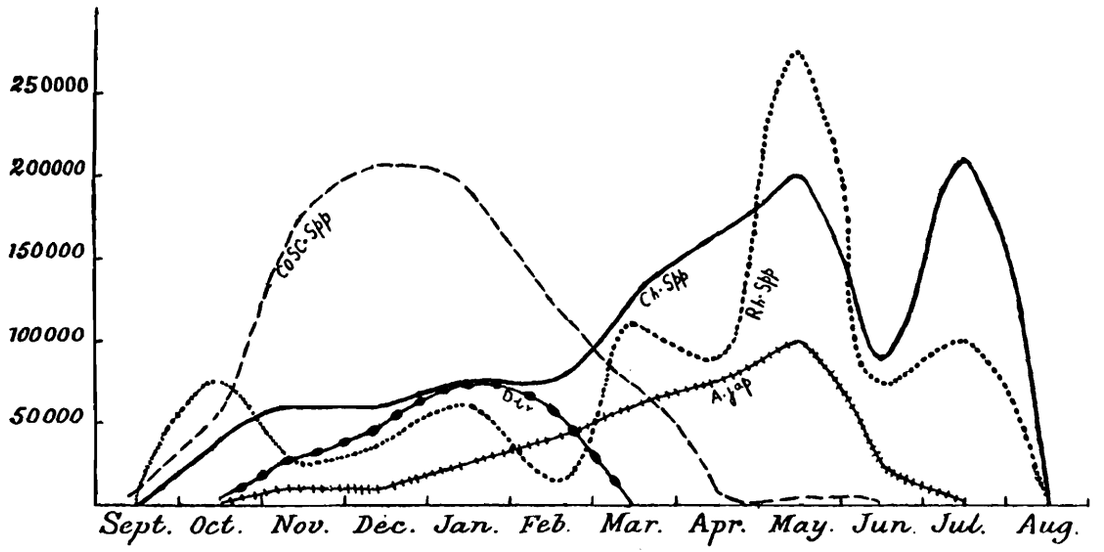
14. *Rhizosolenia calcar avis* Schulze. (Gran, 1905, pp. 54-55). Present in fairly large numbers during the Phytoplankton maximum of April and May. Only very occasionally present during the rest of the year.

15. *Rhizosolenia alata* Brightwell. (Gran, 1905, p. 56.) Period of occurrence the same as that of the preceding.

16. *Rhizosolenia setigera* Brightwell. (Gran, 1905, p. 53). Begins to appear and is common from November to February inclusive. May be said to be present in the largest numbers in January. Never so common as the preceding forms.

17. *Rhizosolenia acuminata* (H. Perag). (Gran, 1905, pp. 50-51). Occurs together with the last species. Broad in structure and when floating on the surface of the water appear as glistening flakes. Often present in chains. Swarms occasionally present from September to February inclusive. Very rare in the other months.

18. *Rhizosolenia robusta* Norman. (Gran, 1905, p. 50). Much rarer than the other species of *Rhizosolenia*. It may be said to be commoner from October to February than during the other months.



TEXT-FIG. 2.—The seasonal variation curves of the Diatom *Coscinodiscus* spp., *Rhizosolenia* spp., *Chaetoceras* spp., *Asterionella japonica* and *Ditylium brightwelli*.

Genus **Chaetoceras** Ehr.

Chaetoceras and *Rhizosolenia* are the two commonest genera of Diatoms in the Madras Plankton. Stray specimens of one species or other of *Chaetoceras* are present in the Plankton throughout the year. The largest number of *Chaetoceras* was collected in 1929, during the last week of June, and in 1930 during the first week of July. In both years, after this climax, the number of Diatoms in the Plankton was found to be very small. From the end of the second week of July the water begins to get bare of Diatoms, till by the end of the month they are almost entirely absent.

C. boreale ? is interesting in that hardly one specimen is found which does not harbour a species of Vorticellid Infusorian. These animals attach themselves to the body of the Diatom, and often upwards of a hundred individuals are found attached to a chain of six cells. These animals propel the Diatom through the water at a fairly rapid rate, and

to the naked eye it looks as if the Diatom itself is endowed with motile powers. These animals seem to favour this particular species of Diatom entirely.

19. *Chaetoceras boreale* Bail.? (Gran, 1905, p. 73). Fairly common in the Plankton from September to March inclusive. Rare from March to July.

20. *Chaetoceras decipiens* Cleve. (Gran, 1905, pp. 74-75). This forms with *C. debile* one of the commonest of the species of *Chaetoceras*. Maximum at the beginning of July or the end of June. Fairly common in the Plankton from February. Appeared in larger numbers in 1929 than in 1930.

21. *Chaetoceras debile* Cleve. (Gran, 1905, p. 92). Spirals of these are common from February to July. Present occasionally also during other months.

22. *Chaetoceras sociale* Lauder. (Gran, 1905, p. 96). Not a very common form. Was observed a few times in January and February, 1930. Occurs as a tangled mass.

23. *Chaetoceras* spp. Unidentified forms of *Chaetoceras* were present in the tow-nettings from April to July.

24. *Bacteriastrum varians* Lauder. (Gran, 1905, pp. 57-58). Common from October to February. Has a maximum in January. Disappears from the Plankton at the end of February. Appeared suddenly in the Plankton on the 18th of June, 1929 and was then present in fairly large numbers on the second and fourth of July.

25. *Bacillaria paradoxa* Gml. (Gran, 1905, p. 131). This interesting motile form is very common during the month of May. It is always found at the bottom as a group of cells which work against each other, lengthening out end to end, and then working slowly back again. Found very rarely during the other months.

26. *Asterionella japonica* Cleve. (Gran. 1905, p. 118). Common from March to July. In March and April they appear in swarms on some days, while on others their numbers are few. Throughout May they appear in consistently large numbers. The individuals present in the Plankton during July are much larger in size than in the previous months.

27. *Asterionella bleakleyi* W. Smith. (Gran, 1905, p. 119). Fairly common from September to February. Rare in other months.

28. *Thalassiothrix nitzchoides* Grun. (Gran, 1905, p. 117). Common throughout the year. Very often occurs in complete rings.

29. *Ceratulina bergonii* H. Perag. (Gran, 1905, p. 101). From the end of December to March. Most common in January and the beginning of February. Never present in very large numbers.

30. *Climacodium frauenfeldianum* Grun. (Gran, 1905, p. 100). A rare Diatom. Present in small numbers in March and April.

31. *Climacodium biconcavum* Cleve. (Gran, 1905, p. 100). Common in April and May.

32. *Bellerochea malleus* (Brightwell). (Gran, 1905, pp. 111-112). A fairly common Diatom and present practically throughout the year in more or less constant numbers.

33. *Nitzchia closterium* W. Smith. (Gran, 1905, p. 129). To be easily identified from its shape. Present in the water in April and May.

Commonest in May. This is one of the forms which Lebour finds to be commoner in water-samples than in tow-nettings.

34. *Nitzchia seriata* Cleve. (Gran, 1905, pp. 129-130). Period of occurrence same as that of the former.

35. *Ditylium brightwelli* (West). Grun. (Gran, 1905, p. 112). From September to February inclusive. Commonest in January and February. Was more common in 1929 than in 1930.

36. *Lauderia borealis* Gran. (Gran, 1905, p. 23). Very common at the end of April and the beginning of May. At other times may be said to be rare.

37. *Detonula schroderii* P. Bergon. (Gran, 1905, p. 22). A rather rare Diatom. Fairly common from May to July.

38. *Pleurosigma* sp. Present in the water throughout the year. Commonest in May. Rare at other times.

39. *Stepanopyxis* sp. Present in the water throughout the year with short intervals of absence. Common from January to May.

40. *Eucampia zodiacus* (Ehr.). (Johnstone, Chadwick and Scott, 1924, p. 20). Very rare. Observed only once in May, 1930.

41. *Trichodesmium erythraeum* Ehr. (Wille, 1905, pp. 17-18). This is a blue-green alga which has been for the sake of convenience treated under the Diatoms. It is one of those forms which occur in huge swarms and discolour the sea for miles round. The Red Sea is supposed to have earned its name from this form. Swarms present mostly in September and February. The greatest swarms are always in September.

42. *Trichodesmium thiebauti* Gomont. (Wille, 1905, pp. 17-18.) Present along with the previous form in September and October. Occurs in tangled masses. Was not observed in the Plankton in February, when *T. erythraeum* was present in swarms.

PERIDINIALES.

The paucity of Peridiniales in our collection must undoubtedly be attributed to the crude methods of collection. It is a fact that has been commented on over and over again, that many of the unarmoured forms of Dinoflagellates are so delicate and minute that they escape through the meshes of even the finest nets. Lohman (1908) showed conclusively that the Gymnodians were practically completely lost by the tow-nets; he therefore devised the method of filtering the water through hardened filter paper and taffeta silk. In this manner he discovered and described various new forms. Lebour (1917) adopted the method of taking water samples direct from the sea, and centrifuging them in tubes with pointed ends. The residue remaining in the points of the tubes was taken out by means of fine pipettes and examined. It was possible in this way, she found, to secure a good many Gymnodians. Many of these were so delicate that preservation was found to be entirely impossible.

It has been a lasting regret to me that I have not been able to follow any of these methods and so Gymnodians are entirely absent from my lists. The bigger armoured forms have been identified. The rest remain a group to be studied and dealt with hereafter.

The Peridiniales seem to attain their maximum in May. The Phytoplankton attains its maximum also at the same time. The chief representatives of the order, however, namely *Ceratium* and *Peridinium*, are present in the Plankton throughout the year: but in May, and in the case of *Ceratium* somewhat earlier, the number of Peridinians in the Plankton rises very high.

The observed Peridinians in the Plankton fall into two families, Prorocentraceae and Peridiniaceae. *Prorocentrum micans* Ehr. is the only observed representative of the first in the Plankton.

1. *Prorocentrum micans* Ehr. (Paulsen, 1908, p. 8). Easily identified by the spine at the anterior end and the absence of either a longitudinal or a cross furrow. Even this fairly big form escapes freely through the meshes of the nets. Judging from the tow-nettings the maximum would seem to be in May.

2. *Dinophysis miles* Cleve. (Karsten, 1907, p. 421, pl. xlvii). From September to February inclusive. Commonest in October.

3. *Dinophysis homunculus* Stein. (Paulsen, 1908, pp. 18-19). Much rarer than the preceding form. Present in October and November. Never more than a few individuals at a time.

4. *Ceratocorys horridus* Stein. (Karsten, 1907, p. 419, pl. lii). This is a very rare form and was observed in the Plankton only a few times between November and February.

