THE MARINE PLANKTON OF THE COASTAL WATERS OF NEW SOUTH WALES. I.

The Chief Planktonic Forms and their Seasonal Distribution.

By Professor William J. Dakin, D.Sc., F.Z.S., and Allen Colefax, B.Sc.,
Zoology Department, University of Sydney.

(Plate vii; seven Text-figures.)

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*Introduction.**

Since this paper is the first of a series of plankton studies which it is intended should come from the Zoology Department of the University of Sydney, and the associated Sydney University Biological Station, it is desirable that the general aim of the work should be explained at the outset.

Systematized studies of the biology of the ocean waters off the coasts of Australia can only be said to have been initiated very recently. It is true that there are some apparent exceptions to this statement. Various expeditions have, from time to time, collected in Australian waters, dating from the "Challenger" Expedition in 1874 to the "Dana" Expedition in 1929. Local expeditions, more especially from Sydney, have brought in vast quantities of dredged materials, and thanks in particular to the activities of the Australian Museum, the systematic zoology of the Australian coastal areas is very well known. A rather elaborately organized expedition spent a year on the Barrier Reef in 1928–1929, and carried out a very thorough biological investigation of the chosen base.

Notwithstanding this, however, it is surprising that until recently there was no marine biological station in the whole of Australia—even at present there is only one small semi-private station in occupation—and no organized work at sea on the plankton or the marine hydrography has been carried out, apart from that of the Barrier Reef Expedition. Again, whilst a systematic study of the Australian fishes has been pursued very satisfactorily indeed, practically no serious researches into the general biology of the fish fauna have ever been made.

To return to the matter of the planktonic life, our knowledge even of the systematics is confined to published accounts of a very few catches taken in Australian waters, by expeditions which were en route to other regions—the "Challenger" made a few catches in the coastal waters, and the British Antarctic Expedition ("Terra Nova"), 1910–1913, made tow-nettings whilst between New Zealand and Australia in the winter of 1911. The German surgeon, Krämer, used a tow-net for Copepoda whilst in New Zealand coastal waters, at Port Jackson, and again at Melbourne.

Tow-nettings have, of course, also been frequently made for teaching purposes —by members of the staffs of different Australian Universities, and by others interested, without any serious attempt being made to diagnose the species obtained.

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It was only the provision by the University of facilities for the continuous collection of plankton and water samples off the coast near Sydney which enabled us to initiate a long period investigation, the chief aims being to discover (1) the seasonal variations in the plankton both qualitatively and quantitatively, (2) the relation of plankton changes to the physical environment, and (3) the eggs and larvae of the food fishes of New South Wales waters and the conditions under which they are spawned and hatched. We are only beginning now to turn our attention seriously to the third of these aspects, for the initial difficulties in opening up a comparatively new field necessitated a considerable expenditure of time on taxonomic plankton studies until we became familiar with at least the organisms most commonly present.

Methods and Stations.

It seemed better at the outset, that the investigation should be concentrated at one station and under conditions which would be as little complicated by estuarine waters as possible. With this in view, a point was selected four miles east of North Head, Port Jackson, Sydney, and efforts were made to reach this spot at fortnightly intervals, at or about the hour of high water, and at about the same time of day on each occasion. The choice of high water was simply to ensure that for five or six hours ocean water had been flooding *into* Sydney Harbour, and we could count definitely on no contamination from that source. It is probable, however, that even at the hour of low water on most occasions we should have been out of the range of ebbing harbour water, which usually moves in a southerly direction rather than northerly, once it has escaped from the harbour.

Although this procedure has been the basis of the main scheme, collections have been made at odd times at other localities, and also on special occasions from trawlers many miles to the south of our station. A few collections have been made at night, with a view to comparing day and night hauls at the same station.

Complete records have been made of the weather and, before taking the plankton catches, a series of water samples were often collected, together with temperature readings at various depths from the surface to the bottom. When this was not done, the station was again visited for this purpose within 24 hours. It might be regarded as better to make hydrographic observations at the same time as the plankton catches, but, in this connection, it must be observed that we were working in unsheltered ocean waters from a small craft and usually under considerable difficulties. As it was, we had to experiment and construct gear to simplify the work with the water bottle in consequence of the rolling and pitching which was almost constantly our lot. Moreover, our early work showed little change at our Station, whether in the planktonic or the hydrographic observations during 24 hours, and it must be remembered that at many places elsewhere physico-chemical observations for the study of seasonal variations during the twelvemonth are only made at monthly intervals. For a considerable period, we conducted hydrographic observations at sea once a week.

The plankton samples have been taken with nets of both silk and cheese-cloth with a mesh rather like Stramin.* For the continuous work, we used conical nets 32 inches in length, with a diameter at the mouth of 14 inches. The silk part of the cone was 26 inches in length. Two nets, fine and coarse, were

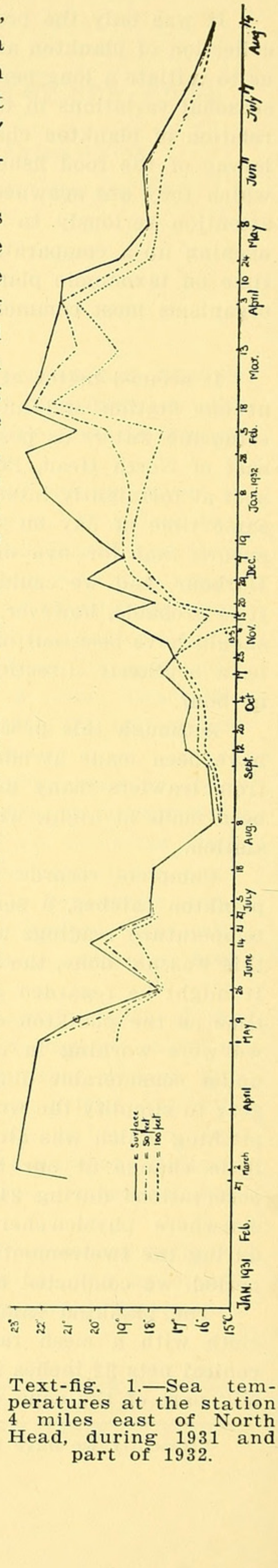
* Recently we have used imported Stramin.

always towed horizontally at the surface for ten minutes, whilst another coarse net was towed horizontally at a depth of approximately 30 metres for the same time. In addition, catches were made, both at the surface and at different depths, with a large cheese-cloth net (mouth 30″ in diameter), but these catches were not used quantitatively.

Qualitative catches were also made by vertical hauls with a large net of the same type and size as one of the "Discovery 2nd" (Whaling Exploration) nets, but these had to be discontinued owing to the difficulty of using this large size net. In addition to the above, two cylindrical nets were made of bolting silk, approximately 25 feet in length, but only 6 inches in diameter. They were long slender cylinders, and were designed so that they could be hauled at full speed (7–8 knots). They worked excellently, but probably our speed rarely exceeded 6 knots when we were out. These nets were towed over a long distance and the contents examined solely for qualitative studies of the plankton.

It is a great pity that no standard nets of reasonably small size have been designed and agreed upon internationally. There is, it is true, a Standard Helgoland Net, but this was designed for vertical hauls, and in any case is not, so far as we are aware, in general use. It is, however, fairly obvious that, for accurate quantitative comparisons of the plankton production of different places, more accurate standards than those of hauls with silk nets are absolutely essential. Another point which is not sufficiently stressed in this connection is the need for using a much greater diversity of nets, and of size of mesh, if a true picture of the plankton is to be obtained.

It was soon realized that only one method could reasonably be adopted for estimating quantitatively the components of our catches—that in which the different organisms are counted in a fraction of, or in the whole catch. In other words the Hensen methods were applied, and although tedious and tiring, they proved as usual that mere estimation that a species is common, very common, or rare, is of little or no value in the accurate determinations of seasonal variation. Counts were made in samples of 0·1 c.c. and 0·5 c.c. of fluid taken from such dilutions of the catch as proved suitable. The larger organisms were counted in the undiluted catch. The small quantities of fluid were extracted by special pipettes after complete shaking of the whole catch, and the sample was estimated on a ruled plate under the microscope.



Text-fig. 1.—Sea temperatures at the station 4 miles east of North Head, during 1931 and part of 1932.

The Hydrographic Conditions.

It has been deemed advisable to describe and discuss the physico-chemical conditions which prevail in the ocean waters from which the plankton has been taken, in another paper which will appear shortly after this. Reference to some of the data will, however, be made in our general discussion. It has been thought advisable to reproduce the chart of the sea temperatures here since it is of prime importance in visualizing the range of seasonal change in our locality. A brief account of the chief forms present in the plankton will first be given and then the seasonal distribution of the more important types will be described and discussed.

THE DIATOMS.

The study of the diatoms was forced upon us by the prime necessity of determining the seasonal changes amongst the "*producers*" of the plankton. It is not the first time by any means that marine zoologists have been compelled to take the marine diatoms into their purview. From the nature of things we have, therefore, treated the diatoms in a more general manner than the zooplankton.

The diatoms were chiefly caught in the finest meshed nets and it was in the quantitative hauls with such nets that we looked for seasonal changes in plankton production of the kind formerly so familiar to one of us (W.J.D.) in the catches round Great Britain. Only on one or two occasions, however, could one speak of really big catches, and probably on no occasion did a net come in coated with the thick brownish or green slime so characteristic of hauls during the diatom maximum in the seas mentioned.

So much work has been carried out on the marine diatoms of the Northern Hemisphere that it was deemed advisable to send samples from our catches for direct comparison with the northern forms. Fortunately very able studies on the diatoms have been made by Professor W. E. Allen, of the Scripps Institute for Oceanography, California, and it was only natural, therefore, to send to that Northern Pacific Station for assistance. We are happy to acknowledge the help unstintingly given by Professor Allen.

The following list represents only a few of the species present, but it includes those which play the most conspicuous part in the make-up of our plankton as a whole. In certain cases where counting of individual species of a genus would have involved much labour and difficulty, the species are lumped together under the head of the genus.*

Family COSCINODISCACEAE Schröeder.

Genus *Coscinodiscus* Ehr.—The only species of this genus, indeed of the family, which we have separately recorded, is *Coscinodiscus concinnus*, a large diatom of wide distribution recorded from North Atlantic waters and from the Northern Pacific off California. Its abundant occurrence is practically confined to the spring months (see tables).

Coscinodiscus Group.—Under this head we have grouped together in the tables not only species of *Coscinodiscus*, but of other genera of the family Coscinodiscaceae, viz. *Asteromphalus*. Further specific studies involving comparisons with types will be necessary before a complete list of the species occurring can be given. With the exception of the genus *Planktoniella*, the group has not played a great part in the make-up of the phytoplankton during the period so far studied.

* Since this paper was written, we have received a further communication from Professor Allen and Miss Cupp embodying a list of some of the species which are more rare than those entering into our quantitative estimations (some of them have been included in our counts but not recorded separately). A more complete systematic list of the diatoms will be given in a subsequent paper.

Planktoniella sol (Wallich).—This is an oceanic plankton species of unmistakable appearance. It occurs in the North Sea and the North Atlantic, but is noteworthy in tropical waters. It was most abundant at an unusual time for the diatoms—the months of June and July, 1931, and in July, 1932, one of the days gave almost nothing but *Planktoniella* in the fine net catches.

Family THALASSIOSIRACEAE Lebour.

Genus *Thalassiosira* Cleve.—Four species of *Thalassiosira* have played a prominent part in the make up of the phytoplankton, and three of these, *T. rotula, T. gravida,* and *T. condensata,* evidently require the same conditions, for they tend to occur in abundance at the same time. The spring maximum is sharply defined and commences in the middle of August or thereabouts, extending into October.

Thalassiosira rotula Meunier.—This species, recorded as a temperate form, is known from the Atlantic off France, and from the Pacific off California.

Thalassiosira gravida Cl.—This species, so well known in the Northern Hemisphere (it is one of the common diatoms of British seas and is recorded from the Northern Pacific), occurred together with *T. rotula,* which exceeded it in numbers. The two species were for convenience counted together.

Thalassiosira condensata (Cleve).—This diatom appeared in huge numbers in the same weeks of 1931 and 1932. It is easily mistaken for *Lauderia,* as several writers have pointed out. Its distribution is also extensive—North Atlantic as well as North Pacific (off California).

Thalassiosira subtilis (Ostenfeld).—Much less common than the other forms. Recorded during June, July and August.

Family SKELETONEMACEAE Lebour.

Stephanopyxis sp.—During a very limited period in the springtime of each of the years 1930–1932, an enormous influx of the genus *Stephanopyxis* occurred. Two species were found together in this "explosive" maximum, the most common one being *S. turris,* the other *S. Palmeriana. Stephanopyxis,* so far as we know, does not seem to have been recorded anywhere else as one of the dozen or less species which make up the bulk of the plankton at the times of maxima. *S. turris* is usually regarded as an Atlantic species. *S. Palmeriana* has a wider range. Their massive occurrence in our waters is particularly interesting since no less than four species were recorded in a catch made by the "Challenger" in the Arafura Sea (North of Australia).