5. *Diplopsalis lenticula* Bergh. (Paulsen, 1908, pp. 35-36). The genus *Diplopsalis* is distinguished from the closely-allied genus *Peridinium* by the presence of five apical plates, instead of seven as in the latter. It is an active form and under the microscope is seen to rotate ceaselessly. From the figures given it would seem to be the same form as the *Peridiniopsis asymmetrica* mentioned by Hornell (1923). Fairly common in the water during May. Has not been observed during the other months.

6. *Ornithocircus* sp. A rare form that has been observed only a few times in February.

Genus **Peridinium** Ehr.

This genus is represented in our Plankton by three identified forms and an unidentified one. The common form *P. depressum* is present in the water nearly throughout the year. In May, however, the numbers of this form are greatly augmented. Moreover, at this time they have a beautiful tinge due to red globules probably of an oily nature. The other three forms are restricted in their seasonal distribution.

7. *Peridinium oceanum* Vanh. (Paulsen, 1908, pp. 54-55). This species belongs to the sub-genus *Euperidinium*. Fairly common in the Plankton in August and September. Rare or absent during the other months.

8. *Peridinium depressum* Bailey. (Paulsen, 1908, pp. 53-54). Present in the Plankton throughout the year. Commonest in April and May. Rare from July to December. From January its numbers increase.

9. *Peridinium ovatum* Pouchet. (Paulsen, 1908, pp. 44-45). Common in April and May. This species, like the last, is tinged red, but the

colour in this case is not due to the presence of oil globules. It belongs to the subgenus *Protoperidinium.*

Genus **Ceratium** (Schrank).

Of all the Peridiniales, *Ceratium* is the most common. *C. tripos* is a common organism in the Plankton throughout the year. The genus is represented by a fairly large number of species. Though present throughout the year *Ceratium* has a well defined maximum in the early part. The largest numbers are present in March. Immediately after the *Ceratium* maximum, that of *Peridinium* begins. The *Ceratium* maximum is made up mostly of the two species, *C. tripos* and *C. massiliense.*

10. *C. tripos* O. F. Muller. (Paulsen, 1908, pp. 80, 88 and 89). This is represented in the Madras Plankton by the variety *C. tripos* var. *subsala* (Ostf.). This is in turn represented by three forms, the type variety, the forma *lineata* (Ehr.), and the forma *hiemale* Pauls. Of these the type variety *subsala* is the most common and is present in the water throughout the year. It is met very frequently from January to April. The forma *lineata* (Ehr.), to be easily distinguished by the short smooth hind horns, also occurs throughout the year without any appreciable maximum. Forma *hiemale* (Pauls.) is very rare and is met with only in October.

11. *Ceratium massiliense* Gourret. (Hornell and Ramaswamy Naidu, 1923, p. 191, pl. iv). A very common form. Occurs throughout the year. Commonest from January to May with a maximum in March.

12. *Ceratium breve* Ostf. and Schmidt. (Hornell and Ramaswamy Naidu, 1923, p. 191, pl. iv). Rare. No fixed time of appearance.

13. *Ceratium schmidti* Jorg ? (Hornell and Ramaswamy Naidu, 1923, p. 191, pl. iv). To be easily identified by means of the hooked hind horns. Never very frequent. No fixed maximum period.

14. *Ceratium trichoceras* Kofoid ? (Hornell and Ramaswamy Naidu, 1923, p. 191, pl. iv.). Fairly common. Occurs all through the year.

15. *Ceratium furca* Ehr. (Paulsen, 1908, pp. 89-90). At first sight very similar to *C. tripos* f. *lineata,* but can be distinguished from that form by the length of the apical horn, the fact that the two hind horns are parallel, and the toothed nature of the outer margins of the hind horns. Not very common. Occurs all through the year.

16. *Ceratium fusus* Ehr. (Paulsen, 1908, pp. 90-91). The most active of all the *Ceratia.* Also the rarest. Fairly common only in March.

17. *Ceratium reticulatum* (Pouchet). (Paulsen, 1908, p. 82). A very rare form met with only in February.

18. *Glenodinium* sp. A species of *Glenodinium,* brick red in colour, is found to be very common in the middle of July. It is very active and minute.

19. *Noctiluca miliaris* (Macartney). (Johnstone, Chadwick and Scott, 1924, p. 16). Very common in July and August. Slightly less common in September. It occurs in huge swarms and colours the water pink. Was more common in 1929 than in 1930. Occurs throughout the year.

20. *Tintinnus* sp. Of all the Infusorians the Tintinnids seem to be the only forms retained by the nets. *Tintinnus* occurs all through the year and is very common.

21. *Acanthometron pellucidum* J. Muller. (Johnstone, Chadwick and Scott, 1924, p. 16). Common in the Plankton from September to May. Commonest in February, March and April. Rare in May.

Coelenterata.

Of these the Hydromedusae are the most important Planktonic forms. These are most common in the early part of the year. From July to September they are rare. Most of the Scyphomedusae also must be treated as planktonic, as they too are at the mercy of the currents and are devoid of active migratory powers. These, however, have been fully dealt with in a paper from this Laboratory by Menon (1930), who is also preparing a paper on the Hydromedusae. I am indebted to him for the identification of some of these forms. The anemones are represented by their larvae which are common from November to March. *Pleurobrachia* is the commonest of the Ctenophores and it has no special maximum period, but periodically occurs in large swarms. It also disappears without warning. The chief Siphonophoran representative is *Diphyes*.

Hydromedusae.

These form some of the most important of the Macroplanktonic forms. They are insatiable feeders and a large number of them left in the same vessel with the rest of the Plankton bring most of the other organisms quickly to grief. They are not very selective in the matter of food-material and all animal matter seems to be equally welcome. Over twenty-two species of Hydromedusae have been observed but only about fifteen forms occur in large numbers. As a paper on this group is already in preparation only these forms will be mentioned here.

The Hydromedusae in general are rare in the Plankton from July to September. From September their numbers increase until there is a maximum in February and March when the largest numbers of them appear. In April, May and June they are still abundant, but by the end of June and the beginning of July their numbers decrease rapidly, and by the end of July they are rare.

Anthomedusae.

1. *Amphinema dinema* (Peron et Lesueur). (Hartlaub, 1913, pp. 259-264). Was collected once in October, 1929. Common at the end of February and in March.

2. *Leuckartiara* sp. Fairly common in February.

3. *Bougainvillia* sp. From December to May. Commonest in February.

4. *Merga violacea* (Ag. and Mayer.) (Hartlaub, 1913, p. 249). Rare at the end of January. Frequent in February.

5. *Cytaeis vulgaris* Ag. and Mayer. (Mayer, 1910, pp. 134-135). The commonest of the Anthomedusae. Begins to appear at the end of

November and is very common from January to March inclusive, during which period it forms one of the most important constituents of the Plankton. Rare at the beginning of April and disappears from the Plankton by the end of the month.

LEPTOMEDUSAE.

6. *Obelia* sp. One of the few Hydromedusae that are present in the Plankton throughout the year. Its numbers are largest in February.

7 *Phortis* sp. The commonest medusa of the coast. Swarms of these medusae appear in the Plankton from February to July at intervals. It begins to appear in the Plankton from November and is rare till February.

8. *Eutima orientalis* Browne. (Browne, 1905, p. 139, pl. iii). Begins to appear in the Plankton from November. Rare till January. Fairly common in February and the beginning of March after which it disappears.

9. *Aquorea pensile* (Modeer). (Browne, 1905, p. 147, pl. ii and Mayer, 1910, pp. 333-334). A common medusa. Occurs throughout the year at intervals.

10. *Aquorea parva* Browne. (Browne, 1905, p. 146, pl. ii). Very common in March. Rare in January and February.

11. *Octocanna plynema* Haeckel. (Browne, 1905, p. 144, pl. ii). Occurs at the same time as the former. Also present occasionally during other months.

12. *Zygocanna* sp. The largest of the Hydromedusae on this coast. Common in March, April and May. Swarms were caught in May, 1930.

13. *Liriope tetraphylla* (Chamisso and Eysenhardt). (Mayer 1910, p. 418, pl. 53). Occurs at intervals throughout the year. No fixed maximum period.

14. *Olindias singularis* Browne. (Mayer, 1910, pp. 357-358). Common only in June when several large forms of these are brought in with the Plankton.

15. *Solmundella bitentaculata* Browne. (Mayer, 1910, pp. 455-458, fig. 301). This is the form which ushers in the Hydromedusan season. Swarms from September to December. Fairly common in January and February.

SIPHONOPHORA.

1. *Diphyes* sp. This is the most common of the Siphonophores. Occurs from September to March. Swarms present in September, October, January and February.

2. *Porpita pacifica* Lesson. (Sundara Raj, 1927, p. 21, pl. iv). A common form from September to March.

3. *Physalia utriculus* La Martiniere. (Sundara Raj, 1927, p. 21, pl. iv). Never very common. No fixed time of occurrence.

CTENOPHORA.

1. *Pleurobrachia globosa* Moser. (Moser, 1903, p. 7, pl. i). A common form with only short intervals of disappearance.

2. *Beroe flemingi* (Eschs.) (Moser, 1903, p. 23, pls. ii and iii). Not so common as *Pleurobrachia*. Occurs from September to March. Sometimes the individuals are very large. Growth forms are occasionally present in the Plankton.

3. *Ocyroe* sp. Rarer than the two preceding forms. Easily distinguishable by the flapping movements.

Zoantharia.

1. *Arachnactis*. From September to March. Occurs only at intervals. Fairly common in January and February.

2. Semper's larva-long (*Sphenopus*). From November to February inclusive. Swarms in January and February.

3. Semper's larva-round. From November to March. Swarms in the early part of March.

Platyhelminthes.

Müller's larva. Mostly present between September and December.

Nemertinea.

Pilidium. From September to April. Common from January to March.

Annelida.

Polygordius larva. Larvae in several stages of development are met with in the Plankton from September to April inclusive. Very common in November and December.

Polychaeta.

The Polychaeta are represented in the Plankton entirely by larval forms, excepting the common *Tomopteris* and the rare *Autolytus*. Of these several are important Planktonic organisms, and occur in swarms some time or other between September and March. The rest of the forms are comparatively rare.

1. Nephthyd. From September to March. Common from October onwards. Swarms in March and April.

2. Capitellid. Never very common. Occurs from September to March. Has a short small maximum at the end of January.

3. Phyllodocid. From September to May. Swarms in December and January. Common in February and March. Absent in the Plankton from May.

4. Eunicid. Rare from November to February. Swarms in March and April.

5. Polynoid. Occurs at intervals throughout the year. Fairly common from November to May. Very common in March.

6. Nereid. Occurs at intervals throughout the year. Common from September to May. Very common in February and March. Rare in May.

7. Spionid. Occurs throughout the year and in fairly large numbers. The months of the year when they are rarest are June and the early part of July. Towards the end of July they appear in huge swarms and form the bulk of the Plankton. Swarms also occur at intervals from September up to June.

8. Polydorid. Much rarer than the Spionids but like them occur practically throughout the year.

9. Chaetosphaerid. Never present in very large numbers. Often met with from October to May. In the latter part of December and the whole of January practically absent.

10. Magelonid. From September to May with maxima in November, January and March. Never very abundant.

11. Mitraria. Occurs throughout the year. Has a large maximum at the end of July and the beginning of August. Seen under a lens the bottom of the vessel containing the tow-net water at this time glistens with the sheen of their setae.

12. Chaetopterid. Never a very common larva. Fairly common in November and March.

13. Terebellid. Occurs throughout the year. Swarms in November, March and June.

14. Sabellarian. From August to May inclusive. Never very common. Commonest in August, September, March, April and May.

15. *Tomopteris* sp. From September to March. Common in November and March.

16. *Autolytus* sp. Rare. Occasionally met with in March.

CHAETOGNATHA.

Sagitta bipunctata (Q. and G.). Present practically all through the year. Scarce in May and July. For the rest of the year very common. Many of these are met with carrying Nematode parasites which are a larval *Ascaris* (Lebour, 1918).

POLYZOA.

Cyphonautes larva. Never very common. In November, January and March.

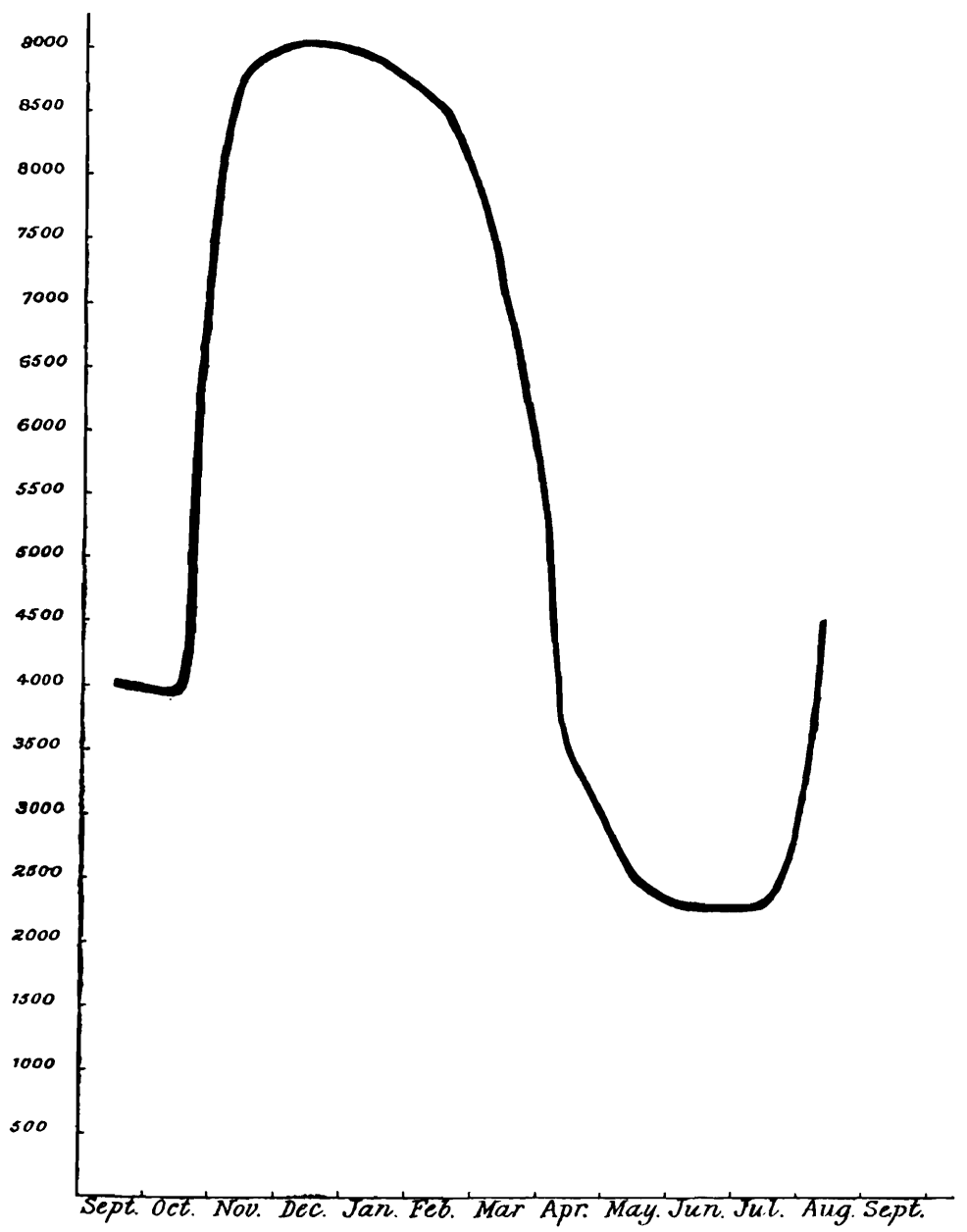
PHORONIDEA.

Actinotrocha larva. Two distinct forms of *Actinotrocha* larva have been observed. One is the kind usually figured in text-books and occurs from September to March and is common in November, January and February. The second is rare and was collected only in March. It is black in colour and the tentacles are much smaller than in the other form. The ordinary form shows great variation in colour but is mostly with crimson and brown markings on a tawny background.

COPEPODA.

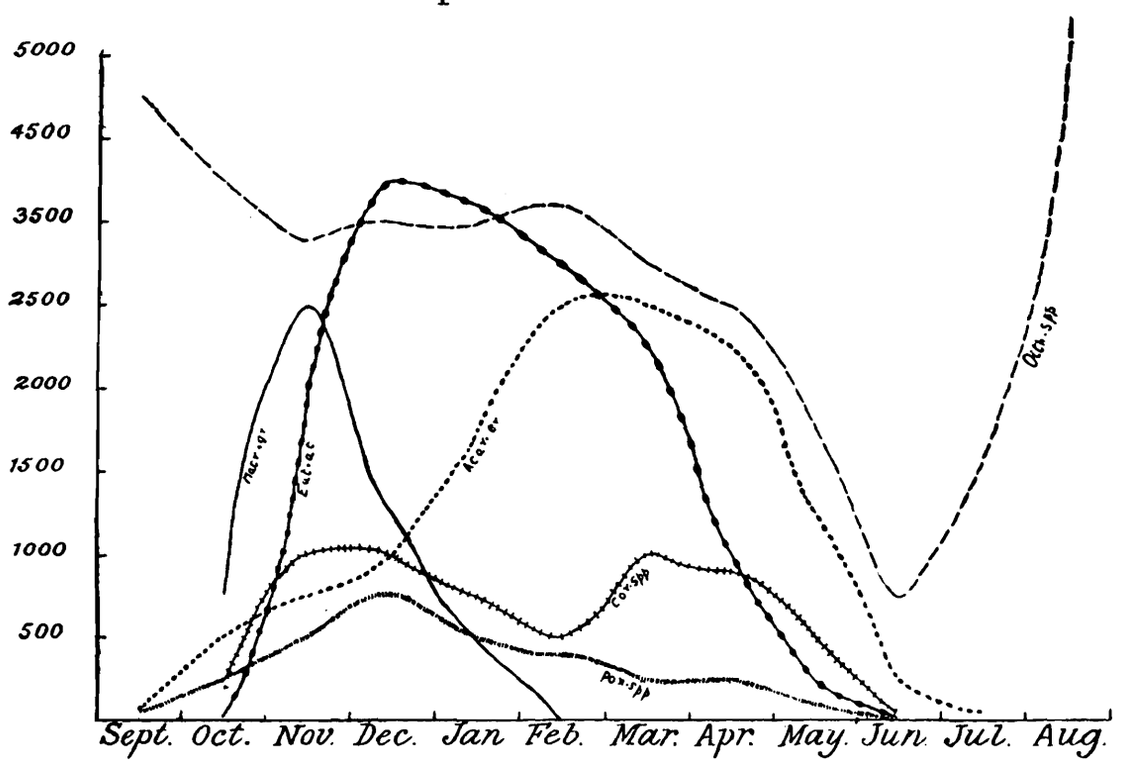
The bulk of the Zooplankton consists of the Copepods and to a lesser extent of the Crustacean larvae and the Polychaete larvae. The Copepod fauna of the Indian and neighbouring waters has been the subject of more or less exhaustive research. Of the collections that

have been made from time to time from the Indian and the Indo-Pacific regions, the "Siboga" collections (1909), Herdman's collections from the Pearl Banks of Ceylon (1903), Gardiner's collections from the Laccadive and Maldive Archipelagoes (1906), Cleve's collection from the Indian Ocean and Malay Archipelago (1901) and the "Investigator" collections (1912, 1913, 1929) may be mentioned as the more important. Important papers on the subject by G. S. Brady and P. T. Cleve, on the Copepoda of Durban Bay and the Arabian Sea respectively, have unfortunately not been consulted. But for purposes of identification the papers cited along with Giesbrecht's classical monograph in the 'Fauna and Flora of the Gulf of Naples' series have been found more or less sufficient. It is not claimed that the list of Copepoda given in the present paper is anywhere near a complete one, but the important Planktonic forms which show a definite seasonal variation have been identified. The present records are not comparable with those already mentioned because here one very restricted area alone has been investigated, and only a surface tow-net has been used.



Text-fig. 3.—The total Copepod curve.

Excepting for a period of about three months from May to August, when they are scarce, the Copepods are always present in the water in considerable numbers. Many of these, typically represented by *Paracalanus parvus* Claus, *Acrocalanus* spp. etc., have a maximum period almost as long as the Copepod period as a whole. In other words they occur practically in constant numbers from about October to May. Another group, represented by *Oithona* spp. and *Euterpina acutifrons* (Dana), though always present in the Plankton in large numbers, May to August excluded, have definite maxima when they occur in very large swarms and form the bulk of the Plankton. Other forms like *Nannocalanus minor* (Claus) and *Canthocalanus pauper* (Giesbrecht) resemble the *Paracalanus* group in being present in the Plankton constantly from October to May, but unlike them are present only in very small numbers. Then there are forms represented by *Macrosetella gracilis* (Dana), which have a short sharp maximum and are absent from the Plankton at other periods.