Curiously enough, the related genus *Skeletonema,* which is one of the most abundant diatoms of the spring maxima of British seas and is regarded as one of the leading half dozen of the Californian Coast, is relatively rare with us.

Skeletonema costatum (Grev.) Cl.—This species, as noted above, is characteristic of Northern Seas; it occurs spasmodically in our catches and was present between May and September.

Family LEPTOCYLINDRACEAE Lebour.

Dactyliosolen mediterraneus Peragallo (*D. tenuis* (Cleve)).—This North Atlantic, Indian Ocean and North Pacific form is never very common, but occurs at odd times almost throughout the year.

Leptocylindrus danicus Cleve.—This diatom was most common during 1931–32 in the summer time. It frequently occurs in large numbers. It has been recorded from Arctic Seas, North Atlantic, U.S.A. Coast of Pacific, Malay Archipelago and Japanese waters, also from Antarctic Seas.

Leptocylindrus minimus Gran.—This species is also common at times, generally occurring with *L. danicus*.

Guinardia flaccida Castr.—This species, of wide range, has occurred at odd times, but has not taken part in making up obvious diatom maxima. It is recorded in a surface catch made by the "Challenger", in the Arafura Sea.

Family CORETHRONACEAE Lebour.

Corethron eriophilum Castr.—This species, recorded from the Arctic, North Atlantic and North Pacific, has been frequently noticed in the plankton. Quantitatively it is insignificant.

BACTERIASTRACEAE Lebour.

Bacteriastrum sp.—Species of this genus are occasionally present, but quantitatively the part played by this genus is insignificant.

Family RHIZOSOLENIACEAE Schröeder.

At least ten or more species of *Rhizosolenia* have been noticed in our catches. Those which play a really big part in the constitution of the diatom plankton are the following:

Rhizosolenia alata Brightw.—This is probably our most common species of *Rhizosolenia*. It is an oceanic diatom of wide range and common occurrence in the world's seas. It extends from sub-Arctic waters to the Antarctic, is found in the Atlantic, Pacific and Indian Oceans, and has even been recorded from the Black Sea.

R. stolterfothii H. Perag.—This species is often very common in our plankton catches and must be ranked as quantitatively important. It does not, however, form such definite maxima as other *Rhizosolenia* species. It ranks as one of the most common species in British Seas.

R. robusta, R. setigera, R. calcaravis, R. styliformis and *R. imbricata* have all been noted in the plankton at different times.

Seasonal distribution of the genus is referred to in the general discussion which follows this section of the paper.

CHAETOCERACEAE Schröeder.

Chaetoceras sp.—The species of this genus may almost be said to play the most important part in the matter of bulk in the phytoplankton. For convenience in counting, all but one species have been lumped together in our quantitative studies. It is scarcely possible to obtain any diatom catch without *Chaetoceras* being present. The quantity increases, however, considerably during the springtime and, in 1931–32, during the late summer (see notes in general discussion).

The following species have been distinguished: *C. affinis* Laud., *C. Lorenzianus* Green, *C. Peruvianus* Gran., *C. didymum* Ehr., *C. curvisetum* Cleve, and *C. debilis* Cleve. One of the most constant is *C. curvisetum*.

C. sociales Lauder.—This characteristic form, in which the small chains are held together in gelatinous colonies, has presented a sharply defined maximum in the early spring (August 2nd–31st) of 1931. The species has been recorded from Arctic Seas, from the North Atlantic, North Sea and from Japanese waters.

BIDDULPHIACEAE Lebour.

Biddulphia mobiliensis (Bail.) and *Biddulphia regia* Schultze.—There is one common *Biddulphia* species in the New South Wales plankton and it was originally named as *B. mobiliensis*, which is probably the most common species of the plankton collections made elsewhere in the world. It is now apparent, however, that *B. mobiliensis* and *B. regia* have frequently been confused. Our specimens are most like *B. mobiliensis* of Gran. (Nordisches Plankton). If this is actually *B. regia*, the form collected in our plankton must be designated under that name. Allen, however, regards it as *B. mobiliensis*.

Biddulphia mobiliensis looms large in the diatom catches of the spring months, August and September. No other species of *Biddulphia* has been diagnosed with certainty and, in any case, no other species is of consequence from the quantitative aspect.

Hemiaulus Hauckii Grün.—Occurs at odd times in small numbers but may at times become very abundant, as in the catch of November 1st, 1931. It is known from the North Atlantic and North Pacific Oceans, as a neritic species.

Dityllium Brightwelli (West.).—This diatom, whilst it may occur sporadically in various months of the year, develops a distinct, and quantitatively an important maximum in springtime (August and September).

It is another neritic planktonic species which is of wide distribution—coasts of England and North Sea, North Atlantic, and Japanese Seas.

EUCAMPIACEAE Schröeder.

Eucampia zoodiacus Ehr.—This is an important constituent of our coastal plankton. It occurs over a wide range of months, and presents a marked maximum in the springtime. In 1931, the greatest abundance occurred as late as November. In Californian waters, where it is very common, it also occurred at any time of the year, and the same thing applies to its presence in Japanese waters. The species is a neritic form found in the North Atlantic and North Pacific, but not extending into Arctic Seas. It is possible that a second *Eucampia* species occurring in much smaller numbers may have been counted in with the above species, but further investigation will be necessary to determine this.

Climacodium Frauenfeldianum Grün.—This diatom, recorded by British workers as an oceanic and tropical Atlantic form, is of frequent occurrence. It is significant that the greatest abundance is recorded for the later summer months, when the sea temperature is at its highest. It would appear, therefore, that in the Southern Pacific, its correlation with high temperature water is equally well demonstrated.

Streptotheca thamensis Shrubs.—In contrast to *Climacodium*, this "chain forming" species is neritic and, whilst occurring sporadically throughout the year, presents a maximum which commences in the later winter months just before spring. Also in contrast to *Climacodium*, it is recorded in Europe as an Arctic species. It is distinctly interesting to see how these correlations with environment recorded in one hemisphere are now borne out in another. A different species of the genus has been recorded from the Indian Ocean.

FRAGILARIACEAE Schröeder.

Asterionella japonica Cleve and Möller.—This species is one of our most abundant types. It occurs over a wide range of the year, but is particularly abundant in the spring and presents a second and smaller maximum in the late summer (see tables). In Japanese waters it attains its maximum in late autumn and winter.

This diatom is a neritic form and of wide distribution, having been recorded from the coasts of European countries, the North Atlantic, North Pacific off Japan, off California where it is one of the most abundant species and from the Indian Ocean. At times it occurs in swarms—this fact noted in European waters holds good also in the New South Wales coastal region.

Thalassiothrix nitzchioides Grün.—The species occurred at odd times during the year, but was most common in September.

Thalassiothrix longissima Cleve and Grün.—Of less importance than *T. nitzchioides*. The only considerable catch appeared on 23rd April, 1932.

Family NITZSCHIACEAE.

Nitzschia seriata Cleve.—This is a common species in New South Wales waters. It is of frequent occurrence in almost all months of the year and is probably always present, even though rare at times. It presented a maximum in the late summer months of 1931 and in the summer of 1932. It also presented a smaller maximum in the spring. It has been recorded at its greatest abundance in Japanese waters in the spring months. The distribution of this diatom is absolutely cosmopolitan—it occurs from the Arctic Seas to the Antarctic. It is termed neritic by Lebour, but its distribution does not seem to be confined to neritic regions.

Nitzschia delicatissima Cleve = *N. longissima* Ralp.—This diatom has been recorded, but is relatively unimportant quantitatively. It is a neritic form, recorded from the North Pacific and from the Indian Ocean, as well as from the European Coasts and North Atlantic.

Nitzschia closterium (Ehr.) Sm.—The species, though not abundant, has been recorded sporadically in different months. It is unimportant quantitatively.

FURTHER NOTES ON THE PLANKTON DIATOMS.

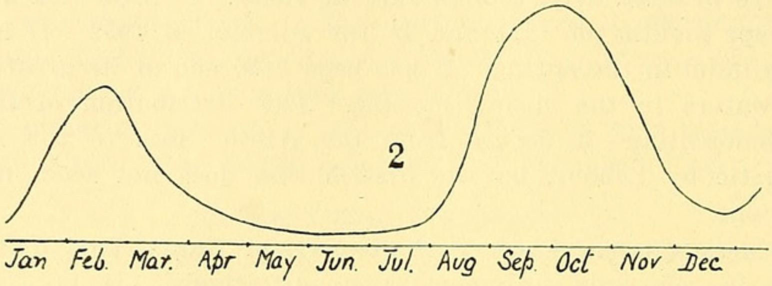
It will be seen from the notes given above, that the diatom plankton of New South Wales waters, so far as our records show, consists of the usual admixture of oceanic and neritic species, which might be expected within the vicinity of a continental shelf and the open ocean and, as usual, only a few species are quantitatively of great significance. Neritic species are those which show some sort of dependence on the presence of land or of shallower water. The dependence may be due to the fact that resting spore stages must rest on the sea bottom, or that other requirements are not met in the open ocean.

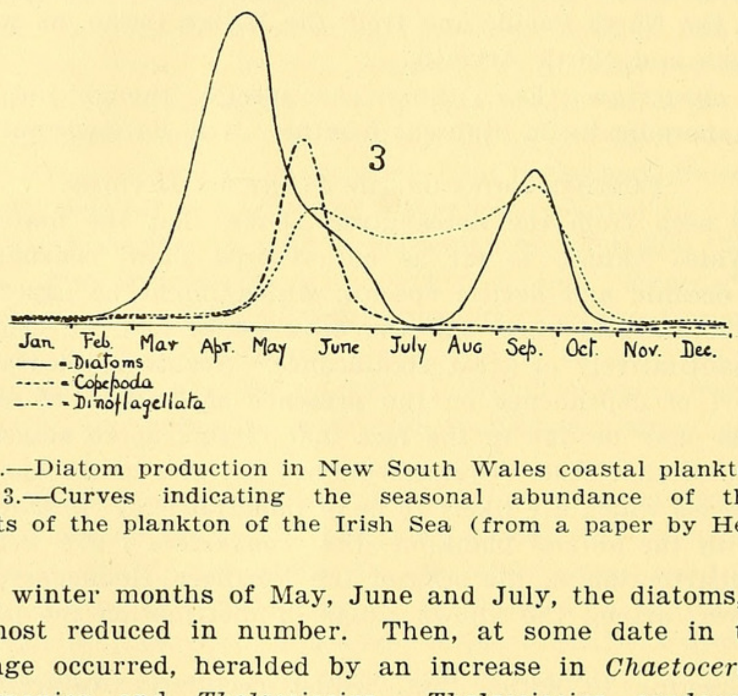
All the species which are likely to be of importance as "*producing*" organisms (contrasted with the animal plankton—the "*consumers*") are well known types, and of wide distribution in the seas of the Northern Hemisphere. The present records, however, extend the known range of distribution for practically every form quoted.

It is interesting to notice that, whilst peculiarly Antarctic species play little part in our catches, there is an admixture of temperate and tropical types. The invasion of *Planktoniella sol*, which sometimes occurs, is particularly interesting in this respect. The diatom facies reflects the fact that we are working on the edge of a tropical current and in a neritic zone. Comparisons of our diatom plankton with that from the Tasmanian region would be most interesting. It might be useful to remind readers of the fact that diatoms play a most important part in neritic phytoplankton because of their power of developing amazingly when the requisite food stuffs are richly present. Coastal waters are, compared with the open ocean, richer in such food stuffs. The same thing applies to certain areas of the sea in high latitudes.

THE SEASONAL DISTRIBUTION OF THE DIATOMS IN NEW SOUTH WALES WATERS.

The quantitative and qualitative changes in the plant life of the plankton is of outstanding importance, for it is the fundamental indicator of productive rhythm in the sea. Now the change in volume of the diatom catches during the year at Sydney is nothing like so marked as it is in certain colder seas. Seasonal variations were scarcely obvious from inspections of the nets. It was not until our enumerations were complete that a picture of diatom change directly comparable with that of Northern Seas became clear. For purposes of comparison, curves showing the seasonal distribution in the Irish Sea as well as in our waters are given in Text-figures 2 and 3.





Text-fig. 2.—Diatom production in New South Wales coastal plankton, 1931.
Text-fig. 3.—Curves indicating the seasonal abundance of the chief constituents of the plankton of the Irish Sea (from a paper by Herdman).