TEXT-FIG. 4.—The seasonal variation curves of the Copepods *Oithona* spp., *Euterpina acutifrons*, *Pontella* spp., *Acartia erythraea*, *Corycaeus* spp. and *Macrosetella gracilis*.

The Copepods begin to appear in the Plankton in large numbers from August. At this time the only organisms the water contains are some Crustacean larvae, mostly post-larval stages of prawns, and a few forms of the Hydromedusan *Eirene*. The Diatoms, which were the chief feature of the Plankton at the beginning of July, have at this time reached their period of minimum development. *Oithona* spp. suddenly appear in large numbers and they have a general maximum from November to April inclusive.

1. *Nannocalanus minor* (Claus). (Giesbrecht, 1893, p. 128, pls. 6, 7, 8). This is the common form described as *Calanus minor*, removed by Sars into his new genus *Nannocalanus* in 1925. Females have a slight pinkish tint. Never very common. From October to April inclusive.

2. *Canthocalanus pauper* (Giesbrecht). (Giesbrecht, 1893, p. 129, pls. 6, 8). Removed into his new genus *Canthocalanus* by A. Scott (1909) due to peculiarities of the left fifth foot of the male and the presence of a hook on the first swimming leg in both sexes. Fairly common from October to April inclusive.

3. *Undinula vulgaris* (Dana). (Brady, 1883, p. 53, pls. xv, xviii and Giesbrecht, 1893, p. 129, pls. 6, 7, 8). The *Calanus vulgaris* of Giesbrecht. It is a common form and is present throughout the Copepod period.

4. *Undinula darwini* (Lubbock). (Brady, 1883, p. 54, pl. xvi). Not so common as the former, the period of occurrence, however, being the same.

5. *Eucalanus elongatus* (Dana). (Giesbrecht, 1893, p. 150, pls. 11, 35). This has been recorded more often from the Atlantic than the other Oceans. It seems to have been recorded from the Indian Ocean by Wolfenden (1911) and Sewell (1913). Sewell records it in large numbers from four of the " Investigator " stations. It has been observed only twice in September, 1929 here.

6. *Eucalanus attenuatus* (Dana). (Giesbrecht, 1893, p. 150, pls. 3, 11, 35). Present occasionally in the Plankton from October to February.

7. *Eucalanus crassus* Giesbrecht. (Giesbrecht, 1893, p. 151, pls. 4, 11, 35). The commonest *Eucalanus* here. Identified easily by the tumid body and very swollen genital segment. It is a permanent feature of the Plankton and is taken occasionally even between May and August. Most frequent from October to February.

8. *Eucalanus subcrassus* Giesbrecht. (Giesbrecht, 1893, p. 151, pls. 11, 35). Sewell claims this as the most common *Eucalanus* of Indian waters. In Madras, however, it is not so common as the preceding form. Period of occurrence the same.

9. *Paracalanus parvus* (Claus). (Giesbrecht, 1893, p. 170, pls. 1, 6, 9). Common from September to May.

10. *Paracalanus aculeatus* Giesbrecht. (Giesbrecht, 1893, p. 170, pl. 9). Closely related to the previous form. Differs in the longer antennae and the armature of the fourth foot. Period of occurrence the same.

11. *Acrocalanus longicornis* Giesbrecht. (Giesbrecht, 1893, p. 175, pls. 6, 10). A common form. Occurs in practically constant numbers from October to April inclusive. Easily distinguishable from the other species of *Acrocalanus* by the length of the antennae which extend beyond the body by five joints.

12. *Acrocalanus gracilis* Giesbrecht. (Giesbrecht, 1893, p. 175, pls. 6, 10). Also a common form with the same period of occurrence as the former. Distinguishable by the large size and the rounded cephalothorax.

13. *Acrocalanus monachus* Giesbrecht. (Giesbrecht, 1893, p. 175, pls. 6, 10). The commonest form of *Acrocalanus* here. Period of occurrence the same as the other species of *Acrocalanus*.

14. *Calocalanus pavo* (Dana). (Giesbrecht, 1893, p. 185, pls. 1, 4, 9, 36). Easily identified by the two-jointed abdomen and the furca joints which are at right angles to the abdomen. None of our form,

show the caudal setae in perfect condition as is shown by Giesbrecht. Occurs sparingly in July.

15. *Calocalanus plumulosus* (Claus). (Giesbrecht, 1893, p. 185, pls. 3, 9, 36). To be distinguished from *C. pavo* by the three-jointed abdomen and the normal but asymmetrical furca. The left furcal seta of the characteristic form figured by Giesbrecht was never observed in perfect condition. It was always broken of at various lengths. This form does not appear to be a denizen of the Madras Plankton. It was brought in once with the tow-net water on the seventh of February, 1930, and on that occasion it was present in considerable numbers. It has never been observed since.

16. *Centropages furcatus* (Dana). (Giesbrecht, 1893, p. 320, pls. 17, 18, 38). A common form. Present off and on from November to February inclusive. To be distinguished from other members of the genus by the slender body, by the structure of the last thoracic segment, and the short middle abdominal segment.

17. *Centropages orsinii* Giesbrecht. (Giesbrecht, 1893, p. 321, pls. 17, 18, 38). Also a common form but does not appear in such large numbers as the previous one. Period of occurrence the same.

18. *Centropages tenuiremis* Thompson and Scott. (Thompson and Scott, 1903, p. 247, pl. i). This characteristic form, described and figured by Thompson and Scott in their report on Copepoda in the 'Ceylon Pearl Oyster Fisheries' series, was observed to be quite common from November to March. It is easy of identification with its very acute lateral thoracic spines and the right fifth leg of the female with the basal joint having a process on the inner margin and bearing three rows of teeth.

19. *Centropages dorsispinatus* Thompson and Scott. (Thompson and Scott, 1903, p. 247, pl. i). Observed only once in November, 1930. Very easily distinguishable by the spine on the cephalic segment.

20. *Temora discaudata* Giesbrecht. (Giesbrecht, 1893, p. 338, pls. 17, 38). Never appears in very large numbers but occurs at intervals from October to May inclusive. The females with their asymmetrical furcal joints are very distinctive.

21. *Temora turbinata* (Dana). (Giesbrecht, 1893, p. 338, pls. 17, 38). The commonest form of *Temora* in the Madras Plankton. It seems to be closely allied to the *T longicornis* of European waters. A. Scott (1909) suggests that it may be the tropical variation of the northern form.

22. *Candacia bradyi* A. Scott. (A. Scott, 1909, p. 156, pl. xlvii). The males of this species are fairly common in the water in November. Sewell (1912) describes certain forms taken along with the males of *Candacia bradyi*, which he takes to be the females of the species, unknown till then. These have not been taken from our Plankton.

23. *Candacia truncata* (Dana). (Giesbrecht, 1893, p. 440, pls. 21, 22, 39). A very common form in November and also in January.

24. *Labidocera acuta* (Dana). (Giesbrecht, 1893, p. 458, pls. 23, 25 and 41). Never present in very large numbers. Occurs at intervals from October to March inclusive.

25. *Pontella danae* Giesbrecht. (Giesbrecht, 1893, p. 477, pls. 24 and 40). Begins to appear in October and has a maximum in December and January. Occurs at intervals till May. Of a bright green colour.

26. *Pontella danae* (Giesbrecht) var. *ceylonica* Thompson and Scott. (Thompson and Scott, 1903, p. 252, pl. ii). Occurs along with the previous form. Also with green pigment. Pigment is lost soon after preservation. The eyes are a beautiful violet. This variety is distinguished from the former by the asymmetrical fifth legs, the left having bigger rami, and the absence of spines on the outer margin of one ramus as well as by differences in the abdomen and furca.

27. *Pontella securifer* Brady. (Brady, 1883, p. 96, pl. xlv and Giesbrecht, 1893, p. 477, pls. 24 and 40). A very common form occurring along with the previous one.

28. *Calanopia elliptica* (Dana). (Giesbrecht, 1893, p. 441, pls. 31, 38 and 43). A rare form, stray specimens being present from November to March.

29. *Acartia erythraea* Giesbrecht. (Giesbrecht, 1893, p. 523, pls. 30 and 43). A very common form. Occurs all through the year but swarms from February to May inclusive. It is one of the commonest Copepods in the Madras Plankton.

30. *Tortanus barbatus* (Brady). (Brady, 1883, p. 71, pl. xxxi and Scott, 1909, p. 189, pl. iv). Easily recognised by the twisted anal segment. Has a sharp maximum in February and the end of March. Scott considers *T. barbatus* to be the same as *T denticulatus* Giesbrecht on the ground that the whip-like ends of the teeth of the left fifth foot, which is the only feature that separates the two species, are easily broken, and that this might account for their absence in the "Siboga" collections and in Giesbrecht's figures. But in our specimens these are quite clear and have a characteristic appearance. Sewell (1912) suggests that Scott's specimens from the "Siboga" material really belong to *T denticulatus* on the ground of the absence of the whip-like ends, and since his specimens possess these characteristic structures, that it would be advisable to retain the distinction between the two species. The condition of our specimens and the definiteness of Giesbrecht's figures would seem to bear out Sewell's suggestion.

31. *Oithona rigida* Giesbrecht. (Wolfenden, 1906, p. 1023, pl. xcix). A very common form in the Madras Plankton. It has a large maximum in August and September. It is common in the Plankton till May. In no month is it entirely absent.

32. *Oithona plumifera* Baird. (Giesbrecht, 1893, p. 548, pls. 4, 34, 44). Never appears in such large numbers as to have a definite maximum. It is, nevertheless, a conspicuous member of the Plankton from September to April with its plumose setae, which, however, are rarely found in perfect condition.

33. *Euterpina acutifrons* (Dana). (Giesbrecht, 1893, p. 555, pl. 44). To be easily identified by the prominent rostrum and the fifth pair of feet, which are large and foliaceous. This Harpacticid is a very important member of the Plankton and is never entirely absent from it. It is rarest however from May to October. It has a maximum immediately succeeding that of the next form in December and January.

34. *Macrosetella gracilis* (Dana). (Giesbrecht, 1893, p. 559, pls. 1, 45). This is the common form described as *Setella gracillis* by Giesbrecht. It begins to appear by the end of September or the beginning of October, coincident with the first rains. It has a big maximum at

the end of October or the beginning of November. It is common in the Plankton at the beginning of December but becomes rare by the end of the month and disappears by the middle of January.

35. *Microsetella rosea* (Dana). (Giesbrecht, 1893, p. 554, pl. 44). A few females of this form occur along with the last one. Not common. The males seem to be unknown.

36. *Clytemnestra rostrata* (Brady). (Giesbrecht, 1893, p. 572, pl. 45). Occurs sparingly in October, November, March and April. Closely allied to *C. scutellata* Dana, which is the characteristic northern member of the genus.

37. *Oncaea conifera* Giesbrecht. (Giesbrecht, 1893, p. 602, pls. 2, 47). A common form in October and November. Rare in December and January. In all cases tinted red, the pigment being confined more or less to the abdominal segments.

38. *Oncaea venusta* Philippi. (Giesbrecht, 1893, p. 602, pls. 2, 3, 47). Distinguishable from the preceding form by the length of the caudal furca. Period of occurrence the same as in the preceding.

39. *Corycaeus elongatus* Claus. (Giesbrecht, 1893, p. 674, pls. 4, 9, 51). This rare member of the genus is occasionally present in November. To be identified easily by the form of the abdomen, narrow in the front, swollen in the middle, and then narrowing again distally. The furcal joints are half the length of the abdomen.

40. *Corycaeus furcifer* Claus. (Giesbrecht, 1893, p. 674, pls. 49, 51). This is a common species and is present in the Plankton from October to May. Commonest in November, December, March and April. Always with red pigment. The furcal joints are characteristic, and in the female are twice as long as the abdomen.

41. *Corycaeus obtusus* Dana. (Giesbrecht, 1893, p. 673, pls. 49 and 51). Also a common form. Has the same maxima as the preceding one ; but appears in larger numbers in April and March than in November and December. Red pigment present. A compact form.

42. *Corycaeus venustus* Dana. (Giesbrecht, 1893, p. 674, pls. 49 and 51). Not so common as the two preceding forms belonging to the genus. The period of occurrence the same.

43. *Saphirina ovato-lanceolata* Dana. (Giesbrecht, 1893, p. 640, pls. 1, 52, 53 and 54). This is a very beautiful form which under the microscope displays all the colours of the rainbow. Occurs rather sparingly in November, December and January. More common in February and March. On the seventh of February, 1930 occurred in more or less large numbers when the most noticeable feature of the Plankton was a swarm of Salpae.

44. *Saphirina stellata* Giesbrecht. (Giesbrecht, 1893, p. 643, pls. 52, 53 and 54). A more or less rare form. Period of occurrence the same as that of the preceding.

45. *Saphirina nigromaculata* Claus. (Giesbrecht, 1893, p. 643, pls. 52, 53 and 54). Also a rare form ; occurs sparingly in November.

Copepod Nauplii are present in the water throughout the year. They are, however, very common at the end of July and the beginning of August. A very noticeable feature of the Plankton at the end of September is the violet-coloured, long Nauplius of some Harpacticid, probably *Macrosetella gracilis.*

Cladocera.

This order is represented by the two forms *Evadne* sp. and *Podon intermedius* Lillj. Of these, the former is an important planktonic form and forms the bulk of the Plankton at some time or other during the year. The latter is a very rare form which occurs at the same time as the other.

1. *Evadne* sp. Swarms occur in October and again in February and March.

2. *Podon intermedius* Lillj. (Johnstone, Chadwick and Scott, 1924, p. 40). A rarer form than the preceding. Occurs sparingly in October and March.

Crustacean Larvae.

These form the most important constituents of the temporary Plankton. They are present in the water in considerable numbers all through the year. But except in such obvious cases as the larvae of Cirripedes, etc., it has not been found possible to refer them with certainty to the adult forms. It is difficult to indicate the seasonal variations of several of these forms except in a general way, *e.g.*, as Macruran larvae, Brachyuran larvae, etc. The Decapod larvae form a large group by themselves and comprise many interesting forms. This will be made the subject of a future paper.

1. Cirripede larvae. The characteristic Cirripedian Nauplius and an occasional *Cypris* are met with in the Plankton throughout the year; but they have a great maximum in March and April. It is curious that the maximum of these larvae in the Madras Plankton should coincide exactly with their maximum at Liverpool as recorded by the Liverpool workers (1907 to 1921). The Nauplii which have been growing in abundance from December occur in swarms in the water in March. Towards the end of the month the *Cypris* larvae begin to get fairly common and these in their turn swarm in April; but now the Nauplii are comparatively few. The *Cypris* larvae undergo reduction in numbers towards the end of the month and become rare in May, in which month they disappear from the Plankton altogether.

2. Copepod Nauplii. Present throughout the year but commonest from July to September inclusive.

3. Stomatopod larvae. These are represented chiefly by the *Alima* larvae of *Squilla* which appear in large swarms during the early part of the year. The swarms are most frequent in February but begin to appear in November. They are not present in the water from July to November.

4. Decapod Zoea larvae. This type of larva occurs throughout the year. Swarms at intervals. The Zoea larva of *Porcellana* is most common in August and September.

5. Decapod Megalopa. Similar in occurrence to the former. Characteristic Megalopae of *Eupagurus* occur in large numbers at the end of August and the beginning of September. Macruran post-larval stages are abundant in the water in March and April, and again in August.

MOLLUSCAN LARVAE.

The same difficulty of identifying the larvae with reference to the parent forms has been experienced with this group as with the former, so only a general account of their occurrence can be given.

1. Larvae of Lamellibranchiata. Very common from October to February inclusive.

2. Scaphopod larvae. Common in November and December. Rare in January.

3. Gastropod larvae. Fairly common from September to November inclusive.

Among the adult Molluscan Planktonic forms are *Glaucus* and *Ianthina*, which are occasional visitors, and *Atlanta* which is a common form from November to March inclusive. Among the Pteropods, *Creseis* is a common form.

ECHINODERMATA.

This phylum is represented by the larvae of the orders Asteroidea, Ophiuroidea, Echinoidea and Holothuroidea. Post-larval Ophiurids and Echinids are also present in the Plankton occasionally. The whole group begins to appear in October and disappears completely in April.

1. Bipinnaria. These Asteroid larvae have been observed occasionally in November. In December they are more common. Large numbers are present in January and February. It disappears in March.

2. Brachiolaria. This rarer variety of Bipinnaria occurs along with it in smaller numbers in January and February.

3. Ophiopluteus. From October to April inclusive. Common from November to March. From February to April post-larval stages of Ophiurids are occasionally met with in the Plankton.

4. Echinopluteus. Similiar in occurrence to the former.

5. Auricularia. Not so common as any of the preceding forms. Occurs in January.

TUNICATA.

1. *Thalia democratica* Forskal. (Sewell, 1926, pp. 92-98.) Swarms of this species are present in September and October. It then becomes sparse till February, when swarms find their way into the tow-nets again. In March it is quite common : it disappears in April.

2. *Appendicularia* sp. Fairly common from October to May.

3. *Fritillaria borealis* Lohman. (Johnstone, Chadwick and Scott, 1924, p. 48). Period of occurrence the same as that of the former.

ENTEROPNEUSTA.

Tornaria. Large numbers of these are present in August and September, and then they are rare till January, when they re-appear in fairly large numbers again. Rare in February.

Cephalochordata.

Amphioxus sp. Small pelagic forms of *Amphioxus* are fairly common from October to December; probably *A. pelagicus* recorded by Herdman from the Gulf of Mannar.

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EXPLANATION OF PLATE IX.

(Figures magnified 50 times.)

FIG. 1.—*Planktoniella sol* Schutt.

„ 2.—*Rhizosolenia robusta* Norman.

„ 3.—*Rhizosolenia setigera* Brightwell.

„ 4.—*Rhizosolenia calcar avis* Schulze.

„ 5.—*Rhizosolenia alata* Brightwell.

„ 6.—*Rhizosolenia acuminata* (H. Perag).

„ 7.—*Bacteriastrum varians* Lauder.

„ 8.—*Climacodium frauenfeldianum* Grun.

„ 9.—*Nitzchia closterium* W. Smith.

„ 10.—*Nitzchia seriata* Cleve.

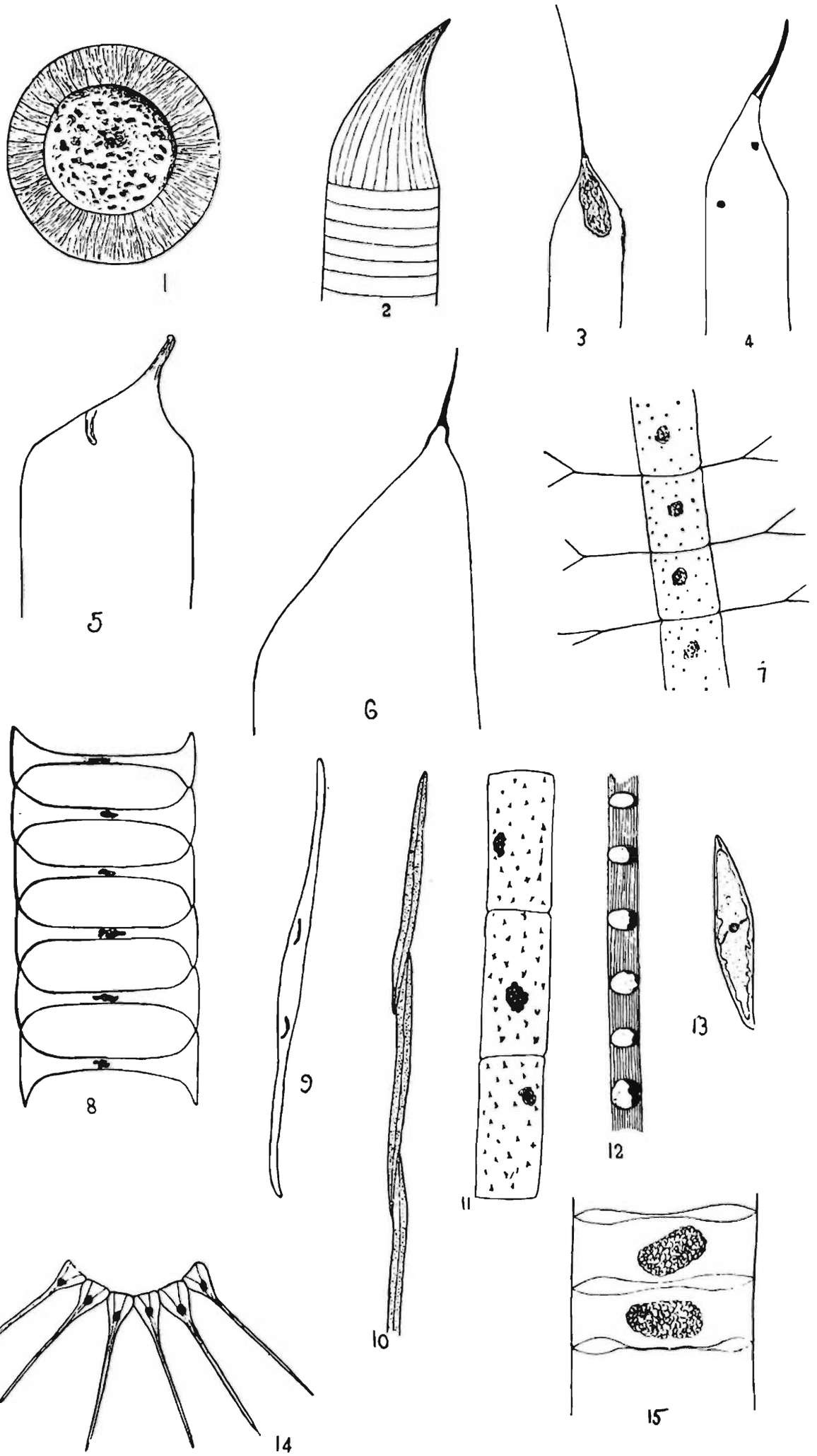
„ 11.—*Detonula schroderii* P. Bergon.