During the winter months of May, June and July, the diatoms, whilst never absent, were most reduced in number. Then, at some date in the month of August, a change occurred, heralded by an increase in *Chaetoceras* species, in *Asterionella japonica* and *Thalassiosira*. *Thalassiosira condensata* appeared almost "explosively" in the two consecutive years under review, at approximately the same date in August. After six weeks or so *Asterionella* began to diminish again (at the end of September), and the *Thalassiosira* maximum was of about the same duration, but species of *Chaetoceras* kept the diatom maximum still up until the month of October was through. Following on the genera mentioned, *Rhizosolenia* increased in numbers and attained its maximum in November, 1931, after most other diatom species had commenced to wane. This marked the end of the vernal maximum. During the last weeks of November and in December the plankton was very poor in diatoms. January, however, brought a recrudescence, mainly due to *Leptocylindrus*, *Rhizosolenia*, and *Chaetoceras*, and this continued into what might be called a small autumn or late summer maximum with *Asterionella japonica* appearing again.

The net result is that a curve representing the rise and fall in the quantity of producing plankton presents a peak in early spring and another smaller one in late summer.

One of the most striking results of this, our first work, is to demonstrate a similarity with the plankton rhythm of European Seas. The abundance of planktonic algae in spring is nothing like so great as in the colder seas about Britain, but it is most marked all the same. *Rhizosolenia* species follow *Chaetoceras* species in the spring outburst in British Seas. They do the same here, although the proportions of the species and the constitution of the catches are not identical (see Text-fig. 4, p. 200).

Our spring maximum commences in August. From the point of view of the calendar this would correspond with February in the Northern Hemisphere and thus our phytoplankton maximum is relatively earlier than it is in British Seas. In the latter it falls in March or as late as April. On the other hand, Steuer records the diatom maximum as beginning in December, in the Adriatic at Trieste, and continuing to the end of February. This is followed by another, but weak maximum in June and July. This locality is, however, not so suitable for comparison as an oceanic coast.

Evidently in the Northern Hemisphere as one passes south from the colder waters of the north, the spring diatom maximum occurs a little earlier in the year. Unfortunately plankton records are rather restricted from the point of view of latitude. The latitude of Sydney corresponds roughly with the northern latitude of Madeira, or with that of Los Angeles on the coast of California.

The temperature of the Irish Sea water varies between 7° C. winter and 14° to 15° C. summer, whilst Steuer records the surface waters off Trieste as ranging from 5° C. winter to 25° C. in summer. The ocean water off Sydney is perhaps slightly more equable, ranging from 16° C. winter to 23° C. summer; the temperatures are distinctly higher than those of British Seas. It will be obvious, therefore, that the spring diatom maximum commences at very different temperatures in the regions named above, although there is the marked resemblance of season.

Our diatom maximum in 1931 occurred just as the sea temperature was beginning to rise after having reached the minimum for the year, but the total increase in temperature during the first month of the diatom maximum was only about 1° C. The spring diatom maximum in British Seas occurs at approximately the same place in the temperature curve of the year as it does with us, the actual temperature being, however, about 10° C. lower in British Seas. So far it has not been possible to correlate definitely the initiation of the diatom outburst with changes in sea temperature. The matter will be discussed later; the outstanding fact to record at present is the existence of a diatom rhythm which follows the seasons, and appears correlated with them on this South Pacific coast in a manner similar to that discovered off the coasts of Europe and recognized elsewhere in the seas of the Northern Hemisphere.

SCHIZOPHYCEAE.

A species of *Oscillatoria* has been recorded at odd times during the year.

The most remarkable Schizophycean, however, is the parasitic *Richelia intracellularis* Schmidt, found parasitizing diatoms. We have found it for the first time on the Australian coast (also the first record for the South Pacific) in a large species of *Rhizosolenia*. This peculiar organism has now been recorded from the Red Sea, the Indian Ocean, the Straits of Malacca, the Gulf of Siam and the African Coast.

The Protozoa.

Only those Protozoa which have appeared abundantly as constituents of our plankton are recorded here.

Mastigophora.

Dinoflagellata.

The members of this group may well be taken first, for they should be considered with the diatoms as belonging to the group of "producers". Most important are species of *Peridinium*, together with *Ceratium furca*. *Ceratium tripos* is not uncommon with interesting oceanic and tropical forms as, for example, the fascinating *Ceratium ranipes* Cl., *C. palmatum* Br. Schroeder, and *C. platycorne*.

Species of *Peridinium* have been taken in every month of the year, the largest catches being in November, 1931, on the same date as the largest catch of *Ceratium furca*. *Peridinium* species are, on the whole, late spring and summer forms, and this fits in with their general occurrence elsewhere. No attempt has been made to separate the species in the enumerations, but the following have been noticed: *Pyrophagus horologium* Stein., *Peridinium ovatum* (Pouchet) Schütt., *Diplopsalis lenticula* Bergh., *Gonyaulax spinifera* Diesing.

Ceratium furca (Ehbg.) Cleve is found throughout the year, but is sparse in the winter months from May onward until October (see Text-fig. 4). *C. furca* is found over a wide range, absent perhaps from the colder waters of the Arctic and Antarctic Seas. It is recorded from the North Atlantic, the South Atlantic, the Indian Ocean, the Japanese Coast of Pacific, etc., viz., from the temperate to tropical seas. The species occurs in the ocean plankton as well as that of neritic waters.

Ceratium fusus Clap. and Lachm.—This species is of relatively rare occurrence here compared with the other species of *Ceratium*, and is of little significance in the quantitative picture of the plankton during the seasons examined. It is probably of cosmopolitan occurrence and of wider range even than *C. furca*.

Gymnodinium sp.—A species of *Gymnodinium* as yet undetermined, but probably new, is of special interest because of its extraordinary swarming habits in the harbour of Port Jackson. It has been known to occur for years owing to the fact that, when at its maximum, which lasts two or three weeks, it is abundant enough to colour the harbour water red. For very many years (actually since 1856) this has often been so striking an occurrence that letters from irate correspondents have appeared in the Sydney papers asserting amongst other explanations that blood from the abattoirs was being allowed to contaminate the harbour. The attention of the public is still periodically aroused.

For three years we have observed this Peridinian appear in the month of July or August, and the date has not varied more than three weeks in the years 1930, 1931 and 1932.

Whitelegge examined the harbour water in 1891 when a similar red coloration appeared in March and April. He wrote at some length on the organisms present and concluded that the coloration of the water was due in the first case to a new peridinian which he called *Glenodinium rubrum* and stated that later there was a marked prevalence of *Gymnodinium spirale* Bergh. At that time, and for many years afterwards, there was no proper knowledge of the structure of the unarmed dinoflagellates and it seems scarcely possible that Whitelegge's *Glenodinium rubrum* could be recognized to-day from the description given. Again, from his illustration, it is certain that our *Gymnodinium* sp. which we have found to occur so regularly in July and August is not the one he calls *G. spirale* Bergh.

There are other dinoflagellates which are responsible for red discoloration of the sea, and it is possible that during the thirty years which have elapsed and which have been accompanied by very considerable faunistic changes in the waters of Port Jackson, other genera and species have taken the place of earlier ones. In view of the absence of micropreparations and accurately detailed drawings of Whitelegge's specimens, it is impossible to go any further. The greatest authority on the group, Professor Kofoid of the University of California, has examined our species and he regards it as belonging to a new species of *Gymnodinium*, but the structure is so delicate that more careful examination of living material is now necessary before an exact diagnosis can be given.

The species never develops to the extraordinary state above described in the outside waters, but it does occur in the ocean catches and often at later dates than those noted for the harbour maximum.

There are other points of interest about this remarkable form. In the first place, its maximum occurs when the water is at its coldest, whilst the Peridinians are usually characterized by maxima in warmer seasons. In the second place, it seems futile at present to try and correlate this extraordinary and regular "outburst" with chemical conditions. The only seasonal conditions which recur so exactly are length of day (and consequently light) and possibly sea temperature. One is reminded very forcibly that the organism itself may possess a very significant inherent reproductive rhythm.

Dinophysis tripos Gourret.—The synonymy of this species is a very tangled one, and is referred to at some length by Kofoid. In view of the difficulty of nomenclature, it is not easy to discuss the matter of geographical distribution. It is known from the Mediterranean Sea, the North Atlantic and South Atlantic and possibly under the name *D. caudata* it is known from the Pacific. On the other hand certain authors consider *D. caudata* a distinct species.

This flagellate is of common occurrence in our plankton catches and is present throughout the year at odd times. The largest numbers and most regular presence were noted in 1931 for the weeks between 3rd October and 1st November.

Noctiluca scintillans (Macartney), (Syn. *N. miliaris* Suriray).—*Noctiluca* has only occurred three times in sufficient numbers to be noted on the counting plates and these occasions were in October, December and January respectively. On another occasion, however, in late summer, the author made a catch at night in Sydney Harbour, well away from the open ocean and the haul was almost entirely *Noctiluca*. Evidently the organism can at times be very common.

CILIATA.

A number of species of Tintinnidae have turned up in moderate numbers in some of our catches, but the time of occurrence seems to bear little relation to season. The following species have been recorded by us, all for the first time from this part of the Pacific Ocean: *Tintinnopsis vasculum* Meunier, *Tintinnopsis urnula* Meunier, *Tintinnopsis radix* (Imhof) Bdt., *Favella campanula* (Schmidt) Jörg.

(the two last mentioned are probably our most common species), *Codonellopsis ostenfeldtii* (Schmidt) (of not infrequent occurrence on certain occasions), *Rhabdonella hebe* (Cleve), *Xystonella* sp., *Coxliella ampla* (Jörgensen) Brandt.

There is evidence that these Tintinnids are much more common in the estuaries than in the open ocean. One of us (W.J.D.) has been struck many times by the abundance of Tintinnids in Australian estuarine waters. The same prevalence has been noted by Mr. T. C. Roughley (verbal communication) in the Hawkesbury and George's Rivers and Tintinnid tests have been found amongst other organic remains in the stomachs of oysters. Amongst these we have recognized from sketches, *Codonellopsis ostenfeldi*, *Tintinnopsis* sp., probably *urnula*, and a *Favella* species.

Radiolaria.

The only common Radiolaria in our catches have been Acantharians like *Acanthometron*, and colonial forms (without skeletons) like *Collozoum inerme* Haeckel.

Acanthometron sp.—Whilst of frequent isolated occurrence the numbers only became sufficient for enumeration on 25th October, 1931, 8th December, 1931, and 23rd February, 1932.

Collozoum inerme Haeckel.—Colonies were only numerous on one occasion, in the month of April, although of sporadic occurrence during the summer months.

Coelenterata.

The most common coelenterates caught in our big nets or observed from the boat have been:

Scyphozoa: *Aurelia caerulea* R.V.L., *Pelagia panopyra* Peron and Less.
Siphonophora: *Physalia physalis* Linné. (? var. *utriculus*), *Velella spirans* Forskål, *Porpita porpita* Linné, and *Diphyes dispar* Chamisso.

Hydroid medusae have been scarce, only *Obelia* medusae having played any serious part in our catches. Probably the medusae of Hydroids would have been more conspicuous had the catches been made closer inshore or in the sheltered inlets where the adult forms lived.

Aurelia caerulea was particularly abundant in October, and in the same month in 1931 and less so in 1932 great numbers of *Pelagia panopyra* entered the harbour.

At the beginning of October, 1932, a great invasion of *Physalia*, *Velella* and the Salp—*Thalia democratica*—came in from the north-east together with the pelagic mollusc *Ianthina violacea*. Millions of large *Physalia* could be observed covering the sea surface, and later on the sea beaches. Bathers were kept out of the water altogether on one day by the prevalence of these stinging creatures. It is said that such an invasion has only been noted two or three times in the past ten years.

Ctenophora.

Ctenophores are at times particularly common in the plankton. On one occasion in the summer, Ctenophores were so abundant that a dredge (prawn-mesh netting) became full as it was lowered to the bottom where it caught nothing else. A broken mass of jelly two feet high was turned out of it on to the deck!

Amongst the common species is a *Beroe* sp., *Bolina chuni*, and a new species of which a rather beautiful photograph is shown (Pl. vii, fig. 1).

PELAGIC MOLLUSCA.

STREPTONEURA.

Platypoda.

Ianthina violacea Bolten.—An invasion of large numbers of this gastropod occurred with *Physalia*, etc., during October, 1932.

Heteropoda.

Pterotrachea subgenus *Euryops* sp.?—On two or three occasions each year (generally with an invasion of Salps and Siphonophores), heteropods have been frequent in our catches with the big coarse nets. The most common species is a member of the subgenus *Euryops* of *Pterotrachea.* It has not been possible as yet to diagnose the species.

Firoloida kowalewskyi (?) Vayssiere.—Less frequently occurring than *Pterotrachea* sp. is a species of *Firoloida*, very probably *kowalewskyi*, but females are necessary for its correct determination, and so far only males have been found; these agree perfectly with the diagnosis of the species. *F. kowalewskyi* has been recorded from the Indo-Pacific region and the Atlantic.

Atlanta sp.—On two occasions small specimens of a species of *Atlanta* have been common.

Pteropoda.