„ 12.—*Skeletonema costatum* (Grev).

„ 13.—*Pleurosigma* sp.

„ 14.—*Asterionella japonica* Cleve.

„ 15.—*Bellerochea malleus* (Brightwell).



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EXPLANATION OF PLATE X.

(Figures magnified 50 times.)

Fig. 1.—*Prorocentrum micans* Ehr.

„ 2.—*Dinophysis homunculus* Stein.

„ 3.—*Dinophysis miles* Cleve.

„ 4.—*Peridinium depressum* Bailey. Front view.

„ 5.—*Peridinium depressum* Bailey. Slightly antapical view.

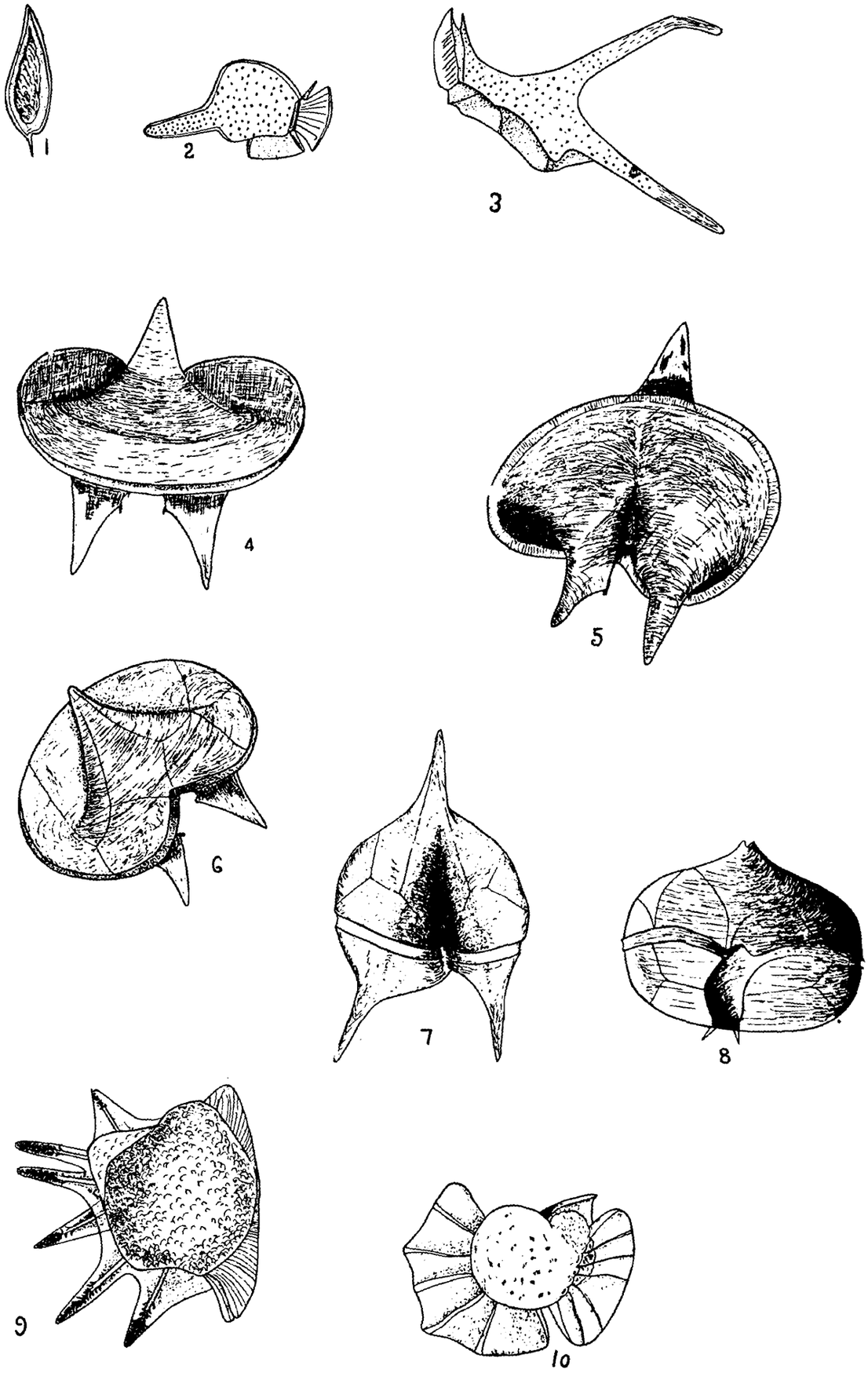
„ 6.—*Peridinium depressum* Bailey. Slightly apical view.

„ 7.—*Peridinium oceanum* Vanh.

„ 8.—*Perdinium ovatum* Pouchet.

„ 9.—*Ceratocorys horridus* Stein.

„ 10.—*Ornithocircus* sp.



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EXPLANATION OF PLATE XI.

(Figures magnified 50 times.)

FIG. 1.—*Ceratium massiliense* Gourret.

„ 2.—*Ceratium schmidti* Jorg ?

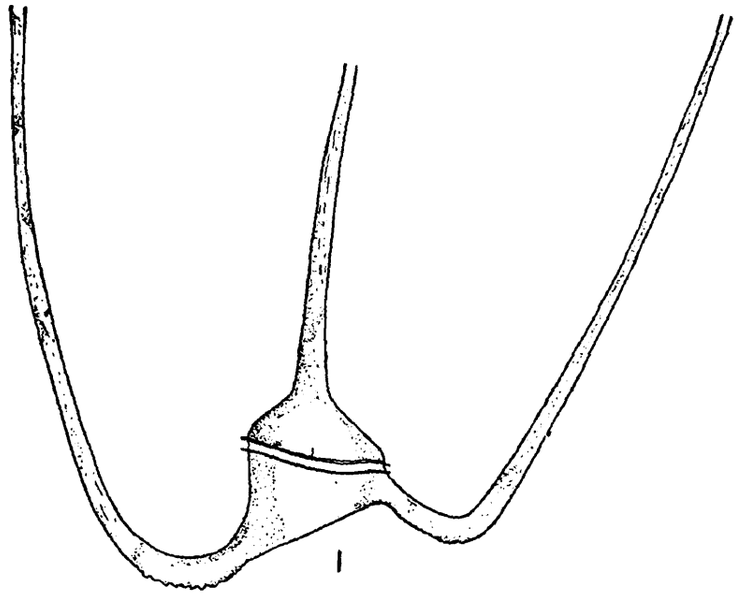
„ 3.—*Ceratium reticulatum* (Pouchet).

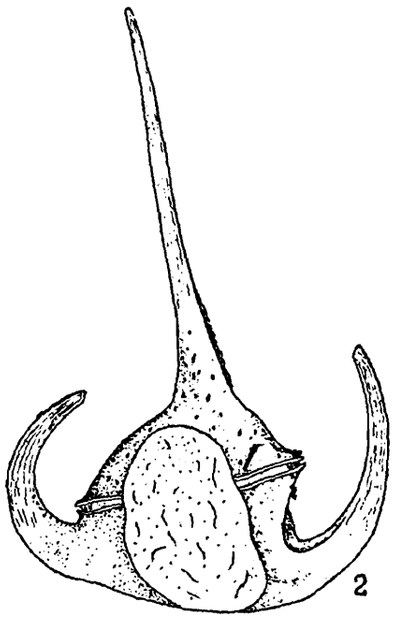
„ 4.—*Ceratium breve* Ostf. and Schmidt.

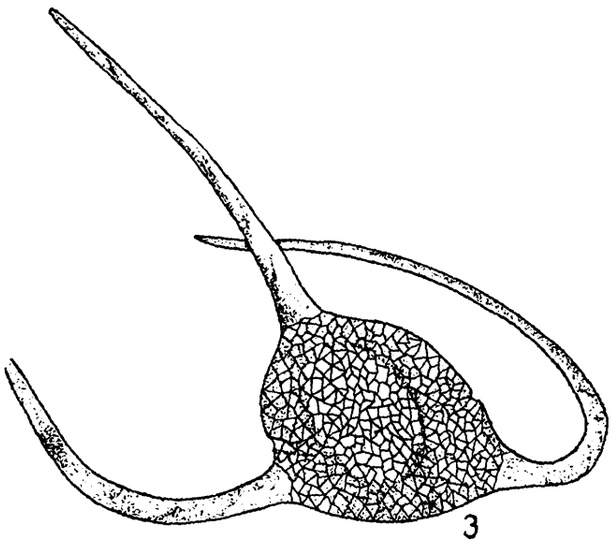
„ 5.—*Ceratium tripos* O. F. Müller var. *subsala* Ostf.

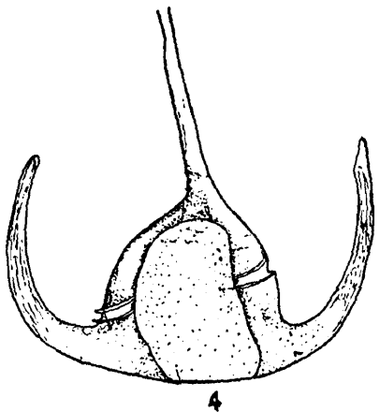
„ 6.—*Ceratium tripos* O. F. Müller forma *lineata* Ehr.

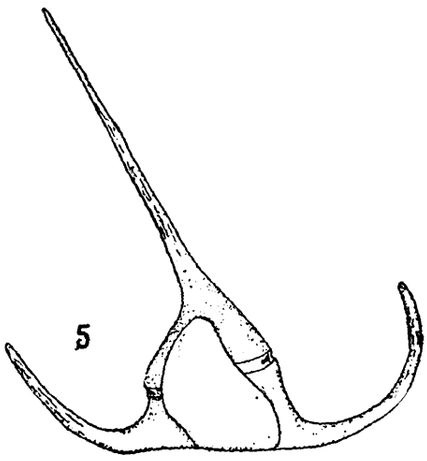
„ 7.—*Ceratium furca* Ehr.

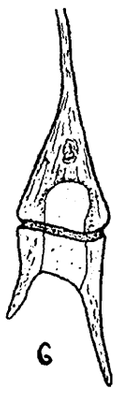


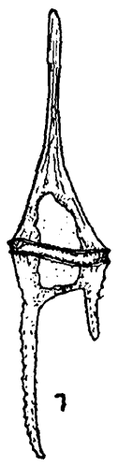












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EXPLANATION OF PLATE XII.

FIG. 1.—*Canthocalanus pauper* (Giesbrecht). ♂ Dorsal view.

„ 2.—*Eucalanus subcrassus* Giesbrecht. ♀ Dorsal view.

„ 3.—*Eucalanus crassus* Giesbrecht. ♂ Dorsal view.

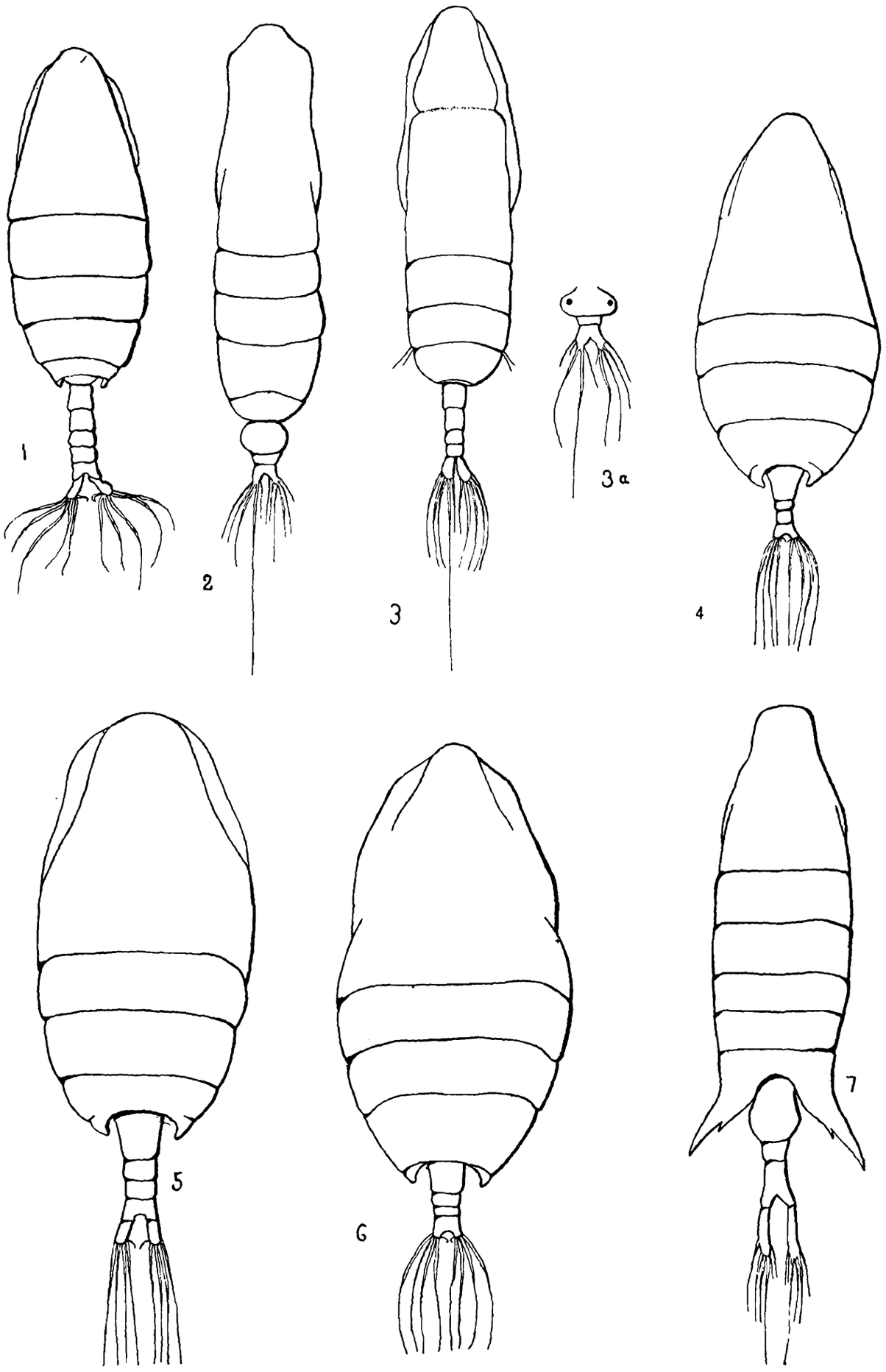
„ 3*a*.—*Eucalanus crassus* Giesbrecht. ♀ Dorsal view of abdomen.

„ 4.—*Acrocalanus monachus* Giesbrecht. ♀ Dorsal view.

„ 5.—*Acrocalanus longicornis* Giesbrecht. ♀ Dorsal view.

„ 6.—*Acrocalanus gracilis*. Giesbrecht. ♀ Dorsal view.

„ 7.—*Centropages furcatus* (Dana). ♀ Dorsal view.



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EXPLANATION OF PLATE XIII.

FIG. 1.—*Centropages orsinii* Giesbrecht. ♂ Dorsal view.

„ 2.—*Centropages dorsispinatus* Thompson and Scott. ♂ Dorsal view.

„ 3.—*Candacia truncata* (Dana). Dorsal view.

„ 4.—*Temora turbinata* (Dana). ♀ Dorsal view.

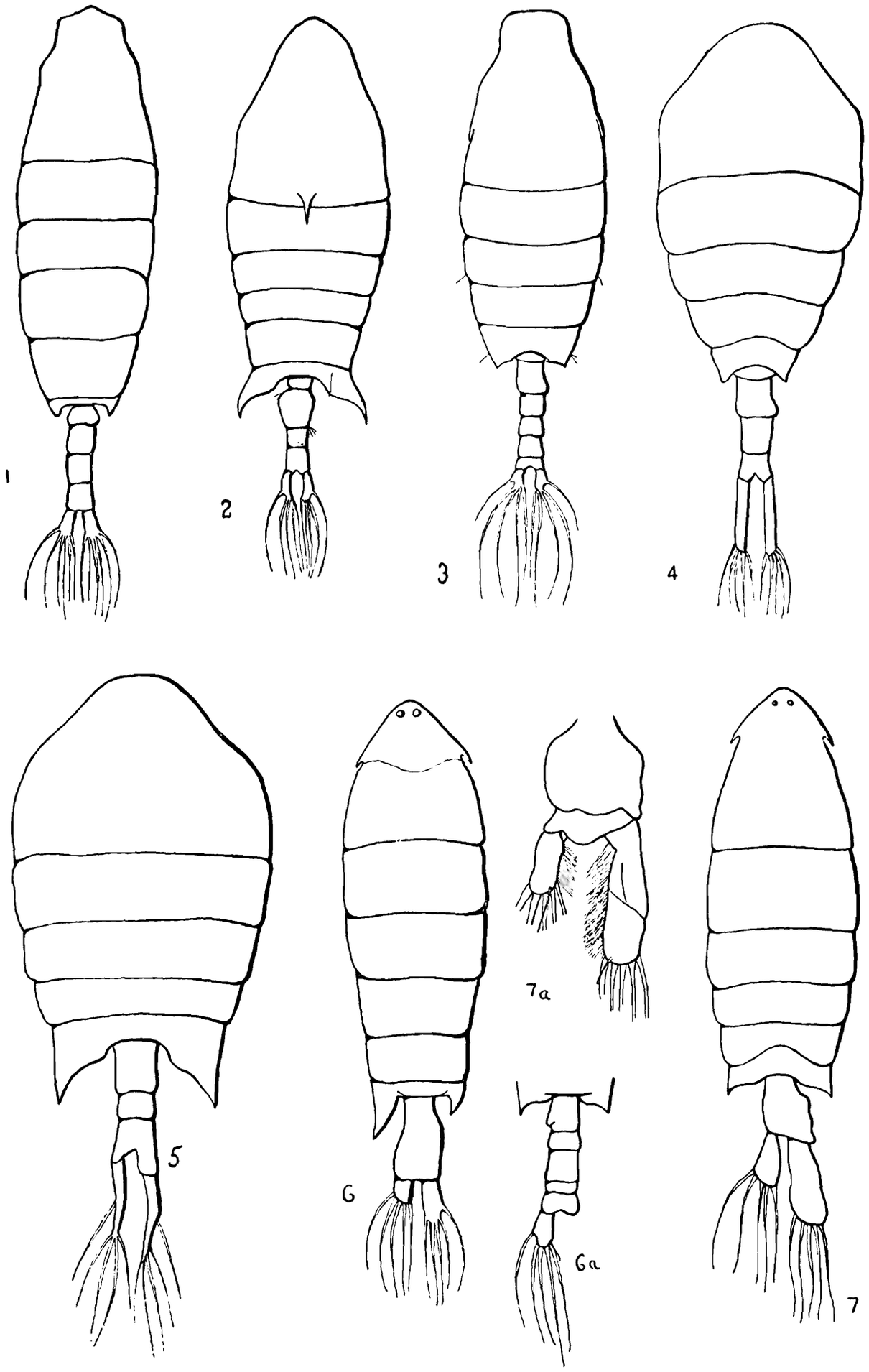
„ 5.—*Temora discaudata* Giesbrecht. ♀ Dorsal view.

„ 6.—*Pontella securifer* Brady. ♀ Dorsal view.

„ 6*a*.—*Pontella securifer* Brady. ♂ Abdomen. Dorsal view.

„ 7.—*Pontella danae* Giesbrecht. ♀ Dorsal view.

„ 7*a*.—*Pontella danae* Giesbrecht var. *ceylonica* Thompson and Scott. ♀ Abdomen. Dorsal view.



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EXPLANATION OF PLATE XIV.