Creseis virgula Rang. var. *conica*.—This is the most common species of our planktonic pteropods. It occurs sporadically throughout the year, and is found most abundantly in catches of May, July, November, December and February. This species is a cosmopolitan form, more characteristic of the warmest parts of the great oceans. It has been recorded already off the East Australian Coast.

CHAETOGNATHA.

Specimens of *Sagitta*, mainly of small size, are of fairly general occurrence throughout the year. Several species occur and, up to date, these have not been worked out. Sagittae have been most abundant in the summer months and autumn, the poorest hauls so far have been those made in October, November and early December.

CRUSTACEA.

Phyllopoda.

The Phyllopoda play a very considerable part quantitatively in the composition of the zooplankton of the locality investigated. Their seasonal distribution is also most marked.

Evadne nordmanni Lovén.—This species appears in the plankton after the spring diatom maximum, in October (although its isolated occurrence before this date is noted). It attained a maximum (in 1931) in November, and then gradually fell off in numbers, to be followed by the other two species of the genus, which seem rather more important in these waters. *E. nordmanni* has a wide oceanic range. It is found in British Seas and the North Atlantic, but during Hensen's plankton expedition was only captured north of latitude 40° in the Atlantic.

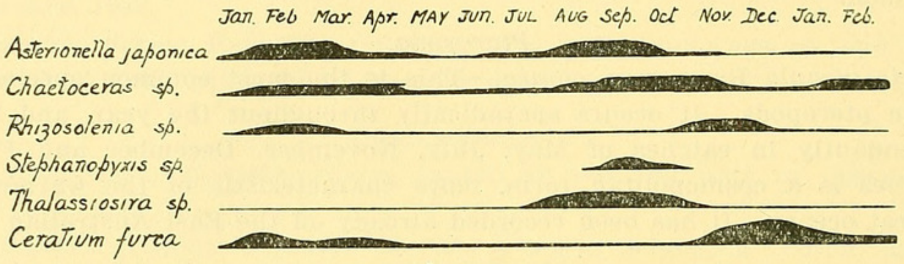
Evadne spinifera P. E. Müller.—This species, after being absent throughout the winter of 1931, appeared after the spring maximum of the phytoplankton in the early summer months and continued practically throughout the summer. The largest numbers recorded in 1931 were in January. The numbers fell off in March and the species practically disappeared in May.

The species has a wide oceanic distribution. It is common in the Mediterranean and the North Atlantic, with a tendency to be a southern form (Sargasso

Sea) there. It is recorded from the Indian Ocean and the west coast of Australia. Krämer states that he found it off the Australian Coast, but does not list it with the other species. It has been recorded by the Scottish National Antarctic Expedition from one station in the South Atlantic, but that was in Latitude 23° 8′ and not in the Antarctic.

Evadne tergestina Claus.—This cladoceran is the most ubiquitous with us, occurring at odd times in the winter. Its maximum developed (in 1931) a little after that of *spinifera*, late in December, and the species continued abundant until May.

The distribution of *E. tergestina* is wide and the species has been recorded from the north-west Atlantic Coasts, to one station by the Scottish Antarctic expedition in the South Atlantic, and from Fremantle, Western Australia. Krämer records an *Evadne* from Auckland, New Zealand, as a new species—*E. aspinosa*—and also from Jervis Bay, but it is supposed by Hansen that this was a mistaken identification and that the species is really *E. tergestina*. This is now almost certainly proven for, whilst *E. tergestina* is common with us, no other *Evadne* species has been recognized apart from those here recorded.



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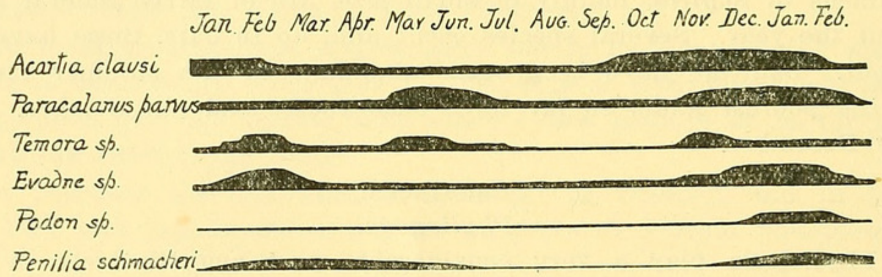

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Text-fig. 4.—Times of maxima of the chief diatoms and dinoflagellates of the New South Wales coastal plankton.

Text-fig. 5.—Times of maxima of the chief Copepoda and Cladocera of the New South Wales coastal plankton.

Podon polyphemoides Leuck.—This species is far less abundant than the *Evadne* species and its temporal distribution more limited. After a complete absence during the winter, it appeared in 1931 late in December at the same time as *E. tergestina*. It rapidly attained its maximum and seems almost to have disappeared again in the month of January, 1932. The same thing occurred at the beginning of January, 1931.

The distribution of *Podon polyphemoides*, like that of the other cladocerans mentioned, is very wide. It has been recorded from the North Sea, North Atlantic, Mediterranean, South Atlantic, and at Auckland (New Zealand). The latter reference is particularly interesting, as it brings it for the first time into the South Pacific.

Penilia schmäckeri Poppe.—This large and handsome cladoceran is quite common in our catches during certain seasons. It occurs in odd numbers during the winter, but its definite maximum begins only in late December (1931), and it then continues numerous throughout the summer and autumn. In 1931 it became rare in June, so that its season appears to be as long as and to coincide with that of *Evadne tergestina*.

The distribution of this species is curiously wide within certain limitations, but it has already been recorded from Hong Kong, from the harbour of Vera Cruz, from the Gulf of Guinea (Atlantic) and lastly by Krämer from Auckland and Port Jackson. It is not recorded in the Nordisches Plankton as occurring in the North Atlantic or adjacent waters. Its distribution is, therefore, rather different from that of the other Cladocera.

Summary Regarding Distribution of Cladocera.

The Cladocera are represented by five common species whose seasonal distribution in our waters in the period 1931–32 is indicated approximately in Text-figure 5.

Ostracoda.

The only ostracod which has played any part worthy of note in our catches is *Euconchoecia aculeata* Scott, and the numbers of this have been too small to record. It would have been necessary to count the examples in whole catches.

Copepoda.

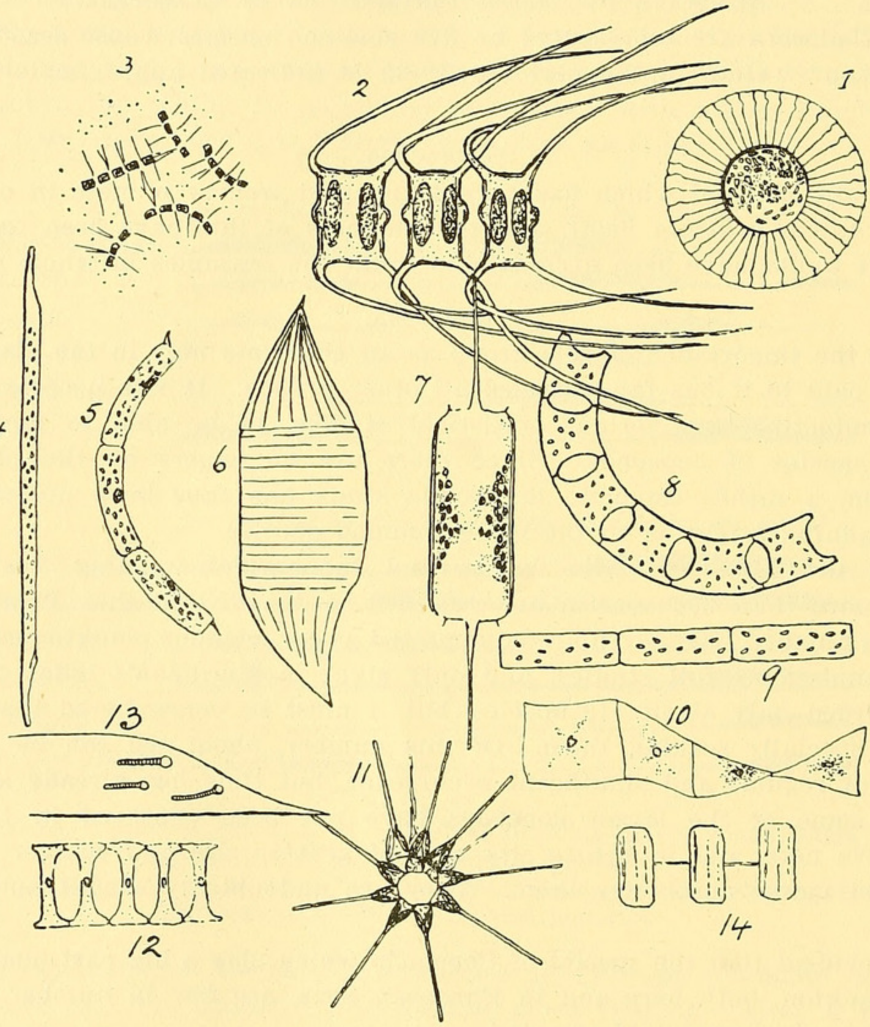
From the importance of this group as an economic unit in the plankton, the attention paid to it has far exceeded all other groups. It was necessary, indeed, before conducting any serious statistical studies, to be able to recognize the different species of copepods. Since there are no papers on the plankton of this region, a rather complete taxonomic study has thus been necessary, even whilst confining attention to the more common species.

From the North Atlantic waters and the waters washing the coasts of Europe, more than 300 species are recorded in the "Nordisches Plankton", but out of this number, only seven are enumerated as conspicuous plankton constituents in Lohmann's very full studies, and only eight in Herdman's lists. So far we have recorded only about 110 species, but it must be remembered that we have not been specially seeking them. Of this number, about ten can be considered as items of regular and significant occurrence, but time has already shown that probably some of the larger copepods have not been captured in the special quantitative nets, and in future silk nets of greater size and coarser mesh will be dragged more rapidly for them. They are undoubtedly sought and captured by fish.

It is evident that the species of Copepoda which play a big part quantitatively in the plankton, both here and in European Seas, are few in number, but these species occur in incalculable myriads.

Like the diatoms and the Cladocera, the copepods which are recorded below have generally a remarkably wide range in the world's seas, and it is very striking to find that the two most common species in this locality also belong to the list of the eight most common copepods of the Irish Sea. They are *Acartia clausi* and *Paracalanus parvus*, and it would probably be not incorrect to say that these were the two commonest crustaceans in the world's seas, indeed possibly the two commonest of all aquatic metazoa.

The following is a list of the species discovered by us in the plankton of the coast near Sydney. Most of these species are recorded for the first time in these waters; a few copepods are recorded in Whitelegge's list of the Invertebrate Fauna of Port Jackson, but these are taken from the records of the odd catches made by the "Challenger" in 1874, and for some reason are by no means representative of the copepod fauna as it occurs to-day. Recently, however, an account has been published of the Copepoda of the "Terra Nova" Expedition (Farran), and since this expedition's track crossed the Pacific between New Zealand and Australia, we have a valuable record of a considerable number of South Pacific copepods from a locality not so very far away. The seasonal distribution of the more important types is shown numerically in Table II, and of the two most common species in Text-figure 5.



Text-fig. 6.—Some of the more important diatom species of the New South Wales coastal plankton. 1.—*Planktoniella sol* (Wallich). 2.—*Chaetoceras didymum* Ehr. 3.—*C. sociales* Lauder. 4.—*Rhizosolenia alata* Brightw. 5.—*R. stolterfothii* H. Perag. 6.—*R.* sp. 7.—*Ditylium Brightwelli* (West). 8.—*Eucampia zoodiacus* Ehr. 9.—*Leptocylindrus danicus* Cleve. 10.—*Streptotheca thamensis* Shrubs. 11.—*Asterionella japonica* Cleve and Möller. 12.—*Climacodium frauenfeldtii* Grun. 13.—*Rhizosolenia* sp. with the parasitic Schizophycean *Richelia intercellularis* Schmidt. 14.—*Thalassiosira rotula* Meunier.

Calanidae.

Calanus brevicornis.—South Atlantic, Southern Ocean, Mediterranean, off New Guinea. Not recorded in New Zealand waters by "Terra Nova" Expedition. Rare except for one big catch in September. It is, however, the most common copepod in the stomach of the fish, *Apogonops*, caught in October, off Newcastle.

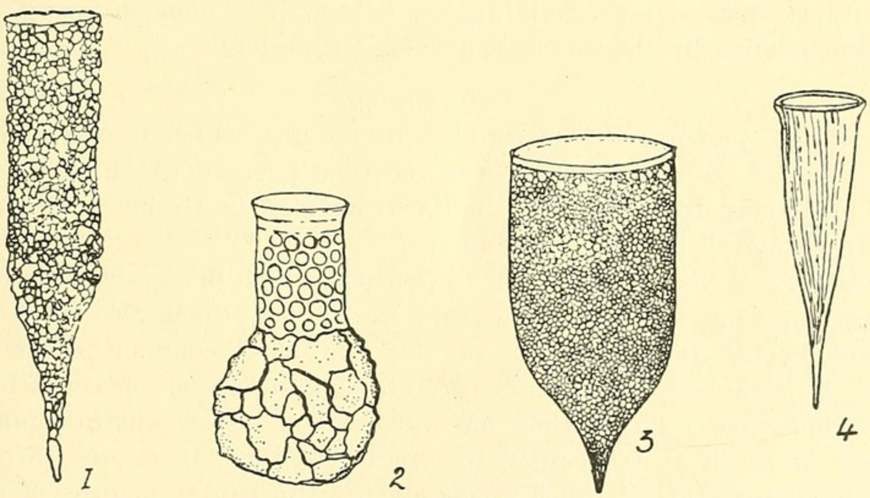
Calanus darwinii (Lubb.) = *Undina darwinii.*—Common off New Zealand, Tropical Atlantic, not recorded Northern Atlantic?. Apparently not recorded North Pacific off California. Recorded from South Pacific ("Siboga" Expedition) and off Australia ("Challenger" Expedition). It was present in our catches in April and May.

Calanus finmarchicus (Gunner).—Cosmopolitan, North Pacific, North Atlantic, Arctic, Tropical Atlantic, common New Zealand waters and in Melbourne Harbour. The Australasian Antarctic Expedition collected the species south of Tasmania. This species occurred infrequently but at odd times throughout the year.

Calanus gracilis Dana.—Cosmopolitan, North Atlantic, Tropical Atlantic, Indian Ocean, Pacific Ocean, Mediterranean, North Pacific off San Diego, rare.

Calanus minor Claus.—Tropical Atlantic and subtropical, Southern Pacific off New Zealand, North Pacific off California. This species is the most abundant of the *Calanus* in our catches, but only reached figures which justified counting towards the end of March, 1931.

The species is closely related to *Calanus finmarchicus*, from which it differs, amongst other things, in having the head and first thoracic segment fused. We have had the typical *C. minor* in our catches, but certain specimens have been captured in which the head and first thoracic segment are separate, although other characters are of the *C. minor* type. Other features are present of intermediate character.



Text-fig. 7.—Common Tintinnids of the New South Wales coastal plankton. 1.—*Tintinnopsis radix* (Imhof) Bdt. 2.—*Codonellopsis ostenfeldti* (Schmidt). 3.—*Favella campanula* (Schmidt) Jörg. 4.—*Rhabdonella hebe* (Cleve).

Calanus patagoniensis (Brady).—Tropical Atlantic. Not recorded in "Siboga" Report, nor in "Terra Nova" Report from South Pacific. This species only turned up twice in our catches, those of 9th August, 1931, and in the same month of 1929.

Calanus pauper Giesbr.—Not recorded off Coast of California. Farran recorded one specimen only off New Zealand, but this species, with *Calanus minor*, is the most abundant species of the genus in our waters. It occurred chiefly in the summer months of 1931, more particularly in January and February.

Calanus tenuicornis Dana.—North Atlantic, North Pacific, Mediterranean Sea, South Pacific and common off North Island, New Zealand. This has not been common in our catches, but its abundant presence in our waters was indicated by the stomach contents of the fish *Apogonops*.

Calanus vulgaris (Dana).—North Atlantic, Tropical Atlantic, South Atlantic, off Australian Coast ("Challenger" Expedition). Not uncommon in our catches, but most specimens have occurred between March and May.

Eucalanidae.

Eucalanus attenuatus Dana.—A species of cosmopolitan range and recorded off the east coast of Australia by "Challenger" Expedition.

Eucalanus crassus Giesbrecht.—Recorded from the Atlantic, Pacific and Indian Oceans. Odd specimens were taken by us in April and May.

Eucalanus elongatus (Dana).—This species is recorded as common off New Zealand by Farran. It occurred in our catches at an immature stage.

Eucalanus monachus Giesbrecht.—This species was represented in our catches by odd specimens in March, May and August.

Rhincalanus cornutus (Dana).—Farran found this twice off New Zealand. It had previously been recorded from the Atlantic, Indian and Pacific Oceans. It occurred twice only, in July and November.

Rhincalanus nasutus Giesbrecht.—This is common off North-west New Zealand according to Farran. It is a species of world-wide distribution, but never common with us. It was most frequent in May and August.

Mecynocera clausi I. C. Thompson.—Although this form has never been numerically strong, several individuals are usually taken in every haul, being readily recognizable by the enormously elongate antennae.

Paracalanidae.

Paracalanus aculeatus Giesbrecht.—This species, which is rare compared with *P. parvus* and of restricted range, was recorded once in the summer months. It is stated by Farran to be frequent in the tropical Atlantic but was captured once by the "Terra Nova" off New Zealand.

Paracalanus parvus (Claus).—This Copepod which is of very wide distribution, being recorded from the Atlantic Ocean, North Sea, Black Sea, Red Sea, Indian Ocean, and Pacific Ocean, is one of the two most common crustacea in our plankton. It is quite extraordinary, therefore, that this species was not recorded by the "Challenger" Expedition off our coasts. The Australasian Antarctic Expedition captured it frequently in the far south. It occurs throughout the year and is common at all times except during the winter months of August and September. It develops an abundant maximum following the phytoplankton maximum during late autumn (May and June). It is noteworthy that this copepod is one of the six or seven species which are so abundant in Northern Seas as to be generally found in numerical estimations.

Acrocalanus gibber Giesbrecht.—This species was originally recorded from the East Pacific Ocean by Giesbrecht. It is known also from the Red Sea. It is not recorded in the "Terra Nova" catches either from the Atlantic or Pacific. The species is rare in our catches, but turned up in April, 1931, in sufficient numbers to be counted.

Acrocalanus gracilis Giesbrecht.—This species has been of frequent occurrence. It was conspicuous in January, 1931, and present during March, April, May and August of that year. It also turned up in January and February, 1932. The range of the species appears very limited. It was first recorded from the East Pacific.

Calocalanus plumulosus (Cls.).—This species has been recorded as plentiful off New Zealand. It occurs in the Atlantic Ocean and Mediterranean Sea. It has only been found once in our plankton catches.

Pseudocalanidae.

Ctenocalanus vanus Giesbr.—This species has been recorded from the Mediterranean, Atlantic Ocean, Pacific Ocean and the Antarctic, and Farran remarks that it is one of the most plentiful species in tow-nettings taken under the ice ("Terra Nova"). It has provided us with a demonstration of the probable deficiency of plankton-catching weapons for, although of characteristic appearance and easy recognition, only one solitary specimen has been obtained by us.

Clausocalanus furcatus Brady; *Clausocalanus arcuicornis* Dana.—These have been two common constituents of our catches and although they are never so abundant as *Paracalanus parvus*, they may be ranked as members of the small group of really common copepods in these waters.

Scolecitricidae.

Scolecithrix danae (Lubb.).—Recorded from the Mediterranean, Atlantic, Indian and Pacific Oceans and regarded as a more or less tropical form, this species is noted as common off North Island, New Zealand. It was only recorded in July in our plankton.

Centropagidae.

Centropages bradyi Wheeler.—Recorded from the North Atlantic by Wheeler and from several stations off New Zealand by Farran. Its only occurrence in our plankton was on 5th March, 1930.

Centropages calaninus (Dana).—Recorded from the Malay Archipelago and from the Indian Ocean. This species occurred in considerable numbers in the catches of 29th March, 1931, but that is the only date.

Centropages chierchiae Giesbrecht.—This *Centropages* is of wide range, already recorded from the more tropical Atlantic Ocean and the Indian Ocean. It was recorded once from our plankton of December, 1929.

Centropages furcatus (Dana).—This species, according to A. Scott, has a wide range in the tropical seas. It was the most abundant species collected by the "Siboga" Expedition in the Malay Archipelago. It is the only *Centropages* species recorded by the "Challenger" from our own locality. The species was relatively common on 2nd February and 7th April, 1931. It also occurred sparingly in May and June.

Centropages orsinii Giesbrecht.—This species of *Centropages* which is an Indian Ocean form, recorded also from Red Sea and Malay Straits, is our commonest species of the genus. This is rather a surprising feature, for there appear to be no records indicating a wider distribution in the Pacific and the species is not recorded from New Zealand waters by Farran. The species is most abundant in late summer; specimens were common from January to May.

Centropages violaceus (Claus).—Recorded from the tropical Atlantic, and parts of the temperate Atlantic, Mediterranean Sea, and, according to Farran, from the more northerly of the New Zealand stations. Of rare occurrence in our catches—recorded in September.

Pontellidae.

Pontellopsis regalis (Dana).—Recorded from Atlantic, Indian and Pacific Oceans. Rare in our plankton. Recorded in one catch, 10th April, 1931.

Labidocera acuta (Dana).—Recorded from the tropical waters of the Atlantic, Pacific and Indian Oceans, and collected by the "Challenger" off our coasts. Not recorded, however, from New Zealand stations by Farran. This species is of very common occurrence in the New South Wales plankton. Specimens have been taken in every month from January to August.

Labidocera acutifrons (Dana).—Recorded from the tropical Atlantic and Pacific Oceans and collected by the "Challenger" off our coasts. Much more rare than *L. acuta* and only found in April, 1930.

Labidocera brunescens Czerniawsky.—Recorded from the Atlantic and Indian Oceans. Taken once by us in January, 1930.

Labidocera cervi Krämer.—This is the only copepod species *limited to the waters between New Zealand and Australia*, which plays any important part in our plankton. It was discovered by Krämer, who only found one specimen, a female, in the Hauraki Gulf, New Zealand, in 1893. Six years later it was found again by Brady in copepoda from New Zealand. Farran discovered it in a few of the "Terra Nova" catches from New Zealand waters and a variety in Melbourne Harbour. We are apparently the first to find it really abundant. It was common in our catches during the summer and in numbers sufficiently great to be counted in small samples in April, 1931.

It might be pointed out that the males in our collection differ slightly from the specimen figured by Farran in details of the fifth feet. The variation is slight and may be a local racial difference.

Labidocera detruncata (Dana).—Recorded only from the Indian and Pacific Oceans. The species was only recorded in the catches of 1st November, 1931.

Labidocera Kröyeri (Brady).—Recorded from North Atlantic, Pacific and Indian Oceans and Malay Straits. A few specimens were present in April in 1930 and 1931.

Candacidae.

Candacia bipinnata Giesbrecht.—Recorded from the tropical Atlantic and the Pacific Ocean (North and South), Malay Straits, etc. This species was the most abundant according to Farran in New Zealand waters. It occurred in our catches in April and May, but probably is more common in our waters.

Candacia ethiopica (Dana).—Recorded chiefly from tropical seas, Atlantic, Pacific and Indian Oceans, Malay Straits and off New Zealand. Occurred not infrequently, particularly in April and May.

Candacia pachydactyla Dana.—Recorded from tropical Atlantic, Pacific Ocean and Indian Ocean. The species was present on one day in April, 1930.

Candacia pectinata Brady.—Recorded from off Port Jackson by the "Challenger" Expedition, and from the North Atlantic, Mediterranean Sea, and Indian Ocean.

The occurrence of this species is fairly common, which is striking in view of its recognition amongst the few copepods captured by the "Challenger" Expedition in our waters and the absence of the name both in Farran's list from

New Zealand waters and the "Siboga" list of Malay Strait forms. It was most common in a night catch taken in November, 1931.

Candacia truncata (Dana).—Recorded from the Atlantic, Indian and Pacific Oceans; was present in our catches of May, 1931.

Temoridae.

Temora discaudata Giesbrecht.—This is practically a Pacific Ocean copepod, although it has been recorded from the Red Sea. Most records are from tropical waters. It is not recorded from New Zealand waters.

The species is of rare occurrence in our catches, but has been noted in several months, April, May, September, and most common in February, 1932, when it was sufficiently abundant to be enumerated.

Temora stylifera (Dana).—Recorded from the warmer waters of the North and South Atlantic Oceans and found commonly in the "Terra Nova" catches from the tropical Atlantic. Rare in our catches except in February, 1932.

Temora turbinata (Dana).—This copepod species is quantitatively one of the most important in our plankton. It is a well known Pacific Ocean form, recorded as of great abundance off New Zealand and common in the Malay Straits. *T. turbinata* occurs throughout the year in our seas; it presented one maximum in the year 1931–32 during the summer months with the peak in February.

Acartiidae.

Acartia clausi Giesbrecht.—This copepod species shares the honour with *Paracalanus parvus* of being the most abundant constituent of the plankton crustacea. It is common throughout the year, but rises to two maxima, the greater in October–November, and a lesser in January, although it is possible that these two are parts of one. It will require further years of observation to become familiar with the variations in seasonal distribution which are bound to occur.