FIG. 1.—*Labidocera acuta* (Dana). ♀ Dorsal view.

„ 2.—*Calanopia elliptica* (Dana). ♂ Dorsal view.

„ 2*a*.—*Calanopia elliptica* (Dana). ♀ Dorsal view.

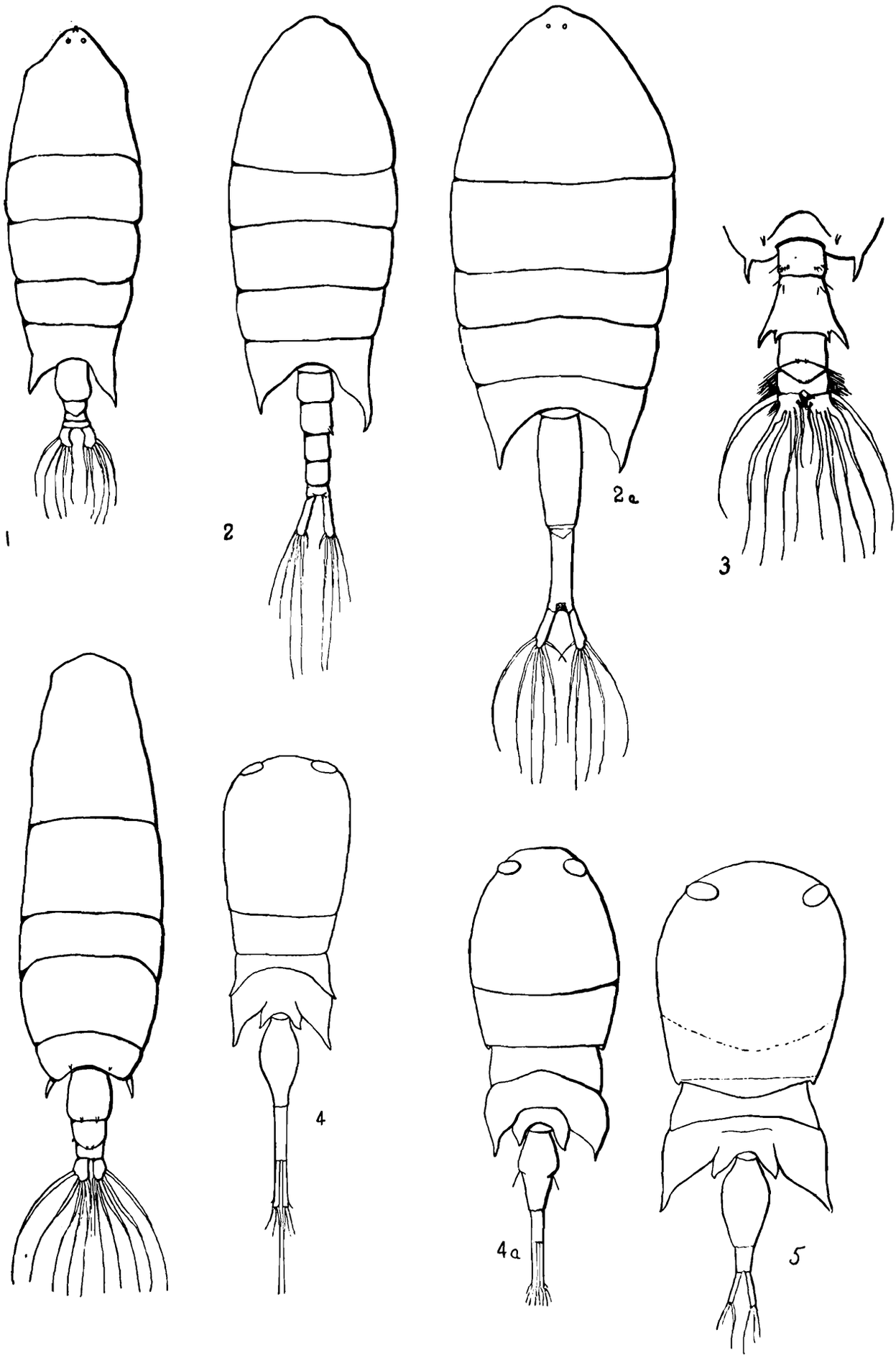
„ 3.—*Acartia erythraea* Giesbrecht. ♂ Abdomen. Dorsal view.

„ 3*a*.—*Acartia erythraea* Giesbrecht. ♀ Dorsal view.

„ 4.—*Corycaeus venustus* Dana. ♂ Dorsal view.

„ 4*a*.—*Corycaeus venustus* Dana. ♀ Dorsal view.

„ 5.—*Corycaeus obtusus* Dana. ♀ Dorsal view.



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EXPLANATION OF PLATE XV.

FIG. 1.—*Corycaeus furcifer* Claus. ♀ Dorsal view.

„ 2.—*Oncaea venusta* Philippi. ♂ Dorsal view.

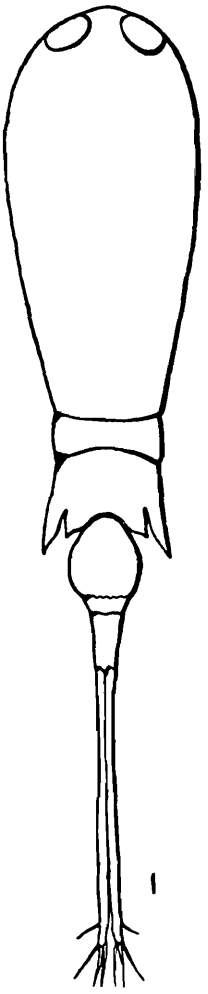
„ 3.—*Saphirina ovato-lanceolata* Dana. ♂ Dorsal view.

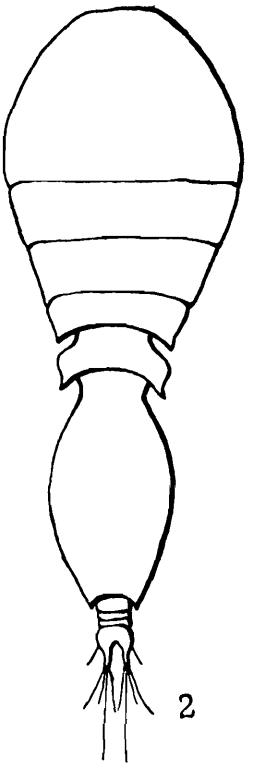
„ 3*a*.—*Saphirina ovato-lanceolata* Dana. ♀ Dorsal view.

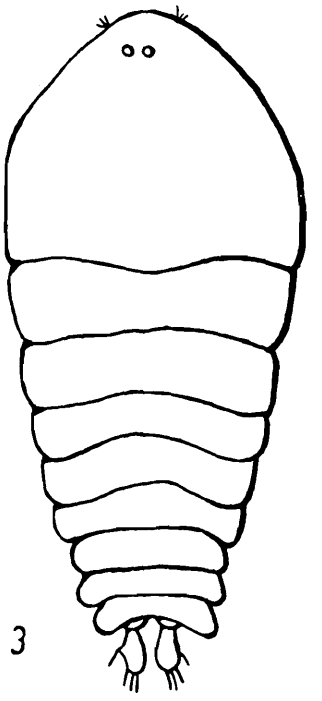
„ 4.—*Saphirina nigromaculata* Claus. ♂ Dorsal view.

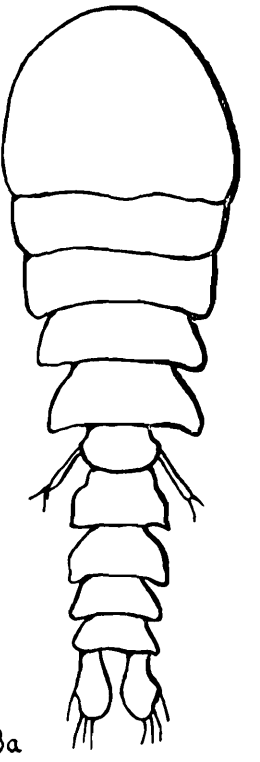
„ 4*a*.—*Saphirina nigromaculata* Claus. ♀ Dorsal view.

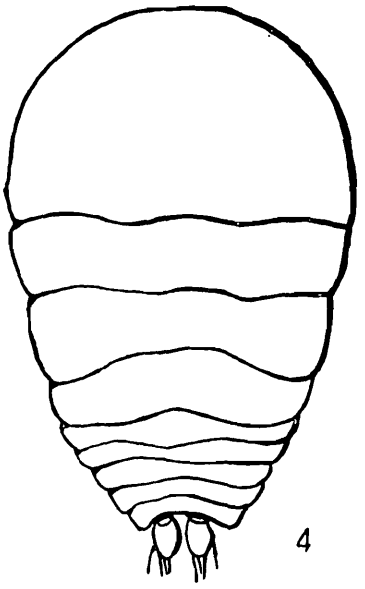
„ 5.—*Saphirina stellata* Giesbrecht. ♂ Dorsal view.

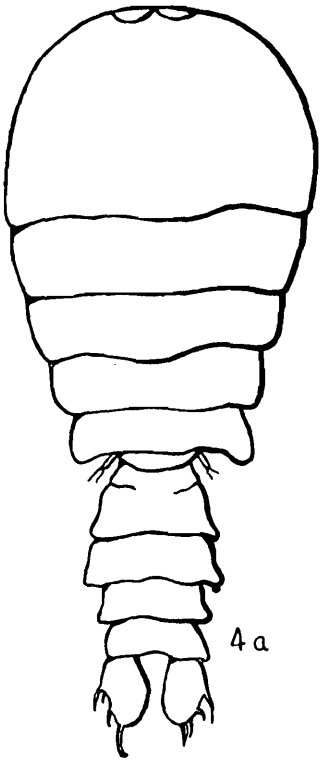


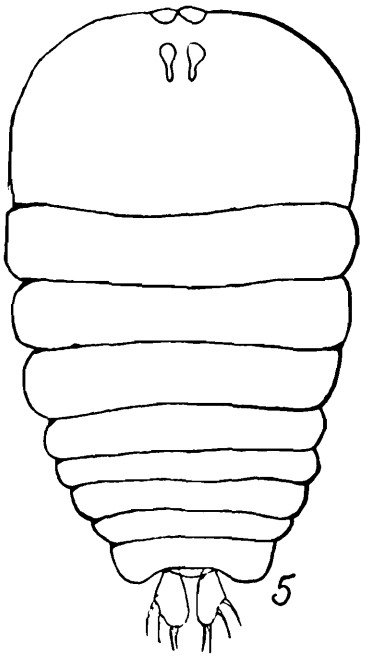












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