This copepod has been recorded from both the cold regions and the tropics, North and South Atlantic, the Indian Ocean, South Pacific and far down towards the ice. It was not recorded from the New South Wales Coast by the "Challenger" and it does not appear in the Malay Straits collections of the "Siboga" Expedition.

Acartia centrura Giesbrecht.—A specimen of *Acartia* which seemed to resemble *A. centrura* most closely was recorded in May, 1931. The species has been recorded from the Red Sea.

Acartia danae Giesbrecht.—This species, recorded from the Atlantic and Pacific Oceans, was recorded as rare in Malay Straits. It is common off New Zealand. It is rare in our catches, being recorded only on 1st May, 1931, and in January, 1930.

Tortanidae.

Tortanus barbatus (Brady).—Recorded Pacific Ocean (Philippines), Malay Archipelago. Occurred on one occasion, 1st November, 1931.

Oithonidae.

Oithona atlantica Farran.—Recorded from west and south-west coast of Ireland, Southern Atlantic and Indian Ocean. This species has not been frequently recorded. It is difficult to separate, when counting, from *O. tenuis*, but there is no doubt that it is not at all common.

Oithona nana Giesbrecht.—Practically cosmopolitan and very common in some regions. Only occurred in our catches on one day of October, 1931.

Oithona oculata Farran.—Recorded by Farran from Indian Ocean catches also from near Samoa. Its occurrence in our plankton was sufficiently common to enumerate in April and July, 1931; it was also present in August and January.

Oithona plumifera Baird.—Of wide range. Recorded from polar seas, Atlantic Ocean, Indian Ocean, Pacific Ocean and common off New Zealand and in Malay Straits. The species occurred at odd times throughout the year in our plankton catches, but was most numerous in May, June, November and February.

Oithona setigera Dana.—Recorded from the Pacific, Indian and Atlantic Oceans, Red Sea and Mediterranean, New Zealand Waters. Not uncommon in certain catches in months of January, February, April and July.

Oithona tenuis Rosendorn.—This *Oithona* species which appears seldom in the literature is apparently our most common species of the genus. It occurs at odd times throughout the year (reaching counting intensity from June to August, 1931, and in November), and was present fairly regularly from December to February. Two specimens were recorded by Farran in New Zealand waters. It was previously known from tropical Indian Ocean and Atlantic.

Ectinosomidae.

Microsetella rosea (Dana).—Already recorded from the Atlantic, Red Sea, Indian Ocean and Pacific Ocean. In the Nordisches Plankton only the female is described and the male said to be unknown. Farran records it "a few times off New Zealand", but only gives dimensions of the female, so that it appears doubtful whether the male has ever been previously seen. The species is quite common in our plankton and was particularly abundant from January to end of May, with a peak in March (1931). Nauplii were obtained in June and July. In view of the non-appearance of males elsewhere in catches, it is particularly interesting that many males were examined, and on 4th January, 1931, when 560 were counted in a sample, the males amounted to about one-third of the total. A description of the male will be given in another paper.

Monstrillidae.

Thaumaleus thompsoni Giesbrecht.—North Atlantic. Recorded on one occasion, March, 1930.

Macrosetellidae.

Setella gracilis Dana.—Recorded from Atlantic, Pacific and Indian Oceans and taken in small numbers off the New Zealand Coast. Recorded by us on one day only, 3rd October, 1931.

Tachidiidae.

Euterpe acutifrons (Dana).—Recorded from North Sea, North Atlantic Coasts, Red Sea, Indian Ocean, Pacific off New Zealand, especially Bay of Islands. This is a very common copepod of our plankton. It was taken in almost every month of the year and was particularly common in the winter months, June to September. The biggest haul occurred in a night catch, so that probably the species is more abundant in deeper water than we regularly "fished".

Oncaeidae.

Oncaea media Giesbrecht.—Recorded from the Mediterranean, Atlantic Ocean, Pacific Ocean, Red Sea, Malay Archipelago, off New Zealand, and possibly down to Antarctic ice.

Oncaea venusta Philippi.—Mediterranean, Atlantic Ocean, Pacific and Indian Oceans, common off New Zealand and Malay Archipelago. This copepod species is quite common in our catches and occurs throughout the year. The greatest abundance occurred in April and May, 1931.

Corycaedidae.

Corycaeus clausi F. Dahl.—Recorded from Sargasso Sea and warm Atlantic, Mediterranean, doubtful from Pacific. This species occurred on two occasions only, but was not uncommon on 1st May, 1931.

Corycaeus crassiusculus Dana.—Recorded doubtfully from Atlantic, an Indo-Pacific species. Common off New Zealand Coast. Recorded at odd times during the year (January, February, April and May).

Corycaeus speciosus Dana.—Recorded from Atlantic, Pacific and Indian Oceans; recorded as scarce off New Zealand. Only found once in our catches (May, 1931).

Corycaeus (*Corycella*) *carinatus* (Giesbrecht).—Atlantic, Indian and Pacific Oceans (tropical part). Common in our plankton from April to June, 1931.

Corycaeus (*Corycella*) *concinnus* (Dana).—Pacific Ocean (tropical south-west region), and tropical part of Indian Ocean. This copepod species was very common in our catches between January and June, 1931, particularly on 20th January and 10th April.

Corycaeus (*Corycella*) *gibbulus* Giesbrecht.—Recorded from Indian Ocean and Pacific Ocean. Occurred only once in our plankton on 5th March, 1930.

Corycaeus (*Corycella*) *rostratus* Claus.—Recorded from Atlantic, South Pacific and Mediterranean Seas. Was not uncommon in our plankton in January, 1932, but occurred also in September and November and December, 1931.

Corycaeus sp.?—A corycaeid appeared in our catches with considerable regularity, which is not only different from the species hitherto described, but which appears to invalidate the separation of the genus *Corycaeus* and the genus *Corycella* in the scheme adopted by Dahl.

Corycaeus (*Ditrichocorycaeus*) *africanus* F. Dahl.—Recorded from the African Coast. The species occurred infrequently and chiefly in catches taken in January and April, 1931, also in May, June and August.

Corycaeus (*Ditrichocorycaeus*) *andrewsi* Farran.—Recorded from Christmas Island, West Coast of Ceylon, and off Sumatra and New Guinea. The species occurred on one date only, 3rd October, 1931.

Corycaeus (*Ditrichocorycaeus*) *tenuis* Giesbrecht.—Recorded from eastern part of tropical Pacific and West Pacific. Occurred in our catches on one date only, 1st May, 1931.

Corycaeus (*Onychocorycaeus*) *catus* F. Dahl.—Recorded from Indian Ocean and Pacific Ocean. This is not uncommon in our plankton catches and was counted during the period February to July, when it was continually present, reaching a peak in February and late April.

Corycaeus (*Onychocorycaeus*) *giesbrechti* F. Dahl.—Recorded from Mediterranean, Bermuda and Pacific Ocean. Occurred only once in our plankton catches on 2nd August, 1931.

Corycaeus (*Urocorycaeus*) *furcifer* Claus.—Recorded from Mediterranean, Atlantic Ocean, East Pacific and Indian Oceans. Occurred on odd occasions rarely in our plankton.

Sapphirinidae.

Sapphirina nigromaculata Claus.—Of world-wide occurrence; Atlantic and Indian Oceans, Pacific Ocean and Malay Archipelago, but not recorded by Farran in New Zealand catches. Recorded twice in our plankton.

Sapphirina angusta Dana.—Of world-wide distribution. Recorded from New Zealand waters. Recorded on one day in November, 1930.

Sapphirina opalina Dana.—Of world-wide distribution. Recorded from New Zealand waters. Recorded on one day—18th July, 1931.

Copilia mirabilis Dana.—Recorded from the Atlantic Ocean, Indian Ocean and Pacific Ocean. The species was recognized on one occasion in our catches, 21st June, 1931.

Schizopoda.

Nyctiphanes australis.—Apart from the Copepoda, this is perhaps the most abundant Crustacean in our plankton, and certainly one of great importance in the food chain of certain of the fishes. Our normal series of catches does not contain many adults, presumably due to insufficient speed of towing when making the hauls, but larvae in various stages of development have been taken, particularly in late winter and early spring. However, catches made from the more rapidly moving trawlers have proved more successful, both adults and larvae coming up.

N. australis occurs in such enormous numbers off the New South Wales coast that at times the sea is coloured blood-red, and on one occasion (Aug., 1930), a solid mass of some two litres volume was taken in the small coarse plankton net after a three-minute haul from the stern of a trawler. The red patches marking the presence of *Nyctiphanes* were some six feet square, and were passed by the boat every few seconds. They were accompanied by numbers of fish larvae and the copepod *Sapphirina*. The solid mass of *Nyctiphanes*, when emptied from the net, emitted a beautiful blue-green phosphorescence.

In March, 1931, an almost pure catch of the larvae was taken from a trawler by one of us (A.N.C.) off the coast of New South Wales near Merimbula, whilst early and late *Calyptopi* have occurred in the normal series of catches from the station off Sydney Heads. We have also found large quantities of *Nyctiphanes* in the stomachs of tiger flathead (*Neoplatycephalus macrodon* Ogilby), whilst the larvae and occasional adults form part of the food of the fish *Apogonops*, which is, in turn, preyed upon extensively by the tiger flathead.

Urochordata.

The Urochordata have played no inconsiderable part in our catches, species of *Oikopleura* being particularly abundant over a long period of each year. At odd times the coastal waters are invaded by great swarms of Salps and then the nets fail to give true pictures of the rest of the plankton, for the nets are soon rendered almost impervious to water by the clogging jelly of the Salps.

Oikopleura sp.—Species of *Oikopleura* were present throughout the year and, whilst high numbers were reached in summer, there were occasions with almost equally high figures in August.

Like the neighbouring genus, *Fritillaria*, *Oikopleura* occurs in enormous numbers at times. In October, 1930, an almost pure catch was taken from the deck of a trawler off Botany (near Sydney). They were present in such quantity that the sea was coloured bright orange and had the appearance of being sprinkled with millions of minute rice grains; the organisms were confined to a belt of water some twenty feet wide, marking, presumably, the course of a minor ocean current.

It so happened that one of us (W.J.D.) was at the Sydney Heads Station at the same hour, also for the purpose of making plankton catches, but here a very different result was obtained; the small coarse plankton net was filled practically solid with small Salps (*Thalia democratica*).

It was also noticed that the sea was teeming with Coelenterates (principally Siphonophores), whilst the copepod *Sapphirina* was so abundant that the separate individuals could be detected in the water in the daytime, by reason of the iridescent flashing of the cuticle.

Fritillaria pellucida Busch.—*Fritillaria* species are far less frequent than *Oikopleura*. The species listed here was abundant from February to April, 1931, and again about the latter part of August, and in October and November. On one occasion, however, on 3rd October, 1931, the deep net caught 40,000 whilst practically none were present in the surface waters. The highest catch otherwise, was about 2,000.

The species is known from all the warm seas, and is noted rarely off the Californian Coast in the Pacific, where apparently it was only recorded during the summer. However, in the Mediterranean, it has been found abundantly in the winter months.

Salpa fusiformis Cuvier.—Only the aggregated zooid form has been obtained —in October and December (fairly common). The species has been recorded over a wide range.

Thalia democratica (Forskål).—This is the common Salp of New South Wales waters. Its appearance is sporadic, but when present it often occurs in very large numbers. Its chief appearances have been in September, October and November, with smaller numbers during the summer. Both the aggregate and solitary forms occur.

The species has the widest recorded distribution of all the Salps.

Pegea confederata (Forskål).—One specimen of this large Salp was obtained in a catch in December, 1931. It was the aggregate form. The species has been recorded for the warm waters of the Pacific and Atlantic. The solitary form of this Salp is unusually rare in the world's collections compared with the aggregate form.

Doliolum sp.?—*Doliolum* is a rare visitor compared with the Salps. Its most abundant visitation was in August, 1931.

LARVAE.

Lamellibranch larvae.—Common during the summer months.

Veliger larvae.—These occurred throughout the year, but were most common in summer.

Ophioplutei.—The Ophiopluteus larva of the brittle starfish occurred in the catches from June to August and then at odd times until December. The maximum, in 1931, was reached in July. It is as yet impossible to say to what species they belong.

Actinotrocha.—The beautiful larvae of *Phoronis* occurred on one occasion in the catch—seven or eight being present on 1st November, 1931.

Peneus.—The larvae of Penaeids occurred in our catches on several occasions and this is the first time they appear to have been found in the sea round the coast of Australia. In fact much mystery has shrouded the place of reproduction of the Penaeid prawns, some species of which are extraordinarily abundant in estuaries and coastal "lakes" connected with the sea.

Mysid stages were present in March, April and May. Nauplii and eggs were obtained from March to August, with a peak in May. Unfortunately, it is impossible to say from the eggs to which species they belong. Reference to the breeding of the common species is being made in another place.

Cirripede nauplii.—Cirripede nauplii were present throughout the year and with little fluctuation in abundance.

Ascidian larvae.—Ascidian eggs and larvae were abundant in some catches in October and particularly abundant in certain inshore catches in which the hatching of the eggs under the microscope was observed.

Other larvae.—Many different kinds of Crustacean and other larvae occurred in our catches, but as casual occurrences, playing little part to speak of quantitatively, although furnishing interesting material for future researches on life histories.

Fish Eggs.

Fish eggs have at times been very abundant in our catches and we have been, from the outset, most keen to collect this constituent of the plankton. The number of different *common* kinds captured up to date, appears, however, to be relatively small, and, in fact, may not be more than six. The earliest egg to be recognized by us was the anchovy, which is very distinctive on account of its elliptical shape and characteristically segmented yolk.

The most striking type of all, however, is one at present referred to for convenience as a "blue" egg. Actually, there are at least two different kinds of "blue" eggs according to measurements (one 1·6 mm. in diameter, and the other 1·3 mm.), but these share the common feature of a "shell" with a distinct blue tinge. The perivitelline space is relatively large, the yolk is segmented and it is considered, therefore, that these eggs may be clupeid (possibly those of *Sardinia neopilchardus*). They have been found with early and late embryos, whilst the very characteristic just-hatched larvae have also been secured. These agree with a clupeid diagnosis.

In addition to the above, there are two other types of eggs which have been common in our catches, but these, apart from their size, have not been marked by any very special features, and it is hoped to treat them, together with the rest, in greater detail in a future paper.

We are chiefly concerned in this survey with the abundance of the eggs in the plankton during the period covered by the present communication.

High figures were reached in January, 1931, the ordinary coarse surface net yielding 329, of which 112 were "Anchovy" eggs and the remainder undetermined. On two other occasions in the same month, the catches were 279 and 561 eggs respectively.

The number continued high (March 5, 644 in one net and 595 in another) during the following months, but the Anchovy eggs had disappeared. The so-called "blue" eggs (two kinds) appeared with startling abruptness in June (1070 in one net haul on 21st June) and continued until August. The period June–August represents therefore, the period of maximum of the blue eggs, although some seem to occur at odd times throughout the year. Most of the "blue" eggs have late embryos in them, early stages being rare.

After August the egg catches remained low until November, when the Anchovy eggs commenced to appear. The Anchovy eggs continued to be present till January, 1932, although not in large numbers during this last summer month. Summarizing, we may say that in the period investigated, there were three periods of abundance in regard to fish eggs, viz., (1) Anchovy eggs, November–

January; (2) a period, January to April, marked probably by the occurrence together of eggs of several unknown species at the same time and with a peak in March; and (3) a winter maximum, between June and August, of the "blue" eggs.

General Conclusions.

The plankton at the station chosen, four miles out from the coast of New South Wales in the latitude of Sydney, is more or less free from littoral forms. It is a complex of oceanic and neritic species and, as one might expect, in view of the fact that there is a tropical current setting southward in these Eastern Pacific waters, one finds a conspicuous tropical and oceanic element, which is particularly marked in the zooplankton.

On the whole, the larvae of benthoic forms are not strikingly abundant, but this again may be explained by the situation of our station and the effort made to avoid estuarine waters and close inshore waters. Night catches which were made closer to the harbour entrance, presented a very different picture in this regard, but these are not treated at all in this paper.

A distinct periodicity has been visible in connection with most of the important constituents of the animal plankton (see Table II) and, whether it be directly due, or not, to the fact that the phytoplankton (see Table I) shows a definite maximum in spring, with another in late autumn, there is a clear indication that the chief constituents of the zooplankton have their maxima about the same times, and just after those of the phytoplankton. Thus the zooplankton presents a maximum in the summer with peaks in the early summer (November to December) and another in autumn. The zooplankton maxima referred to are due to copepoda and cladocera. In addition, however, there are occasional invasions of enormous shoals of Salps and Ctenophores, Siphonophora, and *Ianthina.*

A remarkable feature of the plankton occurred during a fortnight in October, 1932, when the ocean surface was covered with millions of *Physalia, Velella* and *Ianthina.* The invasion was so great that the dried bladders of *Physalia* and *Velella* and the blue shells of *Ianthina* strewed the ocean beaches over a stretch of many miles.

Curiously enough a letter in *Nature* of 29th October, 1932, reported an exactly similar occurrence on the south-western shores of England and Ireland during August.

Presumably the occurrence of these two unusual events (it is years since an invasion of such an extent has been noted on our coast), at about the same time is merely coincidence. It is difficult to regard it otherwise, seeing that we are in the Southern Pacific and the British swarms come from the North Atlantic. One might, however, wonder whether some particular cycle of circumstances had led to an unusual development of the organisms in question in tropical ocean waters, like the numeral fluctuations so well known in the case of more confined terrestrial species of animals. But then it will be difficult to account for the simultaneous abundance of species so far removed zoologically as *Physalia* and *Ianthina.*

Perhaps, therefore, we had better think of it as just coincidence and look for the explanation solely in a similar sequence of meteorological conditions in the regions concerned. Certainly the weather off Sydney during the three months preceding, and since the event has been somewhat unusual.

The State Meteorologist (Mr. Mares) has kindly sent me a comparison of the winds during August–November, 1932, with those prevailing during this season through the past 18 years. From this it would appear that sea breezes (i.e., winds with an easterly component) have been more frequent than usual and, moreover, the velocities have been greater. It seems reasonable, therefore, to suggest that there has been a greater tendency during the period in question for an easterly surface drift to bring shorewards certain organisms of the tropical southward-flowing current which are only infrequently stranded in such numbers.

We have referred to the occurrence of different species in this paper. There are, of course, far more species in our plankton than enumerated or captured and, if other modes of catching were adopted, some of these (chiefly microplanktonic or nannoplankton forms) would no doubt be important also from the quantitative point of view.

The seasonal distribution of the diatoms has already been described at the end of the diatom section of this paper. Although many years of work will be necessary before seasonal fluctuations are thoroughly understood, some additional observations, made by one of us before our ocean station was established, are sufficiently in agreement with the rest to warrant a little discussion on the factors which may control the seasonal changes.

The actual demonstration of this seasonal fluctuation in the plankton production of New South Wales waters emphasizes, however, the need for further observations in other latitudes on the East Coast of Australia, and more particularly to the south and in Tasmanian waters. Surface catches made with one of our ordinary nets from trawlers 200 miles south of Sydney have often yielded very different catches. We have never made huge catches of *Nyctiphanes* at our station, but enormous numbers have been taken both north and south of it, south in July and August, and north in October.

The total variation in the quantity of the zooplankton throughout the year is not great. It might play little part in the migrations of the particular species of fish which are just at present of commercial importance on this coast, since pelagic fish are simply not caught at all. (No doubt plankton studies will be of still greater importance if sardine and other pelagic fish ever become of commercial significance, an achievement much to be desired.) Nevertheless certain creatures such as the fish *Apogonops anomalus*, which is one of the chief foods of the Tiger Flathead (*Neoplatycephalus macrodon* Ogilby, the most important trawled fish of New South Wales), have been found with the stomach contents entirely planktonic in nature. On certain occasions, the copepod *Calanus brevicornis* was present to the exclusion of almost anything else, whilst both adult and larval *Nyctiphanes australis* were abundantly present in the stomach at other times when these species occurred in the plankton. But the copepod *C. brevicornis* has *never* been common in our plankton catches, so that either it occurs in shoals, and is deliberately selected by *Apogonops*, or it has been missed by the net catches taken nearer land.

What information is at hand regarding the passage of shoals of pelagic fish up our coast seems to indicate that these occur in the winter and spring months. *Calanus brevicornis* was taken in *Apogonops* stomachs in October, whilst big hauls of other large copepods have been taken in August, so that there is already some evidence linking the occurrence of planktonic crustacea with the movements of pelagic fish.

The two most abundant types of fish egg which can be recognized in our catches are: (1) an oval egg which is undoubtedly that of an anchovy, and (2) a spherical egg of some clupeoid fish. The latter has been present in great numbers in June and July—the young on hatching would just be ready for the phyto-plankton maximum beginning in August. Apart from these two fish eggs, there are several unrecognized species of pelagic eggs which are most common in the summer catches (January to March). This fits in with the little that is already known about the breeding season of some of the more common marine fishes. It is unfortunate that in this respect so much stands to be done on the Australian Coast.

Behind the fluctuations in the production of animal plankton, is the interesting periodicity of the plants, and regarding this a little more may be added.

The onset of the diatom production in Arctic and Antarctic Seas is probably to be correlated entirely with the occurrence of, and increase in, light after the darkness of winter. In many temperate seas, and certainly in our own coastal waters, the daylight is sufficiently strong for good diatom production at any time throughout the year, even during the season of shortest days, and certain diatoms are indeed always present. In this connection, we may also recall the onset of reproduction of *Gymnodinium* in July, when the days are not far from their shortest. Temperature has frequently been discussed in connection with spring maxima, especially since the beginning of a spring maximum is often coincident with the turn of the temperature "curve" from a downward grade to an upward slope. It has been found, however, that this is not always the case, and Marshall and Orr draw particular attention to the fact that the spring increase may start before the temperature change, whilst one of the conspicuous diatom species in the maximum studied by them in Scottish seas, flourished at 2°–3° C. on the Norwegian Coast, at 8°–9° C. in Loch Striven and occasionally is found in the tropics.

Food substances are apparently present in abundance *before* the spring increase of the diatoms commences. In some places the spring increase has been correlated with melting snows and additions of fresh water and salts to the sea. There is nothing of this sort in our region and nothing to show, up to the present, that any chemical change takes place in the constitution of the seawater which might lead to the onset of the spring increase. Marshall and Orr in Scotland, and Atkins at Plymouth, after a consideration of the various possible factors, are inclined to regard the intensity of the sunlight as the primary causal factor. In regard to this, however, it may be pointed out that there is a big difference between the length of the winter days and the summer days in the regions where most plankton calendars have been worked out, and it is not unusual for meteorological conditions to bring about still further poverty of sunshine during the winter season when the days are shortest. Compared with these conditions, any increase of daylight at Sydney when August is compared with June seems but a small factor, for the duration of daylight only ranges between 9 hours 53 minutes and 14 hours 25 minutes throughout the year.

Steuer affirms that the seasons of the great diatom maxima recede from the warmest months of the year as one approaches the tropics. Bigelow confirms this for the Atlantic Coast of the United States. If this is correct, and actually our Sydney dates for the maxima are not in conflict with it, then latitude seems an important factor in determining the onset of diatom reproduction, quite apart from the well defined oceanographical conditions associated with more extreme limits of latitude—i.e., conditions peculiar to the equatorial as contrasted with Arctic and Antarctic waters. And, so far as one can judge at present, this latitude difference chiefly implies differences in light, and perhaps temperature, although the latter is not so much a function of latitude as is intensity of light and length of day, for ocean currents may be responsible for considerable differences in sea temperature at the same latitudes. Unfortunately, "plankton calendars" from tropical and subtropical regions are not sufficiently numerous and the relation of latitude to the plankton rhythm requires further elucidation yet.

TABLE

The chief Diatoms of the N.S.W. plankton.

	Jan.		Feb.		Mar.		April.			May.		June.	July.			Aug.	
	4	20	12	27	5	14	7	10	10	1	26	21	2	12	18	2	8
Asterionella japonica ..	—	6,600	11,440	800		373,700			2,200			250	400		×	4,000	46,520
Bacteriastrum sp. ..													×		600		×
Biddulphia mobiliensis ..													400		600	6,600	6,480
,, sp.																	
Coscinodiscus concinnus ..	×																
,, group ..	×		6,600						3,500			600	1,600		3,300	1,600	
Cerataulina sp.																	
Chaetoceras sociale ..																440	6,000
,, sp.	880	2,700	12,320				19,800	5,000	48,180			2,000	7,260		1,500	6,160	10,080
Climacodium frauenfeldtii			440	600	2,200	*	1,600	500	700	230					×		
,, *biconcavum*..												250					
Corethron hystrix ..																	
Dactyliosolen tenuis ..							×			200			200	Very poor catch	300		
Dityllium brightwelli ..															600	7,480	10,800
Eucampia zoodiacus ..			440														
Guinardia flaccida ..			440						10,000								
Hemiaulus hauckii ..			400														
Lauderia borealis ..							? 400										
Leptocylindrus danicus ..		153,000	22,000						55,500								
Nitzschia seriata ..			3,080		Debris		? 3,000	880	25,500	400							
,, *longissima* ..									700								
Planktoniella sol												300	220		900		
Rhizosolenia alata ..	4,840								24,000			900	200		300		
,, *delicatula* ..			440														
,, *robusta* ..													600				
,, sp. ..		17,400	12,320	22,440	440		15,620	1,900	11,000	200		600	200		1,200		720
,, *stolterfothii*		2,700	440						7,000			900					720
Stephanopyxis sp. ..													400				
Streptothrix thamensis ..	400		400						700				400		900	1,600	3,600
Thalassiosira condensata			2,000						4,500			3,600	400				172,800
,, *rotula* ..	1,760		1,200						750			300			300		13,680
,, *subtilis* ..												×	600		×		
,, sp.			6,600				400									22,000	
Thalassiothrix nitzchioides	880												880		900		
Oscillatoria			800				? 5,280	900	4,500			900					

**Calcaravis.*

As a matter of fact, there is much more to be investigated in the relation between light and phytoplankton. More accurate estimations of the intensity of light at depths in the sea are now being obtained as the result of the use of "light cells" and direct photometric methods. From these it appears that only 6·62% of the sunlight may reach a depth of 20 metres (it may, of course, be much less) and only 0·7% a depth of 40 metres. The spring diatom maximum in high northern latitudes commences when the light cannot be very intense below the surface. The amount of light which is optimal is another unknown, and the matter is probably more complicated than has been recognized. It has been

I.

Seasonal Range 1931.

Aug.		Sept.			Oct.			Nov.					Dec.		Jan.			Feb.
12	20	5	12	20	3	17	25	1	13	15	22	28	8	26	2	8	28	10
112,700	57,860	×	22,630	23,100				×							6,600			650
			700				200											
8,406	440	×	1,460	1,960	880	4,500		10,000										
								1,600			1,600							
5,600	800		2,200		880			4,000										
												800			3,600	3,000	2,000	200
							450	304,000										
8,400	900																	
17,500	8,800		47,450	64,020	5,720	365,560	16,500	21,120	×		6,600			650	11,000	19,000		85,800
											440		×				440	
											4,400					400		
	3,520		730				2,000	2,400									220	220
12,600	900	Much debris, net blocked.	12,410	6,600											440			
700			2,800	4,800		6,700	800	3,000	300	600	113,520					450		
							450					Very poor catch.			1,200	400		220
									? 100									
	450		1,400	×			2,200	5,000						12,000	78,320	1,200		2,200
700	1,320		3,500	3,500						600				600	3,200	1,200		5,600
	500		700								9,240				8,800	19,000		220
					880													
																17,000*		
3,500			3,500	1,300	450		200	26,400	120,000	28,000	4,400				3,200	15,840		1,000†
	9,000						600	2,400							800		850	
	900		43,800	50,000	2,200	2,500		4,400			1,500							
1,400	400													Catch may have been reduced by ctenophores.		440	? Ctenophore interference.	
8,400	44,660		2,100		880						400					400		
6,300	×		87,600	222,000	7,040						4,000				1,200	800		440
	×																	
			4,200			sp. ? 13,000												
	×		2,200	×														
															3,200	1,200	24,000	15,600

†With parasite *Richelia*.

TABLE

The seasonal distribution of the chief zooplanktonic forms in

The figures are comparative only and indicate the number of organisms counted in each date. It is possible also to compare the numbers of different species of and larvae are enumerated from

1931.

	Jan.		Feb.		Mar.		Apr.		May.		June.	July.		Aug.
	4	20	12	27	5	29	7	10	1	26	21	2	18	2
PROTOZOA														
Favella campanula ..					600		440				250			
Codonellopsis ostenfeldti			440						250			200		
Tintinnopsis radix ..			1,320				220		200				1,200	
Gymnodinium sp. ..													1,600	
Peridinium sp.	4,400	1,200	3,080				1,980	4,000	2,400		600	880	4,200	
Ceratium tripos ..	880	1,800	440		1,400		200	730	1,200		250	880		
,, *furca*	1,760	33,300	880		600		200	5,000	600			440		
,, *fusca*	880		2,200					700						
Dinophysis tripos ..		600			200		220		1,600				300	
COPEPODA														
Acrocalanus gracilis ..		700			×		×	×	140		×			
Acartia clausi	11,480	560	5,740	2,240	280	2,380	1,820	×	140	700	280	2,380	700	700
Calanus pauper	840		700			×	×		×					
Candace pectinata ..									× ×					
,, *ethiopica* ..								×	×	×				
Eucalanus sp. immature						×			×		140			
Euterpe acutifrons ..	140		560			×	420			×	×	700	140	420
Labidocera acuta ..		×	×	×	×	×	×	×	×	×				×
,, *cervi* ..	×	×							×	×				
Mecynocera clausii ..														
Microsetella rosea ..	560	×	×			1,400	560	560	280	140	Naup.			
Oithona setigera														
,, *oculata* ..								×						
,, *plumifera* ..			×						560	280	140		×	
,, *tenuis* ..						420 sp.					840		1,400	560
Oncaea venusta ..	140	×	×		280	×	560	140	700	420	280	140		140
Onychocorycaeus catus ..			3,780	840	140		1,680		1,120	420	×	140	×	×
Paracalanus parvus ..	700	980	5,600	840	7,140	×	4,340	420	17,500	1,400	1,960	11,200	700	280
Temora turbinata ..	980	3,080	15,540	1,820	×	×	140	1,960		700	420	420	140	
OTHER CRUSTACEA														
Evadne nordmanni ..														
,, *spinifera* ..	6,720	1,400	4,060	1,120		140				280	×			
,, *tergestina* ..	280	3,500	4,060	1,260		140	2,660	2,940		1,680	620			140
Podon polyphemoides ..	560													
Penilia schmachkeri ..	×	1,260		420	140	140	1,120	140	280	2,520	140			
PTEROPODA														
Creseis virgula														
UROCHORDATA														
Oikopleura sp.	×	×	700	1,560	560		560	×	×	280	140	×	560	140
Fritillaria pellucida ..	×			140	2,240	140		2,260		140	×			
Thalia democratica ..		v.c.	v.c.	v.c.	v.c.	v.c.			v.c.					v.c.
EGGS AND LARVAE														
Anchovy eggs ..	140													
Other fish eggs ..	×		×					×	280	×				140
Penaeid eggs					560	1,120		2,240	2,380	1,400	420		560	
Lamellibranch larvae ..									1,120		×			
Veliger larvae ..	× f.c.		1,400				980		980		140	140	140	×
Ophiopleuteus											2,380		14,140	140
Nauplii—barnacle ..							280		×			140	140	560
Zooea	×		×		×				×			280		

II.

New South Wales waters off Port Jackson during 1931.

catches made, *so far as any particular species is concerned*, in exactly the same way on

Protozoa, Copepoda, other Crustacea and Urochordata on any date, but the eggs

catches made with a different net.

1931.												1932.				
Aug.		Sept.	Oct.			Nov.			Dec.			Jan.			Feb.	
12	20 Night.	20	3	17	25	1	15	22	7	23	26	2	8	28	10	23
								800								
													400			
700																
700	×					3,200										
2,800	×	×	4,050	3,500	1,500	67,500	1,800	30,000	3,500		×	2,500	3,000	450	5,400	
		×	×		×	2,450						880	880	400	400	
	440			3,000	1,000	80,000	1,760	3,600	10,800		600	3,500	400		4,000	
	450	×	×	1,000	×											
			450	2,000	900	14,080					600	1,200			220	
														140		×
560	14,200	×	2,940	10,000	140	18,000	900	6,500	840	2,400	2,100	8,000	6,580	980	4,201	920
												×		140		
	140				×											
	140							×					×			
×	3,080		140			280		280								140
																×
×	140												140		×	
											280					×
	×					sp. 1,120								×		
		?				420										280
560	140				×	2,000	140	280	280		720	420	980	×	×	1,400
	140	×				140					420	140				280
×		×							×			140			×	×
×	34,440	×	420	3,500	1,000	32,100	4,000	10,000	420	5,000	8,260	17,000	18,500	28,840	17,000	840
×	7,140	×				1,120	×	280		280	280	140	280	840		140
140	140		420	280		8,000	3,400	840	140	4,060		280				
							280		980	1,960	980	560	11,200	1,680	8,200	×
280	1,820		×		×	500				3,080	8,000	5,000	7,400	700	140	3,000
						×				6,020	9,000	2,800	280			
×						140			×	×	700	1,260	420	140		2,800
			140						× f.c.							
1,640	560		280	560	×	560	140	1,260	420		140	280	140	980	2,160	1,680
840	980		Deep ×		×		140	140							420	600
			40,000													
	280		140	o.c.												×
			few	×		× 60		× rare	v. rare					×		
		×	×	×			×	×	× × ×		140	×		×	420	
×	280															
											280	140		560		
											840					
								140			4,010	140	×	140		1,400
	140			140		840			140		×					
	2,240		800		×	700		600		2,000	980		140			
	×												140	×		

shown for example for the higher plants (by Popp, *Amer. Journ. Botany*, Vol. 13, 1926) that the blue-violet end of the spectrum is necessary for normal vigorous growth (ultra-violet rays are not indispensable) and yet photosynthesis proceeded at a more rapid rate at the red end of the spectrum. Illumination with the full spectrum was more important than light intensity with certain wave lengths removed. Now, so far as we are aware, nothing of any consequence has been determined regarding the effect of different wave lengths on the growth of phytoplankton, yet the sea is a medium which differentially filters the longer wave lengths compared with shorter. Moreover, it is just in regard to the ultra-violet and blue-violet rays that there is greatest change in illumination between winter and summer in temperate latitudes.

These facts have been emphasized because it is difficult to escape the conclusion that there is more in the control of plankton maxima than immediate environmental factors. During the plankton maxima in the English Channel the phosphate and nitrate content of the sea diminishes until the phosphate becomes practically zero in the early summer and the nitrate almost as low. It has been suggested that it is this reduction in nutrient salts which brings the diatom maximum to an end. Possibly this may be important in regions where essential nutrient salts are reduced below the minimum by enormous plant reproduction. It is curious, however, that the diatom curves should be so similar in such diverse places. Is the seasonal distribution of nitrates and phosphates always the same? There are other difficulties, too, in applying these theories. Marshall and Orr showed that the diatom increase came to an end before the phosphate was all utilized. And how is the autumn peak to be explained, or the luxuriant development of dinoflagellates and blue green algae immediately *after* a diatom maximum?

In our case the analyses do not show a big reduction in phosphate, or nitrate, after the spring maximum, and one is impressed all the more by the rhythmically occurring reproductive periods of different species. This periodicity must be the result of the interplay of internal factors and environmental factors, and it is even conceivable that the date of onset of a maximum may be determined, not only by the occurrence of favourable environmental factors, but by the previous year's history of events. It may be worth while in this connection to make a comparison with the yearly periodicity of land plants (although once again there seems little enough experiment to elucidate this subject). Certain of the temperate plants exhibit seasonal periodicity after years of growth in tropical or subtropical areas notwithstanding an environment which is practically uniform. It is true that, in the case of the diatoms and other phytoplanktonic forms, we are dealing with single-celled organisms with quite a short life, but it is not unusual by any means for spores, eggs, etc., to require a certain resting period before they are capable of further development. In any case, we must postulate the existence of a delicate adjustment between the organism and its environment exhibiting itself in the control of growth and reproduction. In no other way, for example, can we account for the remarkable burst of reproduction of the *Gymnodinium* which colours Port Jackson water red for two or three weeks every year and which times its occurrence with close adherence to the calendar. In this connection, too, it is significant that the maximum formed by the chief species of *Rhizosolenia* in New South Wales waters bears a time relation to the onset of the spring diatom maximum (the rise in numbers of

Thalassiosira, *Chaetoceras* and *Asterionella*) similar to that observed in British waters. This is particularly interesting in view of the fact that the seasons are alternate (Southern Hemisphere) and that the sea temperatures at our station are at all times higher than those of British Seas. We are inclined, therefore, to regard the periodicity of the plankton as controlled no less by internal factors than by the directly potent factors of the environment in the fullest sense. The external factors may be of greater importance than the internal in "touching the trigger" for the vernal maximum, for example, but the succession of different species, and the whole aspect of the rhythmic cycle of change is probably due to the reaction of one organism on another, and to inherent characters which are little understood.

The first long period study of the plankton conditions in Australian Seas has, up to date, provided material of considerable interest from the point of view of geographical distribution, and it has indicated the occurrence of a regular and definite seasonal change in the plankton of our seas—a change which is both qualitative and quantitative. Since many commercial fishes feed upon plankton during at least some part of their life, there is reason to believe that migratory movements of fishes will be found to be related to these seasonal planktonic conditions in our southern Australian waters. It is necessary, however, to emphasize distinctly the limitations and difficulties of this present work. No complete knowledge of either the hydrographic or the biological conditions of the coastal waters of the Tasman Sea can possibly be obtained without the organization of such work on a much bigger scale and over a large area. The continuation of our work should provide the foundation for such a scheme.

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EXPLANATION OF PLATE VII.

1.—A Ctenophore, n. sp., from the New South Wales coastal plankton.

2, 3.—Some common fish eggs. (2) Anchovy eggs. (3) Clupeid eggs, species doubtful.

4.—*Thalia democratica*.

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